2023 COMPREHENSIVE REVISION

State Wildlife Action Plan

TEXAS

TEXAS PARKS & WILDLIFE

A Guide for Public and Private Conservation Efforts

State Wildlife Action Plan

TEXAS

2023 COMPREHENSIVE REVISION

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Executive Summary

Purpose

Since 2005, each state, territory, and the District of Columbia has been required to maintain a State Wildlife Action Plan. The plan is submitted to the US Fish and Wildlife Service, who approves the required 10-year comprehensive reviews of the plan along with major and minor revisions. The State Wildlife Action Plan identifies species of greatest conservation need, where they live, what threatens their survival, and what actions can be taken to mitigate threats. The plans help state departments prioritize funding for conservation initiatives, but also provide important information to any person or organization that wants to conserve species and habitat effectively. Plan coordinators seek public and partner input to ensure a diversity of priorities and values are addressed.

Primary Updates to this SWAP

Change in name: The 2013 SWAP for Texas was called the Texas Conservation Action Plan (TCAP). In 2023, Texas adopts the national standard naming convention using "State Wildlife Action Plan" and the state wildlife action plan for Texas is entitled 2023 State Wildlife Action Plan: Texas (*SWAP: Texas*).

Updates to SGCN criteria and species list: Building on the advancements of the 2020 SGCN revisions for the 2023 Revision, TPWD undertook an extensive review of SGCN ranking procedures and criteria.

The 2023 SWAP:Texas includes a complete revision of the criteria for ranking Species of Greatest Conservation Need. The resulting criteria are intended to be robust and repeatable. The new standards use individual expert opinion to initiate the decision-making review process only, and the body of scientific knowledge to complete it. 2023 SGCN Ranking Criteria

Update to format: To increase consistency and alignment of SWAPs across jurisdictions so conservation can more readily be implemented at biologically relevant scales (Leading At-Risk Fish and Wildlife Conservation; Wildlife Conservation: A Framework to Enhance Landscape and Cross-Boundary Conservation Through Coordinated State Wildlife Action Plans), and to accommodate near universal desire by partners to access the entire SWAP:Texas in one location online (Chapter 7: 2023 Comprehensive Review Public Survey), the thirteen handbooks of the earlier TCAP are merged into one document, repetitive material is removed, and the remaining content is arranged so that each required element is introduced as a chapter heading. Non-required elements that are no longer relevant were removed, and non-required elements that remain relevant are moved under chapter headings as appropriate. We continue to work toward accessibility and plan to incorporate additional search and customization tools in the 2025 revision.

Finding and Using the Road Map: The *SWAP: Texas* Roadmap is a tool to track changes from one SWAP to its successor, and is a useful tool for partners who integrate SWAP practices or concepts in projects spanning across two or more editions of the SWAP. The Roadmap is in Chapter 2 under the heading Roadmap to the Elements.

How to contribute to the next Comprehensive Review for 2025: Texas' State Wildlife Action Plan is intended to be a comprehensive document that lays out priorities and suggests actions that practitioners can use to plan activities and unlock resources for the conservation of Texas' wild things and wild places.

The heart of conservation is action and if our conservation efforts are to succeed, we'll need to work together. Throughout the process of developing this plan, we've incorporated the ideas

and priorities of a variety of existing partners and new stakeholders as well as our professional biologists on staff. See Supplement 8: Texas Conservation Action Plan Core Partners and Affiliations.

We invite all our existing and prospective partners and all interested stakeholders to get involved. Immediately following the publication of the 2023 State Wildlife Action Plan, we will begin the process of developing our next comprehensive revision which is planned for completion in 2025.

Please register your interest by filling out a short internet form. You can access the form by clicking on this link: https://forms.office.com/g/bue34tythC or typing it into your browser window, or use your phone's camera to access the form online by aiming it at the QR Code below.

Any comments or questions regarding the 2023 or 2025 State Wildlife Action Plan can be referred to the TPWD State Wildlife Action Plan Coordinator at Kelly.simon@tpwd.texas.gov.

Suggested Citation

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Online *SWAP: Texas* Available:

https://tpwd.texas.gov/wildlife/wildlife-diversity/swap/

Acknowledgements

The effectiveness and relevancy of the State Wildlife Action Plan: Texas, like all State Wildlife Action Plans, depend on the enthusiasm and willingness of the people who accepted the invitation to work together toward our common goal of conserving, preserving, and restoring our natural state. It was critical for our advisors, reviewers, and other contributors to reach out beyond their own experiences and gain new perspective to develop valuable recommendations, and that's no small feat. Our writing teams, committees, and partners also persevered through the lengthy and often tedious process required of such a wide-ranging action plan.

State Wildlife Action Plan: Texas is a plan built on the shoulders of previous editions. Steven Bender led the inagural State Wildlife Plan development (2005). He was responsible for setting a high bar for partner inclusion and collaboration, and he developed the initial SWAP road map that influences our conservation planning to this day. The immediate predecessor of this edition was Texas Conservation Action Plan (20132) edited by Wendy Connally. Wendy assembled an intricate plan with exceptional technical skill and clear vision for it's future use, and built an impressive national reputation as an authority of SWAP development.

SWAP: Texas is made much more relevant by the university researchers, private landowners, land trusts, and conservation organizations that have supported the plan and who find new ways to incorporate its use into their research and on-the-ground conservation activities every year. We appreciate the support we've received from those organizations as we refresh the plan, rank SGCNs, and advance the conservation of those SGCNS.

Subsequent minor revisions and the initiation of the required 2023 Comprehensive Revision were expertly directed by Julie Wicker along with Meredith Longoria, Richard Heilbrun, Tim Birdsong, Dakus Geeslin, and John Davis, who all served on the SWAP Steering Committee. The update of SGCN criteria and subsequent evaluation and prioritization of species for SGCN designation were led with tenacity and exceptional diplomacy by Ross Winton and accomplished by a team that included:

Chelsea Acres, Trey Barron, Hanna Bauer, Megan Bean, Lindsay Campbell, Ph.D, Paul Crump, Ph.D, Stephen Curtis, Krysta Demere, Jonah Evans, Nathan Fuller, Ph.D, Bob Gottfried, Tania Homayoun, Ph.D, Dana Karelus, Ph.D, Meredith Longoria, Russell Martin, Fernando Martinez-Andrade, Ph.D, Shaun Oldenburger, Nathan Rains, Clint Robertson, Jason Singhurst, Anna Strong, and James Tolan, Ph.D.

The heavy lifting of the *SWAP: Texas* (2023) initial development was shouldered by the SWAP Writing Teams, lead by Chelsea Acres, Hanna Bauer, Greg Creacy, Jonah Evans, Richard Heilbrun, Rachel Lange, Ross Winton, and Laura Zebehazy. Writing teams incorporated subject matter experts, biologists, and other partners who provided skillful support, expertise, and technical assistance. Writing team members included:

Chelsea Acres, Jessica Alderson, Trey Barron, Elizabeth Bates, Ph.D, Hanna Bauer, Megan Bean, Timothy Birdsong, Sandy Birnbaum, Lindsay Campbell, Ph.D, Emma Clarkson, Ph.D, Greg Creacy, Paul Crump, Ph.D, Stephen Curtis, Krysta Demere, Jonah Evans, Nathan Fuller, Ph.D, Dakus Geeslin, Bob Gottfried, Dave Holdermann, Tania Homayoun, Ph.D, Claire Iseton, Dana Karelus, Ph.D, Nathan Kuhn, Rachel Lange, Russell Martin, Fernando Martinez-Andrade, Ph.D, Kevin Mayes, Alex Nunez, Shaun Oldenburger, Jeff Raasch, Nathan Rains, Clint Robertson, Sarah Robertson, Jackie Robinson, Kelsi Schwind, Tim Siegmund, Kelly Conrad Simon, Jason Singhurst, Anna Strong, James Tolan, Ph.D, and Amie Treuer- Kuehn.

Susan Frentz ensured the publication project progressed so that once the technical writing was finished, people would actually be able to read our SWAP. Chris Hunt makes us all look good by providing the exceptional cover design. Cristina Gonzalez ensured the document is accessible to all, and helped guide the editor through the tribulations of MS Word and Adobe pdf publications. Peggy Oster ensured *SWAP: Texas* is available online in its most updated, functional form. Bob Gottfried envisioned ways to present SGCN documents online in the most useful format possible, and ensured that updates are quickly and accurately presented.

The people, wild things, and wild spaces of Texas are healthier because of your efforts. Thank you.

Chapter 1

Navigating the State Wildlife Action Plan for Texas

Roadmap to the Elements

This Roadmap is a tool for navigation, particularly for partners, collaborators, and the public who incorporate elements of the SWAP into projects that span across two or more editions of the SWAP. Using this Roadmap, readers can locate the position and content of changes to the required elements of the SWAP. Additionally, the *SWAP: Texas* Roadmap is a valuable assistance for the assigned Regional Review Team (RRT) review of the SWAP, to ensure that changes from previous editions are noted and that all required elements are fully represented.

The 2023 Comprehensive Review for the SWAP represents a major overhaul in the formatting and structure of the state wildlife action plan for Texas, but presents only minor changes to most of the plan's content. The following paragraphs detail the locations and content of the changes to content related to the required elements.

Element 1: Species of Greatest Conservation Need.

Element 1 can be found forming the entirety of **Chapter 3: Species of Greatest Conservation Need**.

Significant Changes from 2013 Texas Conservation Action Plan (TCAP) include:

- SGCN Criteria: For the 2023 SWAP revision, staff and partners determined that the development of new, standardized criteria was needed for ranking SGCN. The new criteria can be found in **Chapter 3**, in the **2023 Final SGCN Selection Criteria** section.
- The resulting new list of SGCN and communities can be found in **Chapter 3, 2023 Species of Greatest Conservation Need** section and **Supplement 3.1 SGCN**.
- New Freshwater Fisheries content: During 2018 – 2020, TPWD and cooperators completed a litany of species conservation status assessments, including assessments of 91 freshwater fishes, which were used to inform the 2020 revision of the lists of State Threatened (ST) and State Endangered (SE) species. Given this dramatic influx in available science on the status of Texas freshwater fish biodiversity, TPWD determined that a 2020 revision of the list of Texas SGCN was timely and warranted. Revision of the list of Texas SGCN in 2020 formally occurred as a "minor revision" to the 2013 Texas Conservation Action Plan. The updated list and their critical habitats are incorporated fully into the 2023 *SWAP: Texas* in the following locations:
    - **Chapter 3: Species and Rare Communities of Greatest Conservation Need**, in the Freshwater Fish sections, pages 8-10,
    - **Chapter 3, Supplement 3.1: SGCN** (Excel document),
    - **Chapter 3, Supplement 3.2: Conservation of Texas Freshwater Fish Diversity: Selections of Species of Greatest Conservation Need,**
    - **Chapter 3, Supplement 3.3: Conservation of Texas Freshwater Fishes – Informing State-based Species Protections.**
- Taxonomic nomenclature is updated throughout.

- SGCN are grouped in new ways to facilitate managers in developing management goals. Notes on arrangements and groupings of the species are found in *Chapter 3: SGCN* in the section **A Note on Arrangements and Groupings**.
- Icons are used to assist in recognition of species groups and habitats.

Element 2: Habitats

Element 2 forms the entirety of **Chapter 4: Priority Habitats** and its accompanying **Supplements**. **Chapter 4** introduces how habitats are defined in the *SWAP: Texas.* **Supplement 4.1** provides a analysis of the **condition of Texas habitat** using the Southeast Conservation Adaptation Strategy (SECAS) Blueprint, resulting in a customized Conservation Adaptation Strategy Blueprint for Texas that includes over 20 indices of habitat conditions. For the 2025 SWAP Comprehensive Revision, we are building on that partnership by contributing Texas Conservation Opportunity Area data and analysis to the SECAS platform, thereby increasing opportunities for regional collaboration. **Supplement 4.2** provides detailed **descriptions of habitat** in Texas, including relevant **threats to each habitat community** according to NatureServe (2023). In the 2025 SWAP Comprehensive Revision, we are building on this analysis with the new Texas Conservation Opportunity Atlas, which will include SGCN known distribution, select species habitat modeling, and multiple indices of habitat conditions. This will allow us to prioritize specific habitats for conservation research and actions in the future.

Since the 2013 TCAP, TPWD Inland Fisheries embarked on a wide ranging regional effort to analyze riparian and river ecosystem health and establish habitat and species priorities based on this analysis. **Supplement 4.3: Texas Native Fish Conservation Areas Network**, details the methodology of determining these areas, SGCN affected, descriptions of the habitats of the newly prioritized 20 native fish conservation areas designated in Texas, and outlines conservation actions and goals.

Additional significant changes from the 2013 TCAP include:

- All priority habitats in the 2013 ecoregion handbooks (n=12), the overview handbook, and the statewide and regional handbook are compiled into one section (**Supplement 4.2: Descriptions of Priority Habitats in and Threats**.
- The complete reports on Native Fish Conservation Area habitat designation are provided in full as **Chapter 4, Supplement 4.3: Texas Native Fish Conservation Areas Network.**
- Ecological drainage units (EDUs) and hydrological unit codes (HUCs) have not added functionality or clarity to our application, so these identifiers are no longer incorporated into habitat descriptions. Locations and descriptions of these units are readily available online.

Element 3: Threats

Element 3 forms the entirety of Chapter 5: Priority Threats.

Significant changes from the 2013 TCAP include:

- Threats identified in 2013 from each of the ecoregion handbooks (n=12), the overview handbook, and the statewide handbook are merged into one chapter. Repetitive or outdated material is removed, and changes to formatting have been made to increase clarity and facilitate accessibility.

- Adopting the definitions and hierarchical classification from Salafsky et al's (2008) A Standard Lexicon for Biodiversity Conservation: United Classifications of Threats and Actions (see **Supplement 5.1: Unified Language Describing Conservation Threats**), the merged Threats are now organized according to that hierarchical structure.
- Stresses by level of classification, as defined by Salafsky et al's (2008) A Standard Lexicon for Biodiversity Conservation: United Classifications of Threats and Actions, are added and organized by Threat.
- All threats have been ordered within the unified lexicon by rank according to respondents' perception of the threat, as quantified in the public survey. Most impactful threats were ordered first, and less impactful threats were placed later.
- Supporting information has been updated from the previous edition. Every effort was made to draw information compatible with previous sources. For example, census information was updated from the 2010 US Census to the 2020 US Census.
- Most methodology on plan development is cited from the 2013 document rather than repeated.
- Updated nomenclature. Example, Rasberry Crazy Ant has been updated to Tawny Crazy Ant. Taxonomic nomenclature is also updated throughout.

Since its first iteration in 2005, Texas state wildlife action plans have incorporated Climate Change as a critical component of Threats and Actions. The 2023 SWAP: Texas highlights the threat of climate change in **Chapter 5: Priority Threats**, Section **Climate Change and Severe Weather**, and **Chapter 6: Priority Conservation Actions** in Sections **Land and Water Protection, Land and Water Management, and Species Management**.

Element 4: Conservation Actions

Element 4 forms the entirety of **Chapter 6: Priority Conservation Actions**.

Significant changes from the 2013 TCAP include:

- Actions identified in 2013 from each of the ecoregion handbooks (11), the overview handbook, and the statewide handbook are merged into one chapter. Repetitive or outdated material is removed, and formatting changes have been made to increase clarity and facilitate accessibility.
- Adopting the definitions and hierarchical classification from Salafsky et al's (2008) *A Standard Lexicon for Biodiversity Conservation: United Classifications of Threats and Actions* (see **Supplement 6.1 Unified Language Describing Priority Actions)**, the merged Actions are now organized according to that hierarchical structure.
- Because the ecoregion handbooks, overview handbook, and statewide and regional handbooks are now merged into one document, the scale of each action varies from others in its section, which may be disorienting. To aid the reader, actions are ordered from most geographically expansive to most geographically restricted.
- Most methodology on plan development is cited from the 2013 document rather than repeated.
- Because Actions are compiled from multiple ecoregion handbooks and repetitive or outdated material is removed, some actions include a notation of the specific ecoregions to which actions may especially apply.

Element 5: Monitoring

Element 5 can be found entirely within **Chapter 7: Monitoring**. This chapter comprises material that is completely new for the 2023 revision. Element 5 can be broken into two parts: (1) *Plans for monitoring species and habitats and (2) Plans for monitoring effectiveness and adapting conservation actions in response to new information.*

1. *Plans for monitoring species and habitat* activities primarily involve ensuring that State Wildlife Grant funding is used to efficiently contribute to the recovery of SGCNs according to SWAP priorities, and review of SGCN and threatened and endangered ranks in defined intervals. Readers can find details on the SWG prioritization process the **Monitoring SGCN** section. The rank review process is found in the **Rank Review section**.

SWAP priorities are implemented with the assistance of partners. The new **SWG Partnerships section** details SWG partnerships that accomplish SWAP priorities.

In addition to current monitoring adaptations, recommendations are made for future activities that apply to the monitoring element. These recommendations can be found in the **Future Needs section.**

2. *Plans for monitoring effectiveness and adapting conservation actions in response to new information* revolves around Knowledge Gap Analyses and the creation of S-Rank Improvement Plans. A summary of these processes are on page 7 of *Chapter 7*, a detail of the Knowledge Gap Analysis process is provided in Supplement 7.1, and examples of S-Rank Improvement Plans are included in Supplements 7.2 and 7.3.

Supporting the monitoring efforts are monitoring requirements included in Conservation Actions throughout *Chapter 6: Priority Conservation Actions*. In this chapter, significant changes from the 2013 TCAP include

- Previously, the term "measuring progress and effectiveness" was used interchangeably with "monitoring" in reference to Element 5. For clarity, the phrase "Monitoring progress and effectiveness" and "monitoring" are used exclusively for actions that address element 5.
- Because the ecoregion handbooks (n=12), overview handbook, and statewide and regional handbooks are now merged into one document, there was substantial repetition of content. Repetitive material was deleted, and outdated material was either updated or, if now obsolete, deleted.
- Updated common and taxonomic nomenclature throughout.

Element 6: Plans for Revision

Element 6 can be found **Chapter 8: State Wildlife Action Plan Development** in section **Plan Review and Revision**.

Significant changes from the 2013 TCAP include:

- This section is entirely revised. The new revision cycle will coincide with most other states' comprehensive revision cycles beginning in 2025 and is detailed in the first section of **Chapter 8,** the **Plan Review and Revision (Element 6) section***.*

- Plans for the upcoming 2025 Comprehensive Revision are also detailed in Chapter 7 in the section **Preview of the SWAP: Texas 2025 Process.**

Element 7: Coordinating with Partners

Element 7 can be found in **Chapter 8: State Wildlife Action Plan Development**, in section **Coordination with Partners (Element 7)**. A product of partnership is produced in in **Chapter 4: Priority Habitats***,* in **Supplement 4.1**: Blueprint SECAS Texas Report, and in content throughout **Chapter 6: Conservation Actions**.

Significant changes from the 2013 TCAP include:

- Inclusion of a report from a partnership with Southeast Conservation Adaptation Strategy, found in Supplement 4.1 Blueprint SECAS Texas Report.
- Because the ecoregion handbooks (n=12), overview handbook, and statewide and regional handbooks are now merged into one document, there was substantial repetition of content. Repetitive material was deleted, and outdated material was either updated or, if obsolete, deleted.
- Modeled the chapter and larger structure of the *SWAP: Texas* to fulfill recommendations of the 2020 President's Task Force on Shared Science and Landscape Conservation Priorities – important information on partnering in conservation.

Element 8: Public Participation

Element 8 can be found in *Chapter 8: State Wildlife Action Plan Development*, in section **Element 8: Public Participation**, pages 3-4.

Information on public participation can also be found in *Chapter 6: Priority Conservation Actions*, in all sections, especially in **External Capacity Building**, and **Land and Water Management**.

Significant changes from the 2013 TCAP include:

- Because the 2023 review was not intended to introduce new content, the public participation process was limited. However, a plan for extensive and intensive public participation has been developed for the 2025 revision, which readers can find in the **Preview of the 2025 Comprehensive Revision** section on pages 1-2 of *Chapter 8*.
- A new public participation survey was issued that helped to guide the Threats prioritization and the formatting and delivery method of the 2023 SWAP: Texas. A summary of results informed the construction, review, and delivery methods of the plan, and can be found in *Chapter 8: State Wildlife Action Plan Development* in sections **Coordinating with Partners** and **Element 8: Public Participation**.
- Most methodology on plan development is cited from the 2013 document rather than repeated.

General Changes from the 2013 Texas Conservation Action Plan

Biologists have identified 1124 SGCN and 232 Rare Plant Communities through standardized methodolgy described in the 2023 *SWAP: Texas*. The challenges to effective conservation and restoration are widespread, but the capabilities and dedication of conservation partners are extensive. This plan is designed to help stakeholders access and implement the most important conservation actions to conserve our SGCN and their habitats.

Change in name: The 2013 SWAP for Texas was called the Texas Conservation Action Plan (TCAP). In 2023, Texas adopted the national standard naming convention using "State Wildlife Action Plan," and the state wildlife action plan for Texas is entitled 2023 State Wildlife Action Plan: Texas (*SWAP: Texas*). While partners and staff may still refer to the state wildlife action plan as the TCAP, official documents will use 2023 State Wildlife Action Plan: Texas or *SWAP: Texas*.

Change in structure: The previous Texas Conservation plan was divided into thirteen handbooks to ensure that audiences could quickly and easily access information we thought was most relevant to them. In the 2023 *SWAP: Texas*, the thirteen handbooks are merged into one document, repetitive material is removed, and the remaining content is arranged so that required elements are introduced with chapter headings. This format change is in response to many factors, including:

- Readers want to access information in many different ways than first predicted,
- To increase consistency and alignment of SWAPs across jurisdictions so conservation can more readily be implemented at biologically relevant scales (Association of Fish & Wildlife Agencies, 2021), and
- To accommodate near universal desire by partners to access the entire *SWAP: Texas* in one location online (2023 Comprehensive Review Public Survey).

Additional changes: Non-required elements no longer relevant are removed, and non-required relevant elements are moved under chapter headings as appropriate. We continue to work toward accessibility and plan to incorporate additional search and customization tools in the 2025 revision.

Planning for the Future: Texas SWAP revision plan: This 2023 Comprehensive Review represents the review required for each 10-year period by the USFWS. It incorporates extensive advancements in fish and wildlife science, particularly in developing new and more robust SGCN criteria. However, to match with the revision cycles of most US states, TPWD plans its next comprehensive revision to be completed in 2025. This is well ahead of the required 10-year cycle but will ensure that essential guidance is received in time to be incorporated in relevant revisions. Following this jump, TPWD will maintain the 10-year comprehensive review cycle with minor revisions as necessary between the comprehensive reviews. This will ensure that essential guidance is incorporated and that sufficient time is available to gather and incorporate partner, collaborator, and public input.

Chapter 2

Setting the Stage for Texas' Natural State

The Rich Heritage of the Lone Star State

Texas is one of the largest, most biologically diverse states with prairies, expansive plains and grasslands, woodlands and forests, mountains and canyons, springs and bogs, fast flashy ephemeral streams and deliberate large perennial rivers – all of which eventually feed the Gulf of Mexico. Because we have such variety in our habitats, including isolated systems different from their more extensive surroundings, our state is home to some species which occur nowhere else on earth. Texas habitats are also very important links in the pathways for thousands of migratory wildlife, including songbirds and monarch butterflies, making their annual journeys north and south. Many of our natural resources are shared directly with four other states and Mexico, and indirectly through migratory routes with other states, Central America, and Canada.

Texans share a remarkable sense of place that is rooted in the state's rich history, unique geography, and a multicultural heritage that set the Lone Star State apart from the rest of the United States. Traditionally an agrarian state, Texas has always been home to a distinctive blend of people who are inherently bonded by a deep appreciation of the land and its ability to sustain life. The vast natural heritage of the state, set on the diverse stage of iconic landscapes and watersheds, provides endless opportunities to experience the outdoors and connect with nature through recreation and stewardship.

For over a decade, Texas has been leading the nation in population growth. The widespread fragmentation and loss of open space, along with intensified demands on surface and groundwater to accommodate the growing population, threaten the natural resources and recreational opportunities that define the Lone Star State. The development of effective, forward-looking strategies inclusive of the needs of nature and people is essential to protect the natural and cultural legacy of Texas for present and future generations.

The Changing Face of Texas

It is easy to fall in love with Texas, and the iconic, diverse aquatic and terrestrial landscapes coupled with the abundance of natural resources and recreational opportunities make Texas an attractive place to live. As more and more people choose to call the Lone Star State home, Texas has become the fastest-growing state in the nation, with a current population of more than 30 million residents. Considering the latest population trends, Texas is projected to experience substantial population growth and reach 47.3 million by 2050 (U.S. Census Bureau 2020).

The spatial distribution of the ongoing population growth is not uniform, with much of the increase – approximately 88% – observed within the Texas Triangle, an area formed by counties within and surrounding the metropolitan centers of Dallas, Houston, San Antonio, and Austin (Figure 2.1). Interestingly, while Texas has the largest rural population in the U.S., nearly 84% of Texans live in urban areas (Figure 2.2). In the upcoming decade, energy development-fueled economic growth in the Permian Basin region will drive population growth there in addition to the urban areas that have previously experienced population growth (Figures 2.3 and 2.4) (Federal Reserve Bank of Dallas 2023).

As the population of Texas grows, the ethnic and racial composition of the state is becoming increasingly more diverse. People of Hispanic and Latino origin continue driving the population growth. In 2020, this group alone accounted for nearly half of the total population increase and was less than half a percent away from becoming the majority ethnic group. Projections indicate that the Hispanic and Latino population will continue to rapidly increase and will exceed 20 million by 2050 (U.S. Census Bureau 2020).

Along with the racial and ethnic makeup, the Lone Star State's age profile has also been changing. Texas is a relatively young state, with the current median age approximately 35.5 years – about 3 years younger than the national average. However, the Texas population is expected to grow older as the 65+ cohort continues to increase because of the aging baby boomer generation (people born between 1946 and 1964).

The socio-demographic landscape of Texas will continue to change and shape the demand for a variety of outdoor recreation experiences over the coming years. Recognizing these anticipated demographic transformations is important for keeping the natural heritage and recreational opportunities of the Lone Star State relevant to the lives of the diversifying cultural heritage of Texans in the years to come. Moving forward, ensuring the inclusivity of outdoor recreation services will be critical to minimizing barriers to outdoor recreation and providing all Texans with equal and appealing opportunities to enjoy the great outdoors.

The Ecological Diversity of Texas

From deserts to marshes and plains to Pineywoods, Texas spreads across 12 distinct ecoregions, each with unique topography, hydrology, soil, vegetation, and climate (Figure 2.5). Flowing through those ecoregions are 15 major river basins that comprise an array of aquatic ecosystems from East Texas bayous, Great Plains prairie streams, Central Texas spring run ecosystems, and the grand rivers feeding our rich and productive estuarine ecosystems along the Gulf Coast. The state sustains a remarkable number of species including approximately 5,000 native plants, 639 birds, 142 mammals, 443 butterflies, and 800 fish. Biodiversity is essential for ecosystem function; balanced and healthy ecosystems provide clean water and air, protect soil from erosion, store carbon, assimilate and cycle nutrients, and provide numerous other products and ecosystem services important to the well-being of both humans and the environment.

This exceptionally rich biodiversity is a defining feature of the Lone Star State and a major component of outdoor recreation in Texas. Popular activities such as hunting, fishing, and bird watching cannot be enjoyed without the healthy and diverse natural resources, landscapes, and waterways found across the state. According to the U.S. Bureau of Economic Analysis Outdoor Recreation Satellite Account Report (2021), outdoor recreation added $35.9 billion to Texas' gross state product (GSP) in 2019. Hunting, boating and fishing continue to rank among the largest economic contributors to nature tourism in Texas, adding $930 million and $1.7 billion, respectively, to GSP in 2019. These numbers leave no doubt that Texans and our visitors love the outdoors and appreciate the diversity of wildlife-associated recreation experiences that the Lone Star State has to offer.

The *State Wildlife Action Plan: Texas* helps to ensure that thoughtful and deliberate conservation and management will support the fish and wildlife populations and habitats in Texas for decades to come.

List of Figures

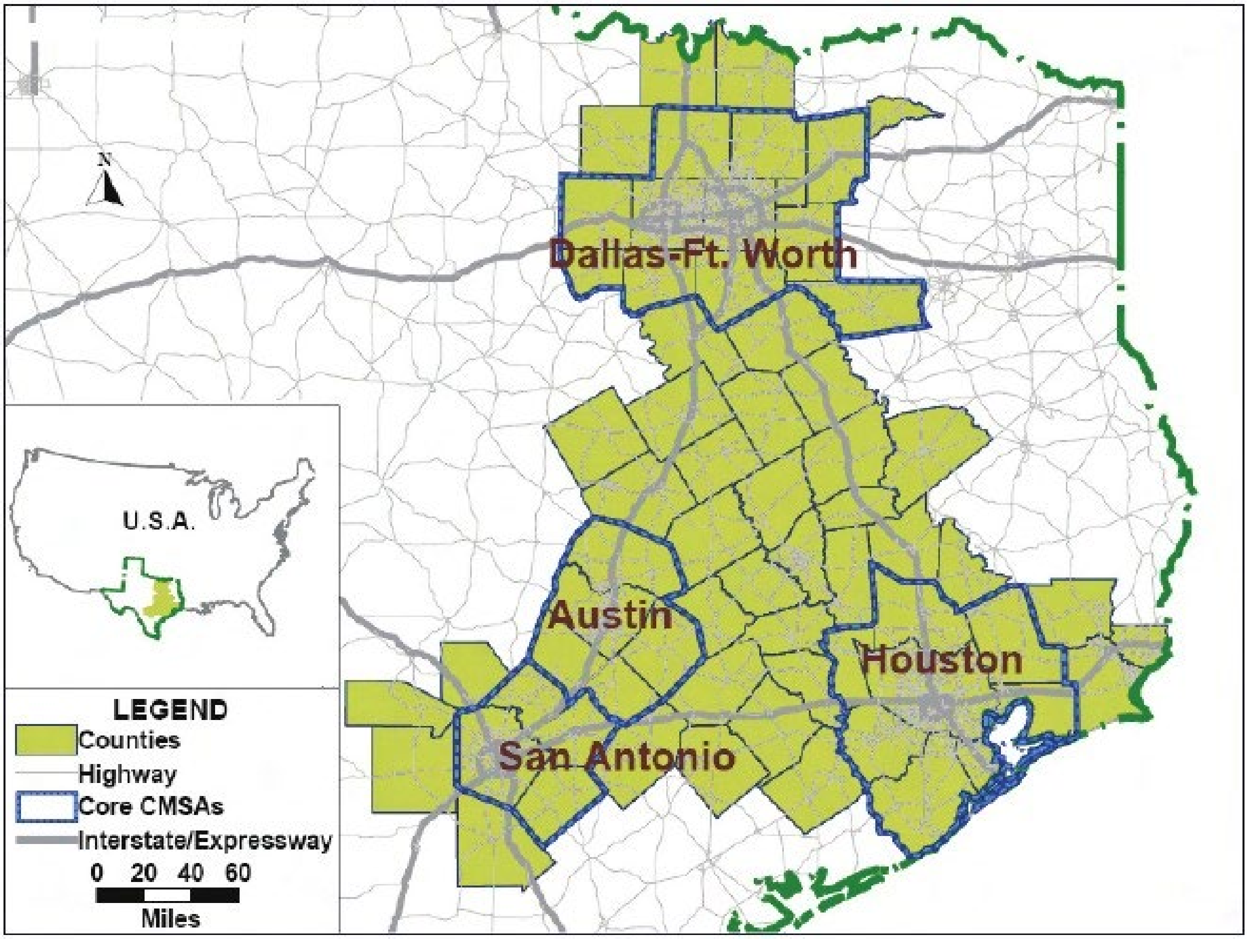


Figure 2.1. Texas Triangle Megaregion. Zhang, Ming & Steiner, Frederick & Butler, Kent. (2007). Connecting the Texas Triangle: Economic Integration and Transportation Coordination.

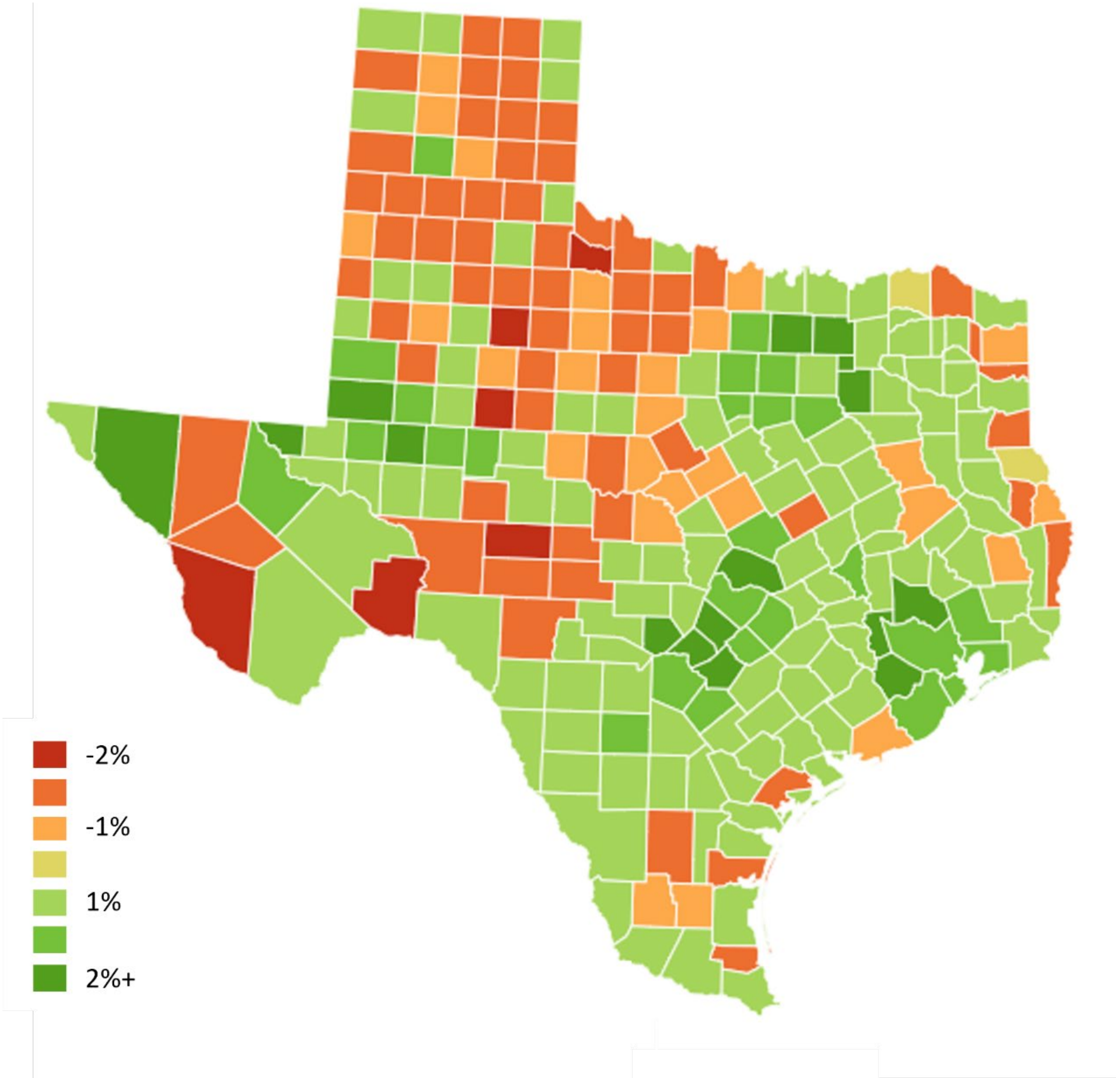


Figure 2.2. Change in human population by county in Texas, 2010 – 2018. The largest population increases happened in counties just outside major cities, like the suburbs of Austin, Dallas, and Houston. Many rural counties experienced population declines between 2010 and 2018. Source: U.S. Census Bureau, 2018 Population Projections by Stephanie Lamm, Dallas Morning News.

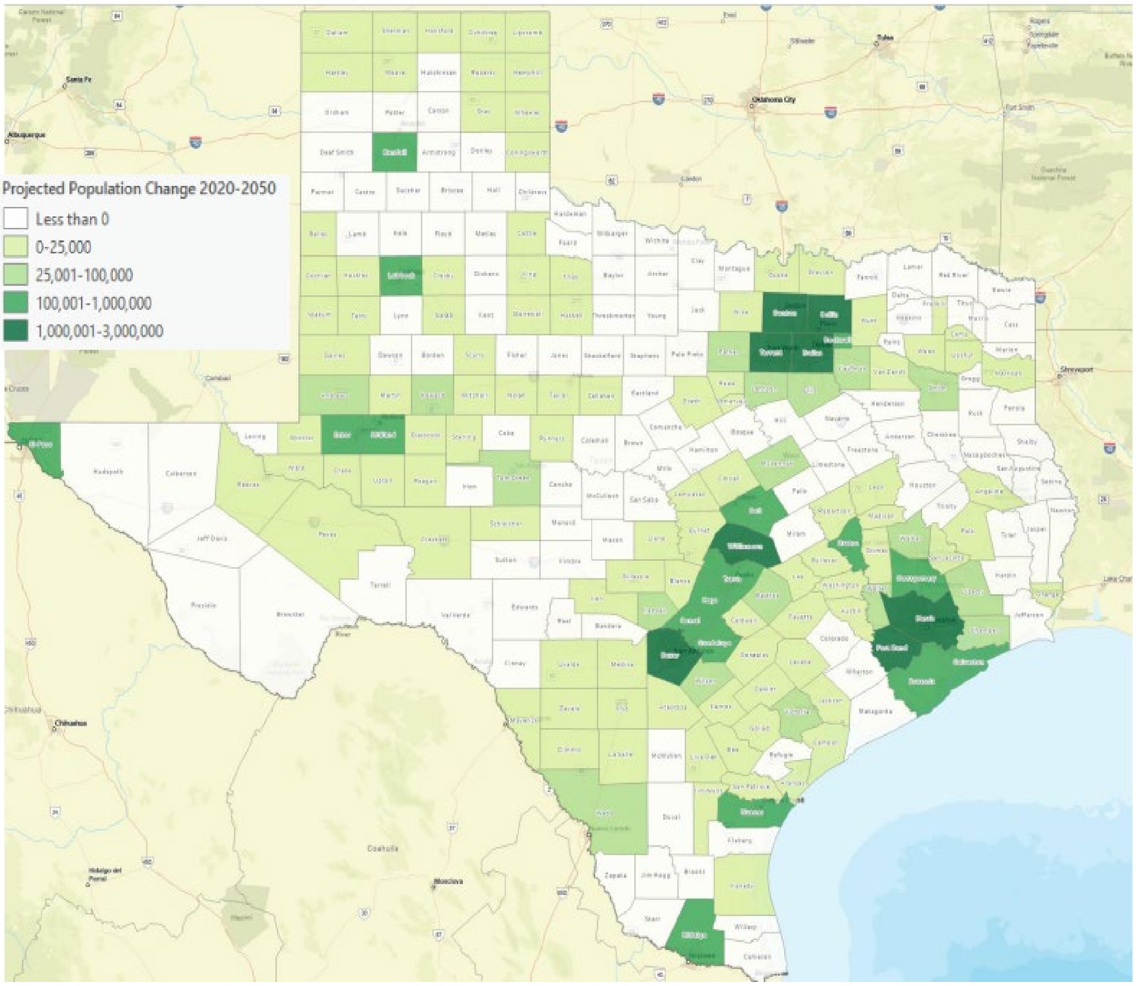


Figure 2.3. Projected Numeric Population Change, Texas Counties, 2020-2050. Source: Texas Demographic Center, 2018 Population Projections

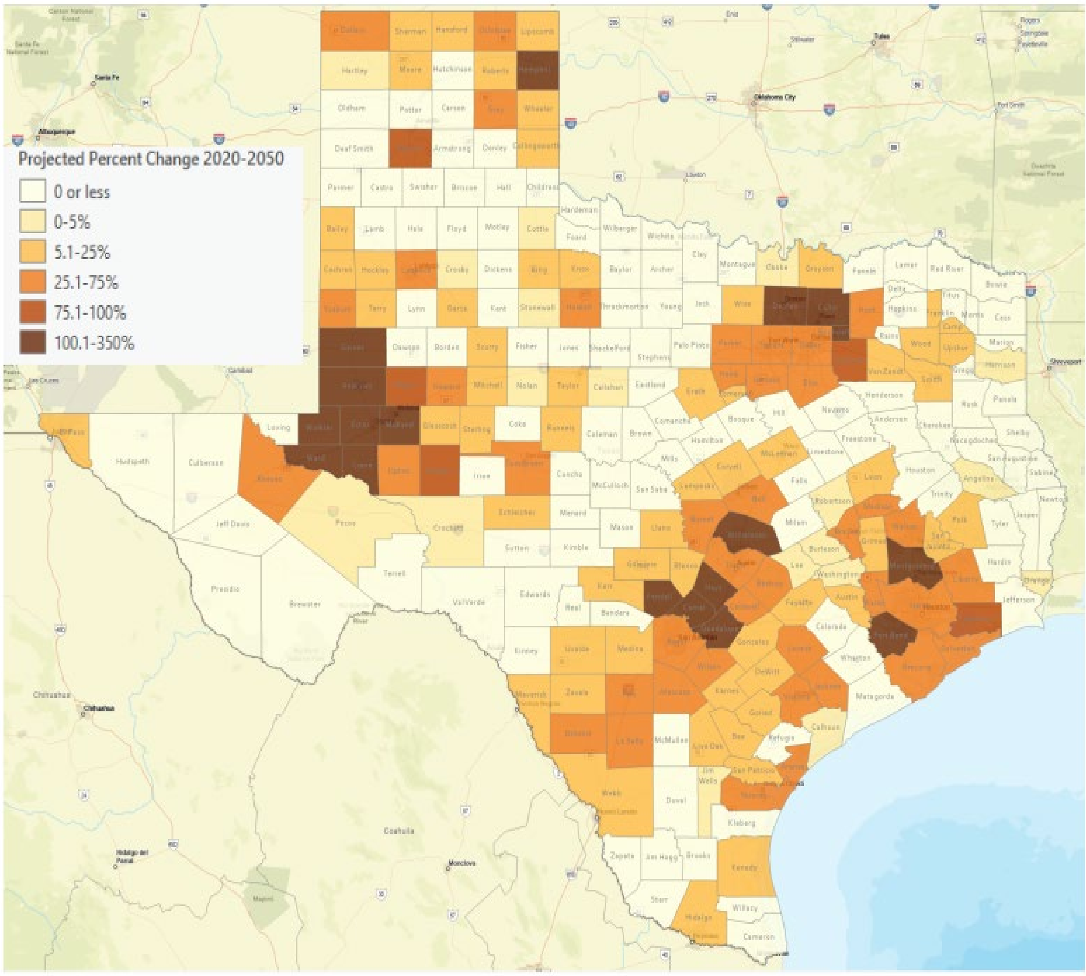


Figure 2.4. Projected Percent Population Change, Texas Counties, 2020-2050. Source: Texas Demographic Center, 2018 Population Projections

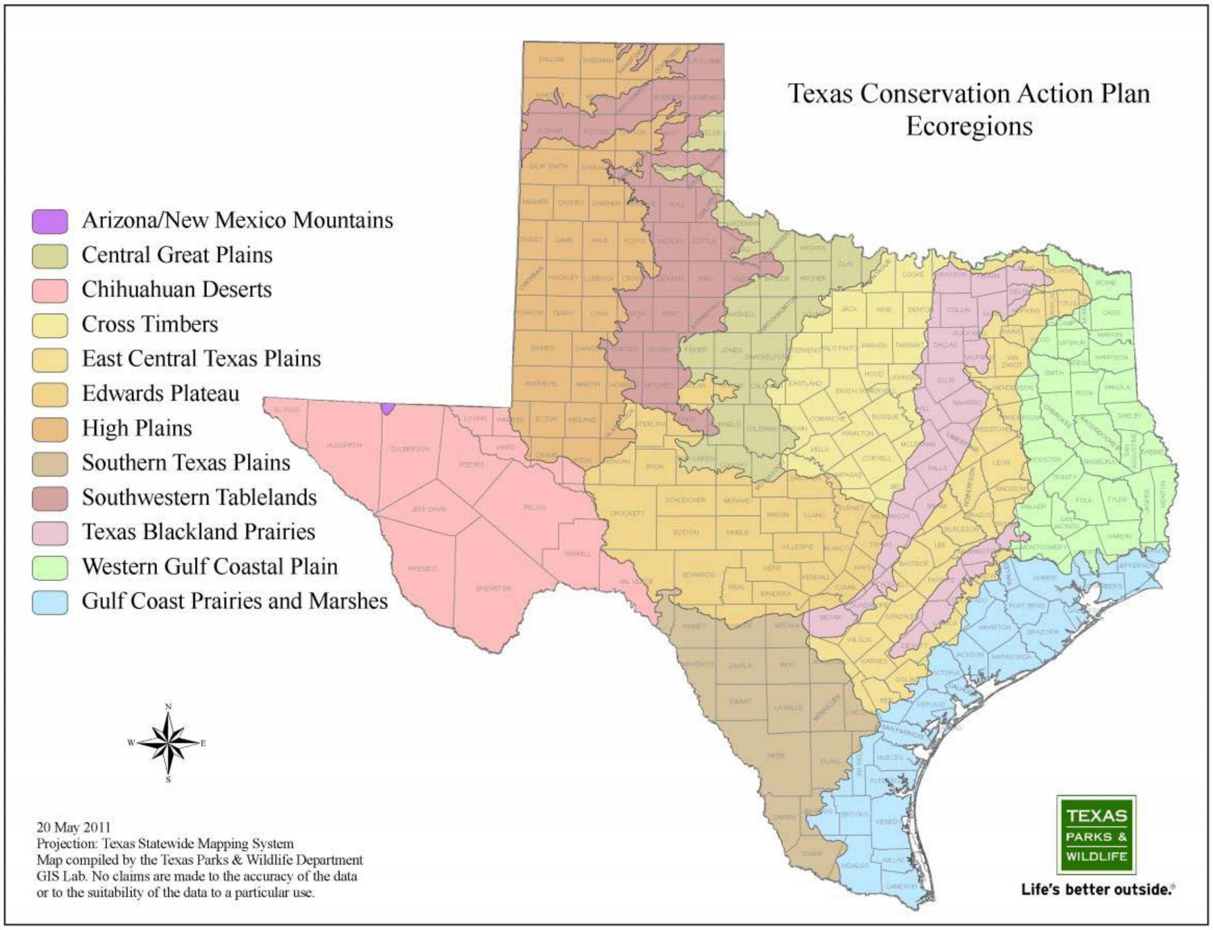


Figure 2.5. An overview of the ecological regions of Texas. (Texas Parks and Wildlife 2013)

Chapter 3

Species of Greatest Conservation Need (Element 1)

While most conservation work in Texas is done at the habitat level to address threats, the stated primary purpose of State Wildlife Action Plan is to improve and sustain populations and prevent the need to list species as federally or state-threatened or endangered. The **Species of Greatest Conservation Need (SGCN)** list, the first of eight required elements in all states' Wildlife Action Plans, is the starting point. The first required element of State Wildlife Action Plans is *Element 1: Information on the distribution and abundance of species of wildlife, including low and declining populations as the State fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the State's wildlife.*

The first Texas SGCN list (TPWD 2005) was compiled by TPWD biologists with statewide collaboration among experts, supported by citable references where available, and contained 888 species. The list did not include plants or rare plant communities because these elements are not eligible for State Wildlife Grant (SWG) funding.

In 2013, the TCAP SGCN and Rare Communities lists were expanded to include plants, plant communities and coastal/marine species. Additionally, in 2019 a complete assessment of all marine fishes was conducted, followed by a complete review of all freshwater fish and mussel species in 2020. Conservation assessments were then refined for all taxa groups, prompting an update to prioritization criteria and a minor revision that updated the SGCN list for all remaining taxa in 2020.

2023 SGCN List Review Process

The SGCN lists constructed for the 2013 TCAP provided the initial list of species proposed for review for the 2020 minor revision and 2023 comprehensive revision lists. The 2023 revision used the available conservation status assessment housed within NatureServe systems as the foundation for ranking. Biologists from TPWD's Texas Natural Diversity Database (TXNDD), Wildlife Diversity Nongame and Rare Species Program, and special projects coordinators from four core resources divisions (Wildlife, Inland Fisheries, and Coastal Fisheries, and State Parks) began the new SGCN review process by refining the criteria that determined conservation need of species to be reviewed.

Candidacy of Species for SGCN Review

Each species or community (except for estuarine, bay and marine fishes) has a NatureServe calculated conservation rank often at the state and/or global level, that accounts for abundance, population stability and threats. These conservation ranks served as the foundational element of determining the 2023 SGCN species designations. Species ranked by NatureServe and having a rounded state rank of Critically Imperiled (S1), Imperiled (S2) or Vulnerable (S3) were included for review as SGCN species. In addition, species ranked by the comparable International Union for the Conservation of Nature (IUCN) methodology as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) were considered for inclusion as SGCN. Avian species identified by Partners in Flight (PIF) as Red Watch, Yellow Watch or Common Birds in Steep Decline (CBISD) as comparable to both the NatureServe and IUCN ranking strategies were also considered to be added to the newest version of the SGCN list. Plant communities were also included based on the G-rank (G1-G3) for those endemic and restricted range communities as the G-rank is considered comparable to the S-rank and is the standard level at which communities are assessed.

To expand on the foundational conservation status of Texas species and communities, several criteria were agreed upon by the team of division and taxa specialists as being required for a species to be considered as an SGCN.

While NatureServe criteria do not solely focus on numbers of a particular species, they can help document baseline and trend of species distribution, abundance, decline, threats, and conservation. Because of this tool's utility for multiple taxa and its use on landscape scales crossing political boundaries, NatureServe rankings are the primary method of incorporating declining and rare species to address in this plan. Additionally, several species have federal and/or state listing (endangered, threatened, candidate) status. State and federal listed species are included in the SGCN list.

Many of the taxa teams took this opportunity to review the NatureServe ranks for proposed SGCN. Several of the ranks in the SGCN and Rare Communities lists may differ from those in the NatureServe database online; these changes are "proposed," supporting information has been documented in our affiliate database (TXNDD), and will be updated with NatureServe through their review and approval process.

2023 Final SGCN Selection Criteria

1. Fully Described Species: Species with "Questionable Taxonomy" (NatureServe – Q) may be considered but would be placed in the Data Deficient category so the priority would be taxonomic resolution first. Undescribed species would need to be fully described or identified as valid taxa (e.g. thesis, dissertation, peer-review literature, agency research results, taxa community consensus) prior to being considered as an SGCN. Described Subspecies or Evolutionary Significant Unit (ESU) inclusion will be determined by Taxa experts as standards vary by group as to species distinction.
2. Native: All SGCN's shall be native to Texas.
3. Confirmed as occurring in Texas: Unconfirmed historic records would need to be confirmed by taxa experts prior to a species being added to the SGCN list.
4. Currently Present: Species that are "Possibly Extirpated" (NatureServe - SH) may remain on the list until survey effort is great enough for the species to be "Presumed Extirpated" (NatureServe - SX) in Texas. Existing state or federal management plans outline the reintroduction of a presumed extirpated species is likely to occur may allow for a species inclusion on the SGCN list.
5. Regularly Occurring: TPWD and the state of Texas needs to have the ability to manage the species at the population level within the duration of the plan. The species should have a regularly occurring non vagrant population on which conservation actions could have a meaningful impact in Texas. Generally, species with less than 5% of the total range wide species distribution and/or species population occurring in Texas constitutes a peripheral species. Peripheral species occurring in Texas but having a significant portion of their range and conservation need in other states, territories or countries would be precluded from the SGCN list to allow for conservation actions to be focused on species that can be conserved and managed in the state. Species with significant range-wide declines and current populations remaining in Texas may be considered for inclusion based on taxonomic expert feedback.
6. *State & Federal Listing Status*
    a. Species Federally listed as Endangered, Threatened, Candidate & Petitioned may be considered for inclusion as SGCN with criteria 1-4 being met. AND/OR

    b. Species State listed as Endangered or Threatened may be considered for inclusion as SGCN with criteria 1-4 being met.
7. Conservation Status & Rank:
    a. Avian species identified by Partners in Flight (PIF) as Red Watch, Yellow Watch or Common Birds in Steep Decline (CBSD) as comparable to the NatureServe and IUCN ranking strategies. AND
    b. Non-avian Species ranked by NatureServe and having a rounded state or global rank of Critically Imperiled (S1 or G1), Imperiled (S2 or G2) or Vulnerable (S3 or G3) OR ranked as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) by the International Union for Conservation of Nature (IUCN) as comparable to the NatureServe ranking methodology. AND
    c. Species considered as SGCN based on assessed ranks must be less than 20 years old to accurately determine the current conservation status.
8. Regional Conservation Priorities: Species included in the SEAFWA (Southeastern Association of Fish and Wildlife Agencies) Regional SGCN list occurring in Texas and meeting the above criteria may be added to the SGCN list.
9. Plant Communities: While not considered SGCN, rare plant communities will be identified as conservation priorities based on the community G-rank (G1-G3) as maintained by NatureServe.

A Note on Arrangements and Groupings

There are many ways to arrange and list species. The SWAP: Texas is not a comprehensive text of taxonomic relationships, but rather provides the most meaningful information in the most concise way so that readers may easily find groups of species important for their purposes. At the same time, editors want to ensure readers who might be more accustomed to a list structured around taxonomic nomenclature also find the groupings useful, and at the very least not a hinderance to understanding. The *SWAP: Texas* is designed to provide SGCN in the most useful, digestible format currently possible for conservationist practitioners, academicians, and the interested public.

In the following SGCN list, the groups that organize species depend on the number and variety of the species within a grouping and the recognizability of groups. Icons presented with the groups are intended to clarify what types of species are collected in the group, but should not be considered neither an exhaustive collection of species types nor a comprehensive identification tool.

While taxonomic information is provided here as an aid to understanding, nomenclature changes often happen between publications. Authoritative nomenclature can be found online at the Integrated Taxonomic Information System.

Groups are arranged in alphabetical order by specific epithet (*Genus species*) within taxonomic families and orders of classes or other taxonomic collection. The following is an explanation of the grouping pattern and information presented for each of the major taxonomic collections.

Plants, is a large group of organisms including monocot and eudicot flowering plants, conifers, and mosses in the SWAP: Texas, and are organized by Class (Division) and then by Family.

Invertebrates are an extremely wide-ranging group that include the Classes of Insects (includes ants, bees, beetles, butterflies and moths, and more), Arachnids (spiders, mites, harvestmen, scorpions, and pseudoscorpion), Gastropods (slugs and snails), Bivalves (including Mussels) and other animals with no vertebral column ("backbone"). Invertebrates included in the SWAP: Texas SGCN list are refined into Orders (dragonflies, beetles, slugs and snails, mussels, scorpions, etc) when those divisions would increase recognition of relevant attributes of the organism.

Fish, in context of the SWAP: Texas is a group of animals are first divided by habitat (freshwater or saltwater(marine)) and then by Family.

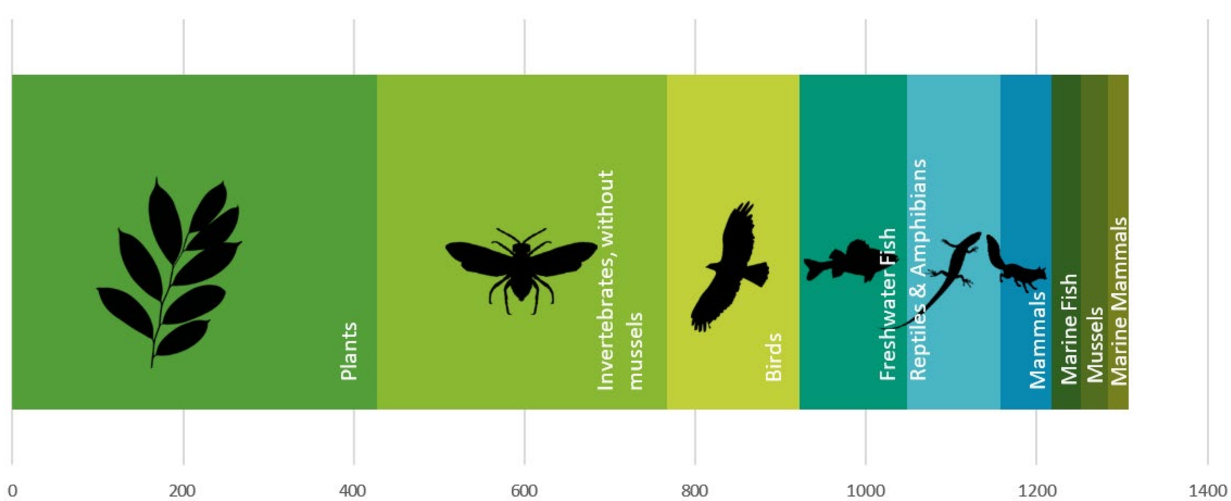
Class **Reptiles** and Class **Amphibians** (sometimes collectively known as "herptiles") and are grouped by Order.

Mammals as a Class are grouped by Family.

Birds as a Class are grouped by Family. The American Ornithological Society's (AOS) Checklist is the official source on the taxonomy of birds found in North and Middle America, and is the standard used in the SWAP: Texas. Because common names are standardized, they appear in the SGCN in bold, and are capitalized according to standard ornithological practice.

Conservation Status information follows NatureServe Conservation Status Ranks and is current March 2023. A key to conservation status ranks can be online at Definitions of NatureServe Conservation Status Ranks. Additional statuses: PIF refers to Partners in Flight conservation status (birds), IUCN refers to International Union of Concerned Scientists Red List of Threatened Species, ESA listing refers to the United States Endangered Species Act. State listing of threatened or endangered species follows Texas Parks and Wildlife Wildlife Code (Sec. § 68.002).

A spreadsheet of SGCNs that includes more information including key habitats and conservation issues can be found linked in Supplement 3.1: Species of Greatest Conservation Need (SGCN) and Habitats. An Microsoft Excel spreadsheet of SGCNs can be obtained online at *SWAP: Texas* [WEBSITE to be added].



An illustration of the relative numbers of SGCN, by taxa group.

2023 Species of Greatest Conservation Need

For conservation ranks and other information related to SGCN prioritization, refer to **Supplement 3.1: Species of Greatest Conservation Need (SGCN) Spreadsheet**.

Amphibians

Order: Anura (Frogs and Toads)

Anaxyrus houstonensis (Houston toad)

Anaxyrus woodhousii (Woodhouse's toad)

Leptodactylus fragilis (white-lipped frog)

Lithobates areolatus areolatus (southern crawfish frog)

Pseudacris streckeri (Strecker's chorus frog)

Rhinophrynus dorsalis (Mexican burrowing toad)

Smilisca baudinii (Mexican treefrog)

Order: Urodela (Salamanders)

Ambystoma tigrinum (eastern tiger salamander)

Desmognathus conanti, (spotted dusky salamander)

Eurycea chisholmensis (Salado Springs salamander)

Eurycea latitans (Cascade Caverns salamander)

Eurycea nana (San Marcos salamander)

Eurycea naufragia (Georgetown salamander)

Eurycea neotenes (Texas salamander)

Eurycea pterophila (Blanco River Springs salamander)

Eurycea rathbuni (Texas blind salamander)

Eurycea robusta (Blanco blind salamander)

Eurycea sosorum (Barton Springs salamander)

Eurycea tonkawae (Jollyville Plateau salamander)

Eurycea troglodytes (Valdina Farms sinkhole salamander)

Eurycea waterlooensis (Austin blind salamander)

Necturus beyeri (Gulf Coast waterdog)

Notophthalmus meridionalis (black-spotted newt)

Reptiles

Order Squamata (Scaled reptiles, e.g. snakes, lizards, and skinks)

Aspidoscelis dixoni (gray-checkered whiptail)

Drymobius margaritiferus (speckled racer)

Holbrookia lacerata (plateau spot-tailed earless lizard)

Holbrookia propinqua (keeled earless lizard)

Holbrookia subcaudalis (Tamaulipan spot-tailed earless lizard)

Ophisaurus attenuates (slender glass lizard)

Phrynosoma cornutum (Texas horned lizard)

Phrynosoma hernandesi (mountain short-horned lizard)

Sceloporus arenicolus (dunes sagebrush lizard)

Plestiodon septentrionalis (prairie skink)

Cemophora lineri (Texas scarlet snake)

Coniophanes imperialis (black-striped snake)

Ficimia streckeri (Mexican hooknose snake)

Leptodeira septentrionalis septentrionalis (northern cat-eyed snake)

Nerodia clarkii (salt marsh snake)

Nerodia harteri (Brazos water snake)

Nerodia paucimaculata (Concho water snake)

Pituophis ruthveni (Louisiana pine snake)

Sistrurus miliarius (pygmy rattlesnake)

Sistrurus tergeminus (western massasauga)

Tantilla atriceps (Mexican blackhead snake)

Tantilla cucullata (Trans-Pecos black-headed snake)

Thamnophis sirtalis (common garter snake)

Order: Testudines (Turtles and tortoises)

Apalone mutica (smooth softshell)

Caretta caretta (loggerhead sea turtle)

Chelonia mydas (green sea turtle)

Chrysemys dorsalis (southern painted turtle)

Deirochelys reticularia miaria (western chicken turtle)

Dermochelys coriacea (leatherback sea turtle)

Eretmochelys imbricata (Atlantic hawksbill sea turtle)

Gopherus berlandieri (Texas tortoise)

Graptemys caglei (Cagle's map turtle)

Graptemys versa (Texas map turtle)

Kinosternon hirtipes murrayi (Chihuahuan mud turtle)

Lepidochelys kempii (Kemp's Ridley sea turtle)

Macrochelys temminckii (alligator snapping turtle)

Malaclemys terrapin littoralis (Texas diamondback terrapin)

Pseudemys gorzugi (Rio Grande river cooter)

Terrapene carolina (eastern box turtle)

Terrapene ornata (western box turtle)

Trachemys gaigeae (Big Bend slider)

Freshwater fish

Family Acipenseridae

Scaphirhynchus platorynchus (shovelnose sturgeon)

Family Anguillidae

Anguilla rostrata (american eel)

Family Catostomidae

Cycleptus elongatus (blue sucker)

Erimyzon claviformis (western creek chubsucker)

Minytrema melanops (spotted sucker)

Moxostoma albidum (longlip jumprock)

Moxostoma austrinum (Mexican redhorse)

Family Centrarchidae

Micropterus treculii (Guadalupe bass)

Family Cyprinidae

Campostoma ornatum (Mexican stoneroller)

Campostoma spadiceum (highland stoneroller)

Cyprinella lepida (plateau shiner)

Cyprinella proserpina (proserpine shiner)

Dionda argentosa (manantial roundnose minnow)

Dionda diaboli (Devils River minnow)

Dionda episcopa (roundnose minnow)

Dionda flavipinnis (Guadalupe roundnose minnow)

Dionda nigrotaeniata (Medina roundnose minnow)

Dionda serena (Frio roundnose minnow)

Dionda texensis (Nueces roundnose minnow)

Gila pandora (Rio Grande chub)

Hybognathus amarus (Rio Grande silvery minnow)

Hybognathus nuchalis (Mississippi silvery minnow)

Hybognathus placitus (plains minnow)

Hybopsis amnis (pallid shiner)

Macrhybopsis aestivalis (speckled chub)

Macrhybopsis australis (prairie chub)

Macrhybopsis hyostoma (shoal chub)

Macrhybopsis marconis (burrhead chub)

Macrhybopsis storeriana (silver chub)

Macrhybopsis tetranema (peppered chub)

Notropis amabilis (Texas shiner)

Notropis atrocaudalis (blackspot shiner)

Notropis bairdi (Red River shiner)

Notropis blennius (river shiner)

Notropis braytoni (Tamaulipas shiner)

Notropis buccula (smalleye shiner)

Notropis chalybaeus (ironcolor shiner)

Notropis chihuahua (Chihuahua shiner)

Notropis girardi (Arkansas River shiner)

Notropis jemezanus (Rio Grande shiner)

Notropis maculatus (taillight shiner)

Notropis megalops (West Texas shiner)

Notropis oxyrhynchus (sharpnose shiner)

Notropis potteri (chub shiner)

Notropis sabinae (Sabine shiner)

Notropis shumardi (silverband shiner)

Phenacobius mirabilis (suckermouth minnow)

Platygobio gracilis (flathead chub)

Pteronotropis hubbsi (bluehead shiner)

Rhinichthys cataractae (longnose dace)

Family Cyprinodontidae

Cyprinodon bovinus (Leon Springs pupfish)

Cyprinodon elegans (Comanche Springs pupfish)

Cyprinodon eximius (Conchos pupfish)

Cyprinodon pecosensis (Pecos pupfish)

Cyprinodon rubrofluviatilis (Red River pupfish)

Family Hiodontidae

Hiodon alosoides (goldeye)

Family Ictaluridae

Ictalurus lupus (headwater catfish)

Prietella phreatophila (Mexican blindcat)

Satan eurystomus (widemouth blindcat)

Trogloglanis pattersoni (toothless blindcat)

Family Lepisosteidae

Atractosteus spatula (alligator gar)

Family Mugilidae

Agonostomus monticola (mountain mullet)

Family Percidae

Ammocrypta clara (western sand darter)

Etheostoma fonticola (fountain darter)

Etheostoma grahami (Rio Grande darter)

Etheostoma radiosum (orangebelly darter)

Etheostoma thompsoni (gumbo darter)

Percina apristis (Guadalupe darter)

Percina maculata (blackside darter)

Percina shumardi (river darter)

Family Poeciliidae

Gambusia gaigei (Big Bend gambusia)

Gambusia heterochir (Clear Creek gambusia)

Gambusia krumholzi (spotfin gambusia)

Gambusia nobilis (Pecos gambusia)

Gambusia senilis (Blotched Gambusia)

Family Polyodontidae

Polyodon spathula (paddlefish)

Marine Fish

Ray-finned fishes

Family: Atherinopsidae (neotropical silversides)

Menidia clarkhubbsi (Texas silverside)

Family: Carangidae (jacks, pompanos, jack mackerels, runners, trevallies, and scads)

Seriola dumerili (Greater amberjack)

Family: Centropomidae (snook)

Centropomus parallelus (fat snook)

Centropomus undecimalis (snook)

Family: Epinephelidae (groupers)

Mycteroperca bonaci (Black grouper)

Mycteroperca phenax (scamp)

Epinephelus flavolimbatus (Yellowedge grouper)

Family: Fundulidae

Fundulus jenkinsi (saltmarsh topminnow)

Family: Gobiidae (gobies)

Ctenogobius claytonii (Mexican goby)

Family: Istiophoridae (marlin)

Istiophorus platypterus (Sailfish)

Makaira nigricans (blue marlin)

Family: Megalopidae (tarpon)

Megalops atlanticus (Atlantic tarpon)

Family: Paralichthyidae (large tooth flounders)

Paralichthys lethostigma (southern flounder)

Family: Rachycentridae (cobia)

Rachycentron canadum (Gulf Cobia)

Family: Syngnathidae (seahorses, pipefishes, and seadragons)

Microphis brachyurus (opossum pipefish)

Family: Xiphiidae (swordfish)

Xiphias gladius (Swordfish)

Cartilaginous fishes

Family: Carcharhinidae (requiem sharks)

Carcharhinus acronotus (Blacknose shark)

Carcharhinus brevipinna (Spinner shark)

Carcharhinus falciformis (Silky shark)

Carcharhinus isodon (Finetooth Shark)

Carcharhinus leucas (Bull Shark)

Carcharhinus longimanus (oceanic whitetip shark)

Carcharhinus obscurus (Dusky shark)

Carcharhinus plumbeus (Sandbar shark)

Carcharhinus porosus (Smalltail shark)

Negaprion brevirostris (Lemon shark)

Rhizoprionodon porosus (Caribbean sharpnose shark)

Family: Lamnidae (mackerel sharks)

Isurus oxyrinchus (shortfin mako shark)

Family: Myliobatidae (eagle ray)

Manta birostris (Giant manta ray)

Family: Pristidae (sawfishes)

Pristis pectinata (smalltooth sawfish)

Pristis pristis (largetooth sawfish)

Family: Rhinobatidae (guitarfish)

Rhinobatos lentiginosus (Atlantic guitarfish)

Family: Sphyrnidae (hammerhead shark)

Sphyrna lewini (Scalloped hammerhead shark)

Sphyrna mokarran (great hammerhead)

Mammals

Family Antilocapridae (Pronghorn)

Antilocapra americana (pronghorn)

Family Balaenidae (Right and bowhead whales)

Eubalaena glacialis (North Atlantic right whale)

Family Balaenopteridae (Rorquals)

Balaenoptera acutorostrata (minke whale)

Balaenoptera borealis (sei whale)

Balaenoptera edeni (Gulf of Mexico's Bryde's whale)

Balaenoptera musculus (blue whale)

Balaenoptera physalus (finback whale)

Balaenoptera ricei (Rice's whale)

Megaptera novaeangliae (humpback whale)

Family Bovidae (cattle, bison, antelope, and others)

Bison bison (bison)

Ovis canadensis (desert bighorn sheep)

Family Canidae (Dogs)

Vulpes velox (swift fox)

Family Cricetidae (hamsters, voles, lemmings, muskrats

Microtus ochrogaster (prairie vole)

Oryzomys couesi (Coues' rice rat)

Oryzomys couesi aquaticus (Coues' rice rat)

Peromyscus truei comanche (Palo Duro mouse)

Sigmodon fulviventer (tawny-bellied cotton rat)

Family Delphinidae (Dolphins)

Feresa attenuata (pygmy killer whale)

Globicephala macrorhynchus (short-finned pilot whale)

Orcinus orca (killer whale)

Pseudorca crassidens (false killer whale)

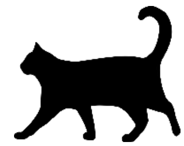
Stenella clymene (clymene dolphin)

Stenella frontalis (Atlantic spotted dolphin) *Stenella longirostris* (spinner dolphin)

Steno bredanensis (roughtoothed dolphin)

Tursiops truncatus (Atlantic bottlenosed dolphin)

Family Felidae (cats)



Leopardus pardalis (ocelot)

Puma concolor (mountain lion)

Family Geomyidae (pocket gophers)

Geomys arenarius (desert pocket gopher)

Geomys knoxjonesi (Jones's pocket gopher)

Geomys personatus davisi (Davis pocket gopher)

Geomys personatus maritimus (maritime pocket gopher)

Geomys streckeri (Strecker's pocket gopher)

Geomys texensis bakeri (Frio pocket gopher)

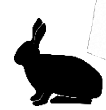
Geomys texensis texensis (Llano pocket gopher)

Thomomys bottae guadalupensis (Guadalupe southern pocket gopher) *Thomomys bottae limpiae* (Limpia southern pocket gopher)

Thomomys bottae texensis (Limpia Creek pocket gopher)

Family Heteromyidae (kangaroo rats, kangaroo mice, pocket mice)

Dipodomys compactus compactus (Padre Island kangaroo rat) *Dipodomys elator* (Texas kangaroo rat)



Liomys irroratus (Mexican spiny pocket mouse)

Family Leporidae (rabbits and hares)

Sylvilagus robustus (Davis Mountains cottontail)

Family Kogiidae (pygmy and dwarf sperm whales)

Kogia breviceps (pygmy sperm whale)

Kogia simus (dwarf sperm whale)

Family Mephitidae (skunks)

Mephitis macroura (hooded skunk)

Spilogale putorius (eastern spotted skunk)

Spilogale putorius interrupta (plains spotted skunk)

Family Mustelidae (weasels, badgers, otters)

Mustela nigripes (black-footed ferret)

Family Physeteridae (sperm whales)

Physeter macrocephalus (sperm whale)

Family Procyonidae (raccoon, ringtail, coati)

Nasua narica (white-nosed coati)

Family Sciuridae (Squirrels)

Cynomys ludovicianus (black-tailed prairie dog)

Tamias canipes (gray-footed chipmunk)

Family Soricidae (Shrew)

Blarina hylophaga hylophaga (Elliot's short-tailed shrew)

Blarina hylophaga plumbea (Aransas short-tailed shrew)

Family Trichechidae (manatees)

Trichechus manatus (West Indian manatee)

Family Ursidae (bears)

Ursus americanus (black bear)

Ursus americanus luteolus (Louisiana black bear)

Family Vespertilionidae (common bats)

Corynorhinus rafinesquii (Rafinesque's big-eared bat)

Corynorhinus townsendii (Townsend's big-eared bat)

Corynorhinus townsendii pallescens (pale Townsend's big-eared bat)

Euderma maculatum (spotted bat)

Eumops perotis (Western mastiff bat)

Eumops perotis californicus (greater western mastiff bat)

Lasiurus cinereus (hoary bat)

Lasiurus ega (southern yellow bat)

Lasiurus seminolus (Seminole bat)

Lasiurus xanthinus (western yellow bat)

Leptonycteris nivalis (Mexican long-nosed bat)

Mormoops megalophylla (ghost-faced bat)

Myotis austroriparius (southeastern myotis bat)

Myotis californicus (California myotis)

Myotis ciliolabrum (western small-footed myotis bat)

Myotis thysanodes (fringed myotis)

Myotis velifer (cave myotis bat)

Myotis volans (long-legged myotis bat)

Myotis yumanensis (Yuma myotis)

Nyctinomops femorosaccus (pocketed free-tailed bat)

Nyctinomops macrotis (big free-tailed bat)

Parastrellus hesperus (Western pipistrelle) *Perimyotis subflavus* (tricolored bat)

Family Ziphiidae (Beaked whales)

Mesoplodon densirostris (Blainville's beaked whale)

Mesoplodon europaeus (Gervais's beaked whale)

Ziphius cavirostris (Cuvier's beaked whale)

Birds

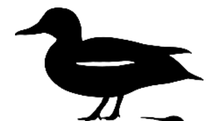
Family Accipitridae (hawks, eagles, kites, harriers and Old World vultures)

Buteo albonotatus **(Zone-tailed Hawk)**

Buteo plagiatus (**Gray Hawk**)

Buteogallus anthracinus (**Common Black-hawk**)

Elanoides forficatus (**Swallow-tailed Kite**)



Family Anatidae (ducks, geese, and swans)

Anas fulvigula (**Mottled Duck**)

Family Trochilidae (hummingbirds)

Calothorax lucifer (**Lucifer Hummingbird**)

Family Ardeidae (herons, egrets, and bitterns)

Butorides virescens (**Green Heron**)

Egretta rufescens (**Reddish Egret**)

Family Calcariidae (longspurs and snow buntings)

Calcarius ornatus (**Chestnut-collared Longspur**)

Rhynchophanes mccownii (**Thick-billed Longspur**)

Family Caprimulgidae (nightjars)

Antrostomus carolinensis (**Chuck-will's-widow**)

Chordeiles minor (**Common Nighthawk**),

Family Cardinalidae (cardinals)

Cardinalis sinuatus (**Pyrrhuloxia**),

Passerina versicolor (**Varied Bunting**)

Family Charadriidae (plovers and related)

Charadrius melodus (**Piping Plover**)

Charadrius montanus (**Mountain Plover**)

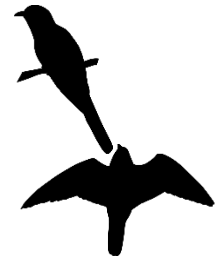
Charadrius nivosus (**Snowy Plover**)

Charadrius wilsonia (**Wilson's Plover**)

Family Family Ciconiidae (storks)

Mycteria americana (**Wood Stork**)

Family Cuculidae (cuckoos)



Coccyzus americanus (**Yellow-billed Cuckoo**)

Family Falconidae (falcons and caracaras)

Falco femoralis septentrionalis (**Northern Aplomado Falcon**)

Family Odontophoridae (quail)

Callipepla squamata (**Scaled Quail**)

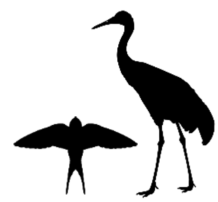
Colinus virginianus (**Northern Bobwhite**)

Family Phasianidae (turkeys, chickens and related)

Tympanuchus cupido attwateri **(Attwater's Greater Prairie-chicken)**

Tympanuchus pallidicinctus **(Lesser Prairie-chicken)**

Family Gruidae (cranes)



Grus americana (**Whooping Crane**)

Family Hirundinidae (swallows, martins, and related)

Riparia riparia (**Bank Swallow**)

Family Icteridae (grackles, New World blackbirds, and New World orioles)

Euphagus cyanocephalus (**Brewer's Blackbird**)

Quiscalus quiscula (**Common Grackle**)

Sturnella magna (**Eastern Meadowlark**)

Family Laniidae (shrikes)

Lanius ludovicianus (**Loggerhead Shrike**)

Family Laridae (gulls, terns, and skimmers)

Chlidonias niger (**Black Tern**)

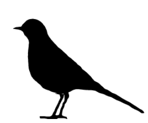
Leucophaeus pipixcan (**Franklin's Gull**)

Onychoprion fuscatus (**Sooty Tern**)

Rynchops niger (**Black Skimmer**)

Sternula antillarum (**Least Tern**)

Family Motacillidae (wagtails and pipits)



Anthus spragueii (**Sprague's Pipit**)

Family Parulidae (New World warblers)

Cardellina pusilla (**Wilson's Warbler**)

Leiothlypis virginiae (**Virginia's Warbler**)

Protonotaria citrea (**Prothonotary Warbler**)

Setophaga chrysoparia (**Golden-cheeked Warbler**)

Setophaga pitiayumi (**Tropical Parula**)

Family Passerellidae (New World sparrows)

Ammodramus savannarum (**Grasshopper Sparrow**)

Ammospiza leconteii (**Le Conte's Sparrow**)

Ammospiza maritima (**Seaside Sparrow**)

Calamospiza melanocorys (**Lark Bunting**)

Centronyx bairdii (**Baird's Sparrow**)

Centronyx henslowii (**Henslow's Sparrow**)

Peucaea botterii (**Botteri's Sparrow**)

Peucaea aestivalis (**Bachman's Sparrow**)

Spizella pusilla (**Field Sparrow**)

Zonotrichia querula (**Harris' Sparrow**)

Family Picidae (woodpeckers)

Dryobates borealis (**Red-cockaded Woodpecker**)

Melanerpes erythrocephalus (**Red-headed Woodpecker**)

Family Psittacidae (true parrots)

Amazona viridigenalis (**Red-crowned Parrot**)

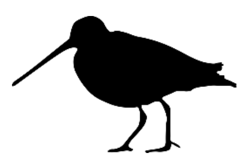
Family Rallidae (rails: crakes, coots, and gallinules)

Coturnicops noveboracensis (**Yellow Rail**)

Laterallus jamaicensis (**Black Rail**)

Rallus elegans (**King Rail**)

Family Scolopacidae (sandpipers, curlew, and snipes)



Calidris alba (**Sanderling**)

Calidris canutus rufa (**Rufa Red Knot**)

Limosa haemastica (**Hudsonian Godwit**)

Numenius borealis (**Eskimo Curlew**)

Tringa semipalmata (**Willet**)

Family Strigidae (owls)

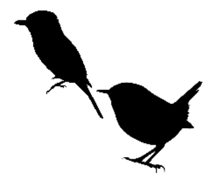
Asio flammeus (**Short-eared Owl**)

Glaucidium brasilianum (**Ferruginous Pygmy-owl**)

Micrathene whitneyi (**Elf Owl**)

Strix occidentalis lucida (**Mexican Spotted Owl**)

Family Tityridae (tityras and allies)



Pachyramphus aglaiae (**Rose-throated Becard**) G4G5, SNA

Family Troglodytidae (wrens)

Campylorhynchus brunneicapillus (**Cactus Wren**)

Family Tyrannidae (tyrant flycatchers)

Camptostoma imberbe (**Northern Beardless-tyrannulet**)

Empidonax traillii extimus (**Southwestern Willow Flycatcher**)

Family Vireonidae (vireos)

Vireo atricapilla (**Black-capped Vireo**)

Invertebrates

Class: Arachnida (spiders, harvestment, mites, and others)

Order: Araneae (spiders)

Cicurina bandera

Cicurina bandida (Bandit Cave spider)

Cicurina baronia (Robber Baron Cave meshweaver)

Cicurina barri

Cicurina browni

Cicurina buwata

Cicurina caverna

Cicurina coryelli

Cicurina ezelli

Cicurina gruta

Cicurina holsingeri

Cicurina machete

Cicurina madla (Madla Cave meshweaver)

Cicurina mckenziei

Cicurina medina

Cicurina menardia

Cicurina obscura

Cicurina orellia

Cicurina pablo

Cicurina pastura

Cicurina patei

Cicurina porteri

Cicurina puentecilla

Cicurina rainesi

Cicurina reclusa

Cicurina russelli

Cicurina sansaba

Cicurina selecta

Cicurina serena

Cicurina sheari

Cicurina sprousei

Cicurina stowersi

Cicurina suttoni

Cicurina travisae

Cicurina ubicki

Cicurina uvalde

Cicurina venefica

Cicurina vespera (Government Canyon Bat Cave meshweaver)

Cicurina vibora

Cicurina watersi

Eidmannella bullata (A cave cobweb spider)

Eidmannella delicata

Eidmannella nasuta

Eidmannella reclusa

Islandiana unicornis

Tayshaneta anopica

Tayshaneta concinna

Tayshaneta devia

Tayshaneta microps (Government Canyon Bat Cave spider)

Tayshaneta myopica (Tooth Cave spider)

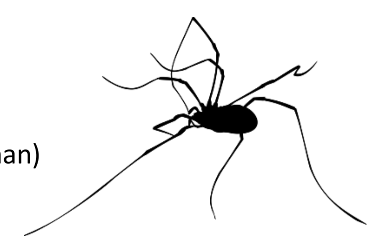
Tayshaneta valverde

Order: Opiliones (harvestmen/daddy long-legs)

Texella brevidenta

Texella brevistyla

Texella cokendolpheri (Cokendolpher Cave harvestman)



Texella diplospina

Texella fendi

Texella grubbsi

Texella hardeni

Texella mulaiki

Texella reddelli (Reddell harvestman)

Texella renkesae

Texella reyesi (Bone Cave harvestman)

Order: Pseudoscorpiones (pseudoscorpions)

Apocheiridium reddelli

Archeolarca guadalupensis (Guadalupe Cave pseudoscorpion)

Chitrella elliotti

Chitrella major

Dinocheirus cavicola

Leucohya texana

Tartarocreagris altimana

Tartarocreagris amblyopa

Tartarocreagris attenuata

Tartarocreagris domina

Tartarocreagris grubbsi

Tartarocreagris hoodensis

Tartarocreagris infernalis

Tartarocreagris intermedia

Tartarocreagris proserpina

Tartarocreagris reyesi

Tartarocreagris texana (Tooth Cave pseudoscorpion)

Tyrannochthonius troglodytes

Order: Scorpiones (scorpions)

Diplocentrus diablo

Paruroctonus williamsi

Vaejovis chisos

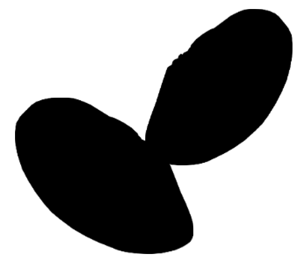
Order: Trombidiformes (mites)

Almuerzothyas comalensis (Euthyadine water mite (arachnid)) GNR, SU

Class: Bivalvia (bivalve molluscs)

Order: Unionoida (freshwater mussels)

Arcidens wheeleri (Ouachita rock pocketbook) G1, SU
ESA, Listed Endangered



Cyclonaias necki (Guadalupe orb) GNR, S2 ESA Proposed Endangered

Cyclonaias nodulata (Wartyback) S3

Cyclonaias petrina (Texas pimpleback) G1, S2 ESA Proposed Endangered

Cyclonaias pustulosa (Pimpleback) S3

Cyrtonaias tampicoensis (Tampico pearlymussel), S3

Fusconaia askewi (Texas pigtoe) G2?, S3

Fusconaia chunii (Trinity pigtoe) GNR, S2

Fusconaia iheringi (Balcones spike) GNR, S2

Fusconaia mitchelli (false spike) GNR, S2 ESA Proposed Endangered

Lampsilis bergmanni (Guadalupe fatmucket) G1, S2 ESA Proposed Endangered

Lampsilis bracteata (Texas fatmucket) G1, S2 ESA Proposed Endangered

Lampsilis hydiana (Louisiana fatmucket), S3

Lampsilis satura (sandbank pocketbook) G2?, S1

Leaunio lienosa (Little spectaclecase) S3

Obovaria arkansasensis (Ouachita Creekshell) GNR, S2

Pleurobema riddellii (Louisiana pigtoe) G1G2, S2

Popenaias popeii (Texas hornshell) G1, S2 ESA Listed Endangered

Potamilus amphichaenus (Texas heelsplitter) G1G3, S3

Potamilus metnecktayi (Salina mucket) G1, S2

Potamilus streckersoni (Brazos heelsplitter) GNR, S2

Quadrula quadrula (Mapleleaf) G5, S3

Sagittunio subrostrata (Pondmussel), S3

Strophitus undulatus (Creeper) G5, S3

Toxolasma parvum (Lilliput) G5, S3

Tritogonia nobilis (Gulf mapleleaf) S3

Tritogonia verrucosa (Pistolgrip) G4G5, S3

Truncilla cognata (Mexican fawnsfoot) G1, S2

Truncilla donaciformis (Fawnsfoot) S3

Truncilla macrodon (Texas fawnsfoot) G1, S3 ESA Proposed Threatened

Truncilla truncata (Deertoe) G5, S3

Uniomerus declivis (Tapered pondhorn) , S2

Class: Branchiopoda (fairy shrimp, clam shrimp, and others)

Order: Anostraca (fairy shrimp)

Dendrocephalus acacioidea (acacia fairy shrimp) G1, S1

Phallocryptus sublettei (Salt Playa Fairy Shrimp) G2, S3

Streptocephalus mattoxi (crenatethumb fairy shrimp) G1, S1

Order: Diplostraca (water fleas)

Paralimnetis texana (Texas paralimnetis, Pointytop Finger Clam Shrimp, branchiopod crustaceans) G1, S1

Class: Collembola (springtails)

Order: Entomobryomorpha

Oncopodura fenestra G2G3, S2

Class: Diplopoda (millipedes)

Order: Polydesmida

Speodesmus falcatus (Sickled Cave Millipede) GNR, S2

Speodesmus ivyi (Ivy's Cave Millipede) GNR, S2

Speodesmus reddelli (Reddell's Cave Millipede) GNR, S3

Class: Gastropoda (slugs and snails)

Order: Littorinimorpha (sea snails and other relative aquatic and terrestrial snails)

Assiminea pecos (Pecos assiminea snail) G1, S1 ESA Listed Endangered

Juturnia brunei (Brune's tryonia) G1, S1

Phreatoceras taylori (Nymph trumpet) G1G2, S3

Phreatodrobia conica G1, S2

Phreatodrobia coronae (crowned cavesnail) G1G2, S2

Phreatodrobia imitata (mimic cavesnail) G1, S1

Phreatodrobia micra G2G3, S2

Phreatodrobia plana G2, S2

Phreatodrobia punctata G2, S1

Phreatodrobia rotunda G1G2, S2

Pseudotryonia adamantina (Diamond Y springsnail) G1, S1 ESA Listed Endangered

Pyrgulopsis davisi (Limpia Creek spring snail) G1, S1

Pyrgulopsis ignota (Caroline's Springs pyrg) G1, S1

Pyrgulopsis metcalfi (Presidio County spring snail) G1, S1

Pyrgulopsis texana (Phantom springsnail) G1, S1 ESA Listed Endangered

Stygopyrgus bartonensis G1, S1

Texapyrgus longleyi (striated hydrobe) G1, S1

Tryonia cheatumi (Phantom tryonia) G1, S1 ESA Listed Endangered

Tryonia circumstriata (Gonzales tryonia) G1, S1 ESA Listed Endangered

Tryonia metcalfi (Metcalf's tryonia) G1, SNR

Tryonia oasiensis (Carolinae tryonia) G1, SNR

Order: Stylommatophora (air-breathing terrestrial snails and slugs)

Ashmunella bequaerti (Goat Cave woodlandsnail) G1, S3

Ashmunella carlsbadensis G1, S3

Ashmunella mudgei (Sawtooth Mountain woodlandsnail) G1, S1

Ashmunella pasonis (Franklin Mountain wood snail) G2G3, S1

Daedalochila hippocrepis (horseshoe liptooth) G1, S1

Euchemotrema leai cheatumi (Palmetto Pill Snail) G5T1, S1

Euglandina texasiana (Glossy Wolfsnail)

Holospira hamiltoni G1, S1

Holospira mesolia G1, S1

Holospira riograndensis G1, S1

Holospira yucatanensis G1, S1

Humboldtiana cheatumi (Davis Mountains threeband) G2, S2

Humboldtiana ferrissiana (Mitre Peak threeband) G2, S2

Humboldtiana fullingtoni (Capote threeband) G1, S1

Humboldtiana hoegiana praesidii (San Carlos Threeband) G3T3, S3

Humboldtiana palmeri (Mount Livermore threeband) G2, S2

Humboldtiana texana (Stockton Plateau threeband) G2, S2

Humboldtiana ultima (northern threeband) G2, S2

Millerelix gracilis G2G3, S2

Nesovitrea suzannae G1, S1

Patera leatherwoodi G1, S1

Praticolella candida G2, S2

Praticolella trimatris G2, S2

Pseudosubulina cheatumi (Chisos foxsnail) G1, S1

Sonorella huecoensis (Huecos Mountains talus snail)

Sonorella metcalfi (Franklin Mountain talus snail) G2, S1

Class: Insecta (joint-leg insects)

Order: Coleoptera (beetles)

Amblycheila hoversoni (Brush Hunter Tiger Beetle) G3, S3

Amblycheila picolominii (A Tiger Beetle) G3G4, S2

Anomala suavis GNR, S1

Anomala tibialis (Padre Island tibial scarab) GH, SH

Batrisodes cryptotexanus (Coffin Cave mold beetle) G2, S2

Batrisodes dentifrons

Batrisodes fanti

Batrisodes feminiclypeus

Batrisodes gravesi G3, S3

Batrisodes grubbsi (A beetle)

Batrisodes incispes G1, S1

Batrisodes pekinsi G1, S1

Batrisodes shadeae G1, S1

Batrisodes texanus (Coffin Cave mold beetle) ESA Listed Endangered

Batrisodes venyivi (Helotes mold beetle) G1, S1 ESA Listed Endangered

Batrisodes wartoni

Calleida fimbriata GNR, S2

Chaetocnema rileyi (Boca Chica flea beetle) GNR, S3

Cicindela cazieri (Cazier's tiger beetle) G2, S1

Cicindela celeripes (swift tiger beetle) G2G4, S2

Cicindela fulgoris albilata G4T3T4, S2

Cicindela hornii (A Tiger Beetle) G3G4, S3

Cicindela nevadica olmosa (Los Olmos tiger beetle) G5T2, S2

Cicindela nigrocoerulea subtropica (subtropical black sky tiger beetle) G5T2, SH

Cicindela obsoleta neojuvenilis (neojuvenile tiger beetle) G5T1, SH

Comaldessus stygius (Comal Springs diving beetle) G1, S1

Cryptocephalus downiei G1, SH

Ereboporus naturaconservatus GNR, S1

Haideoporus texanus (Edwards Aquifer diving beetle)

Heterelmis comalensis (Comal Springs riffle beetle) G1, S1 ESA Listed Endangered

Heterobrenthus texanus GNR, S1

Lymantes nadineae GNR, S2

Nicrophorus americanus (American burying beetle) G3, S1 ESA Listed Endangered

Ormiscus albofasciatus GNR, S2

Ormiscus irroratus GNR, S1

Pachyschelus fisheri GNR, S1

Phoenicobiella schwarzii GNR, S2

Photuris flavicollis (Sky Island Firefly) IUCN Vulnerable

Polyphylla monahansensis (Monahans lined june beetle) GNR, S2

Polyphylla pottsorum GNR, S1

Psychopomporus felipi GNR, S1

Pyractomena vexillaria (Amber Comet Firefly) IUCN Endangered

Rhadine austinica

Rhadine exilis G3, S1 ESA Listed Endangered

Rhadine infernalis G2G3, S1 ESA Listed Endangered

Rhadine infernalis ewersi G2G3T1, S1

Rhadine infernalis infernalis G2G3T2T3, S1

Rhadine insolita

Rhadine koepkei G1, S1

Rhadine noctivaga

Rhadine persephone (Tooth Cave ground beetle) ESA Listed Endangered

Rhadine russelli

Rhadine speca G2, S2

Rhadine speca gentilis G2T1, S1

Rhadine speca speca G2T1, S1

Rhadine subterranea G2, S2

Rhadine tenebrosa

Salimuzzamania howdeni GNR, S1

Spectralia prosternalis GNR, S2

Stygoparnus comalensis (Comal Springs dryopid beetle) ESA Listed Endangered

Texamaurops reddelli (Kretschmarr Cave mold beetle) ESA Listed Endangered

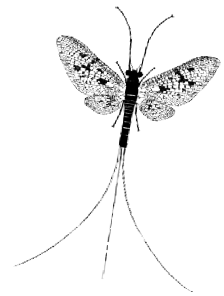
Trichodesma pulchella GNR, S1

Trigonogya reticulaticollis GNR, S1

Trigonoscutoides texanus GNR, S2

Order: Ephemeroptera (mayflies)

Baetodes alleni (A Mayfly)



Baetodes alleni Caenis arwini G1G3, S2

Farrodes mexicanus G1G2, SNR

Latineosus cibola G1G2, SNR

Plauditus texanus G2G3, S1

Procloeon distinctum (a small minnow mayfly) G1G3Q, S2

Pseudocentroptiloides morihari G2G3, S2

Sparbarus coushatta (A small square-gilled mayfly) G1G2, SNR

Susperatus tonkawa G1, SNR

Tortopus circumfluus G1G3, S2

Tricorythodes curvatus G1G3, S2

Order: Hymenoptera (ants, wasps, and bees)

Anthidium michenerorum (A Wool-carder Bee) G2

*Anthophora chihuahua (*A Digger Bee) G2, SNR

*Anthophora fedorica (*Fedor Digger Bee*)* G2, SNR

*Anthophora vallorum (*A Digger Bee*)* G2, SNR

Bombus fervidus (Yellow Bumble Bee) IUCN Vulnerable

Bombus fraternus (Southern Plains Bumble Bee) IUCN Endangered

Bombus morrisoni (Morrison Bumble Bee) IUCN Endangered

Bombus pensylvanicus (American Bumble Bee) G3G4, SNR, IUCN Vulnerable

Bombus variabilis (Variable Cuckoo Bumble Bee) G1G2, SNR, IUCN Critically Endangered

*Megachile amica (*A Leafcutter Bee*) G2*

*Megachile bruneri (*A Leafcutter Bee*) G2*

Megachile dakotensis (A Leafcutter Bee*) G2*

*Megachile deflexa (*A Leafcutter Bee*) G2*

Megachile fortis (Robust Sunflower Leafcutter Bee) G2

*Megachile integra (*A Leafcutter Bee*) G2*

*Megachile melanderi (*A Leafcutter Bee*) G2*

*Megachile oenotherae (*A Leafcutter Bee*) G2*

*Megachile parksi (*A Leafcutter Bee*) GH, SNR*

Megachile rugifrons (A Leafcutter Bee*) G2*

*Megachile victoriana (*A Leafcutter Bee*) GH*

*Osmia illinoensis (*A Mason Bee*) G1*

Osmia watsoni (A Mason Bee) G2

Perdita dolanensis (Dolan Falls perdita) G1, S1

Pogonomyrmex comanche (Comanche harvester ant) G2G3, S2

Order: Lepidoptera (butterflies and moths)

Adhemarius blanchardorum (Blanchards' sphinx moth) G1, S1

Agapema galbina (Tamaulipan agapema) G1, SH

Automeris zephyria (Zephyr eyed silkmoth) G2G3, S2

Cisthene conjuncta (white-streaked lichen moth) G1Q, S1

Euproserpinus wiesti (Wiest's Sphinx Moth) G3, S1

Hemileuca chinatiensis (Chinati sheepmoth) G3, S2

Lintneria eremitoides (sage sphinx moth) G2, S1

Pygarctia lorula G2G3, S2

Sphingicampa blanchardi G1, S1

Apodemia chisosensis (Chisos metalmark) G2, S1

Atrytone arogos (Arogos Skipper) IUCN Endangered

Celotes limpia (scarce streaky-skipper) G3, S2

Danaus plexippus ssp. plexippus (Migratory Monarch Butterfly) IUCN Endangered

Erynnis martialis G3, S1

*Euphyes bayensis (*bay skipper*) G2G3, S1*

*Hesperia ottoe (*Ottoe Skipper*)* IUCN Endangered

*Piruna haferniki (*Chisos skipperling*) G2G3, S1*

*Satyrium polingi (*Poling's hairstreak*) G3, S1*

Stallingsia maculosus (Manfreda giant-skipper) G1, S1

Order: Odonata (dragonflies and damselflies)

Argia leonorae (Leonora's Dancer Damselfly) G3, S2

Cordulegaster sarracenia (Sarracenia Spiketail) IUCN Endangered

Gomphus gonzalezi (Tamaulipan clubtail dragonfly) G2, S2

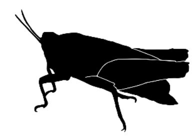
Leptobasis melinogaster (Cream-tipped Swampdamsel) IUCN Vulnerable

Somatochlora margarita (Texas emerald dragonfly) G2G3, S2

Order: Orthoptera (grasshoppers and crickets)

Amblycorypha uhleri (Uhler's Virtuoso Katydid) G2G3, SNA SNA

*Cibolacris samalayucae (*Samalayuca Dune grasshopper*) G2?, S2*



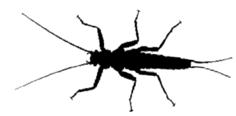
*Heliastus subroseus (*Rose-wing beach grasshopper*) G2G3, S2*

*Melanoplus alexanderi (*Spur-throat grasshopper*) G1G2, S2*

*Schistocerca camerata (*A Grasshopper*) GNR, S1*

Order: Plecoptera (stoneflies)

*Isoperla jewetti (*grande stripetail*) G1, S1*



*Isoperla sagittata (*arrowhead stripetail*) G1, S1*

*Taeniopteryx starki (*Texas willowfly*) G1, S1*

Order: Trichoptera (caddisflies)

Austrotinodes texensis (Texas austrotinodes caddisfly) G2, S2

*Cheumatopsyche flinti (*Flint's Net-spinning Caddisfly*) G3, S3*

*Cheumatopsyche morsei (*Morse's net-spinning caddisfly*) G1G3, S1*

*Chimarra holzenthali (*Holzenthal's philopotamid caddisfly*)*

*Hydroptila melia (*purse casemaker caddisfly*) G2G3, S2*

Hydroptila ouachita

Limnephilus adapus G1, S1

Nectopsyche texana G1G3, S2

Neotrichia juani G1, S1

Neotrichia mobilensis

Neotrichia sonora G1, S1

Ochrotrichia capitana G1G3, S2

Ochrotrichia guadalupensis

Phylocentropus harrisi

*Protoptila arca (*San Marcos saddle-case caddisfly*)* G1, S1

*Protoptila balmorhea (*Balmorhea saddle-case caddisfly*)* G1, S1

Xiphocentron messapus G1G3, S2

Class: Malacostraca (crabs lobsters shrimps and more)

Order: Amphipoda (malacostracan crustaceans with no carapace and generally with laterally compressed bodies)

Artesia subterranea (Subterranean amphipod crustacean) G1G2, S2

Artesia welbourni G1G2, S3

Gammarus hyalelloides (diminutive amphipod) G1, S1 ESA Listed Endangered

Gammarus pecos (Pecos amphipod) G1, S1 ESA Listed Endangered

Hyalella texana (Clear Creek amphipod) G1, S1

Mexiweckelia hardeni G2G3, S2

Monodella texana (A Cave Obligate Crustacean) G2G3, S1

Paraholsingerius smaragdinus GNR, S2

Paramexiweckelia ruffoi G1G2, S2

Seborgia hershleri G1G2, S2

*Stygobromus alabamensis (*A Cave Obligate Amphipod) G5, S1

Stygobromus balconis (Balcones Cave amphipod) G2G3, S2

Stygobromus bifurcatus (Bifurcated Cave Amphipod) G3G4, S3

Stygobromus dejectus (Cascade Cave amphipod)

Stygobromus flagellatus (Ezell's Cave amphipod) G2G3, S3

Stygobromus hadenoecus (Devil's Sinkhole amphipod) G1G2, S2

Stygobromus limbus (Border Cave amphipod) G1G2, S3

Stygobromus pecki (Peck's Cave amphipod) ESA Listed Endangered

Stygobromus reddelli (Reddell's Cave amphipod)

Texiweckelia texensis G2G3, S2

Texiweckeliopsis insolita G3, S2

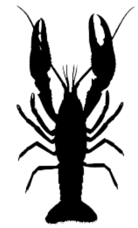
Order: Bathynellacea

Texanobathynella bowmani (Crustacean, freshwater) GNR, S3

Order: Decapoda (crabs, lobsters, crayfish, shrimp and prawns)

Calathaemon holthuisi (Purgatory Cave shrimp)

Cambarellus texanus (A Crayfish) G3G4, S3



Fallicambarus devastator (Texas Prairie Crayfish) G3, S2

*Fallicambarus houstonensis (*Houston burrowing crayfish) G2, S3

Fallicambarus kountzeae (Big Thicket burrowing crayfish) G2, S3

Faxonella blairi G2, SNR

Orconectes maletae (Kisatchie painted crayfish) G2, S2

Palaemonetes texanus (Texas river shrimp)

Procambarus brazoriensis (Brazoria crayfish) G1, S1

Procambarus nechesae (Neches crayfish) G2, S1

Procambarus nigrocinctus (blackbelted crayfish)

Procambarus nueces (Nueces crayfish) G1, S1

Procambarus regalis (regal burrowing crayfish) G2G3, SNR

Procambarus steigmani (Parkhill Prairie crayfish)

Procambarus texanus (Bastrop crayfish) G1, S1

Order: Isopoda (woodlice and relatives)

Brackenridgia reddelli G2G3, S2

Caecidotea bilineata G2G3, S1

Cirolanides texensis (A cave obligate isopod) G4, S3

Lirceolus bisetus

Lirceolus cocytus GNR, S1

Lirceolus nidulus GNR, S3

Lirceolus smithii (Texas troglobitic water slater)

Speocirolana hardeni G2G3, S2

Class: Maxillopoda (ostracods, copepods, barnacles and others)

Order: Harpacticoida

Nitocrellopsis texana GNR, SU

Class: Ostracoda (seed shrimp)

Order: Podocopida

Bicornucandona fineganensis GNR, SU

Class: Turbellaria (non-exclusively parasitic flatworms)

Order: Tricladida (planarians)

Sphalloplana mohri (A Cave Obligate Planarian) G3G4, S3

Plants

Class: Bryopsida (true mosses)

Family: Brachytheciaceae (mosses)

Donrichardsia macroneuron (Don Richards' spring moss) G1 S1

Eudicot Clade: Flowering plants that are dicots (two seed leaves)

Family: *Acanthaceae (*acanthus)

Justicia runyonii (Runyon's water-willow) G2 S2

Justicia warnockii (Warnock's water-willow) G3 S3

Justicia wrightii (Wright's water-willow) G2 S1

Family: *Aizoaceae:* (fig-marigold or ice plants)

Sesuvium trianthemoides (roughseed sea-purslane) GH SH

Family: *Amaryllidaceae* (amaryllis)

Allium canadense var. ***ecristatum*** (crestless onion) G5T3 S3

Allium elmendorfii (Elmendorf's onion) G2 S2

Atriplex klebergorum (Kleberg saltbush) G2 S2

Tidestromia carnosa (fleshy tidestromia) G3 S2

Zephyranthes jonesii (Jones's rainlilly) G3Q S3

Zephyranthes traubii (Traub's rainlily) G3 S3

Family*: Apiaceae* (carrots)

Osmorhiza bipatriata (Livermore sweet-cicely) G5T1 S1 State Threatened

Eurytaenia hinckleyi (Hinckley's spreadwing) G3 S3

Tauschia texana (Texas tauschia) G3 S3

Family: *Apocynaceae* (dogbane)

Amsonia tharpii (Tharp's blue-star) G1 S1

Asclepias prostrata (prostrate milkweed) G1G2 S1

Matelea atrostellata (black corona milkvine) G1? S1

Matelea brevicoronata (shortcrown milkvine) G3 S3

Matelea edwardsensis (plateau milkvine) G3 S3

Matelea radiata (Falfurrias milkvine) G1 S1

Matelea sagittifolia (arrowleaf milkvine) G3 S3

Matelea texensis (Texas milkvine) G1 S1

Family: Asparagaceae (asparagus)

Echeandia chandleri (lila de los Llanos) G2G3 S2

Echeandia texensis (Green Island echeandia) G1 S1

Echinacea atrorubens (Topeka purple-coneflower) G3 S3

Family: *Asteraceae* (daisy)

Shinnersia rivularis (springrun whitehead) G2G3 S1

Ambrosia cheiranthifolia (South Texas ambrosia) G2 S1 ESA Endangered State Endangered

Brickellia baccharidea (resin-leaf brickellbush) G3 S1

Brickellia dentata (gravelbar brickellbush) G3G4 S3

Brickellia eupatorioides var. *gracillima* (narrowleaf brickellbush) G5T3 S3

Brickellia hinckleyi var. hinckleyi (Hinckley's brickellbush) G2T2 S2

Brickellia hinckleyi var. terlinguensis (Terlingua brickellbush) G2TH SH

Brickellia parvula (Mt. Davis brickellbush) G3 S1

Chaetopappa hersheyi (mat leastdaisy) G3 S2

Chaetopappa imberbis (awnless leastdaisy) G3 S3

Chaetopappa parryi (Parry's leastdaisy) G3 S1

Chrysothamnus spathulatus (Douglas rabbitbrush) G3 S2

Cirsium turneri (cliff thistle) G3 S3

Cirsium wrightii (Wright's marsh thistle) G2 ESA Proposed

Coreopsis intermedia (goldenwave tickseed) G3 S3

Encelia scaposa (one-head encelia) G3 S2

Ericameria nauseosa var. *texensis* (Guadalupe Mountains rabbitbrush) G5T2T3, S1

Flyriella parryi (Shinner's brickellbush) G3 S3

Gaillardia aestivalis var. winkleri (white firewheel) G5T2 S2

Grindelia oolepis (plains gumweed) G2 S2

Helianthus neglectus (neglected sunflower) G2Q S2

Helianthus paradoxus (Pecos sunflower) G2 S1 ESA Threatened State Threatened

Helianthus praecox ssp. hirtus (Dimmit sunflower) G4T2Q S2

Helianthus praecox ssp. praecox (Texas sunflower) G4T2 S2

Hymenopappus biennis (biennial woolywhite) G3G4 S2

Hymenopappus carrizoanus (sandhill woolywhite) G2 S2

Hymenoxys perpygmaea (pygmy prairie dawn) G1 S1

Hymenoxys texana (Texas prairie dawn) G2 S2 ESA Endangered State Endangered

Hymenoxys vaseyi (Vasey's bitterweed) G2 S1

Laennecia turnerorum (Turner's horseweed) G1 S1

Lepidospartum burgessii (gypsum scalebroom) G2 S1 State Threatened

Leucosyris blepharophylla (gypsum hotspring aster) G1 S1

Leucosyris mattturneri (Matt Turner's aster) G1 S1

Liatris bracteata (coastal gay-feather) G2G3 S2

Liatris cymosa (branched gay-feather) G2 S2

Liatris glandulosa (glandular gay-feather) G3 S2

Liatris tenuis (slender gay-feather) G3 S3

Packera texensis (Llano butterweed) G2 S2

Perityle aglossa (limestone rock-daisy) G3G4 S3

Perityle angustifolia (rayless rock-daisy) G3G4 S3

Perityle bisetosa var. appressa (apressed two-bristle rock-daisy) G2T2 S2

Perityle bisetosa var. bisetosa (two-bristle rock-daisy) G2T2 S2

Perityle bisetosa var. scalaris (stairstep two-bristle rock-daisy) G2T1 S1

Perityle cinerea (grayleaf rock-daisy) G2 S2

Perityle dissecta (slimlobe rock-daisy) G2 S2

Perityle fosteri (Foster's rock-daisy) G1 S1

Perityle huecoensis (Hueco rock-daisy) G1 S1

Perityle lindheimeri var. halimifolia (Devils River rock-daisy) G4T3Q S3

Perityle rupestris var. albiflora (whiteflower leafy rock-daisy) G4T3 S3

Perityle rupestris var. rupestris (leafy rock-daisy) G4T3 S3

Perityle vitreomontana (Glass Mountains rock-daisy) G1 S1

Perityle warnockii (Warnock's rock-daisy) G1 S1

Pinaropappus parvus (little rock lettuce) G3 S3

Prenanthes barbata (barbed rattlesnake-root) G3 S3

Prenanthes carrii (canyon rattlesnake-root) G2 S2

Pseudoclappia arenaria (cienega false clappia-bush) G3 S3

Pseudoclappia watsonii (Watson's false clappia-bush) G1 S1

Pseudognaphalium arizonicum (Arizona cudweed) G3G4 S3

Pseudognaphalium austrotexanum (South Texas false cudweed) G3 S3

Psilactis heterocarpa (Welder machaeranthera) G2G3 S2

Rayjacksonia aurea (Houston daisy) G1 S1 State Threatened

Rudbeckia scabrifolia (bog coneflower) G3G4 S2

Senecio quaylei (Quayle's butterweed) G1Q S1

Symphyotrichum puniceum var. scabricaule (rough-stem aster) G5T2 S1

Tetraneuris turneri (Billie's bitterweed) G3 S3

Thelesperma burridgeanum (Burridge greenthread) G3 S3

Thurovia triflora (threeflower broomweed) G2G3 S2

Thymophylla tephroleuca (ashy dogweed) G2 S2 ESA Endangered State Endangered

Trichocoronis wrightii var. wrightii (Wright's trichocoronis) G4T3 S2

Xanthisma viscidum (sticky tansy aster) G3 S2

Xylorhiza wrightii (Wright's machaeranthera) G3 S3

Family: *Berberidaceae* (barberry)

Berberis swaseyi (Texas barberry) G3 S3

Family: *Betulaceae (*birch)

Ostrya chisosensis (Big Bend hop-hornbeam) G2 S1

Family: *Boraginaceae* (forget-me-nots)

Cryptantha crassipes (Terlingua Creek cat's-eye) G1 S1 ESA Endangered State Endangered

Cryptantha paysonii (Payson's hiddenflower) G3 S1

Onosmodium helleri (Heller's marbleseed) G3 S3

Family: *Brassicaceae* (mustards)

Physaria angustifolia (threadleaf bladderpod) G3 S1

Physaria mcvaughiana (McVaugh's bladderpod) G3 S3

Physaria pallida (white bladderpod) G1 S1 ESA Endangered State Endangered

Physaria thamnophila (Zapata bladderpod) G1G2 S1 ESA Endangered State Endangered

Physaria valida (strong bladderpod) G3 S1

Cardamine macrocarpa var. *texana* (Texas largeseed bittercress) G3T2 S2

Draba standleyi (Standley's draba) G2G3 S1

Leavenworthia texana (Texas golden gladecress) G1 S1 ESA Endangered State Endangered

Rorippa ramosa (Durango yellow-cress) G2 S1

Selenia grandis (large selenia) G3 S3

Selenia jonesii (Jones' selenia) G3 S3

Stanleya pinnata var. texana (Texas golden prince's-plume) G5T1 S1

Streptanthus bracteatus (bracted twistflower) G1 S1 ESA Proposed

Streptanthus carinatus ssp. carinatus (lyreleaf twistflower) G4T3T4 S3

Streptanthus cutleri (Cutler's twistflower) G2 S2

Streptanthus maculatus ssp. maculatus (clasping twistflower) G3T2T3Q S2

Streptanthus platycarpus (broadpod twistflower) G3 S3

Streptanthus sparsiflorus (sparsely-flowered jewelflower) G2Q S1

Thelypodiopsis shinnersii (Shinner's rocket) G2G3 S2

Thelypodium texanum (Texas thelypody) G3 S3

Family: *Buddlejaceae* (buddleja)

Emorya suaveolens (Emory-bush) G3 S1

Family: *Cactaceae* (cactus)

Astrophytum asterias (star cactus) G1G2 S1 ESA Endangered State Endangered

Coryphantha macromeris var. runyonii (Runyon's cory cactus) G5T2T3 S2

Coryphantha nickelsiae (Nickels' cory cactus) G2 SH

Coryphantha ramillosa ssp. ramillosa (bunched cory cactus) G2G3T2T3 S2 ESA Threatened State Threatened

Coryphantha scheeri var. uncinata (Scheer's cory cactus) G4TUQ S2

Echinocereus chisosensis (Chisos Mountains hedgehog cactus) G2T1 S1 ESA Threatened State Threatened

Echinocereus chloranthus var. neocapillus (golden-spine hedgehog cactus) G4T1 S1

Echinocereus coccineus var. paucispinus (Texas claret-cup cactus) G5T3 S3

Echinocereus davisii (Davis' green pitaya) G5T1 S1 ESA Endangered State Endangered

Echinocereus milleri (Miller's hedgehog cactus) G1 S1

Echinocereus papillosus (yellow-flowered alicoche) G3 S3

Echinocereus reichenbachii var. albertii (black lace cactus) G5T1Q S1 ESA Endangered State Endangered

Echinocereus reichenbachii var. baileyi (Bailey's hedgehog cactus) G5T3 S1

Echinocereus reichenbachii var. fitchii (Fitch's hedgehog cactus) G5T3 S3

Echinocereus viridiflorus var. canus (graybeard cactus) G5T1 S1

Echinocereus viridiflorus var. correllii (Correll's green pitaya) G5T2 S2

Epithelantha bokei (Boke's button cactus) G4T3 S3

Escobaria albicolumnaria (white column cactus) G2G3 S2

Escobaria dasyacantha var. chaffeyi (Chaffey's cory cactus) G3T1 S1

Escobaria dasyacantha var. dasyacantha (dense cory cactus) G3T3 S3

Escobaria dasyacantha var. duncanii (Duncan's cory cactus) G3T2T3 S1

Escobaria guadalupensis (Guadalupe Mountains pincushion cactus) G1 S1

Escobaria hesteri (Hester's cory cactus) G2 S2

Escobaria minima (Nellie's cory cactus) G1 S1 ESA Endangered State Endangered

Escobaria sneedii var. sneedii (Sneed's pincushion cactus) G2G3QT2Q S2 ESA Endangered State Endangered

Mammillaria wrightii var. wrightii (Wright's fishhook cactus) G4T3 S1

Opuntia arenaria (sand prickly-pear) G2 S2

Opuntia aureispina (golden-spine prickly-pear) G1 S1

Opuntia imbricata var. argentea (silver cholla) G5T1 S1

Peniocereus greggii var. greggii (desert night-blooming cereus) G3G4T3 S2

Sclerocactus brevihamatus ssp. tobuschii (Tobusch fishhook cactus) G4T3 S3 ESA Threatened State Endangered

Sclerocactus mariposensis (Lloyd's mariposa cactus) G3 S2 ESA Threatened State Threatened

Thelocactus bicolor var. flavidispinus (straw-spine glory-of-Texas) G4T2 S2

Family: *Campanulaceae* (bellflower)

Campanula reverchonii (basin bellflower) G2 S2

Family: *Capparaceae* (caper)

Polanisia erosa ssp. *breviglandulosa* (South Texas yellow clammyweed) G5T3T4 S3

Peritoma multicaulis (manystem spiderflower) G2G3 S1

Family: Caryophyllaceae (pinks)

Geocarpon minimum (earth fruit) G2 S1 ESA Threatened State Threatened

Paronychia congesta (bushy whitlow-wort) G1 S1

Paronychia jonesii (Jones' nailwort) G3G4 S3

Paronychia maccartii (McCart's whitlow-wort) GH SH

Paronychia setacea (bristle nailwort) G3 S2

Paronychia wilkinsonii (Wilkinson's whitlow-wort) G2G3 S2

Silene plankii (Plank's catchfly) G2 S1

Silene subciliata (scarlet catchfly) G3 S3

Arenaria livermorensis (Livermore sandwort) G1 S1

Family: *Cistaceae* (rock roses)

Lechea mensalis (Chisos pinweed) G1 S1

Family: Cleomaceae

Cleomella longipes (stalked rhombopod) G3G4 S3

Family: *Convolvulaceae* (bindweeds)

Bonamia ovalifolia (bigpod bonamia) G1 S1

Cuscuta attenuata (marsh-elder dodder) G1G3 S2

Cuscuta exaltata (tree dodder) G3 S3

Ipomoea shumardiana (Shumard's morning glory) G2G3 S1

Family: *Crassulaceae* (stonecrops)

Lenophyllum texanum (Texas stonecrop) G3 S3

Sedum havardii (Havard's stonecrop) G2 S2

Family: Crossosomataceae

Glossopetalon texense (Texas greasebush) G1 S1

Family: *Cucurbitaceae* (gourds)

Sicyos glaber (smooth bur-cucumber) G3 S1

Family: *Euphorbiaceae* (spurge)

Adelia vaseyi (Vasey's adelia) G3 S3

Argythamnia aphoroides (Hill Country wild-mercury) G2G3 S3

Argythamnia argyraea (silvery wild-mercury) G2 S2

Croton alabamensis var. *texensis* (Texabama croton) G3T2 S2

Croton coryi (Cory's croton) G3 S3

Croton pottsii var. *thermophilus* (leatherweed croton) G5T1 S1

Croton suaveolens (scented croton) G3 S2

Euphorbia astyla (alkali spurge) G2 S1

Euphorbia chaetocalyx var. triligulata (three-tongue spurge) G5T1 S1

Euphorbia geyeri var. wheeleriana (Wheeler's spurge) G5T2 S1

Euphorbia golondrina (swallow spurge) G2 S2

Euphorbia innocua (velvet spurge) G3 S3

Euphorbia jejuna (dwarf broomspurge) G2 S2

Euphorbia peplidion (low spurge) G3 S3

Euphorbia perennans (perennial broomspurge) G3 S3

Euphorbia simulans (Big Bend spurge) G3 S3

Euphorbia strictior (tall plains spurge) G3 S3

Manihot walkerae (Walker's manioc) G2 S1 ESA Endangered

Phyllanthus abnormis var. riograndensis (sand sheet leaf-flower) G5T3 S3

Phyllanthus ericoides (heather leaf-flower) G2 S1

Tragia nigricans (darkstem noseburn) G3 S3

Family: Fabaceae (legumes or beans)

Amorpha laevigata (smooth indigobush) G3? S1

Amorpha paniculata (panicled indigobush) G3 S3

Amorpha roemeriana (Texas amorpha) G3 S3

Astragalus gypsodes (gyp locoweed) G3 S2

Astragalus mollissimus var. coryi (Cory's woolly locoweed) G5T3 S3

Astragalus mollissimus var. marcidus (withered woolly loco) G5T2 S2

Astragalus reflexus (Texas milk vetch) G3 S3

Astragalus soxmaniorum (Soxman's milkvetch) G3 S3

Astragalus waterfallii (Waterfall's milkvetch) G3? S3

Astragalus wrightii (Wright's milkvetch) G3 S3

Bauhinia lunarioides (Anacacho orchid tree) G3 S1

Brongniartia minutifolia (little-leaf brongniartia) G2 S1

Caesalpinia phyllanthoides (South Texas rushpea) G2? S1

Calliandra biflora (two-flower stick-pea) G3 S3

Dalea austrotexana (dune dalea) G2 S2

Dalea bartonii (Cox's dalea) G1 S1

Dalea hallii (Hall's prairie clover) G3 S2

Dalea reverchonii (Comanche Peak prairie clover) G2 S2

Dalea sabinalis (Sabinal prairie clover) GH SH

Dermatophyllum guadalupense (Guadalupe Mountains mescal bean) G2 S1

Desmanthus reticulatus (net-leaf bundleflower) G3 S3

Desmodium lindheimeri (Lindheimer's tickseed) G3G4 S1

Eysenhardtia spinosa (spiny kidney-wood) G2 S2

Galactia watsoniana (Watson's milk-pea) G1 S1

Genistidium dumosum (brush-pea) G1 S1 State Threatened

Hoffmannseggia drummondii (Drummond's rushpea) G3 S3

Hoffmannseggia tenella (slender rush-pea) G1 S1 ESA Endangered

Nissolia platycalyx (broadsepal nissolia) G3 S1

Pediomelum cyphocalyx (turnip-root scurfpea) G3G4 S2

Pediomelum humile (Rydberg's scurfpea) G1 S1

Pediomelum pentaphyllum (Chihuahua scurfpea) G1G2 SH

Pediomelum reverchonii (Reverchon's scurfpea) G3 S3

Phaseolus texensis (canyon bean) G2 S2

Pomaria austrotexana (stinking rushpea) G3 S3

Pomaria brachycarpa (broadpod rushpea) G2 S2

Senna orcuttii (Orcutt's senna) G2 S2

Senna ripleyana (Ripley's senna) G1 SH

Family: Fagaceae (beeches, chestnuts, and oaks)

Quercus arkansana (Arkansas oak) G3 S1

Quercus boyntonii (Boynton's oak) G1 SH

Quercus carmenensis (Sierra del Carmen oak) G2? S1

Quercus depressipes (Mexican dwarf oak) G3 S1

Quercus graciliformis (Chisos oak) G1 S1

Quercus hinckleyi (Hinckley's oak) G2 S2 ESA Threatened State Threatened

Quercus robusta (robust oak) G1Q S1

Quercus tardifolia (lateleaf oak) G1 S1

Family: *Frankeniaceae* (sea heath)

Frankenia johnstonii (Johnston's frankenia) G3 S3

Family: *Gentianaceae* (gentians)

Bartonia paniculata ssp. texana (Texas screwstem) G2G3 S2

Gyrandra blumbergiana (Blumberg's centaury) G1 S1

Family: *Hydrangeaceae* (hydrangeas)

Fendlera linearis (stiff fendlerbush) G3 S1

Philadelphus texensis var. *ernestii* (canyon mock-orange) G3T3 S3

Philadelphus texensis var. *texensis* (Texas mock-orange) G3T2 S2

Family: Hydrophyllaceae

Nemophila sayersensis (Sayersville blue eyes) G2 S2

Phacelia petiolata (stalk-leaf phacelia) G2 S1

Family: *Lamiaceae* (mints)

Hedeoma apiculata (McKittrick pennyroyal) G3 S2

Salvia penstemonoides (big red sage) G1 S1

Brazoria arenaria (sand Brazos mint) G3 S3

Brazoria enquistii (Enquist's sandmint) G2 S2

Brazoria truncata var. *pulcherrima* (Centerville Brazos-mint) G4T3 S3

Hedeoma mollis (hairy false pennyroyal) G3G4 S3

Hedeoma pilosa (old blue pennyroyal) GH SH

Monarda maritima (seaside beebalm) G2Q S2

Monarda stanfieldii (Stanfield's beebalm) G3 S3

Monarda viridissima (Texas beebalm) G3 S3

Physostegia correllii (Correll's false dragon-head) G2 S2

Physostegia longisepala (long-sepaled false dragon-head) G2G3 S2

Rhododon angulatus (Tharp's rhododon) G1Q S1

Rhododon ciliatus (Texas sandmint) G3 S3

Salvia summa (great sage) G3 S2

Scutellaria laevis (smooth-stem skullcap) G1 S1

Family: *Leitneriaceae* (corkwood)

Leitneria pilosa ssp. pilosa (corkwood) G2G3T2 S2

Family: Loganiaceae

Spigelia texana (Texas pinkroot) G3 S3

Family: *Lythraceae* (loosestrifes)

Ammannia grayi (longstalk heimia) G2G3 S2

Lythrum ovalifolium (Plateau loosestrife) G3G4 S3

Family: *Malvaceae* (mallows)

Ayenia limitaris (Texas ayenia) G2 S1 ESA Endangered E

Batesimalva violacea (purple gay-mallow) G1 S1

Callirhoe scabriuscula (Texas poppy-mallow) G2 S2 ESA Endangered State Endangered

Fryxellia pygmaea (small fryxell-wort) G1 SH

Hibiscus dasycalyx (Neches River rose-mallow) G1 S1 ESA Threatened State Threatened

Wissadula parvifolia (small-leaved yellow velvet-leaf) G1 S1

Family: *Nyctaginaceae* (four o'clocks)

Abronia ameliae (Amelia's sand-verbena) G3 S3

Abronia macrocarpa (large-fruited sand-verbena) G2? S2 ESA Endangered State Endangered

Acleisanthes acutifolia (Havard trumpets) G3 S1

Acleisanthes crassifolia (Texas trumpets) G2 S2

Acleisanthes parvifolia (littleleaf moonpod) G3 S3

Acleisanthes wrightii (Wright's trumpets) G2 S2

Anulocaulis leiosolenus var. *lasianthus* (Chihuahuan ringstem) G4T2 S2

Anulocaulis reflexus (Ojinaga ringstem) G2 S1

Family: *Oleaceae* (olives)

Fraxinus papillosa (Chihuahua ash) G2G3Q S1

Family: *Onagraceae* (evening primroses)

Oenothera sessilis (Grand Prairie evening primrose) G5T2 SH

Oenothera boquillensis (Boquillas lizardtail) G3 S2

Oenothera cinerea ssp. parksii (woolly butterfly-weed) G5T3 S3

Oenothera cordata (heartleaf evening-primrose) G3 S3

Oenothera coryi (Cory's evening-primrose) G3 S3

Oenothera triangulata (prairie butterfly-weed) G3G4 S3

Family: *Orobanchaceae* (broomrape)

Agalinis auriculata (earleaf false foxglove) G3 SH

Agalinis calycina (Leoncita false-foxglove) G1 S1 State Threatened

Agalinis densiflora (Osage Plains false foxglove) G3 S2

Agalinis navasotensis (Navasota false foxglove) G1 S1

Family: *Pedaliaceae* (sesames)

Proboscidea sabulosa (dune unicorn-plant) G3 S2

Proboscidea spicata (many-flowered unicorn-plant) GH S1

Family: *Phrymaceae* (lopseed)

Erythranthe chinatiensis (fringed monkeyflower) G1 S1

Family: Phyllanthaceae

Phyllanthopsis arida (Trans-Pecos maidenbush) G2Q S1

Family: *Polemoniaceae* (phloxes)

Gilia ludens (South Texas gilia) G3 S3

Ipomopsis havardii (Havard's standing cypress) G3 S3

Phlox drummondii ssp. *johnstonii* (Johnston's phlox) G5T3 S3

Phlox nivalis ssp. *texensis* (Texas trailing phlox) G4T2 S2 ESA Endangered E

Phlox oklahomensis (Oklahoma phlox) G3 SH

Polemonium pauciflorum ssp. *hinckleyi* (Hinckley's Jacob's-ladder) G3G5T2Q S1

Hebecarpa palmeri (Palmer's milkwort) G3 S2

Rhinotropis maravillasensis (Maravillas milkwort) G2 S1

Rhinotropis rimulicola var. *rimulicola* (rock crevice milkwort) G3T3 S2

Family: *Polygonaceae* (buckwheats)

Eriogonum correllii (Correll's wild-buckwheat) G2G3 S2

Eriogonum greggii (Gregg's wild-buckwheat) G2 S1

Eriogonum hemipterum var. *hemipterum* (Chisos Mountains wild-buckwheat) G3T2 S2

Eriogonum nealleyi (Irion County wild-buckwheat) G2 S2

Eriogonum suffruticosum (bushy wild-buckwheat) G2 S2

Eriogonum tenellum var. ramosissimum (basin wild-buckwheat) G5T3 S3

Polygonella parksii (Parks' jointweed) G2 S2

Family: *Ranunculaceae* (buttercups)

Aquilegia chaplinei (Guadalupe Mountains columbine) G4T2 S2

Aquilegia hinckleyana (Hinckley's columbine) G4T1 S1

Aquilegia longissima (long-spurred columbine) G3 S2

Clematis carrizoensis (Carrizo Sands leather-flower) G2 S2

Clematis texensis (scarlet leather-flower) G3G4 S3

Thalictrum arkansanum (Arkansas meadow-rue) G2Q S2

Thalictrum texanum (Texas meadow-rue) G2Q S2

Family: *Rhamnaceae* (buckthorn)

Colubrina stricta (Comal snakewood) G2 S1

Family: *Rosaceae* (roses)

Agrimonia incisa (incised groovebur) G3 S3

Crataegus mollis var. *viburnifolia* (sawtooth hawthorn) G3 S3

Crataegus nananixonii (Nixon's dwarf hawthorn) G1 S1

Crataegus turnerorum (Turner's hawthorn) G3 S3

Crataegus viridis var. *glabriuscula* (Sutherland hawthorn) G5T3T4 S3

Prunus havardii (Havard plum) G3 S3

Prunus minutiflora (Texas almond) G3G4 S3

Prunus murrayana (Murray's plum) G2 S2

Prunus texana (Texas peachbush) G3G4 S3

Rosa stellata ssp. *mirifica* var. *erlansoniae* (Erlanson's desert rose) G4T1 S1

Family: *Rubiaceae* (coffee)

Stenaria butterwickiae (Mary's bluet) G1 S1

Stenaria mullerae var. *pooleana* (Jackie's bluet) G1Q S1

Galium correllii (cliff bedstraw) G2 S1

Houstonia correllii (Correll's bluet) G1 S1

Houstonia croftiae (Croft's bluet) G3 S3

Houstonia parviflora (Greenman's bluet) G3 S3

Family: *Rutaceae* (citrus)

Zanthoxylum parvum (Shinners' tickle-tongue) G2 S2

Family: *Sapindaceae* (soapberry)

Cardiospermum dissectum (Chihuahua balloon-vine) G3 S3

Family: Scrophulariaceae (figwort)

Penstemon alamosensis (Alamo beardtongue) G3 S1

Penstemon cardinalis var. regalis (royal red penstemon) G3T2T3 S2

Penstemon guadalupensis (Guadalupe beardtongue) G3 S3

Penstemon triflorus var. integrifolius (Heller's beardtongue) G3T2 S2

Penstemon triflorus var. triflorus (threeflower penstemon) G3T3 S3

Penstemon wrightii (Wright's beardtongue) G3G4 S3

Seymeria texana (Texas seymeria) G3 S3

Family: *Solanaceae* (nightshade)

Lycium puberulum var. *berberioides* (silvery wolfberry) G4T3 S3

Lycium texanum (Texas wolf-berry) G2 S2

Solanum davisense (Davis Mountains horse-nettle) G3 S2

Styrax platanifolius ssp. platanifolius (sycamore-leaf snowbell) G3T3 S3

Styrax platanifolius ssp. stellatus (hairy sycamore-leaf snowbell) G3T3 S3

Styrax platanifolius ssp. texanus (Texas snowbells) G3T1 S1 ESA Endangered

Styrax platanifolius ssp. youngiae (Young's snowbell) G3T1 S1

Family: Valerianaceae (Caprifoliaceae) (valerians)

Valeriana texana (Guadalupe valerian) G2 S2

Valerianella florifera (Texas cornsalad) G3 S3

Valerianella stenocarpa (bigflower cornsalad) G3 S3

Valerianella texana (Edwards Plateau cornsalad) G2 S2

Family: *Violaceae* (violets and pansies)

Viola guadalupensis (Guadalupe Mountains violet) G1 S1

Family: *Vitaceae* (grapes)

Vitis rupestris (rock grape) G3 S1

Family: *Zygophyllaceae* (bean-capers and caltrops)

Kallstroemia perennans
(perennial caltrop) G1 S1

Class: Gnetopsida (conifers or closely related to the conifers)

Family: Ephedraceae (Morman-tea)

Ephedra coryi (Cory's ephedra) G3 S3

Ephedra torreyana var. *powelliorum* (Powells' joint-fir) G5?T2 S1

Class: Lycopodiopsida (spikemosses and quillworts)

Family: *Isoetaceae* (quillworts)

Isoetes lithophila (rock quillwort) G1 S1 State Threatened

Family: *Selaginellaceae* (spikemosses and clubmosses)

Selaginella viridissima (green spikemoss) G2 S1

Monocot Clade (Flowering plants that are monocots)

Family: Agavaceae (agaves and yuccas)

Hesperaloe funifera ssp. funifera (Mexican hesperaloe) G3TNR S1

Hesperaloe parviflora (red yucca) G3 S3

Manfreda longiflora (St. Joseph's staff) G2 S2

Manfreda sileri (Siler's huaco) G3 S3

Nolina arenicola (sand sacahuiste) G2Q S2

Yucca cernua (nodding yucca) G1 S1

Yucca necopina (Glen Rose yucca) G1G2 S3

Family: *Bromeliaceae* (bromeliads)

Tillandsia baileyi (Bailey's ballmoss) G2G3 S2

Family: *Commelinaceae* (spiderworts)

Tradescantia buckleyi (Buckley's spiderwort) G3 S3

Tradescantia pedicellata (granite spiderwort) G2Q S2

Family: *Cyperaceae* (sedges)

Carex decomposita (cypress knee sedge) G3G4 S1

Carex edwardsiana (canyon sedge) G3G4 S3

Carex mckittrickensis (Guadalupe Mountains sedge) G1 S1

Carex shinnersii (Shinner's sedge) G3 S2

Cyperus cephalanthus (giant sharpstem umbrella-sedge) G3?Q S1

Cyperus grayoides (Mohlenbrock's sedge) G3G4 S3

Cyperus onerosus (dune umbrella-sedge) G2 S2 State Threatened

Eleocharis austrotexana (South Texas spikesedge) G3 S3

Eleocharis brachycarpa (short-fruited spikesedge) GH SH

Rhynchospora indianolensis (Indianola beakrush) G3Q S3

Rhynchospora macra (large beakrush) G3G4 S2

Schoenoplectus deltarum (Delta bulrush) G3G4 S1

Schoenoplectiella hallii (Hall's baby bulrush) G3 S1

Family: *Eriocaulaceae* (pipeworts)

Eriocaulon koernickianum (small-headed pipewort) G2 S1 State Threatened

Lachnocaulon digynum (tiny bog button) G3G4 S1

Family: *Liliaceae* (lilies)

Schoenolirion wrightii (Texas sunnybell) G3 S3

Trillium texanum (Texas trillium) G3 S3

Zephyranthes refugiensis (Refugio rainlily) G2G3 S2

Zephyranthes smallii (Small's rainlily) G1G2Q S1

Family: *Orchidaceae* (orchids)

Hexalectris revoluta (Chisos coral-root) G2T1T2 S1

Calopogon oklahomensis (Oklahoma grass pink) G2 S1

Cypripedium kentuckiense (Southern lady's-slipper) G3 S1

Hexalectris nitida (Glass Mountains coral-root) G3 S3

Hexalectris warnockii (Warnock's coral-root) G2G3 S2

Malaxis wendtii (Wendt's malaxis) G1G2 S1

Platanthera chapmanii (Chapman's orchid) G2 S1

Platanthera integra (yellow fringeless orchid) G3G4 S1

Spiranthes brevilabris (Texas ladies'-tresses) G1G2 S1

Spiranthes longilabris (giant spiral ladies'-tresses) G3 S1

Spiranthes parksii (Navasota ladies'-tresses) G3 S3 ESA Endangered

Triphora trianthophoros var. *texensis* (Texas three-birds orchid) G4?T1Q S1

Family: *Poaceae* (grasses)

Achnatherum curvifolium (Guadalupe needlegrass) G3 S2

Allolepis texana (Texas false saltgrass) G2 S1

Blepharidachne bigelovii (Bigelow's desert grass) G3 S3

Bouteloua kayi (Kay's grama) G1 S1

Chloris texensis (Texas windmill grass) G2 S2

Festuca ligulata (Guadalupe fescue) G1 S1 ESA Endangered

Festuca versuta (Texas fescue) G3 S3

Muhlenbergia villiflora var. villosa (villous muhly) G5T3 S2

Poa strictiramea (Big Bend bluegrass) G3 S1

Schizachyrium spadiceum (honey false bluestem) G3? S1

Tridens buckleyanus (Buckley tridens) G3G4 S3

Willkommia texana var. *texana* (Texas willkommia) G3G4T3 S3

Zizania texana (Texas wild-rice) G1 S1 ESA Endangered

Family: Pontederiaceae

Heteranthera mexicana (Mexican mud-plantain) G2G3 S1

Family: *Potamogetonaceae* (pondweeds)

Potamogeton clystocarpus (Little Aguja pondweed) G1 S1 ESA Endangered

Family: *Xyridaceae* (yellow-eyed grass)

Xyris chapmanii (Chapman's yellow-eyed grass) G3 S3

Xyris drummondii (Drummond's yellow-eyed grass) G3G4 S2

Xyris scabrifolia (roughleaf yellow-eyed grass) G3 S2

Class: Pinopsida (conifers)

Family: *Pinaceae* (pines)

Pinus arizonica var. stormiae (pino real) G4T3 S1

Supplement 3.1 SGCN data included in Excel spreadsheet as a separate file to maintain functionality

Conservation of Texas Freshwater Fish Diversity

Selection of Species of Greatest Conservation Need

October 2020
Inland Fisheries Division
Texas Parks and Wildlife Department
Austin, Texas

Authors and Affiliations

Timothy W. Birdsong, Chief of Habitat / Conservation, Inland Fisheries Division, Texas Parks and Wildlife Department, Phone: (512) 389-4744, Email: Timothy.Birdsong@tpwd.texas.gov

Gary P. Garrett, Research Scientist, Department of Integrative Biology, University of Texas at Austin

Megan G. Bean, Conservation Biologist, Inland Fisheries Division, Texas Parks and Wildlife Department

Preston Bean, Fisheries Research Biologist / Senior Scientist, Inland Fisheries Division, Texas Parks and Wildlife Department

Stephen Curtis, Aquatic Biologist, Inland Fisheries Division, Texas Parks and Wildlife Department

Paul Fleming, Fisheries Research Biologist / Senior Scientist, Inland Fisheries Division, Texas Parks and Wildlife Department

Archis Grubh, Aquatic Biologist, Inland Fisheries Division, Texas Parks and Wildlife Department

Dijar Lutz-Carrillo, Geneticist / Senior Scientist, Inland Fisheries Division, Texas Parks and Wildlife Department

Kevin B. Mayes, Aquatic Biologist / Senior Scientist, Inland Fisheries Division, Texas Parks and Wildlife Department

Clint Robertson, Aquatic Biologist / Senior Scientist, Inland Fisheries Division, Texas Parks and Wildlife Department

Sarah Robertson, Aquatic Biologist, Inland Fisheries Division, Texas Parks and Wildlife Department

J. Warren Schlechte, Fisheries Research Biologist / Senior Scientist, Inland Fisheries Division, Texas Parks and Wildlife Department

Nathan G. Smith, Fisheries Research Biologist / Senior Scientist, Inland Fisheries Division, Texas Parks and Wildlife Department

Cover Photo: Lateral view of a Guadalupe Bass *Micropterus treculii*, the official state fish of Texas and a Species of Greatest Conservation Need (photo credit: Living Waters Fly Fishing)

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Introduction

Texas Parks and Wildlife Department (TPWD) has broad authorities and mandates to manage and conserve freshwater fish diversity, including mandates to perform ecological research, species propagation, biological surveys and monitoring, habitat restoration, habitat protection, and other actions to ensure the continued ability of native freshwater fishes "to perpetuate themselves" (Texas Parks & Wildlife Code, §§ 67.001–67.0041, Nongame Species). Such actions are prioritized by TPWD for freshwater fishes recognized as Species of Greatest Conservation Need (SGCN; TPWD 2012, Birdsong et al. 2019). Status as a SGCN is afforded to species with low or declining populations in need of conservation action, including species at risk due to threats to their life history needs or habitats; species considered rare due to few, small or declining populations, abundance, or distribution; and species with declining trends in their habitats and populations (AFWA 2012).

Maintaining a frequently updated list of SGCN supports prioritization of conservation investments toward species in need of conservation intervention. It also enables access to project-based funding for research, monitoring, habitat restoration, repatriation, and other actions that have the potential to reverse trends for species at risk or in decline (Birdsong et al. 2019, Birdsong et al., in press). A prime example of such investments is the State Wildlife Grants Program, which was authorized by U.S. Congress to provide a source of funding to state fish and wildlife agencies explicitly for the conservation of SGCN. Since the initial appropriation of funding to the program by U.S. Congress in 2002, TPWD has received annual apportionments totaling $34.3 million to fill critical science needs and implement conservation actions to restore and preserve the more than 1,300 species recognized as SGCN in Texas (TPWD 2012). Since 2008, approximately 25% of that funding ($8.6 million) has been invested in the conservation and recovery of freshwater fishes and mussels, corresponding to average annual investments of roughly $660,000. Birdsong et al. (2017) identified an annual funding need of over $132 million to adequately address the needs of Texas SGCN (across all taxa within the resource management purview of TPWD), including $6.2 million annually to conserve native freshwater fishes. In recognition of the substantial conservation needs of SGCN in Texas and nationwide, the Recovering America's Wildlife Act has been repeatedly introduced into U.S. Congress. Passage of the Act would result in the apportionment of more than $50 million annually in new funding to TPWD to conserve SGCN.

One of the most noteworthy conservation success stories for a freshwater fish SGCN in Texas is the restoration of Guadalupe Bass *Micropterus treculii*. This species is endemic to the clear, spring-fed rivers of central Texas where populations are threatened with local extirpation from habitat degradation, flow alteration, and hybridization with non-native Smallmouth Bass *Micropterus dolomieu* (Curtis et al.

2015). While these threats are enormously challenging to address, the species was recently repatriated to the Blanco River and the Mission Reach of the San Antonio River (Magnelia et al. 2019a, Birdsong et al. 2020). A previously hybridized population of Guadalupe Bass was also recently restored in the South Llano River (Birdsong et al. 2015, Garrett et al. 2015, Birdsong et al. 2020). Since 2009, over $1.4 million has been invested through the State Wildlife Grants Program in applied research to guide and inform Guadalupe Bass conservation strategies. Those funds were leveraged many times over with project-based funding contributed by TPWD, Texas Parks and Wildlife Foundation, National Fish and Wildlife Foundation, National Fish Habitat Partnership, Southeast Aquatic Resources Partnership, Natural Resources Conservation Service, and other cooperators invested in habitat restoration, habitat preservation, and invasive species management (Birdsong et al. 2020). Ongoing Guadalupe Bass conservation efforts are guided by a 10-year (2017–2026), range-wide conservation plan for the species (Bean 2017), which identifies a goal of establishing and maintaining 10 self-sustaining populations. While that goal was achieved in 2018, efforts to maintain intact populations of Guadalupe Bass continue throughout the native range (Birdsong et al. 2020).

Given the substantial conservation investments afforded to Guadalupe Bass and other SGCN in Texas, it is of obvious importance that the list of Texas SGCN be frequently revisited with consideration of the best available science on status, trends, and threats to species and their habitats. The initial list of Texas SGCN was published within the 2005 Texas Comprehensive Wildlife Conservation Strategy (TPWD 2005) and subsequently updated within the 2012 Texas Conservation Action Plan (TPWD 2012). The Texas Conservation Action Plan is scheduled to be updated in 2023, at which time TPWD will complete a comprehensive revision of both the plan and list of SGCN. Meanwhile, significant advancements have occurred in the available science on status and trends of Texas biodiversity since the current list of SGCN was published in 2012 (e.g., taxonomic verifications, documentation of species extirpations, range reductions and expansions, and hybridization with nonindigenous species). Furthermore, during 2018–2020, TPWD and cooperators completed a litany of species conservation status assessments, including assessments of 91 freshwater fishes, which were used to inform the 2020 revision of the lists of State Threatened (ST) and State Endangered (SE) species (Birdsong et al., in press). Given this dramatic influx in available science on the status of Texas freshwater fish biodiversity, TPWD determined that a 2020 revision of the list of Texas SGCN was timely and warranted. Revision of the list of Texas SGCN in 2020 is expected to formally occur as a “minor revision” to the 2012 Texas Conservation Action Plan. The updated list is then expected to remain active until the next version of the Texas Conservation Action Plan and associated list of SGCN are published in 2023.

Conservation Status of Texas Freshwater Fishes

To inform the 2020 revision of the list of freshwater fish SGCN, TPWD relied primarily upon data available through the Biodiversity Center Fish Collection at the University of Texas at Austin and related science products and conservation planning tools assembled by the Fishes of Texas Project Team. The Biodiversity Center Fish Collection contains more than 1.7 million specimens and most (>75%) are from Texas freshwater systems. These specimens were used to compile the open-access database accessible through the Fishes of Texas website (http://www.fishesoftexas.org/home/). The database consists of a carefully curated, fully georeferenced, high-quality compilation of all specimen-based records of fish occurrences in Texas dating back to 1850 and is among the highest quality regional fish-occurrence databases in the world (Hendrickson et al. 2020). The Biodiversity Center Fish Collection has been used for pertinent information in field guides (Page and Burr 2011), documentation of species ranges (Craig and Bonner 2019) and range expansions (Martin et al. 2012), historical community composition (Labay et al. 2011), bioassessments (Labay and Hendrickson 2014, Labay et al. 2015, Robertson 2015, Robertson et al. 2016, Robertson et al. 2017, Labay et al. 2019), biodiversity conservation (Cohen et al. 2013, Birdsong et al. 2018, Cohen et al. 2018, Garrett et al. 2019, Magnelia et al. 2019b, Mayes et al. 2019) including identification of Native Fish Conservation Areas (Birdsong et al. 2019), endangered species listing decisions (USFWS 2014, Birdsong et al., in press), and invasive species management (Poulos et al. 2012, Cohen et al. 2014, McGarrity 2019).

During 2014–2020, TPWD contracted with the University of Texas at Austin (supported through State Wildlife Grants T-106 and T-182) to utilize the Biodiversity Center Fish Collection to assemble maps of species native ranges, develop species distribution models and spatial conservation prioritizations, conduct species trend analyses and species status assessments, and to ultimately provide data-driven recommendations on freshwater fishes to be included in the next revision of the list of freshwater fish SGCN. Most of those deliverables were contained in a report by Cohen et al. (2018) titled *Conserving Texas Biodiversity: Status, Trends, and Conservation Planning for Fishes of Greatest Conservation Need*. The report identified recommended revisions to the list of Texas freshwater fish SGCN (see Appendix 3 in Cohen et al. 2018), which were assembled in cooperation with 26 subject matter experts from 10 organizations representing conservation non-profits, state and federal agencies, and academia (see Appendix 2 in Cohen et al. 2018). With consideration of trends in species occurrence and distributional changes over time, subject matter experts recommended that 91 of the 191 species of Texas freshwater fish be recognized as SGCN in the next revision of the list.

In addition to considering the recommendations of Cohen et al. (2018), TPWD also reviewed NatureServe species conservation status ranks (Faber-Langendoen et al. 2012, Master et al. 2012) for Texas freshwater fishes. The species conservation status ranks were recently reassessed and updated by the Fishes of Texas Project Team and TPWD to inform the 2020 revision of the Texas lists of species recognized as ST or SE (Birdsong et al., in press). The NatureServe species conservation status methodology considers 10 individual core factors (i.e., population size; range extent; area of occupancy; number of occurrences; number of occurrences with good viability; environmental specificity; scope, severity, and timing of threats; intrinsic vulnerability; and long-term and short-term trends), which serve as indicators of species rarity, threats, and trends (See Table 1 in Master et al. 2012). Scores are weighted and combined across factors (See Table 9 in Faber-Langendoen et al. 2012) to calculate a final conservation status score for individual species and assign a corresponding conservation status rank of Critically Imperiled (S1), Imperiled (S2), Vulnerable (S3), Apparently Secure (S4), or Secure (S5) (Table 1). Additional unpublished data available from the Inland Fisheries Division were also considered as TPWD examined the status and trends of Texas freshwater fishes and sought to identify those in need of recognition as SGCN.

Selection of Freshwater Fish Species of Greatest Conservation Need

Through this species conservation status assessment process, 89 species of freshwater fish were selected for inclusion in the 2020 revision of the list of Texas SGCN (Table 2). This included retention of all but three species or subspecies, San Felipe Gambusia *Gambusia clarkhubbsi*, Chihuahua Catfish *Ictalurus* sp., and Devils River Pupfish *Cyprinodon eximius* ssp., of the 64 freshwater fishes contained on the most recent list of Texas SGCN (TPWD 2012). San Felipe Gambusia was previously thought to be a unique species endemic to San Felipe Creek. However, a recent genetic assessment by Echelle et al. (2013) concluded that *Gambusia clarkhubbsi* is not a valid species, but rather a population of Spotfin Gambusia *Gambusia krumholzi*, also found in Sycamore Creek in Texas and ríos San Diego and la Compuerta in Mexico. Spotfin Gambusia was assigned a NatureServe conservation status rank of Critically Imperiled (S1) and selected to be added to the list of Texas SGCN. It should also be noted that San Felipe Gambusia is currently identified as ST by TPWD. Upon the next revision of the lists of ST and SE species, TPWD intends to replace San Felipe Gambusia with Spotfin Gambusia.

Chihuahua Catfish was excluded from the revised list of Texas SGCN based on the results of a genetic assessment conducted by TPWD (authors M. Bean and D. Lutz-Carrillo, unpublished data), which resolved available sequences within the Headwater Catfish *Ictalurus lupus* haplotype and genotype groups. Headwater Catfish is listed by

TPWD as ST and was also retained in the 2020 revision of the list of Texas SGCN. Devils River Pupfish was once considered a subspecies of Conchos Pupfish *Cyprinodon eximius* endemic to the Devils River. Although morphologically distinct from other populations, Devils River Pupfish is now considered to be a disjunct population of Conchos Pupfish. Conchos Pupfish is currently listed by TPWD as ST and was retained on the list of Texas SGCN.

Species selected to be added to the list of Texas SGCN consisted of Highland Stoneroller *Campostoma spadiceum*, Guadalupe Roundnose Minnow *Dionda flavipinnis*, Conchos Roundnose Minnow *Dionda* sp. 1, Colorado Roundnose Minnow *Dionda* sp. 3, Nueces Roundnose Minnow *Dionda texensis*, Mississippi Silvery Minnow *Hybognathus nuchalis*, Plains Minnow *Hybognathus placitus*, Pallid Shiner *Hybopsis amnis*, Shoal Chub *Macrhybopsis hyostoma*, Burrhead Chub *Macrhybopsis marconis*, River Shiner *Notropis blennius*, West Texas Shiner *Notropis megalops*, Suckermouth Minnow *Phenacobius mirabilis*, Flathead Chub *Platygobio gracilis*, Llano River Carpsucker *Carpiodes cf. cyprinus*, Spotted Sucker *Minytrema melanops*, Longlip Jumprock *Moxostoma albidum*, Mexican Blindcat *Prietella phreatophila*, Mountain Mullet *Agonostomus monticola*, Spotfin Gambusia *Gambusia krumholzi*, Gumbo Darter *Etheostoma thompsoni*, and River Darter *Percina shumardi.* Each of these species was assigned a NatureServe conservation status rank of Critically Imperiled (S1) or Imperiled (S2) and identified by Cohen et al. (2018) as experiencing recent declines in occurrence and distribution. The decision was also made to include the following native freshwater fishes considered extirpated from the state or likely extinct: Maravillas Red Shiner *Cyprinella lutrensis blairi*, Conchos Shiner *Cyprinella panarcys*, Phantom Shiner *Notropis orca*, Rio Grande Bluntnose Shiner *Notropis simus simus*, Amistad Gambusia *Gambusia amistadensis*, and San Marcos Gambusia *Gambusia georgei*. Although generally thought to be gone from the state, inclusion on the list will enable focused surveys to provide confirmation and enable support for possible repatriation efforts for extirpated species.

Although recommended for inclusion on the revised list of Texas SGCN by Cohen et al. (2018), Rio Grande Blue Catfish was excluded by TPWD based on the results of a recent genetic assessment (authors M. Bean and D. Lutz-Carrillo, unpublished data). The assessment concluded it is not a unique species but rather a form of Blue Catfish *Ictalurus furcatus*. Cohen et al. (2018) also recommended removal of Texas Shiner *Notropis amabilis* from the list of SGCN. Although the species received a NatureServe conservation status rank of Apparently Secure (S4), TPWD continues to have concerns about the status of the species and intends to reassess the most recent NatureServe conservation status rank in advance of the next revision of the list of Texas SGCN in 2023. In the meantime, the species will remain on the list. If the updated conservation status assessment again assigns a rank of Apparently Secure (S4), it is anticipated that the species will be removed from the list in 2023. Taxonomic concerns were also identified for Spotted Sucker *Minytrema melanops*. Thus, the decision was made to include Spotted Sucker on the list as a research priority to enable taxonomic verification to be completed in advance of the next update of the list of Texas SGCN in 2023. Lastly, changes are needed to align the list of Texas SGCN with recent taxonomic updates. This includes an update to the common name of *Dionda nigrotaeniata*, which was previously referred to as Guadalupe Roundnose Minnow and now has the common name of Medina Roundnose Minnow (Schönhuth et al. 2012). A similar update is needed for *Dionda serena*, which was previously referred to as Nueces Roundnose Minnow and now has the common name of Frio Roundnose Minnow (Schönhuth et al. 2012; Carson et al. 2014).

Discussion

Through this process, a data-driven, inclusive, and transparent review was completed to select freshwater fishes for inclusion in the 2020 revision of the list of Texas SGCN. The 89 species selected through this review process were collated alongside other species selected by taxa experts in the TPWD Coastal Fisheries and Wildlife divisions and then submitted to the U.S. Fish and Wildlife Service as a minor revision to the current Texas Conservation Action Plan (TPWD 2012). As noted previously, a comprehensive revision of the Texas Conservation Action Plan is scheduled to be completed in 2023, which will offer another opportunity for TPWD and cooperators to review and reassess the list of SGCN.

Inclusion of individual species on the list of Texas SGCN is typically justified under one or more criteria, such as if the species is considered rare, experiencing population declines, extirpated from the state and considered a priority for repatriation, considered extinct but in need of confirmation, or has an unknown status and is considered a priority for surveys or research. As TPWD assembles the 2023 Texas Conservation Action Plan, associated list of Texas SGCN, and related TPWD web content, it would be beneficial to share more explicit background, reasoning, and justification for inclusion or removal of individual species on the list of Texas SGCN. This could be completed by communicating the specific criteria under which the species were selected for inclusion or by providing a descriptive narrative profiling the status and conservation needs of species recognized as SGCN. During implementation of the 2023 Texas Conservation Action Plan, which is anticipated to be a 10-year plan, it would be beneficial to track investments in research, monitoring, habitat restoration, habitat protection, invasive species management, and other actions implemented to benefit individual SGCN, recognizing the many projects will undoubtedly provide multi-species benefits (e.g., habitat restoration, habitat preservation, invasive species management). Investments by TPWD in conservation of SGCN extend well beyond investments supported through the State Wildlife Grants Program. For example, the native ranges of SGCN have been prioritized for investments in habitat preservation through the Texas Farm and Ranch Lands Conservation Program (i.e., conservation easements), restoration of springs, creeks, and riparian habitats through the TPWD Landowner Incentive Program, control of riparian invasive plants through the Texas Healthy Creeks Initiative, and conservation planning within the Texas Native Fish Conservation Areas Network. Development of a GIS-based database for tracking and reporting investments in SGCN would undoubtedly enhance efforts by TPWD and partners to plan and deliver conservation measures that achieve the mantra of the Texas Conservation Action Plan of “keeping common species common.”

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Table 1. Definitions of NatureServe state-based conservation status ranks, status rank codes, and their corresponding range of conservation status scores (adapted from Faber-Langendoen et al. 2012).

Conservation Status Rank	Conservation Status Rank Code	Range of Conservation Status Scores	Conservation Status Rank Definition
State Extirpated	SX	N/A	Extirpated from the state
Possibly Extirpated	SH	N/A	Known only from historical records but some hope for rediscovery
Critically Imperiled	S1	$\leq$ 1.5	Very high risk of extirpation due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors
Imperiled	S2	1.6–2.5	High risk of extirpation
Vulnerable	S3	2.6–3.5	Moderate risk of extirpation
Apparently Secure	S4	3.6–4.5	Considered stable but with some cause for concern from recent localized declines or threats
Secure	S5	4.6–5.5	Extensive range, abundant populations or occurrences, limited concern with declines or threats

Table 2. Freshwater fishes recommended for inclusion on the list of Texas Species of Greatest Conservation Need (revised 2020) with associated NatureServe state-based conservation status ranks (revised 2019), state listing status (revised 2020), and current federal listing status. NatureServe State Rank: see Table 2. Listing status: State Threatened (ST), State Endangered (SE), Federally Threatened (FT), Federally Endangered (FE), Threatened due to similarity of appearance (SAT)

Family	Scientific Name	Common Name	NatureServe State Rank	State Listing Status	Federal Listing Status
Acipenseridae	*Scaphirhynchus platorynchus*	Shovelnose Sturgeon	S1	ST	SAT
Polyodontidae	*Polyodon spathula*	Paddlefish	S1	ST	
Lepisosteidae	*Atractosteus spatula*	Alligator Gar	S2		
Hiodontidae	*Hiodon alosoides*	Goldeye	S2		
Anguillidae	*Anguilla rostrata*	American Eel	S2		
Cyprinidae	*Campostoma ornatum*	Mexican Stoneroller	S1	ST	
	Campostoma spadiceum	Highland Stoneroller	S1		
	Cyprinella lepida	Plateau Shiner	S2	ST	
	Cyprinella lutrensis blairi	Maravillas Red Shiner	SX		
	Cyprinella panarcys	Conchos Shiner	SH		
	Cyprinella proserpina	Proserpine Shiner	S1	ST	
	Cyprinella sp.	Nueces River Shiner	S1		
	Dionda argentosa	Manantial Roundnose Minnow	S2		
	Dionda diaboli	Devils River Minnow	S1	ST	FT
	Dionda episcopa	Roundnose Minnow	S1	ST	
	Dionda flavipinnis	Guadalupe Roundnose Minnow	S2		
	Dionda nigrotaeniata	Medina Roundnose Minnow	S1	ST	
	Dionda serena	Frio Roundnose Minnow	S1		
	Dionda sp. 1	Conchos Roundnose Minnow	S1		
	Dionda sp. 3	Colorado Roundnose Minnow	S1		
	Dionda texensis	Nueces Roundnose Minnow	S2	ST	
	Gila pandora	Rio Grande Chub	S1	ST	

Family	Scientific Name	Common Name	NatureServe State Rank	State Listing Status	Federal Listing Status
Cyprinidae	*Hybognathus amarus*	Rio Grande Silvery Minnow	SX	SE	FE
	Hybognathus nuchalis	Mississippi Silvery Minnow	S2		
	Hybognathus placitus	Plains Minnow	S2		
	Hybopsis amnis	Pallid Shiner	S2		
	Macrhybopsis aestivalis	Speckled Chub	S1S2	ST	
	Macrhybopsis australis	Prairie Chub	S1	ST	
	Macrhybopsis hyostoma	Shoal Chub	S2		
	Macrhybopsis marconis	Burrhead Chub	S2		
	Macrhybopsis storeriana	Silver Chub	S2		
	Macrhybopsis tetranema	Peppered Chub	S1	ST	
	Notropis amabilis	Texas Shiner	S4		
	Notropis atrocaudalis	Blackspot Shiner	S2		
	Notropis bairdi	Red River Shiner	S1		
	Notropis blennius	River Shiner	S2		
	Notropis braytoni	Tamaulipas Shiner	S1S2	ST	
	Notropis buccula	Smalleye Shiner	S1S2	SE	FE
	Notropis chalybaeus	Ironcolor Shiner	S2		
	Notropis chihuahua	Chihuahua Shiner	S1	ST	
	Notropis girardi	Arkansas River Shiner	S1	ST	FT
	Notropis jemezanus	Rio Grande Shiner	S1	ST	
	Notropis maculatus	Taillight Shiner	S2		
	Notropis megalops	West Texas Shiner	S1		
	Notropis orca	Phantom Shiner	SX		
	Notropis oxyrhynchus	Sharpnose Shiner	S1S2	SE	FE
	Notropis potteri	Chub Shiner	S2	ST	
	Notropis sabinae	Sabine Shiner	S2		
	Notropis shumardi	Silverband Shiner	S3		
	Notropis simus pecosensis	Pecos Bluntnose Shiner	SX	ST	FT

Family	Scientific Name	Common Name	NatureServe State Rank	State Listing Status	Federal Listing Status
Cyprinidae	*Notropis simus simus*	Rio Grande Bluntnose Shiner	SX		
	Phenacobius mirabilis	Suckermouth Minnow	S2		
	Platygobio gracilis	Flathead Chub	S1		
	Pteronotropis hubbsi	Bluehead Shiner	S1	ST	
	Rhinichthys cataractae	Longnose Dace	S1		
Catostomidae	*Carpiodes cf. cyprinus.*	Llano River Carpsucker	S2		
	Cycleptus elongatus	Blue Sucker	S1	ST	
	Cycleptus sp.	Rio Grande Blue Sucker	S1		
	Erimyzon claviformis	Creek Chubsucker	S2	ST	
	Minytrema melanops	Spotted Sucker	SU		
	Moxostoma albidum	Longlip Jumprock	S1		
	Moxostoma austrinum	Mexican Redhorse	S1		
Ictaluridae	*Ictalurus lupus*	Headwater Catfish	S1S2	ST	
	Prietella phreatophila	Mexican Blindcat	S1	SE	FE
	Satan eurystomus	Widemouth Blindcat	S1	ST	
	Trogloglanis pattersoni	Toothless Blindcat	S1	ST	
Salmonidae	*Oncorhynchus clarkii virginalis*	Rio Grande Cutthroat Trout	SX		
Mugilidae	*Agonostomus monticola*	Mountain Mullet	S2		
Poeciliidae	*Gambusia amistadensis*	Amistad Gambusia	SX		
	Gambusia gaigei	Big Bend Gambusia	S1	SE	FE
	Gambusia georgei	San Marcos Gambusia	SX	SE	FE
	Gambusia heterochir	Clear Creek Gambusia	S1	SE	FE
	Gambusia krumholzi	Spotfin Gambusia	S1	ST	
	Gambusia nobilis	Pecos Gambusia	S1	SE	FE
	Gambusia senilis	Blotched Gambusia	S1	ST	
Cyprinodontidae	*Cyprinodon bovinus*	Leon Springs Pupfish	S1	SE	FE
	Cyprinodon elegans	Comanche Springs Pupfish	S1	SE	FE
	Cyprinodon eximius	Conchos Pupfish	S1	ST	

Family	Scientific Name	Common Name	NatureServe State Rank	State Listing Status	Federal Listing Status
Cyprinodontidae	*Cyprinodon pecosensis*	Pecos Pupfish	S1	ST	
	Cyprinodon rubrofluviatilis	Red River Pupfish	S2	ST	
Centrarchidae	*Micropterus treculii*	Guadalupe Bass	S1		
Percidae	*Ammocrypta clara*	Western Sand Darter	S2		
	Etheostoma fonticola	Fountain Darter	S1	SE	FE
	Etheostoma grahami	Rio Grande Darter	S1	ST	
	Etheostoma radiosum	Orangebelly Darter	S1		
	Etheostoma thompsoni	Gumbo Darter	S2		
	Percina apristis	Guadalupe Darter	S1	ST	
	Percina maculata	Blackside Darter	S1	ST	
	Percina shumardi	River Darter	S2		

Conservation Status of Texas Freshwater Fishes: Informing State-based Species Protections

Timothy W. Birdsong, *Inland Fisheries Division, Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, TX 78744, USA*

Gary P. Garrett, *Department of Integrative Biology, University of Texas at Austin, 10100 Burnet Road, Austin, TX 78744, USA*

Megan G. Bean, *Inland Fisheries Division, Texas Parks and Wildlife Department, 5103 Junction Highway, Mountain Home, TX 78058, USA*

Stephen G. Curtis, *Inland Fisheries Division, Texas Parks and Wildlife Department, 505 Staples Road, Building 1, San Marcos, TX 78666, USA*

Kevin B. Mayes, *Inland Fisheries Division, Texas Parks and Wildlife Department, 505 Staples Road, Building 1, San Marcos, TX 78666, USA*

Sarah M. Robertson, *Inland Fisheries Division, Texas Parks and Wildlife Department, 505 Staples Road, Building 1, San Marcos, TX 78666, USA*

Abstract: In Texas, freshwater fishes recognized as State Threatened or Endangered (STE) receive special attention when Texas Parks and Wildlife Department (TPWD) consults with other agencies on projects that have the potential to alter freshwater systems. Regulatory oversight by TPWD of scientific and zoological collections, fish stockings, commercial fishing, disturbances to state-owned streambeds, and exotic species management must also ensure that no adverse impacts occur to STE freshwater fishes. Furthermore, STE species are prioritized by TPWD for voluntary-based investments in research, monitoring, habitat restoration, and habitat protection. Given these and other protections afforded to STE freshwater fishes, it is important that the lists of STE species be frequently assessed using the best available science on status, trends, and threats to species and their habitats. In 2018, TPWD adopted standardized methodologies, listing criteria, and listing thresholds to comprehensively assess the status of the diversity of species of fish, wildlife, and plants within the resource management purview and jurisdiction of TPWD. This methodology was applied to assess the status of Texas freshwater fishes and recommend revisions to the lists of STE species. As a result, 16 additional species of freshwater fish were recognized as STE in 2020. This article profiles the species conservation status assessment and stakeholder input processes used to identify species recommended as STE, and shares recommendations and lessons learned transferrable to other states that maintain similar state-based protected species lists.

Key words: native fish conservation, threatened and endangered species, conservation status assessment, species protection

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Declining freshwater fish diversity is a conservation issue not unique to Texas (Haslouer et al. 2005, Jelks et al. 2008). Freshwater fishes are threatened globally (Dudgeon et al. 2006, Strayer and Dudgeon 2010, Dodds et al. 2013) and currently have the highest extinction rate among vertebrates; of the 13,661 species of freshwater fish known to the planet, 83 are considered extinct (Burkhead 2012). Of the 1213 freshwater fishes found in North America, 39 species and 18 subspecies are considered extinct (Miller et al. 1989, Jelks et al. 2008). The primary causes of extinction of North American freshwater fishes have been physical habitat alteration, introduction of non-native species, water quality degradation, hybridization, and overharvest (Miller et al. 1989; Stein et al. 2000; H. John Heinz III Center for Science, Economics and the Environment 2002; Jelks et al. 2008). Since the 1950s, the extinction rate for North American freshwater fishes is approximately 7.5 extinctions per decade, and models predict 53 to 86 additional freshwater fishes will become extinct in North America between 2010 and 2050 (Burkhead 2012).

Texas harbors 191 species of native freshwater fish, 91 of which are considered imperiled (Cohen et al. 2018, Birdsong et al. 2019). An additional 67 native estuarine fishes have been documented to occur in Texas freshwater systems, with nine of those species considered imperiled (Cohen et al. 2018). Similar to other areas of the United States, the primary cause of fish imperilment in Texas is anthropogenic alteration of freshwater systems (e.g., groundwater extraction and concomitant reductions in spring discharge, river fragmentation, alteration of natural river flow patterns, degradation of water quality, introduction of non-indigenous species), which continues to occur at rates and scales that threaten the long-term persistence of native freshwater fishes (Costigan and Daniels 2012, Dodds et al. 2013, Perkin et al. 2014). Furthermore, changing climate trends have the potential to impact freshwater fishes (Lynch et al. 2016). Droughts are expected to increase in frequency and severity in Texas, affecting the timing and frequency of flows and water levels necessary to support spawning and other habitat requirements of freshwater fishes. Complex interactions are also expected to occur between climate change and existing anthropogenic stressors. Left unchecked, these issues will likely continue to contribute to the imperilment and loss of native fishes and other freshwater species (Gido et al. 2010, Hoagstrom et al. 2011). Five of the 191 species of Texas freshwater fish are considered likely extinct. Another six species are currently considered extirpated from the state but continue to occur in other portions of their native ranges in adjacent U.S. states or Mexico, and concerted efforts to repatriate some taxa to Texas are ongoing (Birdsong et al. 2019).

A suite of specific regulatory and voluntary-based conservation measures has been implemented by Texas Parks and Wildlife Department (TPWD) and cooperators in the management and conservation of Texas freshwater fishes (Table 1), many of which are unique to species recognized as Species of Greatest Conservation Need (SGCN) or State Threatened or Endangered (STE). Fish recognized as SGCN (TPWD 2012) represent state-level recognition of species with low or declining populations in need of conservation action. This may include species already recognized as STE, species at risk due to threats to their life history needs or habitats, species that are rare due to few, small or declining populations, abundance, or distribution, or species with declining trends in their habitats and populations (Association of Fish and Wildlife Agencies 2012). Species listed as State Endangered (SE) are defined as species native to Texas that are listed as endangered under the U.S. Endangered Species Act (ESA) or those threatened with extinction or statewide extirpation. Species listed as State Threatened (ST) are generally defined as those species with a high potential to become SE without conservation intervention.

Freshwater fishes recognized as SGCN or STE are prioritized by TPWD for voluntary based investments in research, monitoring, habitat restoration, and habitat protection (Table 1; Birdsong et al. 2019, Garrett et al. 2019). Those species also receive special consideration as TPWD provides recommendations through regulatory based consultations to local, state, and federal agencies that permit, construct, or manage projects that alter freshwater systems and fish habitats (e.g., hydropower relicensing, wastewater discharge, and construction or maintenance of dams, bridges, and stream crossings). For instance, projects that disrupt or remove stream bed materials may only be permitted by TPWD if determined to not damage or injuriously affect the river or freshwater fishes, not significantly or injuriously change the hydrology of the river, and not significantly accelerate erosion upstream or downstream (Table 1). Regulatory oversight of scientific and zoological collection of freshwater fishes, stocking of fishes into public waters, commercial fishing activities in public waters, and exotic species management also ensure that no adverse impacts occur to STE species.

Another regulatory based authority for protection of freshwater fishes is to seek full restitution or restoration of fish and habitat losses occurring as a result of anthropogenic activities (Table 1). This authority applies to any freshwater fish considered public trust resources that are unlawfully killed, caught, taken, possessed, or injured, regardless of their listing status. These broadly-defined authorities have been applied as a proactive deterrent through consultations with responsible parties who manage, construct, or maintain projects that alter freshwater systems, and have routinely resulted in cooperation between TPWD and responsible parties on development of conservation plans that attempt to avoid, minimize, and mitigate project-level impacts. When necessary, restitution value of the lost or injured resources is determined through use of assessment procedures and cost values established by the American Fisheries Society (Southwick and Loftus 2017). Occurrence of STE freshwater fishes within a project area offers additional incentive for responsible parties to implement proactive avoidance measures, given the stipulated values of SE and ST fish (Table 1). Since 2010, a total of US$140,842 was collected by TPWD in civil restitution penalties for take of freshwater species, and penalties for pending cases exceeded $600,000. These restitution funds were primarily invested in the restoration or enhancement of aquatic and riparian habitats. An event on the Sulphur River, Texas in 2010 killed large numbers of ST paddlefish (*Polyodon spathula*) valued at approximately $54,000, and precipitated the proactive consultations now considered routine between TPWD and responsible parties.

The existence of protective regulations for STE species in Texas is one reason why the lists of STE fishes should be frequently updated and informed by the best available science on status, trends, and threats to species and their habitats. Frequently updating these lists also supports prioritization of species in need of conservation action and enables access to project-based funding for research, monitoring, and habitat restoration and provides the basis for additional regulatory authorities used to intervene and reverse trends for species in decline. Furthermore, these actions have the potential to contribute to recovery of species listed as endangered or threatened under the ESA or support proactive measures that avoid the need for federal listing.

As TPWD prepared to revise the lists of STE fish species in 2018, we decided to adopt a species conservation status assessment approach that uses standard methods and consistent assessment criteria and provides a starting point to obtain additional input from subject-matter experts. Prior updates and revisions to our lists of STE fishes were infrequent and without standard methodologies, listing criteria, or thresholds. Updates to the lists were typically made in response to surveys, monitoring, or research conducted by TPWD biologists or academic researchers that recognized population declines for specific species. The new TPWD strategy was

Table 1. Examples of voluntary and regulatory based conservation programs that support the conservation of freshwater fishes in Texas recognized as State Threatened or Endangered (STE) or as Species of Greatest Conservation Need (SGCN) by Texas Parks and Wildlife Department (TPWD).

Conservation program	Responsible organization(s)	Type of authority	Program description
National Fish Habitat Partnership	Desert Fish Habitat Partnership, Southeast Aquatic Resources Partnership, TPWD	Voluntary	Since 2008, nearly 60 fish habitat restoration projects have been supported in Texas through the Desert Fish Habitat Partnership and Southeast Aquatic Resources Partnership; projects restored more than 4000 ha of fish habitats
Crucial Habitat Assessment Tool (CHAT)	Western Association of Fish and Wildlife Agencies	Voluntary	GIS-based tool developed for the western USA; informs consideration of fish and wildlife habitats in land-use planning, zoning, and development decisions
Southeast Conservation Blueprint	Southeastern Association of Fish and Wildlife Agencies	Voluntary	Serves as a living, spatial plan that identifies important areas for fish and wildlife conservation across the southeastern USA and Caribbean
Texas Aquatic Gap Sampling Program	TPWD, University of Texas at Austin	Voluntary	Fills gaps in distributional data for freshwater fishes and mussels recognized as STE or SGCN; surveys are primarily conducted within riverscapes recognized by TPWD as Native Fish Conservation Areas
Cooperative Endangered Species Conservation Fund	TPWD, U.S. Fish and Wildlife Service	Voluntary	Provides cost-share funding to fill critical science needs and implement conservation measures to conserve federally listed species
State Wildlife Grants Program	TPWD, U.S. Fish and Wildlife Service	Voluntary	Provides cost-share funding to fill critical science needs and implement conservation measures to conserve freshwater fishes recognized as STE or SGCN
Landowner Incentive Program	TPWD, USFWS Partners for Fish and Wildlife Program, and numerous local cooperators	Voluntary	Provides cost-share funding to cooperating landowners to implement fish and wildlife habitat restoration projects on private lands; since 2010, the program has cooperated with approximately 140 landowners to support 160 projects that restored over 24,000 ha
Texas Farm and Ranch Lands Conservation Program	TPWD	Voluntary	Provides cost-share funding to cooperating land trusts for the purchase of conservation easements on private lands
Texas Instream Flow Program	TPWD, Texas Water Development Board, and Texas Commission on Environmental Quality	Voluntary	Performs studies to identify instream flow regimes needed to maintain sound ecological environments in Texas rivers and streams; studies use SGCN and STE freshwater fishes as focal species
Collaborative Conservation Agreements	TPWD and numerous cooperators	Voluntary	Through multi-agency conservation plans, TPWD cooperates with partners to implement interjurisdictional, watershed-scale, and range-wide conservation efforts for focal species
Texas Native Fish Conservation Areas	TPWD	Voluntary	Consists of a network of 20 watershed-based management units that serve as strongholds for freshwater fish SGCN and STE freshwater fishes
Texas Parks & Wildlife Code, §§ 67.001–67.0041, Nongame Species	TPWD	Regulatory	Provides authorities and mandates for conservation of non-game freshwater fishes, including research, species propagation, survey and monitoring, etc. to ensure the continued ability of non-game fishes "to perpetuate themselves"
Texas Parks & Wildlife Code, § 12.0011, Resource Protection	TPWD	Regulatory	Provides authorization to seek full restitution or restoration of fish and habitat losses occurring as a result of anthropogenic activities
Texas Parks & Wildlife Code, § 69.23, Fish and Wildlife Values	TPWD	Regulatory	Authorizes a substantial increase in the restitution value of STE species, with each State Endangered fish valued at US$1000 per individual and each State Threatened fish valued at $500 per individual
Texas Administrative Code, §§ 69.301–69.311, Scientific, Educational, and Zoological Permits	TPWD	Regulatory	Authorizes regulatory oversight by TPWD of scientific and zoological collection of freshwater fishes; listing as STE prohibits the take, possession, transport, or sale of a species in the absence of a Scientific Permit for Research
Texas Parks & Wildlife Code, §§ 52.101–52.401, Introduction of Fish, Shellfish, and Aquatic Plants	TPWD	Regulatory	Authorizes regulatory oversight by TPWD of stocking of fishes into public waters, ensuring that no adverse impacts occur to STE freshwater fishes
Texas Parks & Wildlife Code, sections §§ 57.377–57.386, Permits to Possess or Sell Nongame Fish Taken from Public Freshwater	TPWD	Regulatory	Authorizes regulatory oversight by TPWD of commercial fishing activities in public waters, ensuring that no adverse impacts occur to STE freshwater fishes
Texas Parks & Wildlife Code, §§ 57.111–57.137, Harmful or Potentially Harmful Fish, Shellfish, and Aquatic Plants	TPWD	Regulatory	Authorizes regulatory oversight by TPWD for management of aquatic invasive species, ensuring that no adverse impacts occur to STE freshwater fishes
Texas Parks & Wildlife Code, §§ 69.101–69.121, Issuance of Marl, Sand, and Gravel Permits	TPWD	Regulatory	Regulates disturbance of instream habitats within state-owned streambeds; projects that disrupt or remove stream bed materials may only be permitted if determined to not damage or injuriously affect the river or freshwater fishes

designed to comprehensively assess the status of the diversity of Texas plants and animals and ensure that the lists of STE species accurately reflect current status and trends.

Enabling a Data-Driven Approach for Assessing the Conservation Status of Texas Freshwater Fishes

Comprehensive and reliable data are foundational for determining conservation status and threats to any species. To inform fish species conservation status assessments, TPWD relied upon data available through the Biodiversity Center Fish Collection at the University of Texas at Austin. This collection contains more than 1.7 million specimens, and most (>75%) are from Texas freshwater systems. These specimens were used to compile the open-access database accessible through the Fishes of Texas website (www.fishesoftexas.org/home/). The database consists of a carefully curated, fully georeferenced, and high-quality compilation of all known specimen-based records of fish occurrences in Texas dating back to 1850.

The Biodiversity Center Fish Collection has been used for field guides (Page and Burr 2011), documentation of species ranges (Craig and Bonner 2019) and range expansions (Martin et al. 2012), historical community composition (Labay et al. 2011), bioassessments (e.g., Labay and Hendrickson 2014, Robertson et al. 2017, Labay et al. 2019), biodiversity conservation (e.g., Birdsong et al. 2018, Cohen et al. 2018, Birdsong et al. 2019), endangered species listing decisions (U.S. Fish and Wildlife Service [USFWS] 2014a), and invasive species management (Poulos et al. 2012, Cohen et al. 2014, McGarrity 2019). The high-quality data provided by the collection improve understanding of the distributional history of Texas fishes and current conservation status and provide insights into factors affecting the future of the state's fish fauna. For example, historical ranges and successive range changes (Figure 1)

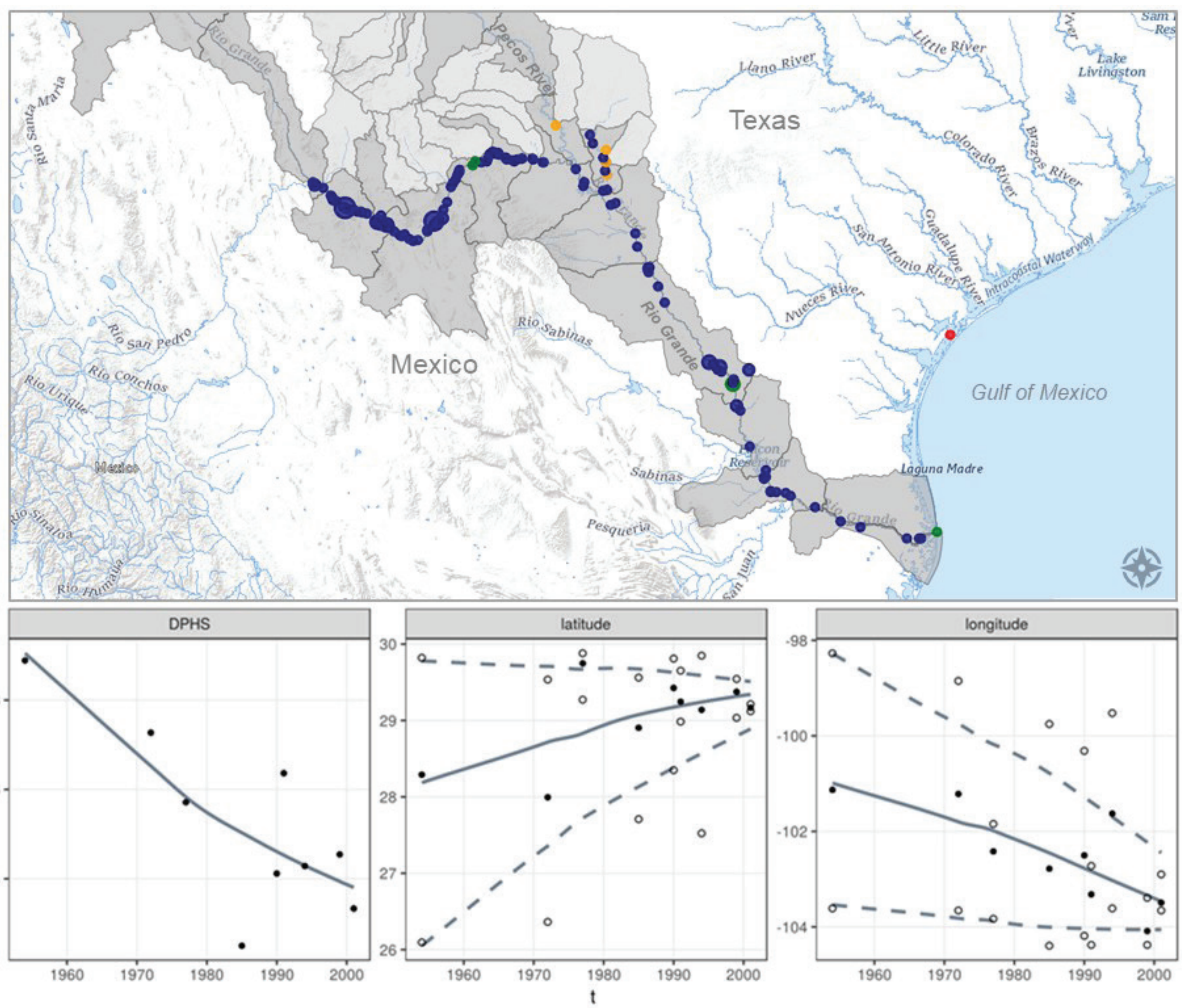

Figure 1. Native range (dark grey HUCs) of Rio Grande shiner (*Notropis jemezanus*) within the middle and lower Rio Grande basin, occurrence records for Rio Grande shiner contained within the Biodiversity Center Fish Collection at the University of Texas at Austin (green and blue dots represent reliable records; red and yellow dots are considered suspect), and analysis of spatial and temporal trends for the species, which indicate declines in detections per HUC sampled (DPHS) and a shift and reduction in the occupied range to the middle basin (Cohen et al. 2018).

coupled with species distribution models yield important information about how community ecology, demographic changes, habitat loss, the spread of invasive exotics, and impacts of climate change affect species status. Those insights can then support conservation planning and policy decisions by TPWD and others. As described below, data and information from the collection also provided foundational science for recommended revisions to the list of freshwater fish SGCN (Cohen et al. 2018) and the lists of STE freshwater fishes.

Adopting a Standardized Species Conservation Status Assessment Methodology

In 2018, TPWD established a multidisciplinary STE Listing Work Group with representatives from the Coastal Fisheries, Inland Fisheries, and Wildlife divisions of TPWD. The TPWD STE Listing Work Group was tasked with coordinating development or adoption of consistent methodologies for assessing conservation status of Texas fish, wildlife, and plants and for coordinating development of science-based and data-driven recommendations for revision of STE species lists. To determine the relative degree of conservation concern, and ultimately whether to designate species as STE, the TPWD STE Listing Work Group adopted the NatureServe Rank Calculator as a standardized methodology (Faber-Langendoen et al. 2012, Master et al. 2012). This methodology was developed to provide a consistent approach because NatureServe and its network of state-based natural heritage programs periodically assess conservation status of species and ecosystems across North America. As the state-based natural heritage program for Texas, TPWD is an active cooperator within the NatureServe network. The NatureServe Rank Calculator methodology and associated tools provide a data-driven and regionally consistent approach to evaluate extirpation risk of species at national or state scales, extinction risk of species at global scales, and elimination risk of ecosystems at global scales. Furthermore, the methodology was designed to be compatible with international efforts to assess conservation status of species and contribute to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, which is intended to serve as a tool to inform and catalyze action for global biodiversity conservation (IUCN 2019).

As an initial step to inform potential revisions to the set of freshwater fishes contained on the lists of Texas STE species, the NatureServe Rank Calculator methodology and the Biodiversity Center Fish Collection data were used to assess the conservation status of 91 Texas SGCN freshwater fishes (Figure 2) and also to map the locations of these fishes by number and by sub-watershed locations (Figure 3). These species were recommended by Cohen et al. (2018) as SGCN for the forthcoming 2023 revision of the State Wildlife Action Plan for Texas and were recently adopted by TPWD as focal species for implementation of a statewide network of Native Fish Conservation Areas (Birdsong et al. 2019, Garrett et al. 2019). For each species, scores were assigned to each of 10 individual core factors (i.e., population size, range extent, area of occupancy, number of occurrences, number of occurrences with good viability, environmental specificity, scope, severity, and timing of threats, intrinsic vulnerability, and long-term and short-term trends), which serve as indicators of species rarity, threats, and trends (See Table 1 in Master et al. 2012). Scores assigned to each factor were scaled and weighted according to the perceived level of contribution of each factor to overall species imperilment and risk of extinction (See Table 9 in Faber-Langendoen et al. 2012). Weighted scores were then combined across factors to calculate a final conservation status score for each species and assigned a corresponding conservation status rank (Tables 2 and 3). If data and information used as the basis for scoring of a specific factor were lacking or uncertain, factor scores were assigned a wider range of values, which introduced greater levels of uncertainty into the final conservation status score. Depending on the degree of uncertainty, the NatureServe Rank Calculator assigned either an individual conservation status rank (e.g., Imperiled [S2]), which indicated low levels of uncertainty, or a dual rank (e.g., Imperiled/Vulnerable [S2S3]), which recognized higher levels of uncertainty within one or more factor scores (Table 3).

Listing thresholds established by the TPWD STE Listing Work Group centered on these updated state-based species conservation status ranks. Species assigned a state-based rank of Critically Imperiled (S1), Imperiled (S2), or the dual ranks of Critically Imperiled/Imperiled (S1S2) or Imperiled/Vulnerable (S2S3) were included in subsequent phases of the species conservation status assessment process (Figure 2). For species endemic to Texas, updated state-based conservation status ranks assembled through this process are expected to be adopted by NatureServe as the updated global conservation status ranks for those species. For the subset of freshwater fishes with native ranges that extend beyond the borders of Texas, our updated state-based ranks are expected to inform forthcoming updates to the NatureServe global conservation status ranks.

Global species conservation status ranks use the same methodology, but with consideration of data and information from throughout a species' native and occupied range (Faber-Langendoen et al. 2012). Although not a primary consideration in the development of our STE species listing recommendations, global ranks were reviewed by TPWD for non-endemic species with attention given to the extent of the occupied range that occurs outside the state, recognition of whether Texas exists on the periphery

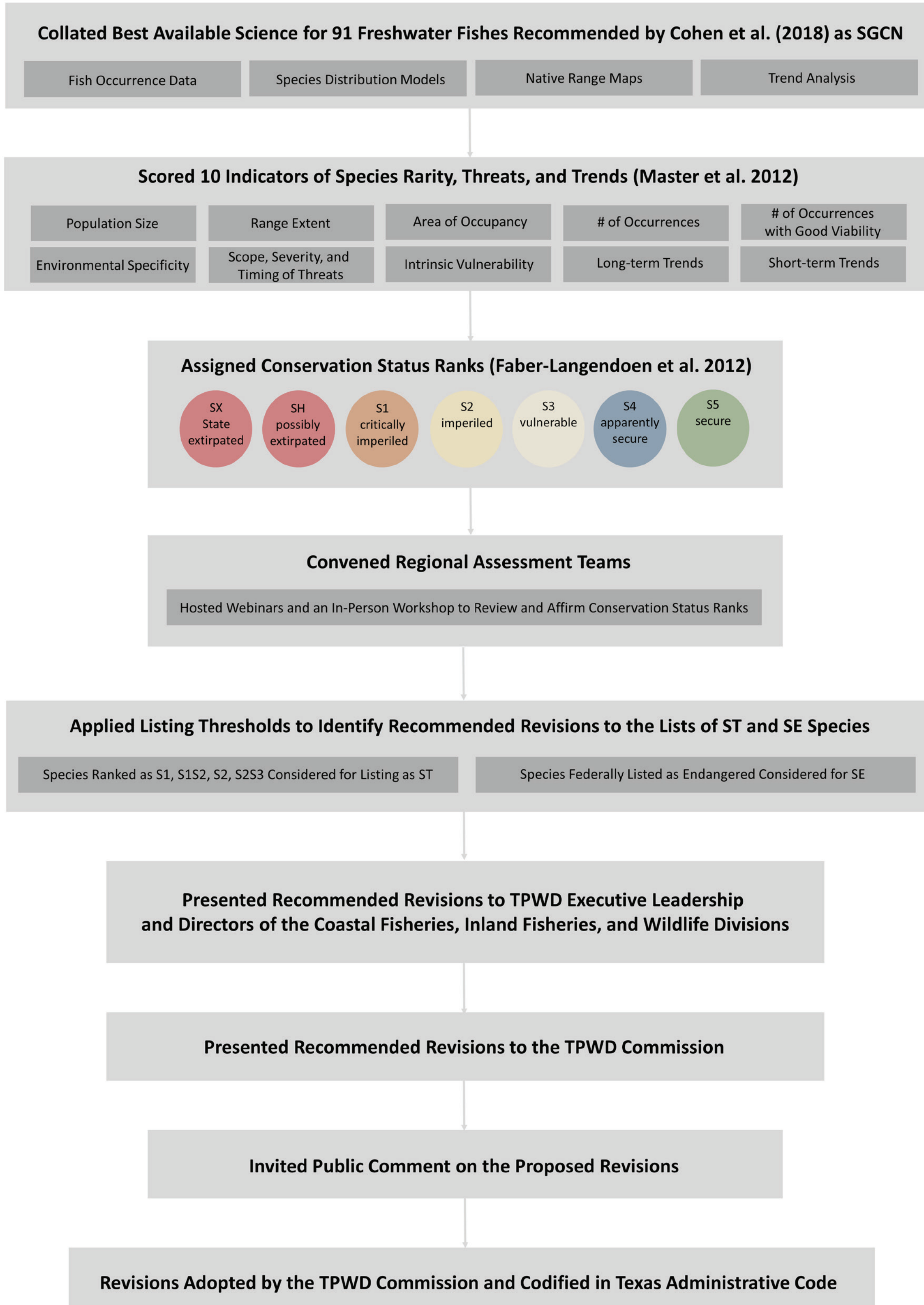

Figure 2. Flow chart illustrating the steps taken by TPWD to revise the lists of State Threatened or Endangered freshwater fishes.

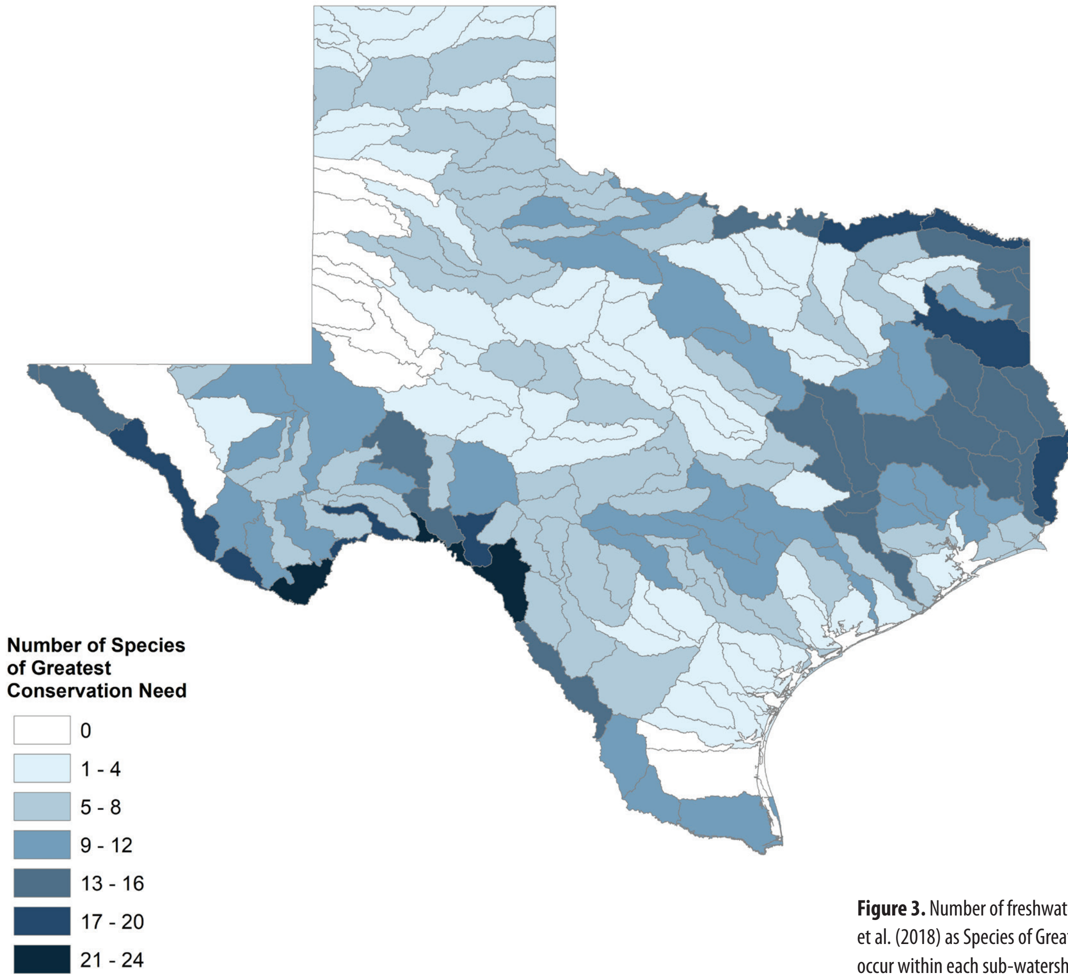

Figure 3. Number of freshwater fishes identified by Cohen et al. (2018) as Species of Greatest Conservation Need that occur within each sub-watershed of Texas.

Table 2. Definitions of NatureServe state-based conservation status ranks, status rank codes, and their corresponding range of conservation status scores (adapted from Faber-Langendoen et al. 2012).

Conservation status rank	Conservation status rank code	Range of conservation status scores	Conservation status rank definition
State extirpated	SX	N/A	Extirpated from the state
Possibly extirpated	SH	N/A	Known only from historical records but some hope for rediscovery
Critically imperiled	S1	≤ 1.5	Very high risk of extirpation due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors
Imperiled	S2	1.6–2.5	High risk of extirpation
Vulnerable	S3	2.6–3.5	Moderate risk of extirpation
Apparently secure	S4	3.6–4.5	Considered stable but with some cause for concern from recent localized declines or threats
Secure	S5	4.6–5.5	Extensive range, abundant populations or occurrences, limited concern with declines or threats

Table 3. Freshwater fishes recognized as State Threatened or State Endangered in Texas (revised 2020) with associated NatureServe state-based conservation status ranks (revised 2019), state listing status prior to 2020, and current federal listing status. NatureServe State Rank: see Table 2. Listing status: State Threatened (ST), State Endangered (SE), Federally Threatened (FT), Federally Endangered (FE), Threatened due to similarity of appearance (SAT).

				State listing status		
Family	**Scientific name**	**Common name**	**NatureServe state rank**	**Previous listing status**	**Updated listing status**	**Federal listing status**
Acipenseridae	*Scaphirhynchus platorynchus*	shovelnose sturgeon	S1	ST	ST	SAT
Polyodontidae	*Polyodon spathula*	paddlefish	S1	ST	ST	–
Cyprinidae	*Campostoma ornatum*	Mexican stoneroller	S2	ST	ST	–
	Cyprinella lepida	plateau shiner	S2	–	ST	–
	Cyprinella proserpina	proserpine shiner	S2S3	ST	ST	–
	Dionda diaboli	Devils River minnow	S1	ST	ST	FT
	Dionda episcopa	roundnose minnow	S1	–	ST	–
	Dionda nigrotaeniata	Medina roundnose minnow	S1	–	ST	–
	Dionda serena	Nueces roundnose minnow	S2	–	ST	–
	Gila pandora	Rio Grande chub	S1	ST	ST	–
	Hybognathus amarus	Rio Grande silvery minnow	SX	SE	SE	FE
	Macrhybopsis aestivalis	speckled chub	S1S2	–	ST	–
	Macrhybopsis australis	prairie chub	S1	–	ST	–
	Macrhybopsis tetranema	peppered chub	S1	–	ST	–
	Notropis braytoni	Tamaulipas shiner	S1S2	–	ST	–
	Notropis buccula	smalleye shiner	S1S2	–	SE	FE
	Notropis chihuahua	Chihuahua shiner	S1	ST	ST	–
	Notropis girardi	Arkansas River shiner	S1	ST	ST	FT
	Notropis jemezanus	Rio Grande shiner	S1	–	ST	–
	Notropis oxyrhynchus	sharpnose shiner	S1S2	–	SE	FE
	Notropis potteri	chub shiner	S2	–	ST	–
	Notropis simus pecosensis	Pecos bluntnose shiner	SX	ST	ST	FT
	Pteronotropis hubbsi	bluehead shiner	S2	ST	ST	–
Catostomidae	*Cycleptus elongatus*	blue sucker	S1	ST	ST	–
	Erimyzon claviformis	creek chubsucker	S2	ST	ST	–
Ictaluridae	*Ictalurus lupus*	headwater catfish	S1S2	–	ST	–
	Prietella phreatophila	Mexican blindcat	S1	–	SE	FE
	Satan eurystomus	widemouth blindcat	S1	ST	ST	–
	Trogloglanis pattersoni	toothless blindcat	S1	ST	ST	–
Poeciliidae	*Gambusia clarkhubbsi*	San Felipe gambusia	S1	ST	ST	–
	Gambusia gaigei	Big Bend gambusia	S1	SE	SE	FE
	Gambusia georgei	San Marcos gambusia	SX	SE	SE	FE
	Gambusia heterochir	Clear Creek gambusia	S1	SE	SE	FE
	Gambusia nobilis	Pecos gambusia	S1	SE	SE	FE
	Gambusia senilis	blotched gambusia	S1	ST	ST	–
Cyprinodontidae	*Cyprinodon bovinus*	Leon Springs pupfish	S1	SE	SE	FE
	Cyprinodon elegans	Comanche Springs pupfish	S1	SE	SE	FE
	Cyprinodon eximius	Conchos pupfish	S1	ST	ST	–
	Cyprinodon pecosensis	Pecos pupfish	S1	ST	ST	–
	Cyprinodon rubrofluviatilis	Red River pupfish	S2	–	ST	–
Percidae	*Etheostoma fonticola*	fountain darter	S1	SE	SE	FE
	Etheostoma grahami	Rio Grande darter	S1	ST	ST	–
	Percina apristis	Guadalupe darter	S1	–	ST	–
	Percina maculata	blackside darter	S1	ST	ST	–

or is core to the species range, and how recently the last global species conservation status assessment was completed by NatureServe. Other criteria considered in the development of STE listing recommendations included the scope of voluntary-based conservation measures directed at individual species, and the potential role or implications of STE listing in addressing specific conservation challenges and needs of that species. The TPWD STE Listing Work Group also decided that STE listing of freshwater fishes (and marine fishes) would be limited to species currently recognized by the American Fisheries Society (Page et al. 2013). Similar requirements were established for other groups of taxa with corresponding professional societies which maintain lists of recognized species. Furthermore, the STE Listing Work Group determined that SE status would be reserved for species currently listed as endangered under the ESA, ensuring consistency and alignment between the two protected species lists.

Ensuring Transperency and Incorporating Input from Subject-Matter Experts

Subject-matter experts from the TPWD Inland Fisheries and Wildlife divisions, universities, and non-governmental organizations were invited to participate in a series of three introductory webinars and an in-person workshop used to obtain input into recommended revisions to the lists of Texas STE freshwater fishes. An open invitation to participate was broadly disseminated by TPWD to professionals actively involved in native fish research and conservation in the state. Webinars were designed to familiarize participants with 1.) state-based conservation measures available for the restoration and protection of native freshwater fishes, 2.) conservation implications for listing of a species as STE, 3.) the species conservation status assessment methodology adopted by TPWD to identify species recommended for listing, and 4.) the process that would be used to facilitate additional input from subject-matter experts. During the webinars, these experts were invited to participate in one or more of four regional assessment teams (i.e., Chihuahuan Desert, East Texas and Coastal Plains, Edwards Plateau, and Southern Great Plains). The primary role of each regional assessment team was to review the state-based species conservation status ranks assigned to each species in those regions. The regional teams were asked to 1.) determine whether they agreed with the updated state-based conservation status ranks, 2.) provide supporting observations or evidence for their responses, 3.) provide additional data on the status and trends of the species assessed in their regions, and 4.) provide specific case studies of diminished or value-added protections potentially occurring because of listing of a specific species as STE. Input from each team was collated in advance of the in-person workshop, with a regional summary of recommendations presented at the workshop by each regional assessment team. A facilitated discussion then occurred at the workshop, with all workshop attendees invited to offer input, feedback, and ask questions on the recommendations of each regional assessment team. Regional recommendations were finalized at the workshop and then combined and formatted into a proposed statewide revision to the lists of STE species.

Summary of Changes to the State Threatened or Endangered Species Lists

The proposed statewide revision of freshwater fishes was combined with recommended statewide revisions by TPWD for other taxonomic groups within the resource management purview of the agency. The combined lists of SE species and ST species were presented to the TPWD STE Listing Work Group and TPWD senior leadership for review and then presented to the Texas Parks and Wildlife Commission at their August 2019 meeting. The proposed revisions were subsequently published in the Texas Register, which serves as the journal of state agency rulemaking. At the January 2020 Texas Parks and Wildlife Commission Meeting, TPWD staff summarized public comments received in response to the notice in the Texas Register and then offered a proposal for rulemaking, which was unanimously adopted by the Texas Parks and Wildlife Commission. Following adoption, this rulemaking action was codified in Texas Administrative Code in April 2020. Revisions made to the STE species lists as a result of this process expanded state-based protections for 16 species of freshwater fishes (Table 3; Figure 4), including recognition of an additional 13 species as ST and three species as SE. Three new species listed as SE were previously listed as endangered under the ESA. Two shiners have experienced substantial range reductions, with their current occupied range limited to the Brazos River upstream of Possum Kingdom Lake; both were listed in 2014 (USFWS 2014b). Mexican blindcat (*Prietella phreatophila*), a species thought to be limited in range to areas of northern Coahuila, Mexico, was recently documented in Texas within a cave located at the Amistad National Recreation Area (Cohen et al. 2018). Through an international agreement with Mexico, the species was listed as endangered under the ESA in 1970 (USFWS 1970).

Through this species conservation status assessment process, an additional six species of Texas freshwater fish met the ST criteria and were proposed for listing; however, these species had not yet been formally recognized as valid species by the American Fisheries Society Names of Fishes Committee (Page et al. 2013). Four of these six species were previously thought to be populations of already described species but were recently determined to be unique, genetically distinct species, most with extremely limited

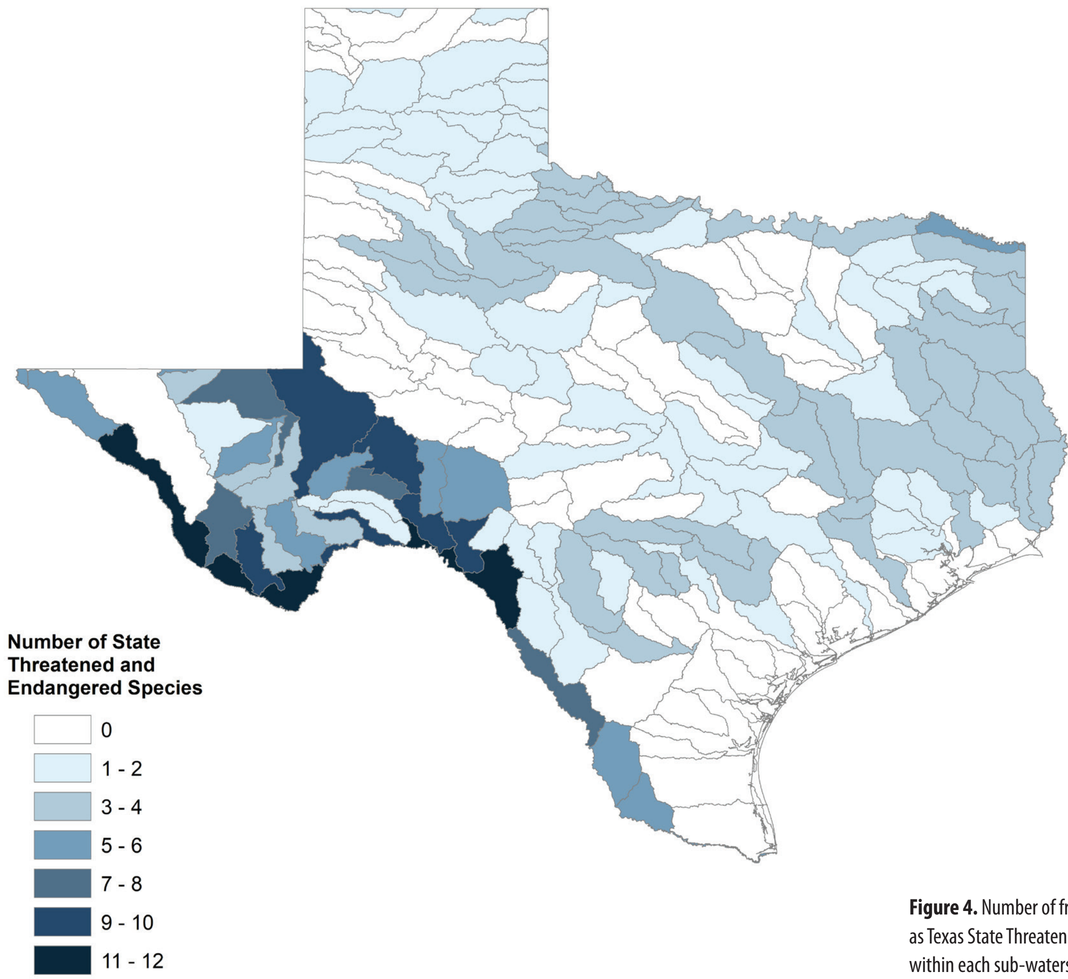

Figure 4. Number of freshwater fishes identified as Texas State Threatened or Endangered that occur within each sub-watershed of Texas.

ranges confined to individual river systems. TPWD will revisit the consideration for listing these six species upon inclusion of these species in future publications of the American Fisheries Society Names of Fishes Committee. Conservation status of six additional species of freshwater fish also met basic criteria to be considered for listing as ST, but subject-matter experts recommended that additional data were needed to accurately assess their conservation status globally and in Texas. These species subsequently were adopted as research priorities of TPWD, with the expectation that their listing status will be reassessed during the next revision of the lists of STE species. Lastly, the potential existed for delisting of STE freshwater fishes with conservation status ranks that did not meet or exceed the listing threshold established by the TPWD STE Listing Work Group (i.e., species with conservation status ranks of Vulnerable [S3], Apparently Secure [S4], or Secure [S5]). While none of the freshwater fishes previously contained on the lists of STE species were assigned a conservation status score below the listing threshold, several terrestrial and marine species within the resource management purview of the TPWD Coastal Fisheries and Wildlife divisions received scores (and affirmation from subject-matter experts) that resulted in their delisting.

Discussion

Through this process, a comprehensive, data-driven, inclusive, and transparent review was completed of the conservation status of Texas freshwater fishes. Adoption of the NatureServe Rank Calculator as the standard methodology for evaluation of Texas freshwater fish for listing as STE was advantageous in that it aligned this review with similar species conservation status assessments being undertaken in other states, territories, and provinces throughout North America by natural heritage programs and other cooperators of the NatureServe network. Using a standardized methodology will facilitate communications and coordination among stakeholders involved in range-wide conservation assessment and planning efforts for species with native ranges encompassing multiple jurisdictions (i.e., states, provinces, territories). Adoption of the NatureServe Rank Calculator aligned our review with criteria considered in development of the IUCN Red List of Threatened Species, ensuring that conservation status of Texas freshwater fishes more accurately reflects and considers global biodiversity conservation status assessments and species conservation initiatives. Furthermore, because this risk-based species conservation status methodology was used across all taxonomic groups under the purview of TPWD, it enabled a consistent, equitable, and repeatable approach for consideration of species in need of added protections offered to those contained on the lists of STE species. For these same reasons, use of this methodology should also be considered for adoption by TPWD for the next update of the list of SGCN in 2023, as its prior use for that purpose was previously limited to species within the purview of the TPWD Wildlife Division.

This review of conservation statuses of Texas freshwater fishes included opportunities for stakeholder engagement and input from subject-matter experts actively involved in native fish research and conservation in the state. Use of webinars and an in-person workshop to obtain input from subject-matter experts ensured that the best available science was considered in species conservation status assessments. This stakeholder process also contributed to a more unified and defensible set of recommendations from native fish conservation professionals in the state. The geographic boundaries of the four regional assessment teams established for this stakeholder process directly corresponded to the four fish conservation planning regions previously adopted by TPWD for implementation of a network of Native Fish Conservation Areas in Texas (Birdsong et al. 2019). Those four regions are ecologically meaningful in that they closely align with the biotic provinces of Texas (Blair 1950). It was apparent throughout both planning processes that many of the researchers and conservationists engaged in native fish conservation in Texas were also geographically aligned with those regions (Birdsong et al. 2019, Garrett et al. 2019). Use of these planning regions for the revision of the lists of STE freshwater fishes allowed formation of teams comprising individuals with existing professional relationships who were comfortable interacting and sharing data, observations, ideas, and strategies, and who recognized the direct value of participating in the process to advance the conservation of species and habitats within the geographic focus of their respective programs. These observations underscore the importance of engagement with stakeholders and subject-matter experts at local or regional scales, which proved beneficial and effective for this species conservation status assessment process.

A shortcoming of the stakeholder process was lack of proactive communication and coordination with the regulated community potentially affected by revision of the lists of STE species. Several organizations representative of the regulated community inaccurately interpreted or perceived specific added regulatory burdens from species additions to the lists of STE species, often confusing the lists of STE species with the regulatory protections provided through the ESA. It is recommended that future revisions to the lists of STE species include proactive stakeholder communication and coordination efforts directed explicitly at the regulated community in order to explain regulatory implications of state-based species listings and provide a detailed description of the species conservation status assessment methodology and supporting data used by TPWD to recommend species for listing.

The TPWD should consider establishing a recurring, cyclical schedule for completion of comprehensive species conservation status assessments and necessary revisions to the lists of STE species across taxa. Such a decision should consider the timing and frequency that new data and information become available on status and trends of species. Other potential considerations include the timing and frequency that recurring updates are made to the State Wildlife Action Plan for Texas and associated list of SGCN, and opportunities that exist to integrate the species conservation status assessments used for these two processes. As noted earlier, the TPWD Wildlife Division previously utilized the NatureServe species conservation status ranks to select species for inclusion on the list of SGCN. It is recommended that the Inland Fisheries and Coastal Fisheries divisions also adopt this strategy, with all natural resources divisions cooperating on the development of standard thresholds that consider the NatureServe state-based species conservation status ranks in determination of species to be listed or removed as SGCN. For example, species with conservation status ranks of Vulnerable, Imperiled, and Critically Imperiled might be considered for listing as SGCN. This would enable investments of research and conservation funding available through the State Wildlife Grants Program (and the Recovering America's Wildlife Act, should it be passed by the U.S. Congress) toward all species on the lists of STE species (i.e., typically those ranked as Imperiled or Critically Imperiled) and toward other species considered at moderate risk of statewide extirpation (i.e., typically those ranked as Vulnerable) given rarity, threats, and current population trends (Master et al. 2012).

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We thank the following subject-matter experts for their helpful reviews and comments on the species conservation status assessments, and for their active participation in the related in-person workshop used to collate input on recommended revisions to the lists of STE species: Matt Acre (Texas A&M University), Melissa Casarez (University of Texas at Austin), Adam Cohen (University of Texas at Austin), Kevin Conway (Texas A&M University), Laura Dugan (TPWD Wildlife Division), Robert Edwards (University of Texas at Austin), Stephanie George (Texas A&M University), Bob Gottfried (TPWD Wildlife Division), George Guillen (University of Houston at Clear Lake), Dean Hendrickson (University of Texas at Austin), Ken Kurzawski (TPWD Inland Fisheries Division), Gordon Linam (TPWD Inland Fisheries Division), Stephan Magnelia (TPWD Inland Fisheries Division), Josh Perkin (Texas A&M University), Lauren Reynolds (TPWD Inland Fisheries Division), Clint Robertson (TPWD Inland Fisheries Division), Nate Smith (TPWD Inland Fisheries Division), Ryan Smith (The Nature Conservancy of Texas), Gene Wilde (Texas Tech University), Lance Williams (University of Texas at Tyler), and Kirk Winemiller (Texas A&M University). We thank the TPWD STE Listing Work Group for their coordination and communication with TPWD division and agency leadership and with the Texas Parks and Wildlife Commission to facilitate the revision of the lists of STE species. We also thank Dr. Steven Sammons and three anonymous reviewers for their helpful comments and improvements to this article. Funding for this project was provided by Texas State Wildlife Grants TX T-106-R-1 and TX T-182-R-1 in cooperation with the USFWS Wildlife and Sport Fish Restoration Program.

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Chapter 4

Priority Habitats (Element 2) as Communities of Greatest Conservation Need

Overview of Texas Habitats

Across its more than 260,000 square miles, Texas is one of the largest, most biologically diverse states with prairies, expansive plains and grasslands, woodlands and forests, mountains and canyons, springs and bogs, fast flashy ephemeral streams and deliberate large perennial rivers – all of which eventually contribute to the Gulf of Mexico in some way. Twelve major ecological regions (Figure 4.1), fifteen major river basins, and nine major aquifers occupy about 172 million acres in Texas (Table 4.1) Refer also to the Texas Water Development and Texas Water Development river basin information.

Priority Habitats

Element 2 required in state wildlife action plans is to provide *descriptions of locations and relative conditions of habitats essential to species in need of conservation*.

All SGCN have lifecycle requirements which need to be better understood and/or conserved in a way that supports healthy, resilient populations, and all SGCN contribute in some way to the systems in which they occur. It's important to conserve populations in the context in which they thrive, where they can contribute to and benefit from the systems in which they live. Texas is home to some species which occur nowhere else but Texas – certain plants are dependent on specific soils or geology, some invertebrates and fishes are dependent on springs and spring-fed systems, cave and karst species require specific geological formations, and some small mammals and amphibians require very specific, geographically isolated locations. Our lands and waters provide very important pathway links among Central America, Canada, and points-in-between for thousands of seasonal migratory birds. From several species catalogues for Texas, we are known to have over 5,000 species of plants, 300 of which are known to be endemic; 636 species of birds; over 180 mammal species; and more than 30,000 insect species. Texas has tens of thousands of species, most of which are not hunted or fished. All wildlife and fish resources are important contributors, from decomposers to top predators, in every habitat and ecosystem in our state.

It is impossible to fully understand every need and/or contribution of a species or population; however, conservation usually starts with a better understanding of and actions to protect or improve sufficient physical place(s) with specific conditions to benefit the species historically using the place as habitat. Texas Parks and Wildlife has geographically referenced and described the habitats of Texas in the Texas Ecosystem Analytical Mapper (TEAM) (Figure 4.2). In this Plan, "habitats" are these physical places – places where we need to work as a conservation community. Specific conditions (the quality of those places) and other needs are further discussed in **Chapter 6: Priority Conservation Actions**.

Ecological communities important to SGCN

General Habitat categories are described in **Supplement 4.2 Descriptions of Texas Habitats and Threats**. Each Priority Community as it occurs in Texas and relevant Threats to Habitats have been described. Ecological Systems are classified using the International Ecological Classification Standard: Terrestrial Ecological Classifications for Ecological Systems of Texas' Central Great Plains. (NatureServe, 2023)

National Fish Conservation Areas

The development of the Texas Native Fish Conservation Areas Network (Texas NFCAs Network; Birdsong et al. 2019) was driven the need for an integrated and holistic approach to conservation of freshwater systems. The Texas NFCAs Network consists of springs, ciénegas, creeks, rivers, and associated watersheds uniquely valued in preservation of Texas freshwater fish diversity. Twenty native fish conservation areas have been designated throughout the state. These were selected based on a spatial prioritization focused on identification of freshwater systems critically important to the long-term persistence of 91 freshwater fishes considered species of greatest conservation need.

More information about the locations, conservation priorities, and conservation plans can be found in the comprehensive Texas NFCAs Network website.

List of Tables

Ecoregion	Ecoregion Acronym	Acres
Arizona/New Mexico Mountains	AZNM	52,250
Central Great Plains	CGPL	11,566,650
Chihuahuan Deserts	CHIH	22,624,930
Cross Timbers	CRTB	12,829,240
East Central Texas Plains (Post Oak Savanna)	ECTP	13,535,080
Edwards Plateau	EDPL	18,523,970
High Plains	HIPL	20,964,630
West Gulf Coastal Plain (Pineywoods)	WGCP	15,732,780
Southern Texas Plains	STPS	13,197,610
Southwestern Tablelands	SWTB	14,904,220
Texas Blackland Prairies	TBLP	10,719,910
Gulf Coast Prairies and Marshes	GCPM	14,661,490
All Ecoregions' Total Acres*		169,312,760*

* Acreage calculations are approximate and rounded to nearest ten acres, based on geographic information systems data and accuracy of the ecoregions' boundaries. Acre figures in various print and web sources range from approximately 165 million to 172 million.

Table 4.1 Ecoregion Acres in Texas

List of Figures

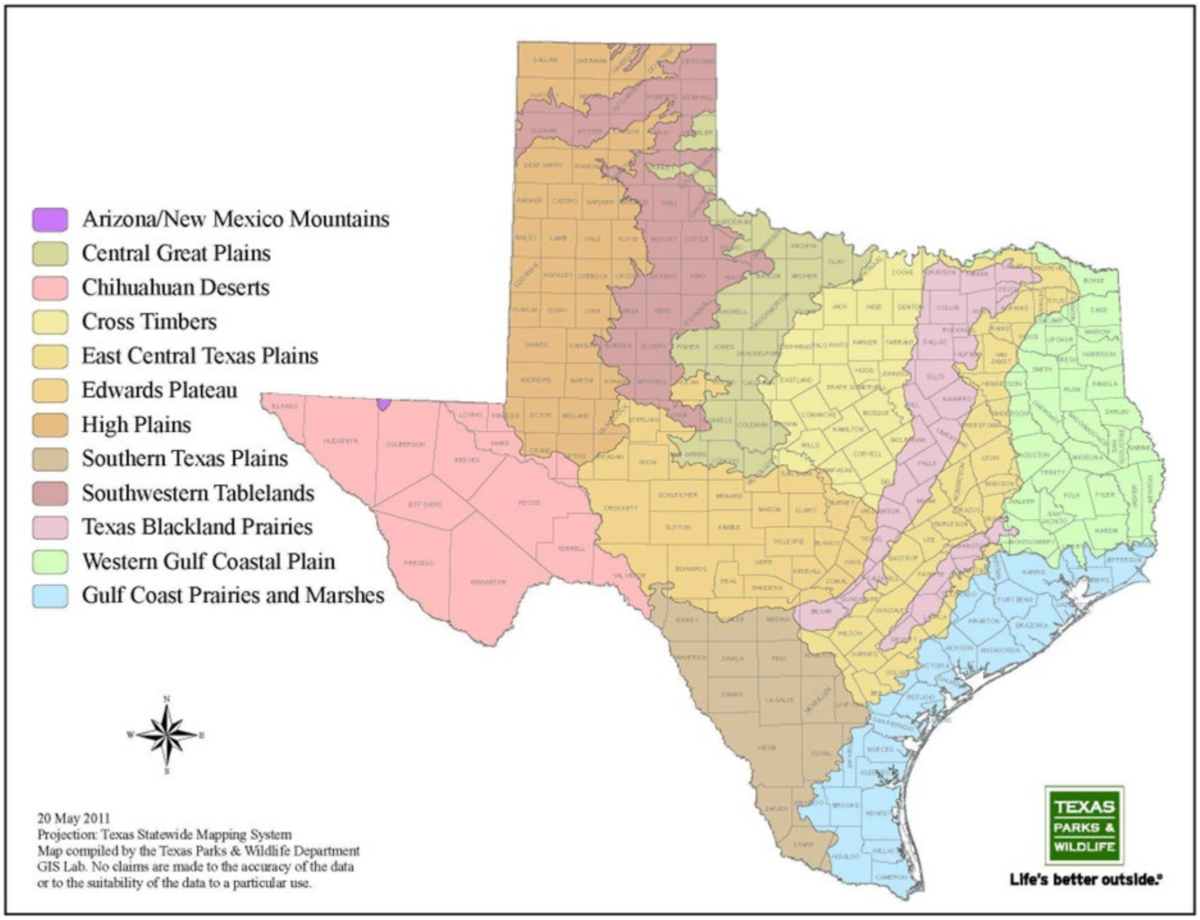


Figure 4.1 Overview of the ecological regions of Texas

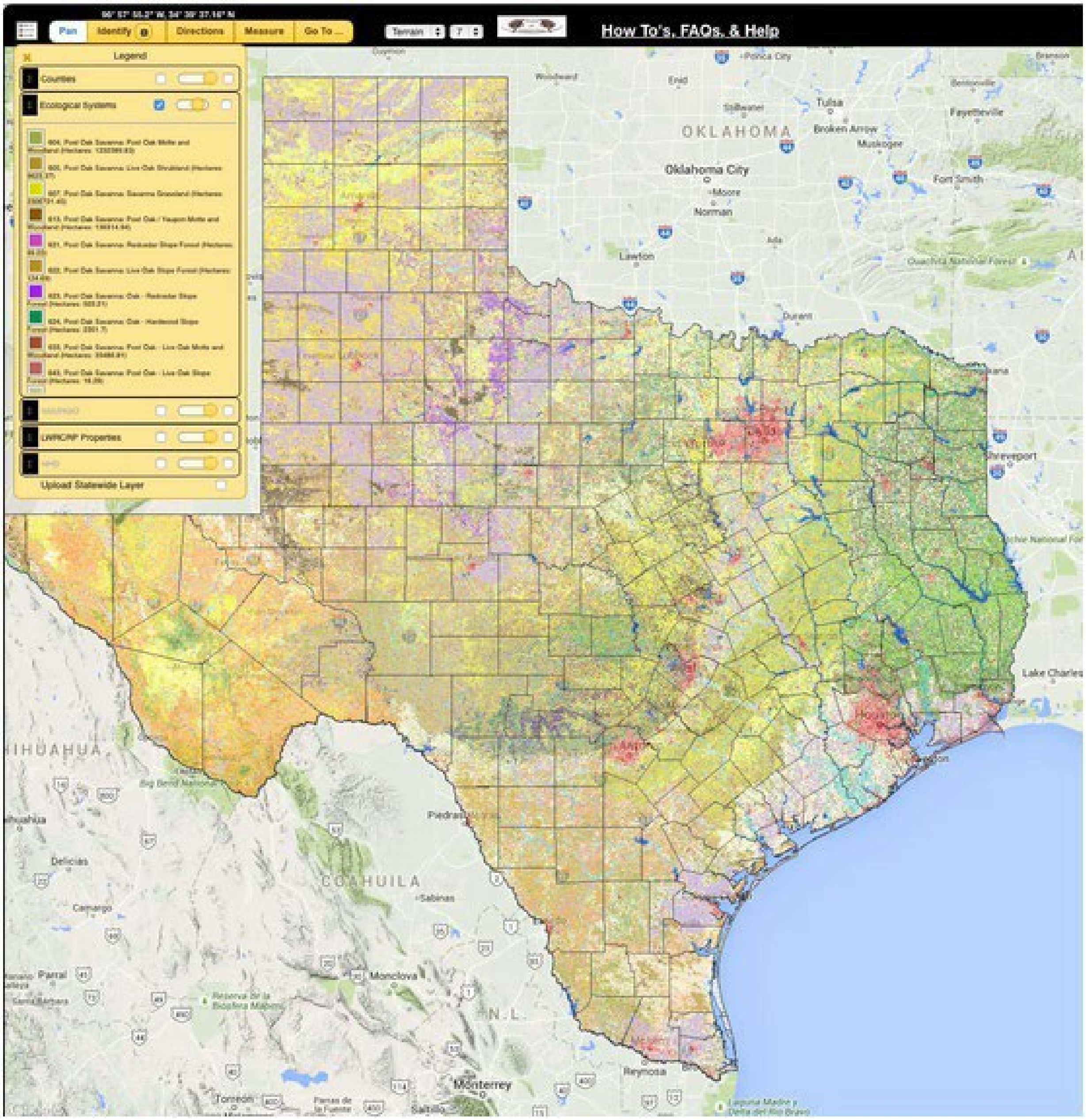


Figure 4.2. Texas Ecosystem Analytical Mapper (TEAM) preview. TEAM is an online tool to assist in understanding Texas habitats and to integrate Ecological Mapping Systems (EMS) data with land management and resource planning of all types.

Supplement 4.1: Southeast Conservation Blueprint Summary for Texas

Created 04/18/2023
The Southeast Conservation Adaptation Strategy (SECAS)

About the Southeast Blueprint

The Southeast Conservation Blueprint is the primary product of the Southeast Conservation Adaptation Strategy (SECAS). It is a living, spatial plan to achieve the SECAS vision of a connected network of lands and waters across the Southeast and Caribbean. The Blueprint is regularly updated to incorporate new data, partner input, and information about on-the-ground conditions.

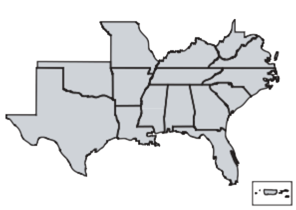
Across 15 states of the Southeast, the Blueprint identifies priority areas based on a suite of natural and cultural resource indicators representing terrestrial, freshwater, and marine ecosystems. A connectivity analysis identifies corridors that link coastal and inland areas and span climate gradients. This portion of the Southeast Blueprint is referred to as the "Base Blueprint".

To provide more complete coverage of the SECAS geography, the Blueprint incorporates two additional input plans: the Florida Marine Blueprint for marine areas in Florida and the Caribbean Landscape Conservation Design for inland areas in Puerto Rico.

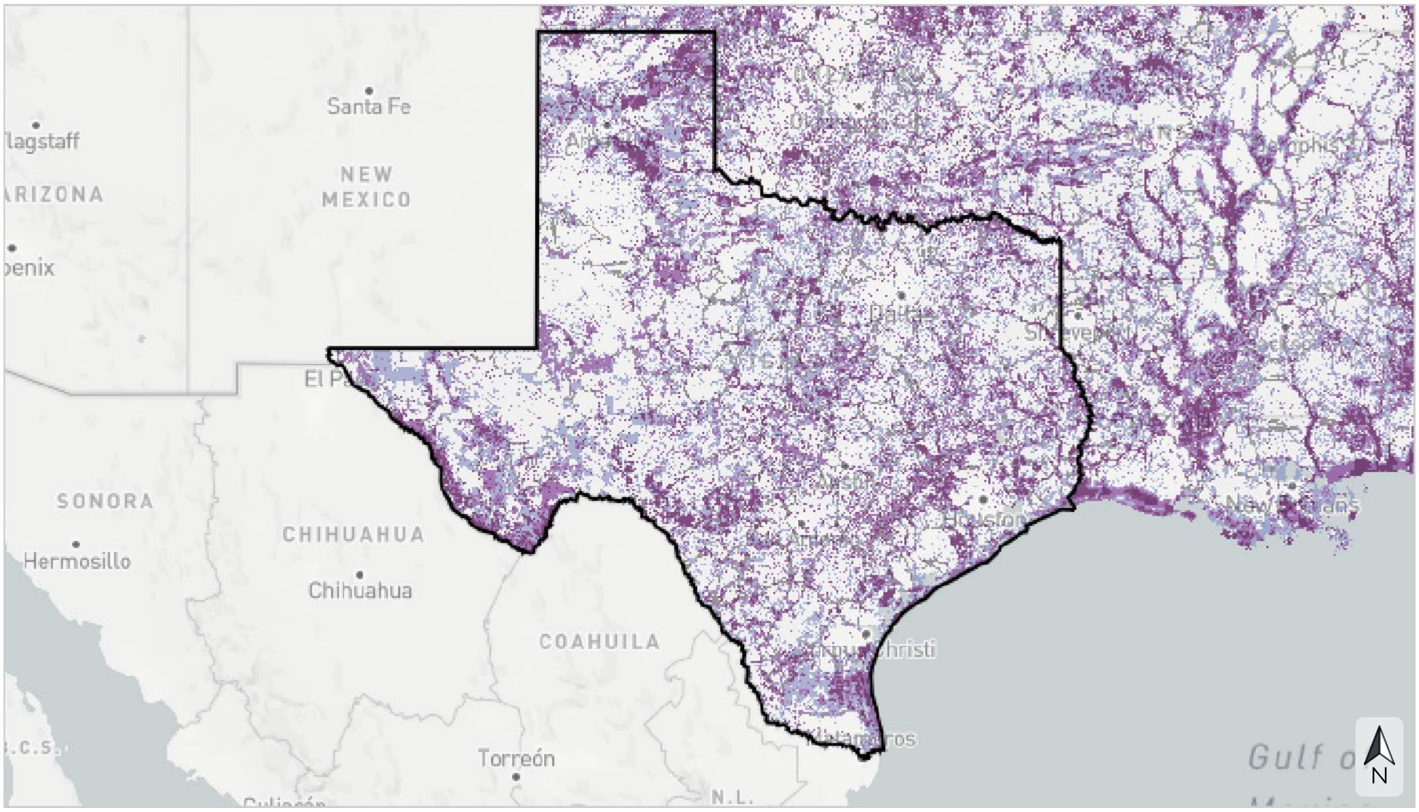
For more information:

- Visit the Blueprint webpage
- Review the Blueprint 2022 Development Process
- View and download the Blueprint data and make maps on the Blueprint page of the SECAS Atlas

If you need help or have questions about the Southeast Blueprint, you can contact Southeast Blueprint staff by reaching out to a member of the user support team.

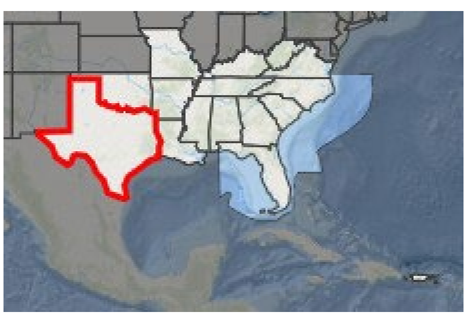


Southeast Blueprint Priorities



Basemap credits: © Mapbox © OpenStreetMap **Improve this map**

139 279 557 miles



Priorities for a connected network of lands and waters

- Highest priority
- High priority
- Medium priority

- Priority connections

Priority Categories

For a connected network of lands and waters

In total, Blueprint priorities and priority connections cover roughly 50% of the Southeast Blueprint geography.

Highest priority

Areas where conservation action would make the biggest impact, based on a suite of natural and cultural resource indicators. This class covers roughly 10% of the Southeast Blueprint geography.

High priority

Areas where conservation action would make a big impact, based on a suite of natural and cultural resource indicators. This class covers roughly 15% of the Southeast Blueprint geography.

Medium priority

Areas where conservation action would make an above-average impact, based on a suite of natural and cultural resource indicators. This class covers roughly 20% of the Southeast Blueprint geography.

Priority connections

Connections between priority areas that cover the shortest distance possible while routing through as much Blueprint priority as possible. This class covers roughly 5% of the Southeast Blueprint geography.

Table 1: Extent of each Blueprint priority category.

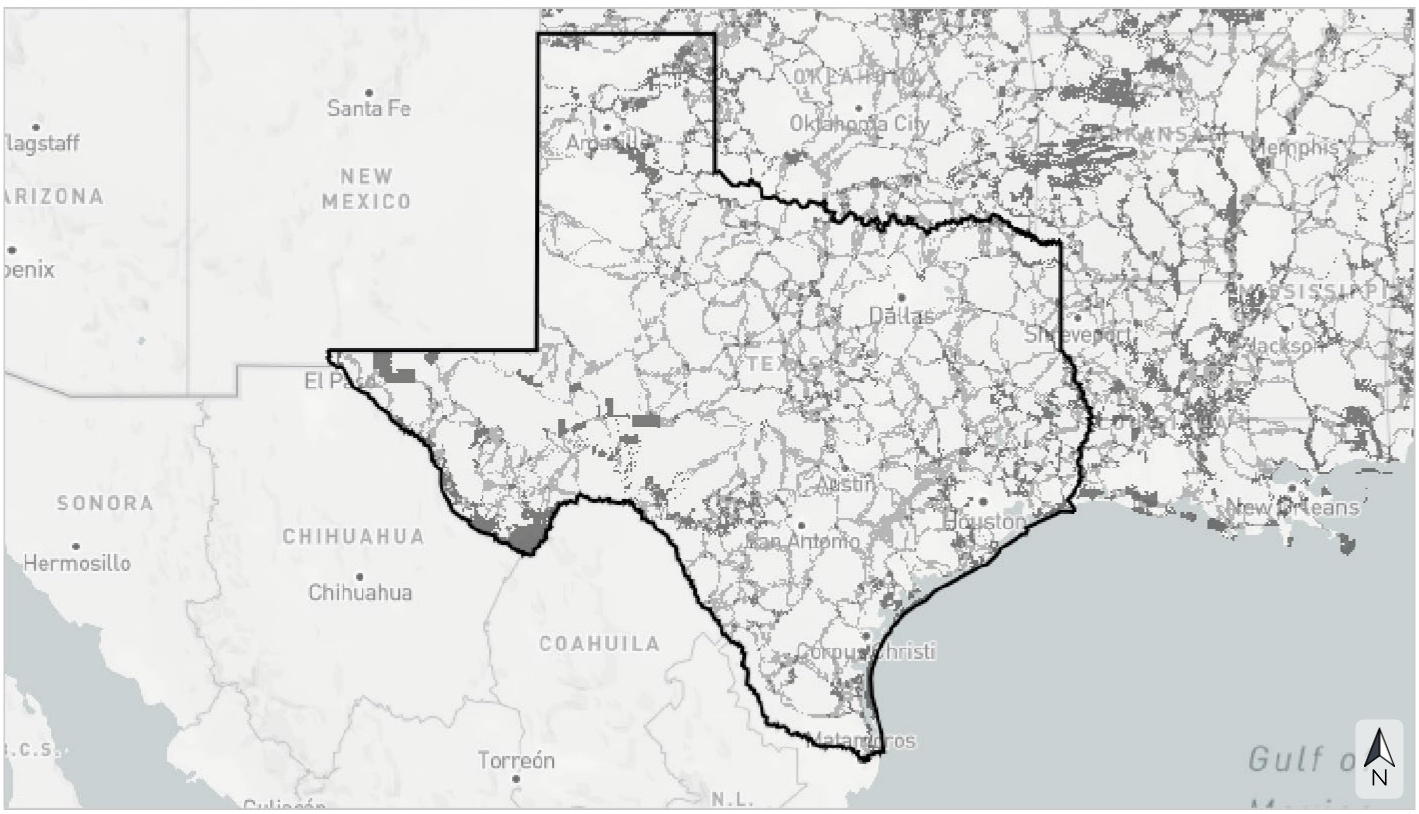
Priority Category	Acres	Percent of Area
Highest priority	16,267,005	9.5%
High priority	25,090,871	14.6%
Medium priority	35,157,201	20.5%
Priority connections	8,853,890	5.2%
Lower priority	86,509,732	50.3%
Outside Southeast Blueprint	*22,348*	*<0.1%*

Total area	**171,901,047**	**100%**

Hubs and Corridors

The Blueprint uses a least-cost path connectivity analysis to identify corridors that link hubs across the shortest distance possible, while also routing through as much Blueprint priority as possible.

Inland hubs are large patches (~5,000+ acres) of highest priority Blueprint areas and/or protected lands, connected by inland corridors. Marine and estuarine hubs are large estuaries and large patches (~5,000+ acres) of highest priority Blueprint areas. Marine and estuarine corridors connect those hubs within broad marine mammal movement areas.



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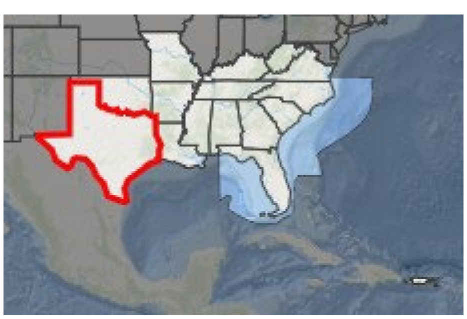


Inland hubs

Inland corridors

Marine & estuarine hubs

Marine & estuarine corridors

Not a hub or corridor

Table 2: Extent of hubs and corridors.

Type	Acres	Percent of Area
Inland hubs	12,842,885	7.5%
Inland corridors	32,747,132	19.0%
Not a hub or corridor	126,288,682	73.5%
Outside Southeast Blueprint	*22,348*	*<0.1%*
Total area	**171,901,047**	**100%**

Indicator Summary

Table 3: Terrestrial indicators.

Indicator	Present
East Coastal Plain open pine birds	-
Equitable access to potential parks	√
Fire frequency	√
Great Plains perennial grasslands	√
Greenways & trails	√
Intact habitat cores	√
Interior Southeast grasslands	-
Mississippi Alluvial Valley forest birds (protection)	-
Mississippi Alluvial Valley forest birds (reforestation)	-
Playas	√
Resilient terrestrial sites	√
South Atlantic amphibian & reptile areas	-
South Atlantic forest birds	-
South Atlantic low-urban historic landscapes	-
Urban park size	√
West Coastal Plain & Ouachitas forested wetland birds	√
West Coastal Plain & Ouachitas open pine birds	√
West Gulf Coast mottled duck nesting	√

Table 4: Freshwater indicators.

Indicator	Present
Atlantic migratory fish habitat	-
Gulf migratory fish connectivity	-
Imperiled aquatic species	√
West Virginia imperiled aquatic species	-
Natural landcover in floodplains	√
Network complexity	√
Permeable surface	√

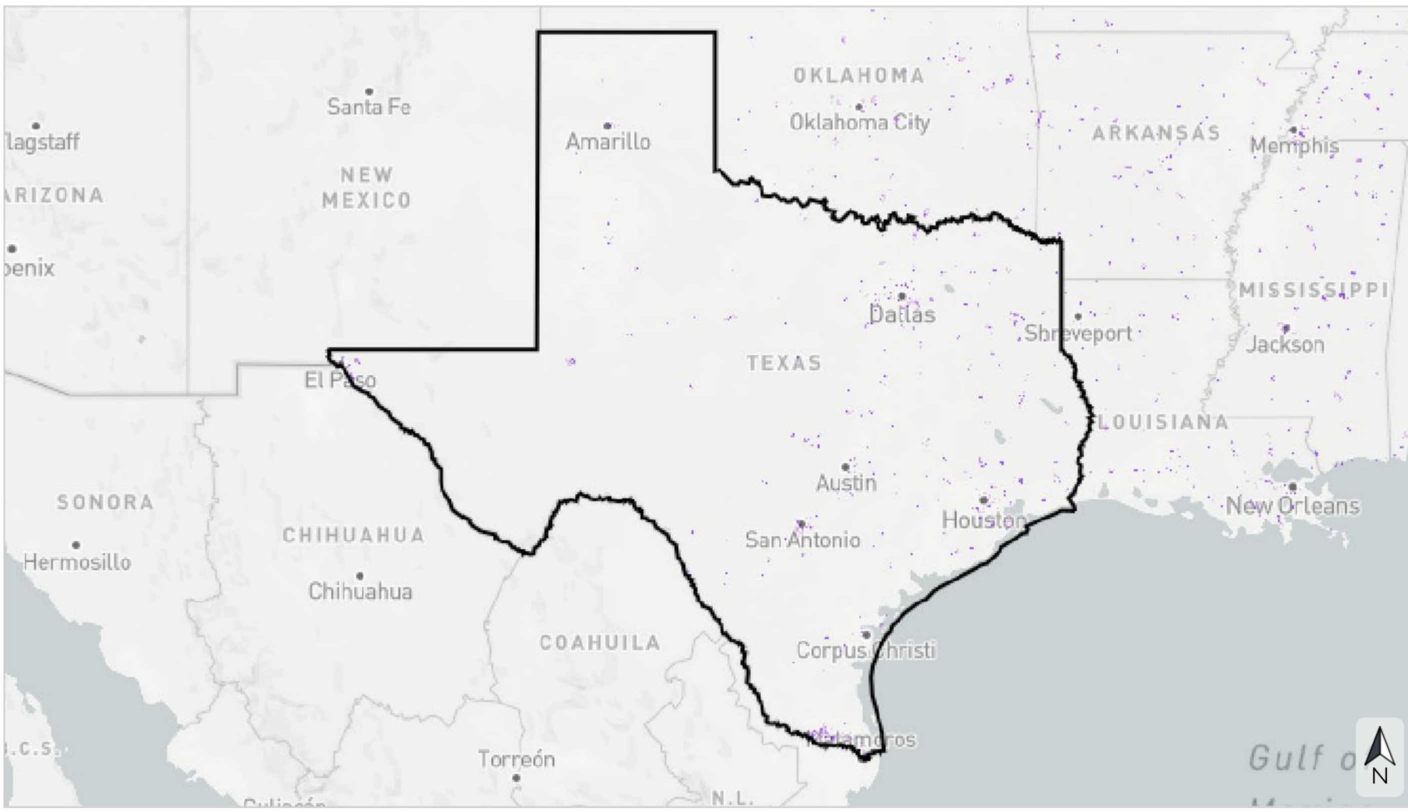
Table 5: Coastal & marine indicators.

Indicator	Present
Atlantic estuarine fish habitat	-
Coastal shoreline condition	√
Estuarine coastal condition	√
Islands	√
Resilient coastal sites	√
Seagrasses	√
South Atlantic beach birds	-
South Atlantic hardbottom & deep-sea coral	-
South Atlantic marine mammals	-
South Atlantic marine birds	-
South Atlantic maritime forest	-
Stable coastal wetlands	√

Terrestrial

Equitable access to potential parks

This cultural resource indicator prioritizes places to create new parks that would fill gaps in equitable access to open space within socially vulnerable communities. It identifies areas where residents currently lack access to parks within a 10-minute walk (accounting for walkable road networks and access barriers like highways and fences), then prioritizes based on park need using demographic and environmental metrics. Parks help improve public health, foster a conservation ethic by providing opportunities for people to connect with nature, and support critical ecosystem services. This indicator originates from the Trust for Public Land's ParkServe park priority areas.



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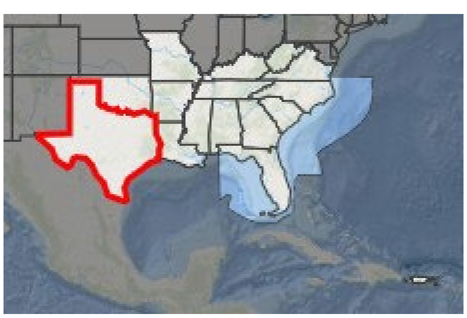


Very high priority for a new park that would create nearby equitable access

High priority for a new park that would create nearby equitable access

Moderate priority for a new park that would create nearby equitable access

Table 6: Indicator values for equitable access to potential parks in this area. A good condition threshold is not yet defined for this indicator.

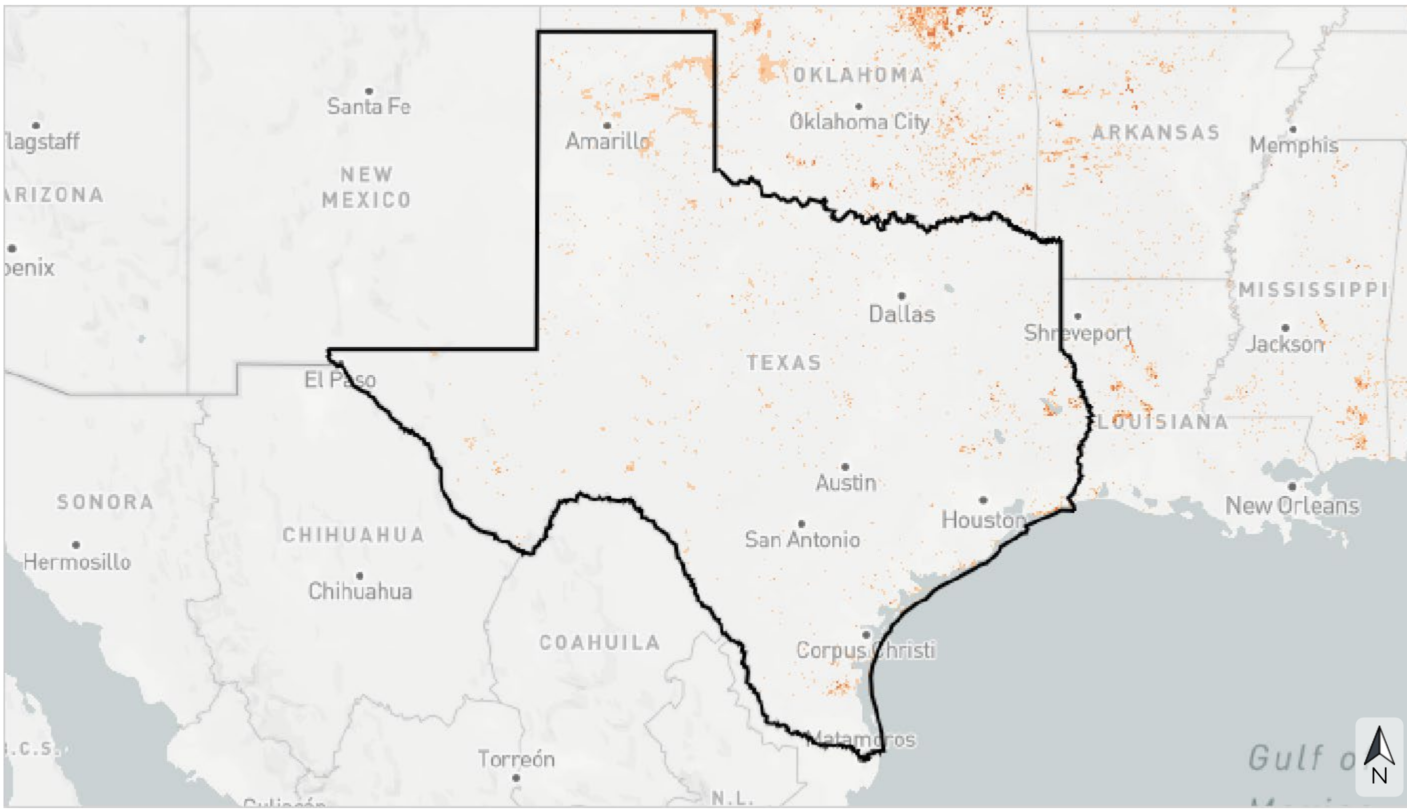
	Indicator Values	Acres	Percent of Area
↑ High	Very high priority for a new park that would create nearby equitable access	325,796	0.2%
	High priority for a new park that would create nearby equitable access	450,230	0.3%
	Moderate priority for a new park that would create nearby equitable access	764,278	0.4%
	Area not evaluated for this indicator	*170,338,395*	*99.1%*
↓ Low	*Outside Southeast Blueprint*	*22,348*	*<0.1%*

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Terrestrial

Fire frequency

This indicator uses remote sensing to estimate the number of times an area has been burned from 2013 to 2021. Many Southeastern ecosystems rely on regular, low-intensity fires to maintain habitat, encourage native plant growth, and reduce wildfire risk. This indicator combines burned area layers from both U.S. Geological Survey Landsat data and the inter-agency Monitoring Trends in Burn Severity program. Landsat-based fire predictions within the range of longleaf pine are also available through Southeast FireMap.



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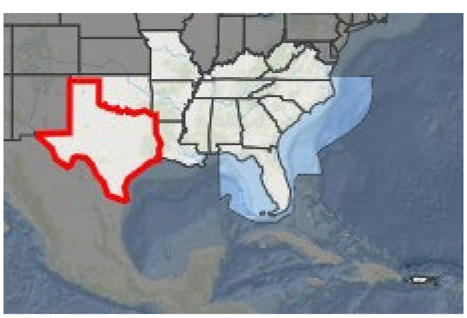


Burned 3+ times from 2013-2021

Burned 2 times from 2013-2021

Burned 1 time from 2013-2021

Not burned from 2013-2021 or row crop

Table 7: Indicator values for fire frequency in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

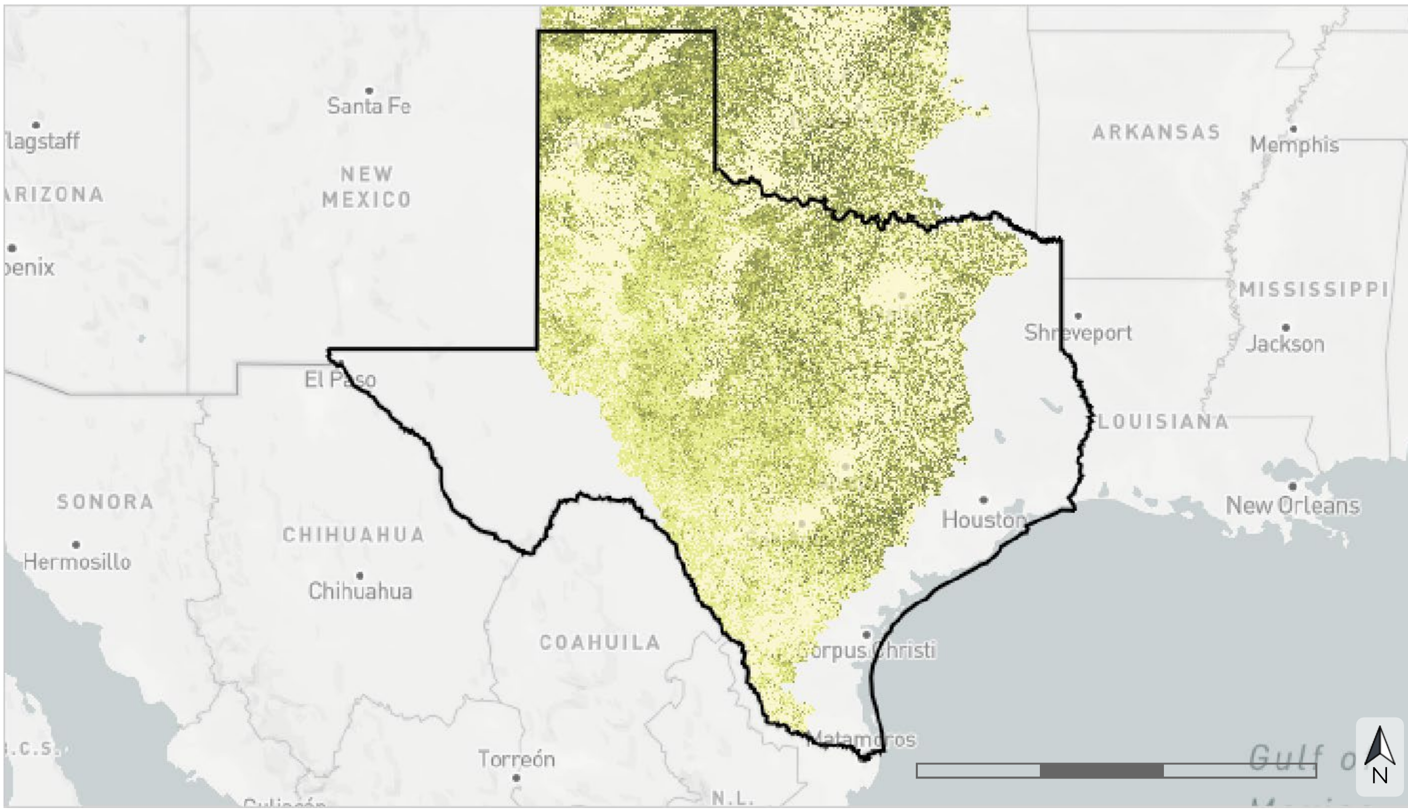
	Indicator Values	Acres	Percent of Area	
↑ High	Burned 3+ times from 2013-2021	76,345	<0.1%	
	Burned 2 times from 2013-2021	355,188	0.2%	↑ In good condition
	Burned 1 time from 2013-2021	3,050,860	1.8%	↓ Not in good condition
↓ Low	Not burned from 2013-2021 or row crop	168,396,305	98.0%	

To learn more and explore the GIS data, [view this indicator in the SECAS Atlas](#).

Terrestrial

Great Plains perennial grasslands

This indicator measures the percent of perennial forbs and perennial grass to evaluate grassland condition across the Great Plains. Grasslands in this area with a high percentage of perennials are less likely to be impacted by woody encroachment, less susceptible to non-native annual grasses, and more likely to support important plants, birds, and pollinators. This indicator originates from Rangeland Analysis Platform vegetation cover data.



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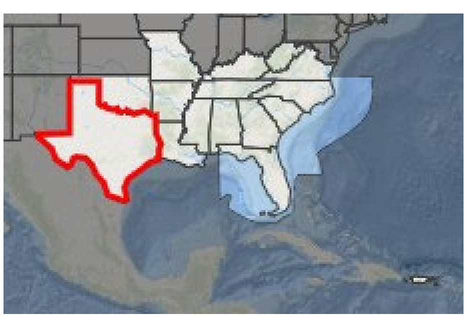


81-100% perennial forbs and perennial grass 61-
80% perennial forbs and perennial grass 41-
60% perennial forbs and perennial grass 21-
40% perennial forbs and perennial grass 0-20%
perennial forbs and perennial grass

Table 8: Indicator values for Great Plains perennial grasslands in this area. A good condition threshold is not yet defined for this indicator.

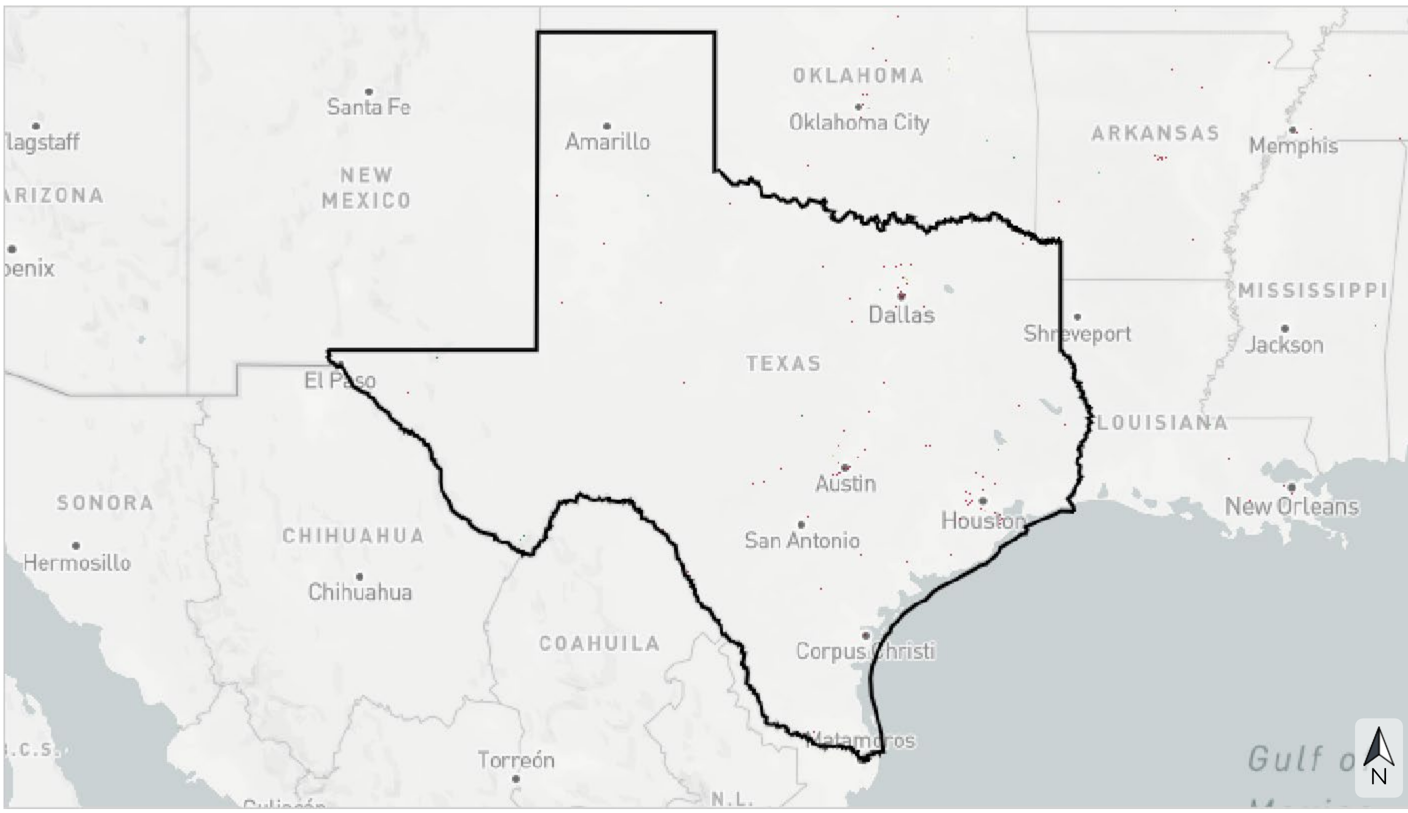
	Indicator Values	Acres	Percent of Area
↑ High	81-100% perennial forbs and perennial grass	1,702,121	1.0%
	61-80% perennial forbs and perennial grass	15,504,557	9.0%
	41-60% perennial forbs and perennial grass	23,140,264	13.5%
	21-40% perennial forbs and perennial grass	29,122,227	16.9%
	0-20% perennial forbs and perennial grass	46,763,827	27.2%
↓ Low	*Area not evaluated for this indicator*	*55,645,703*	*32.4%*
	Outside Southeast Blueprint	*22,348*	*<0.1%*

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Terrestrial

Greenways & trails

This cultural resource indicator measures both the natural condition and connected length of greenways and trails to characterize the quality of the recreational experience. Natural condition is based on the amount of impervious surface surrounding the path. Connected length captures how far a person can go without leaving a dedicated path, based on common distances for walking, running, and biking. This indicator originates from OpenStreetMap.



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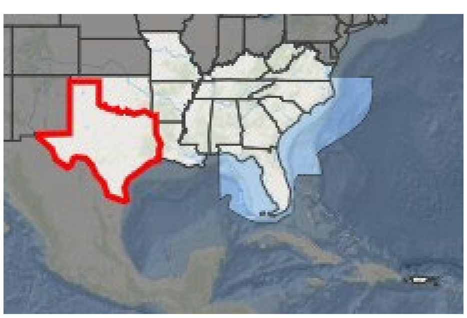


Mostly natural and connected for ≥40 km

Mostly natural and connected for 5 to <40 km or partly natural and connected for ≥40 km

Mostly natural and connected for 1.9 to <5 km, partly natural and connected for 5 to <40 km, or developed and ≥40 km

Mostly natural and connected for <1.9 km, partly natural and connected for

1.9 to <5 km, or developed and connected for 5 to <40 km

Partly natural and connected for <1.9 km or developed and connected for 1.9 to <5 km

Developed and connected for <1.9 km Sidewalk or other path

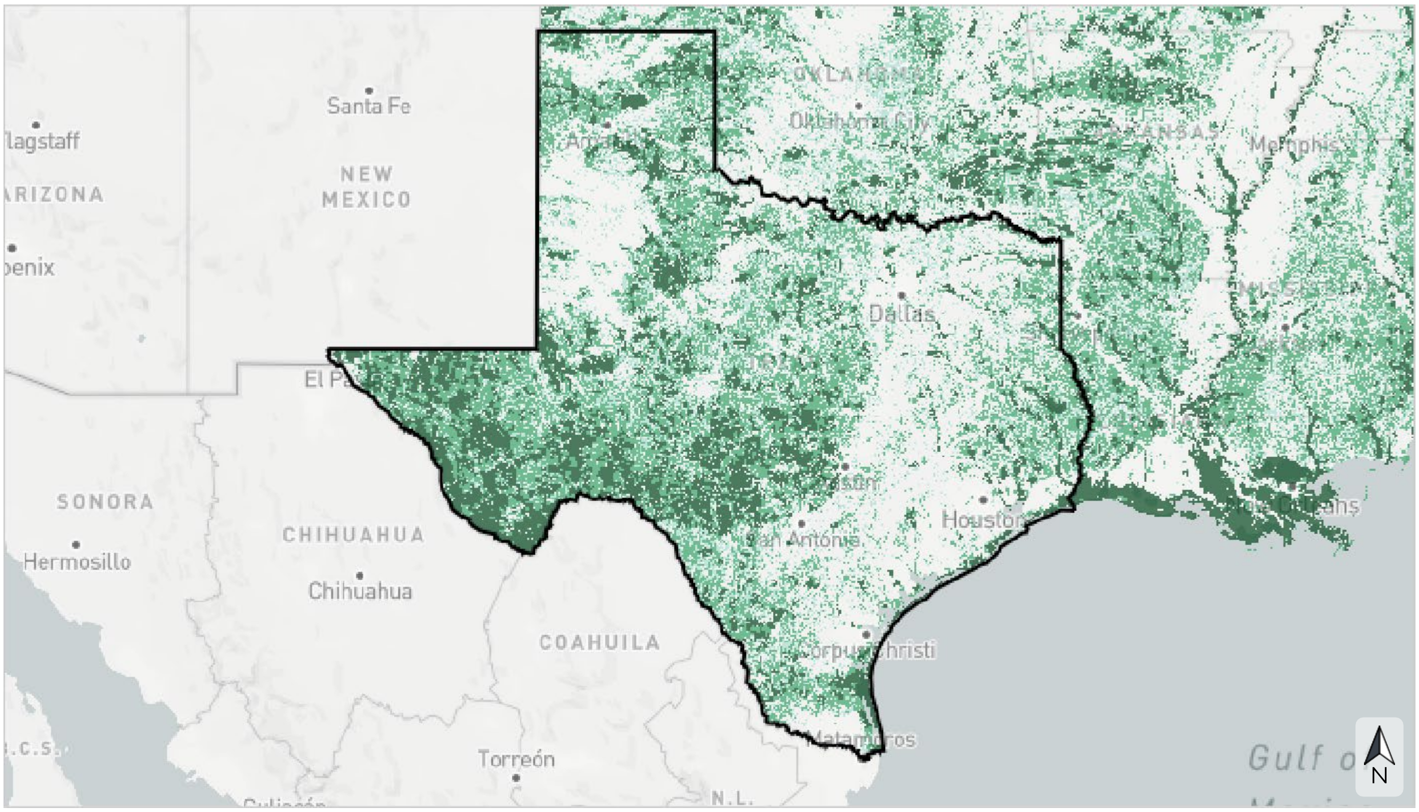
Table 9: Indicator values for greenways & trails in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

	Indicator Values	Acres	Percent of Area	
↑ High	Mostly natural and connected for ≥40 km	7,162	<0.1%	
	Mostly natural and connected for 5 to <40 km or partly natural and connected for ≥40 km	9,621	<0.1%	
	Mostly natural and connected for 1.9 to <5 km, partly natural and connected for 5 to <40 km, or developed and ≥40 km	9,655	<0.1%	
	Mostly natural and connected for <1.9 km, partly natural and connected for 1.9 to <5 km, or developed and connected for 5 to <40 km	3,671	<0.1%	↑ In good condition
	Partly natural and connected for <1.9 km or developed and connected for 1.9 to <5 km	2,186	<0.1%	↓ Not in good condition
↓ Low	Developed and connected for <1.9 km	1,207	<0.1%	

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Intact habitat cores

This indicator represents the size of large, unfragmented patches of natural habitat. It identifies minimally disturbed natural areas at least 100 acres in size and greater than 200 meters wide. Large areas of intact natural habitat are important for many wildlife species, including reptiles and amphibians, birds, and large mammals. This indicator originates from Esri's green infrastructure data.



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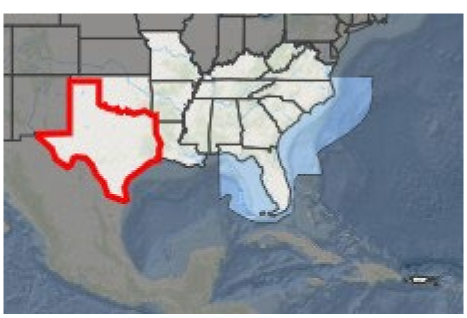

Large core (>10,000 acres)

Medium core (>1,000-10,000 acres)
Small core (>100-1,000 acres)

Not a core

Table 10: Indicator values for intact habitat cores in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

	Indicator Values	Acres	Percent of Area	
↑ High	Large core (>10,000 acres)	31,196,958	18.1%	
	Medium core (>1,000-10,000 acres)	44,940,424	26.1%	
	Small core (>100-1,000 acres)	22,634,492	13.2%	↑ In good condition
↓ Low	Not a core	73,106,825	42.5%	↓ Not in good condition

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Terrestrial

Playas

This indicator represents the condition and location of playas, which are round, shallow depressions found primarily in the western Great Plains that serve as temporary wetlands by collecting water from rainfall and runoff. It defines a healthy playa as one that is not farmed, hydrologically modified, within a wind farm, or impacted by sediment accumulation due to agriculture. It also considers the increased benefits to wildlife provided by clusters of nearby playas, compared to more sparsely distributed playas. Playas play a critical role in recharging the Ogallala aquifer and provide habitat and food for birds and other animals. This indicator originates from the Playa Lakes Joint Venture's probable playas dataset.

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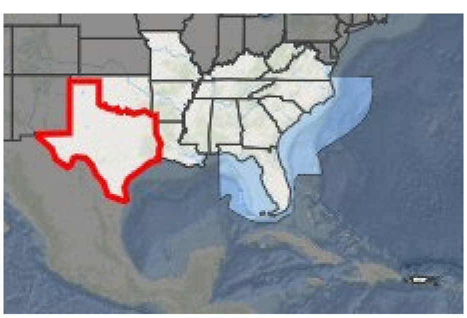


Healthy playa and part of a larger cluster

Healthy playa

Other playa

Table 11: Indicator values for playas in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

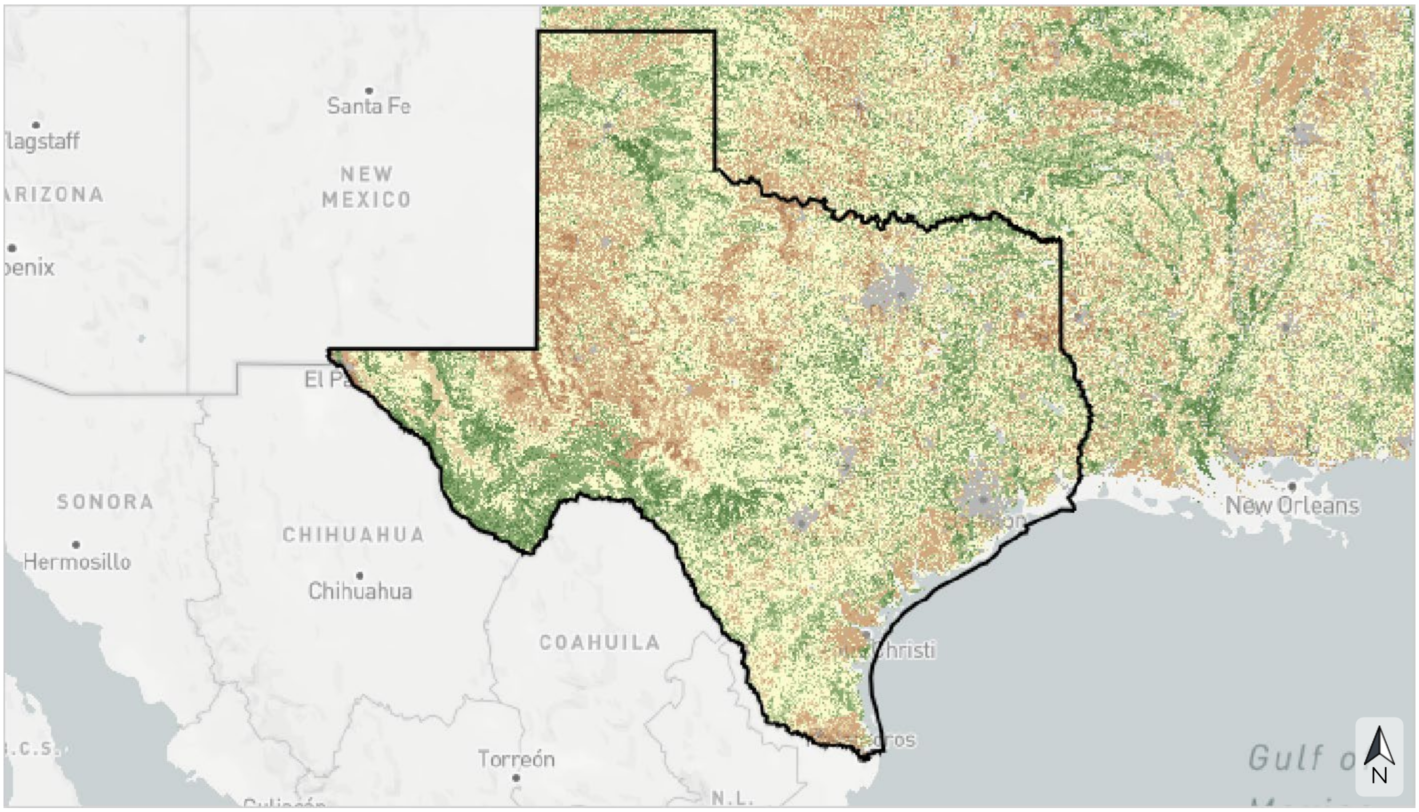
	Indicator Values	Acres	Percent of Area	
↑ High	Healthy playa and part of a larger cluster	139,261	<0.1%	
	Healthy playa	4,004	<0.1%	↑ In good condition
↓ Low	Other playa	249,050	0.1%	↓ Not in good condition
	Area not evaluated for this indicator	*171,486,385*	*99.8%*	

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Terrestrial

Resilient terrestrial sites

This indicator depicts an area's capacity to maintain species diversity and ecosystem function in the face of climate change. It measures two factors that influence resilience. The first, landscape diversity, reflects the number of microhabitats and climatic gradients created by topography, elevation, and hydrology. The second, local connectedness, reflects the degree of habitat fragmentation and strength of barriers to species movement. Highly resilient sites contain many different habitat niches that support biodiversity, and allow species to move freely through the landscape to find suitable microclimates as the climate changes. This indicator originates from The Nature Conservancy's Resilient Land data.



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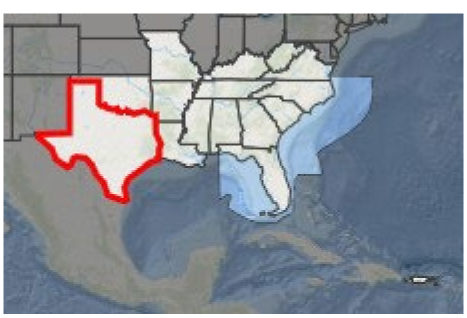


- Most resilient
- More resilient
- Slightly more resilient
- Average/median resilience
- Slightly less resilient
- Less resilient
- Least resilient
- Developed

Table 12: Indicator values for resilient terrestrial sites in this area. A good condition threshold is not yet defined for this indicator.

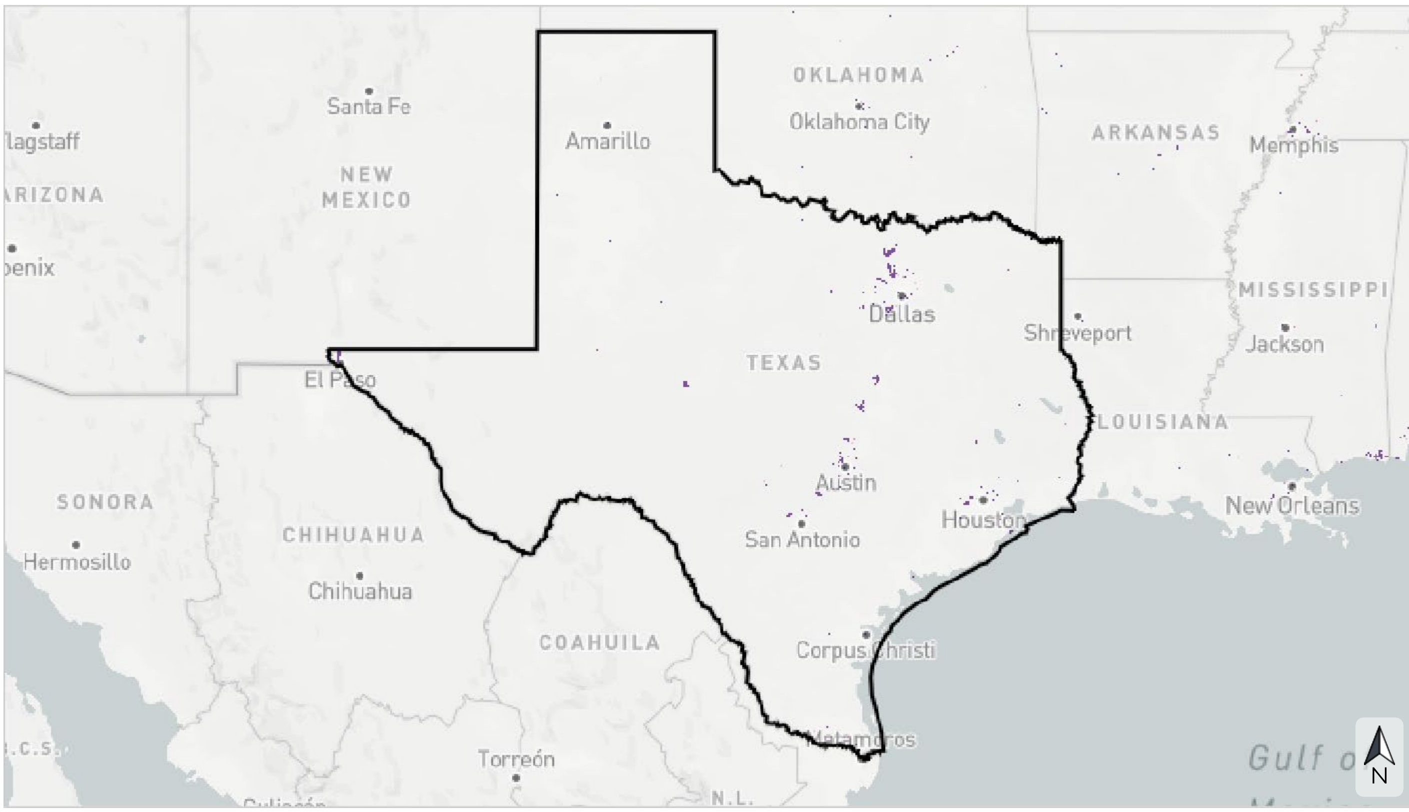
	Indicator Values	Acres	Percent of Area
↑ High	Most resilient	5,940,038	3.5%
	More resilient	26,512,527	15.4%
	Slightly more resilient	25,389,141	14.8%
	Average/median resilience	53,304,136	31.0%
	Slightly less resilient	24,129,665	14.0%
	Less resilient	21,829,734	12.7%
	Least resilient	3,342,247	1.9%
	Developed	5,423,119	3.2%
	Area not evaluated for this indicator	*6,008,093*	*3.5%*
↓ Low			

To learn more and explore the GIS data, [view this indicator in the SECAS Atlas].

Terrestrial

Urban park size

This cultural resource indicator measures the size of parks larger than 5 acres in the urban environment. Protected natural areas in urban environments provide urban residents a nearby place to connect with nature, and offer refugia for some species. This indicator complements the equitable access to potential parks indicator by capturing the value of existing parks. It originates from the U.S. Geological Survey's Protected Areas Database and 2019 National Land Cover Database percent developed impervious layer.



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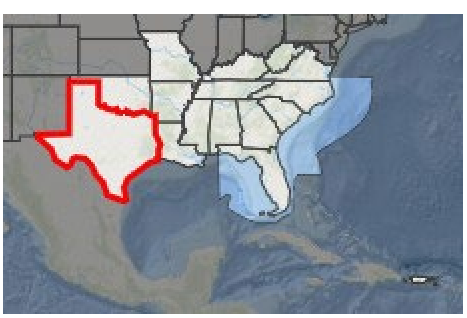


>75 acre urban park

>50-75 acre urban park

>30-50 acre urban park

>10-30 acre urban park 5-10 acre urban park

Table 13: Indicator values for urban park size in this area. A good condition threshold is not yet defined for this indicator.

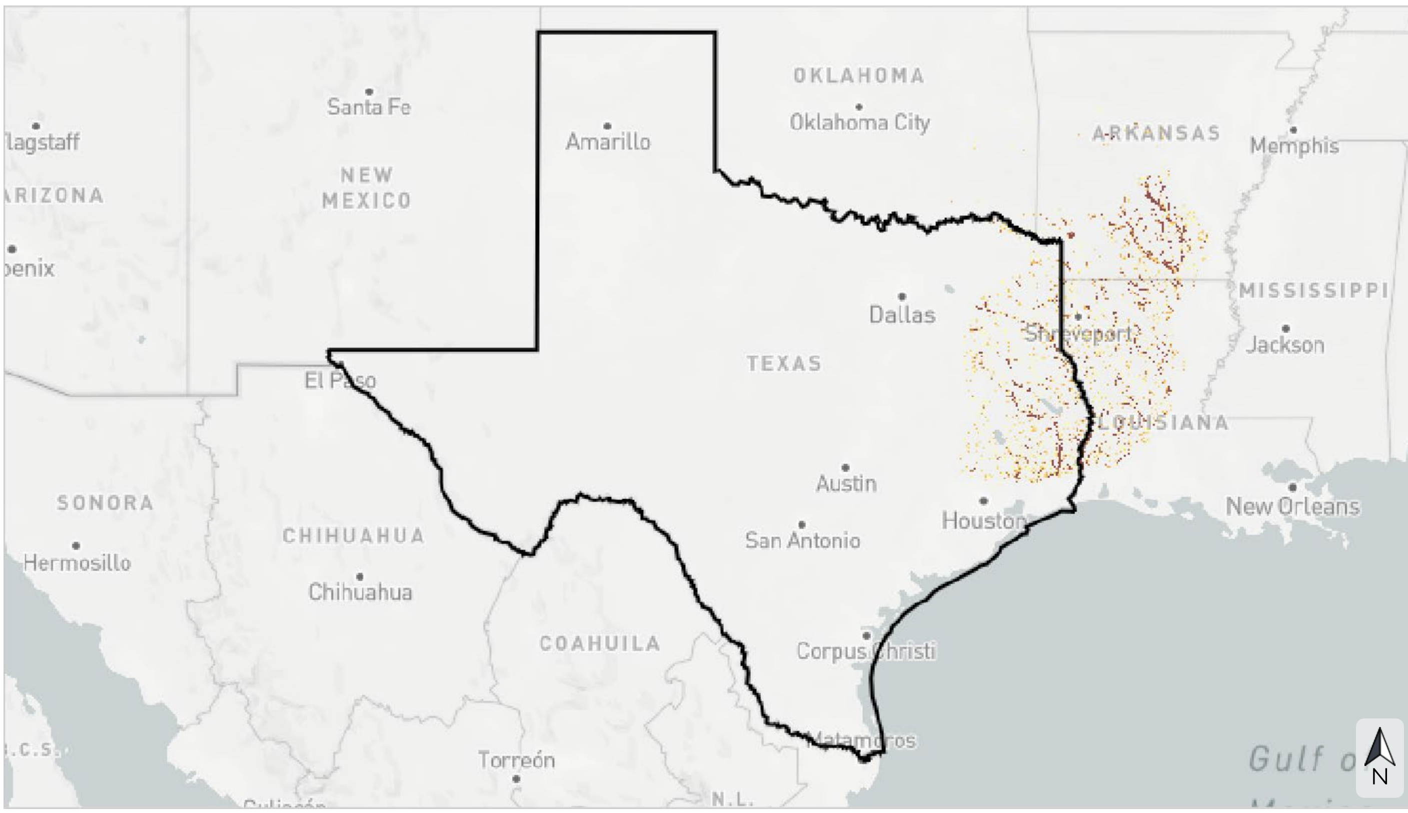
	Indicator Values	Acres	Percent of Area
↑ High	>75 acre urban park	461,778	0.3%
	>50-75 acre urban park	16,778	<0.1%
	>30-50 acre urban park	19,702	<0.1%
	>10-30 acre urban park	29,864	<0.1%
	5-10 acre urban park	11,529	<0.1%
↓ Low	*Area not evaluated for this indicator*	*171,339,047*	*99.7%*
	Outside Southeast Blueprint	*22,348*	*<0.1%*

To learn more and explore the GIS data, [view this indicator in the SECAS Atlas].

Terrestrial

West Coastal Plain & Ouachitas forested wetland birds

This indicator is an index of habitat suitability for five forested wetland bird species (Acadian flycatcher, Kentucky warbler, yellow-throated warbler, prothonotary warbler, red-shouldered hawk) within bottomland hardwood forests and riparian areas in the West Gulf Coastal Plain and Ouachitas Bird Conservation Region. It uses metrics like patch size, dispersal distance, distance to water, and more to assess the potential for habitat to support sustainable populations of these birds. This indicator originates from the Lower Mississippi Valley Joint Venture's forested wetland decision support model for the West Gulf Coastal Plain and Ouachitas region.



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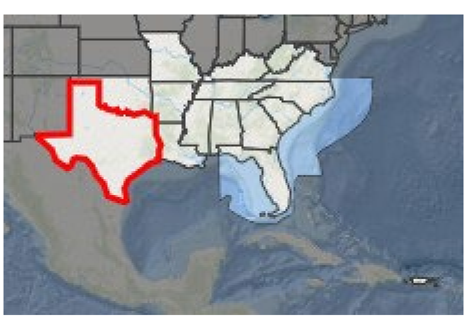


High habitat suitability for forested wetland bird umbrella species (Acadian flycatcher, Kentucky warbler, yellow-throated warbler, prothonotary warbler, red-shouldered hawk) (score >80)

Medium-high habitat suitability (score >60-80)

Medium habitat suitability (score >40-60)

Medium-low habitat suitability (score >20-40)

Low habitat suitability for forested wetland bird umbrella species (score 0-20)

Table 14: Indicator values for West Coastal Plain & Ouachitas forested wetland birds in this area. A good condition threshold is not yet defined for this indicator.

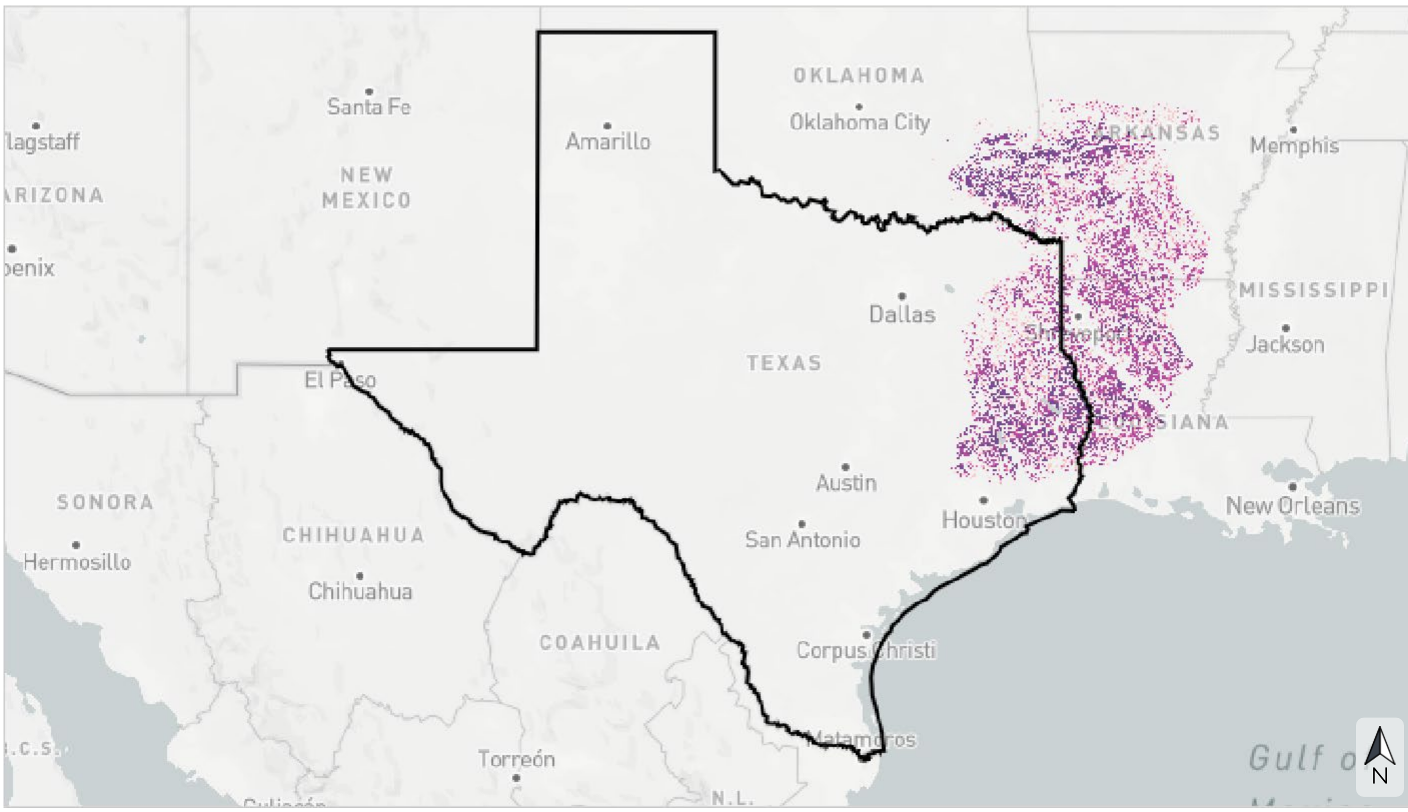
	Indicator Values	Acres	Percent of Area
↑ High	High habitat suitability for forested wetland bird umbrella species (Acadian flycatcher, Kentucky warbler, yellow- throated warbler, prothonotary warbler, red-shouldered hawk) (score >80)	471,261	0.3%
	Medium-high habitat suitability (score >60-80)	316,932	0.2%
	Medium habitat suitability (score >40-60)	358,581	0.2%
	Medium-low habitat suitability (score >20-40)	560,119	0.3%
	Low habitat suitability for forested wetland bird umbrella species (score 0-20)	545,026	0.3%
	Area not evaluated for this indicator	*169,626,781*	*98.7%*
↓ Low	*Outside Southeast Blueprint*	*22,348*	*<0.1%*

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Terrestrial

West Coastal Plain & Ouachitas open pine birds

This indicator identifies areas with existing pine trees that, if managed for open condition, could support a population of three umbrella bird species (brown-headed nuthatch, Bachman's sparrow, red-cockaded woodpecker). It evaluates potential habitat based on each species' habitat needs and population dynamics, prioritizing opportunities to restore and manage habitat to benefit open pine birds. Final scores reflect both the selectiveness of the species and whether an area meets the habitat requirements through one large patch, or clusters of smaller patches in sufficiently close proximity for breeding pairs to disperse. This indicator updates the Lower Mississippi Valley Joint Venture's open pine decision support model for the West Gulf Coastal Plain and Ouachitas region.



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557 miles

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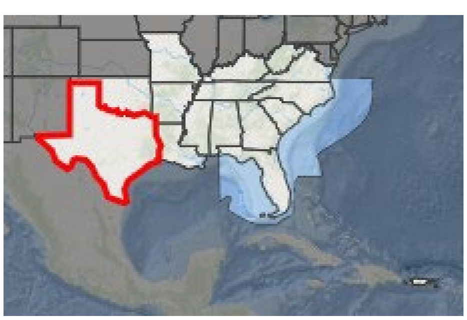


Pine patch large enough to support a population of all 3 umbrella bird species (brown-headed nuthatch, Bachman's sparrow, red-cockaded woodpecker) if managed in open condition

Pine patch large enough to support a population of 2 umbrella bird species if managed in open condition

Pine patch large enough to support a population of 1 umbrella bird species if managed in open condition

Pine patch part of a cluster of nearby patches able to support a population of all 3 umbrella bird species if managed in open condition

Pine patch part of a cluster of nearby patches able to support a population of 2 umbrella bird species if managed in open condition

Pine patch part of a cluster of nearby patches able to support a population of 1 umbrella bird species if managed in open condition

Pine patch too small and isolated to support a population of any umbrella bird species or not an upland pine patch

Table 15: Indicator values for West Coastal Plain & Ouachitas open pine birds in this area. A good condition threshold is not yet defined for this indicator.

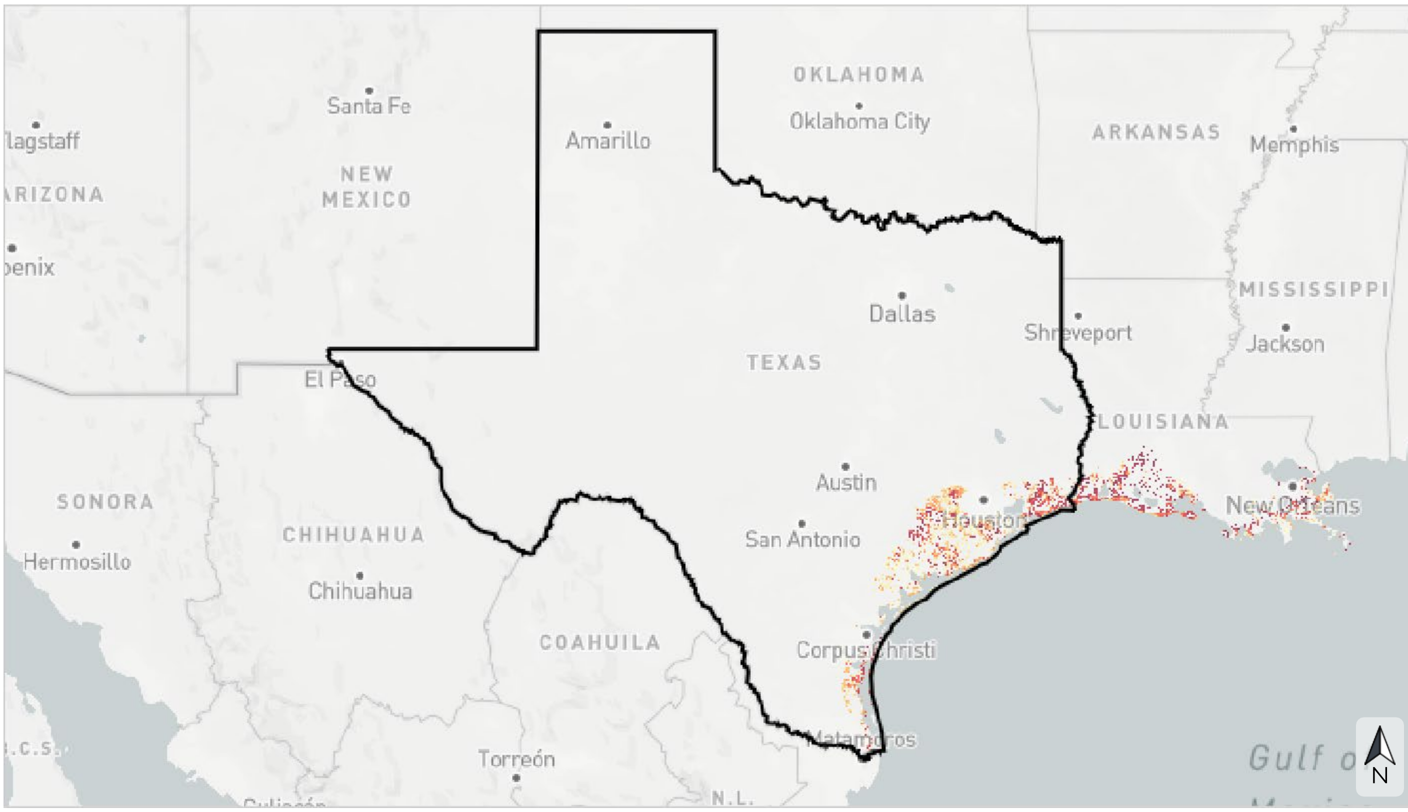
	Indicator Values	Acres	Percent of Area
↑ High	Pine patch large enough to support a population of all 3 umbrella bird species (brown-headed nuthatch, Bachman's sparrow, red-cockaded woodpecker) if managed in open condition	1,587,070	0.9%
	Pine patch large enough to support a population of 2 umbrella bird species if managed in open condition	2,165,245	1.3%
	Pine patch large enough to support a population of 1 umbrella bird species if managed in open condition	557,515	0.3%
	Pine patch part of a cluster of nearby patches able to support a population of all 3 umbrella bird species if managed in open condition	414,071	0.2%
	Pine patch part of a cluster of nearby patches able to support a population of 2 umbrella bird species if managed in open condition	1,049,289	0.6%
	Pine patch part of a cluster of nearby patches able to support a population of 1 umbrella bird species if managed in open condition	4,320	<0.1%
	Pine patch too small and isolated to support a population of any umbrella bird species or not an upland pine patch	9,835,723	5.7%
	Area not evaluated for this indicator	*156,265,466*	*90.9%*
	Outside Southeast Blueprint	*22,348*	*<0.1%*
↓ Low			

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Terrestrial

West Gulf Coast mottled duck nesting

This indicator depicts marshes and grasslands along the coast of Louisiana and Texas that are important for mottled duck nesting, based on key biological parameters such as patch size, land cover type, and distance to brood rearing habitat. As a non-migratory bird endemic to the Gulf coast, mottled ducks serve as good indicators of coastal marsh health and function. Urban growth, agricultural development, and hydrologic changes due to human alteration and climate change have caused significant mottled duck habitat loss and population declines. This indicator originates from a mottled duck decision support tool developed by the Gulf Coast Prairie Landscape Conservation Cooperative.



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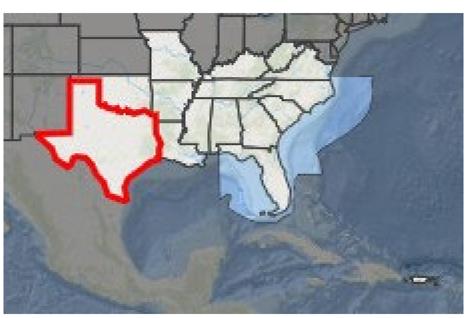


90th-100th percentile of suitable mottled duck nesting habitat 80th-90th percentile of suitable mottled duck nesting habitat 70th-80th percentile of suitable mottled duck nesting habitat 60th-70th percentile of suitable mottled duck nesting habitat 50th-60th percentile of suitable mottled duck nesting habitat 40th-50th percentile of suitable mottled duck nesting habitat 30th-40th percentile of suitable mottled duck nesting habitat 20th-30th percentile of suitable mottled duck nesting habitat 10th-20th percentile of suitable mottled duck nesting habitat 0-10th percentile of suitable mottled duck nesting habitat

Table 16: Indicator values for West Gulf Coast mottled duck nesting in this area. A good condition threshold is not yet defined for this indicator.

	Indicator Values	Acres	Percent of Area
↑ High	90th-100th percentile of suitable mottled duck nesting habitat	152,241	<0.1%
	80th-90th percentile of suitable mottled duck nesting habitat	232,610	0.1%
	70th-80th percentile of suitable mottled duck nesting habitat	264,442	0.2%
	60th-70th percentile of suitable mottled duck nesting habitat	280,144	0.2%
	50th-60th percentile of suitable mottled duck nesting habitat	304,455	0.2%
	40th-50th percentile of suitable mottled duck nesting habitat	373,547	0.2%
	30th-40th percentile of suitable mottled duck nesting habitat	385,903	0.2%
	20th-30th percentile of suitable mottled duck nesting habitat	395,842	0.2%
	10th-20th percentile of suitable mottled duck nesting habitat	384,953	0.2%
	0-10th percentile of suitable mottled duck nesting habitat	335,480	0.2%
	Area not evaluated for this indicator	*168,769,085*	*98.2%*
	Outside Southeast Blueprint	*22,348*	*<0.1%*

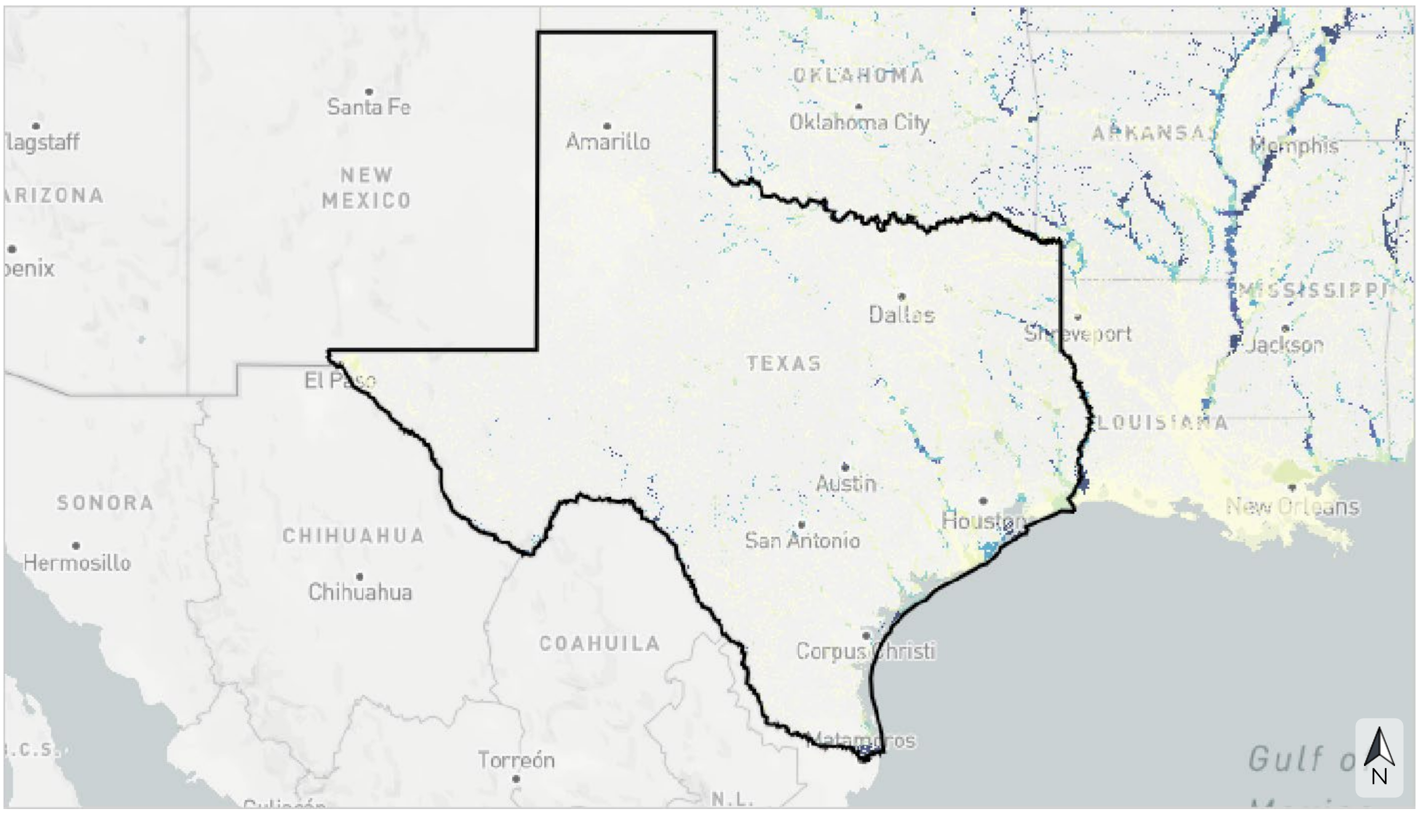
↓ Low

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Freshwater

Imperiled aquatic species

This indicator measures the number of aquatic animal Species of Greatest Conservation Need (SGCN) observed within each 12-digit HUC subwatershed, including fish, mussels, snails, crayfish, and amphibians. SGCN are identified in State Wildlife Action Plans as most in need of conservation action. This indicator captures patterns of rare and endemic species diversity not well-represented by other freshwater aquatic indicators. It originates from state Natural Heritage Program data collected by the Southeast Aquatic Resources Partnership and applies to the Environmental Protection Agency's estimated floodplain, which spatially defines areas estimated to be inundated by a 100-year flood, also known as the 1% annual chance flood.



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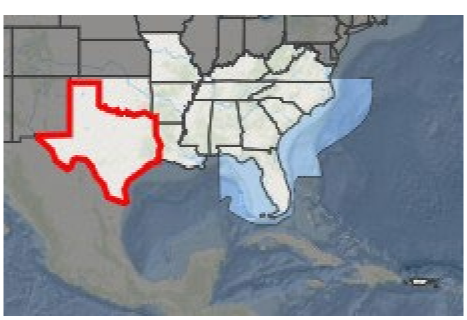
139 279 557 miles



8+ aquatic Species of Greatest Conservation Need (SGCN) observed 7
aquatic SGCN observed

6 aquatic SGCN observed 5
aquatic SGCN observed 4
aquatic SGCN observed 3
aquatic SGCN observed 2
aquatic SGCN observed 1
aquatic SGCN observed No
aquatic SGCN observed

Table 17: Indicator values for imperiled aquatic species in this area. A good condition threshold is not yet defined for this indicator.

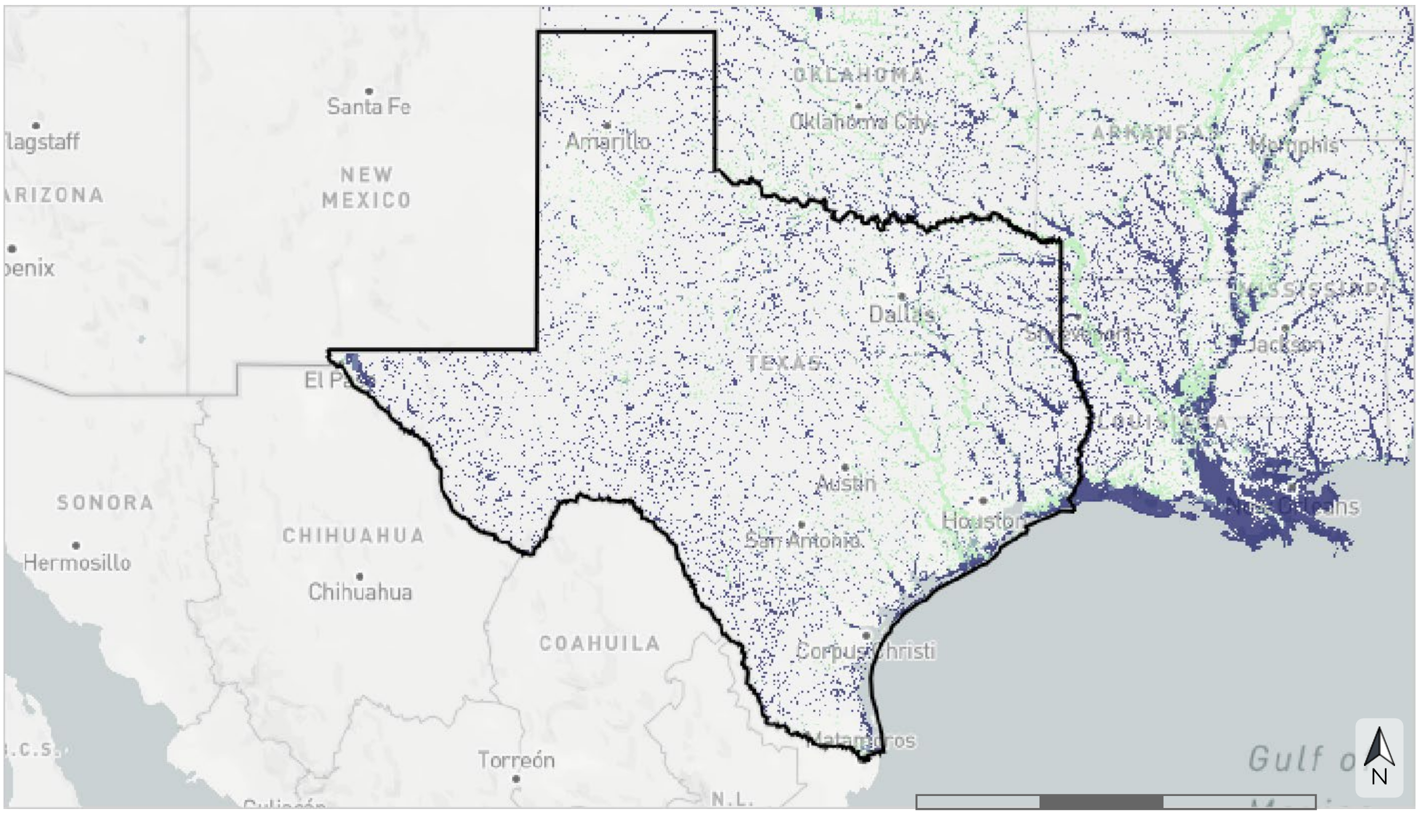
	Indicator Values	Acres	Percent of Area
↑ High	8+ aquatic Species of Greatest Conservation Need (SGCN) observed	392,595	0.2%
	7 aquatic SGCN observed	119,402	<0.1%
	6 aquatic SGCN observed	175,113	0.1%
	5 aquatic SGCN observed	457,800	0.3%
	4 aquatic SGCN observed	444,563	0.3%
	3 aquatic SGCN observed	740,350	0.4%
	2 aquatic SGCN observed	1,550,503	0.9%
	1 aquatic SGCN observed	3,193,593	1.9%
	No aquatic SGCN observed	15,267,679	8.9%
↓ Low	*Area not evaluated for this indicator*	*149,537,101*	*87.0%*

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Freshwater

Natural landcover in floodplains

This indicator measures the amount of natural landcover in the estimated floodplain of rivers and streams within each catchment. It assesses the stream channel and its surrounding riparian buffer, measuring the percent of unaltered habitat like forests, wetlands, or open water (rather than agriculture or development). Intact vegetated buffers within the floodplain of rivers and streams provide aquatic habitat, improve water quality, reduce erosion and flooding, recharge groundwater, and more. This indicator originates from the 2019 National Land Cover Database and applies to the Environmental Protection Agency's estimated floodplain, which spatially defines areas estimated to be inundated by a 100-year flood, also known as the 1% annual chance flood.



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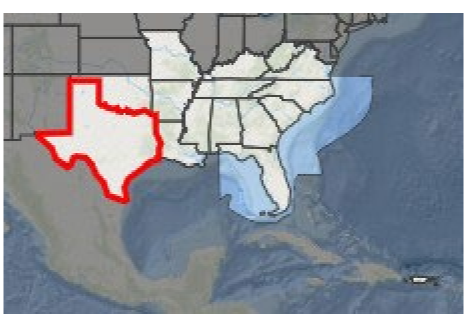


>90% natural habitat within the estimated floodplain, by catchment

>80-90%

>70-80%

>60-70%

≤60% natural habitat within the estimated floodplain, by catchment

Table 18: Indicator values for natural landcover in floodplains in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

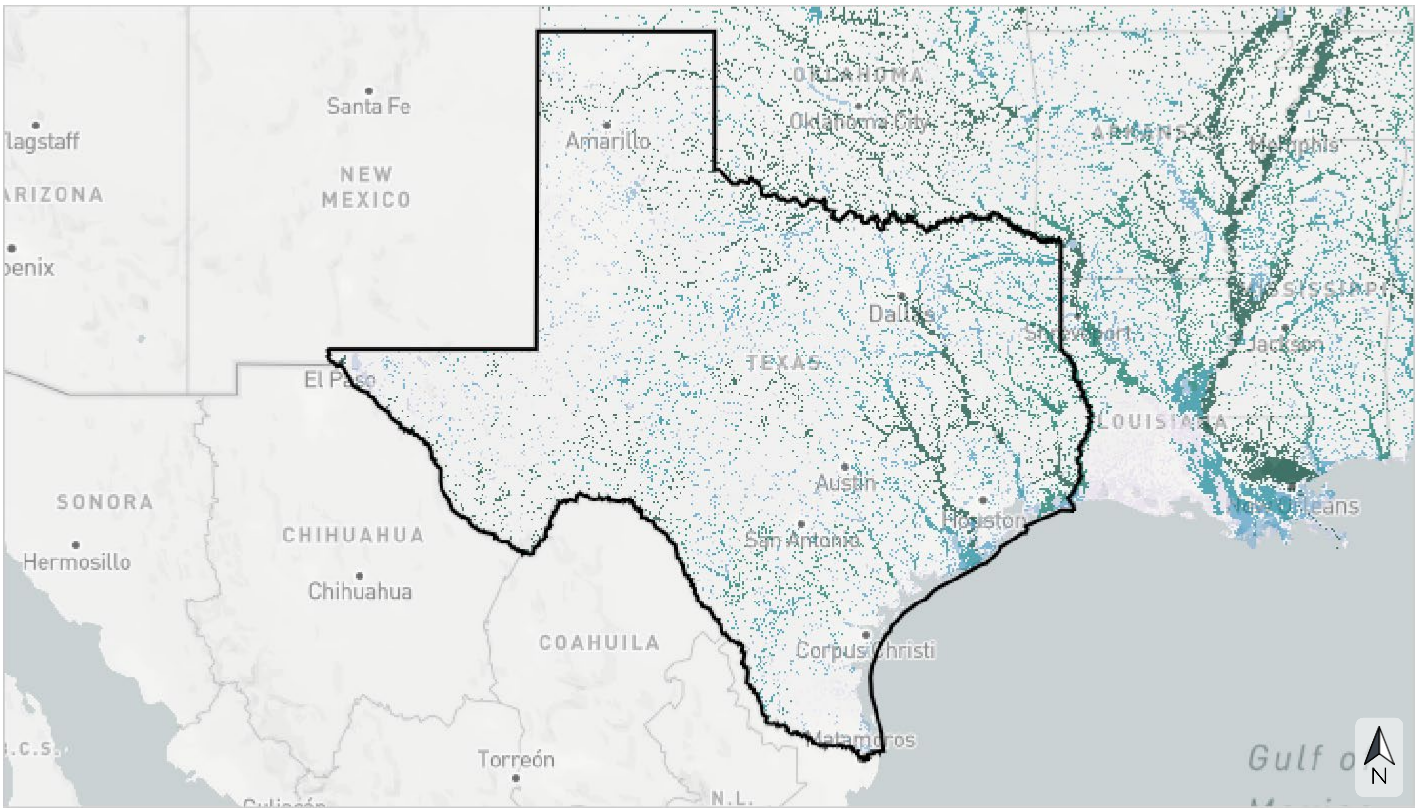
	Indicator Values	Acres	Percent of Area	
↑ High	>90% natural habitat within the estimated floodplain, by catchment	11,434,453	6.7%	
	>80-90%	2,551,115	1.5%	↑ In good condition
	>70-80%	1,838,172	1.1%	↓ Not in good condition
	>60-70%	1,419,478	0.8%	
	≤60% natural habitat within the estimated floodplain, by catchment	5,098,440	3.0%	
↓ Low	*Area not evaluated for this indicator*	*149,537,042*	*87.0%*	

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Freshwater

Network complexity

This indicator depicts the number of different stream size classes in a river network not separated by dams or waterfalls. River networks with a variety of connected stream classes help retain aquatic biodiversity in a changing climate by allowing species to access climate refugia and move between habitats. This indicator originates from the Southeast Aquatic Resources Partnership and applies to the Environmental Protection Agency's estimated floodplain, which spatially defines areas estimated to be inundated by a 100-year flood, also known as the 1% annual chance flood.



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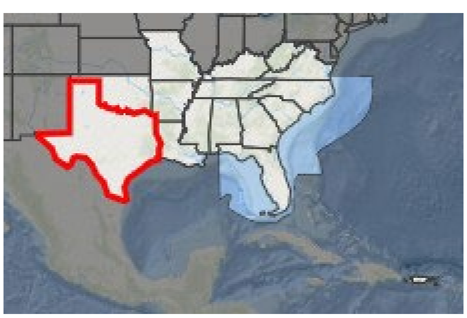


7 connected stream classes 6
connected stream classes 5
connected stream classes 4
connected stream classes 3
connected stream classes 2
connected stream classes 1
connected stream class

Table 19: Indicator values for network complexity in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

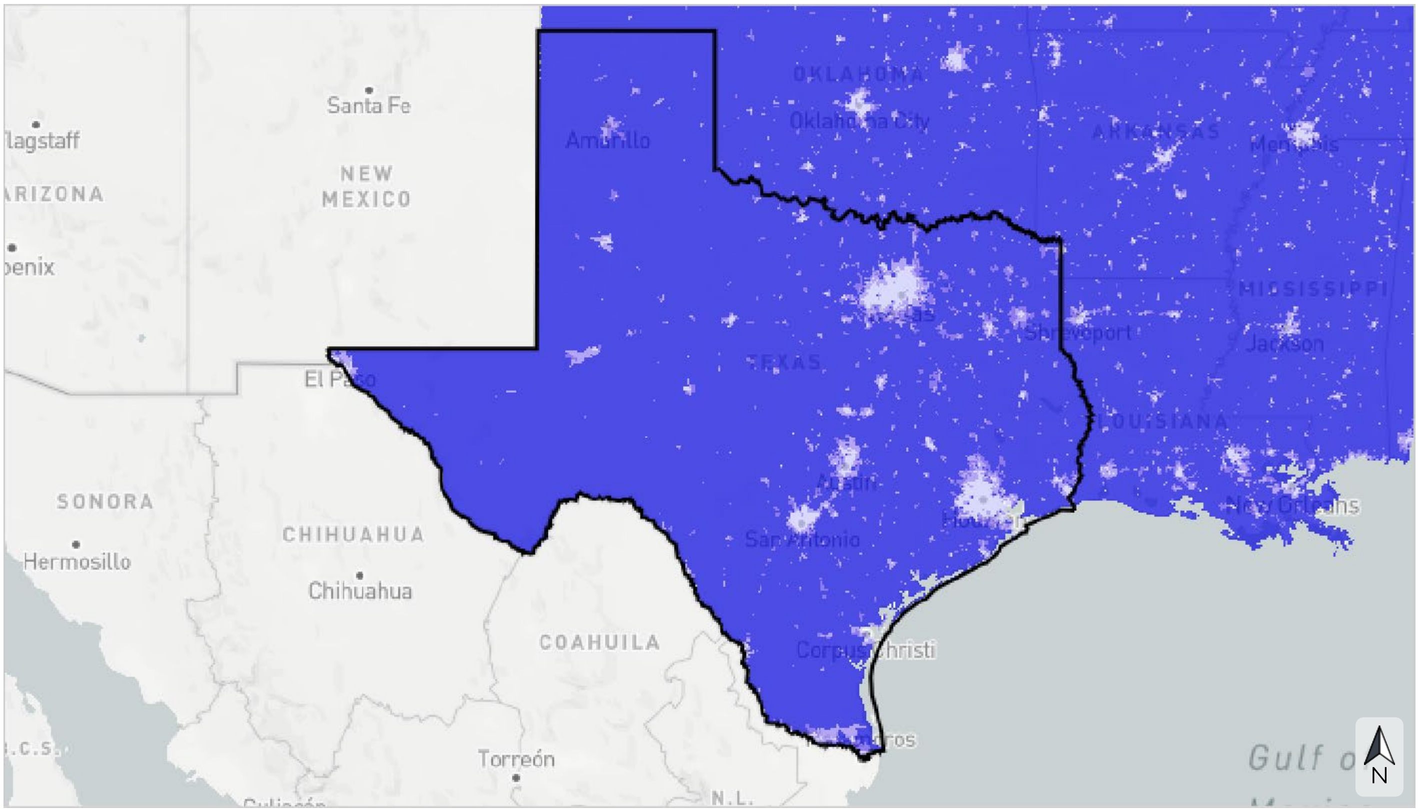
	Indicator Values	Acres	Percent of Area	
↑ High	7 connected stream classes	5,178,200	3.0%	
	6 connected stream classes	3,045,395	1.8%	
	5 connected stream classes	4,912,291	2.9%	
	4 connected stream classes	2,939,122	1.7%	↑ In good condition
	3 connected stream classes	2,062,518	1.2%	↓ Not in good condition
	2 connected stream classes	2,221,221	1.3%	
↓ Low	1 connected stream class	1,287,964	0.7%	

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Freshwater

Permeable surface

This indicator measures the average percent of non-impervious cover within each catchment. High levels of impervious surface degrade water quality and alter freshwater flow, impacting both aquatic species communities and ecosystem services for people, like the availability of clean drinking water. This indicator originates from the 2019 National Land Cover Database percent developed impervious layer.



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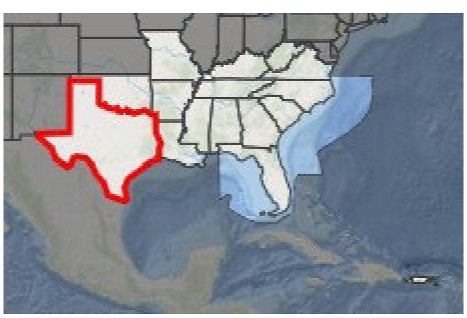

>95% of catchment permeable (likely high water quality and supporting most sensitive aquatic species)

>90-95% of catchment permeable (likely declining water quality and supporting most aquatic species)

>70-90% of catchment permeable (likely degraded water quality and not supporting many aquatic species)

≤70% of catchment permeable (likely degraded instream flow, water quality, and aquatic species communities)

Table 20: Indicator values for permeable surface in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

	Indicator Values	Acres	Percent of Area	
↑ High	>95% of catchment permeable (likely high water quality and supporting most sensitive aquatic species)	157,414,014	91.6%	↑ In good condition
	>90-95% of catchment permeable (likely declining water quality and supporting most aquatic species)	4,367,609	2.5%	↓ Not in good condition
	>70-90% of catchment permeable (likely degraded water quality and not supporting many aquatic species)	4,674,997	2.7%	
	≤70% of catchment permeable (likely degraded instream flow, water quality, and aquatic species communities)	2,950,905	1.7%	
	Area not evaluated for this indicator	*2,471,174*	*1.4%*	
↓ Low	*Outside Southeast Blueprint*	*22,348*	*<0.1%*	

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Coastal & marine

Coastal shoreline condition

This indicator assesses shoreline condition based on the presence of hardened structures like jetties, groins, and riprap, as well as other human development. By restricting the natural movement of sediment, shoreline armoring increases erosion, prevents the inland migration of coastal ecosystems in response to sea-level rise, and degrades habitat for birds, sea turtles, fish, plants, and other species both on and offshore. Natural shorelines in harder-to- develop coastal areas receive the highest shoreline condition scores, while hardened shorelines receive the lowest scores. This indicator originates from the National Oceanic and Atmospheric Administration's Environmental Sensitivity Index dataset.

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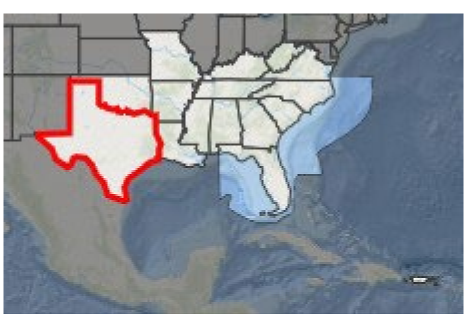


Natural and harder to develop Natural

Partially armored and harder to develop Partially armored

Armored

Table 21: Indicator values for coastal shoreline condition in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

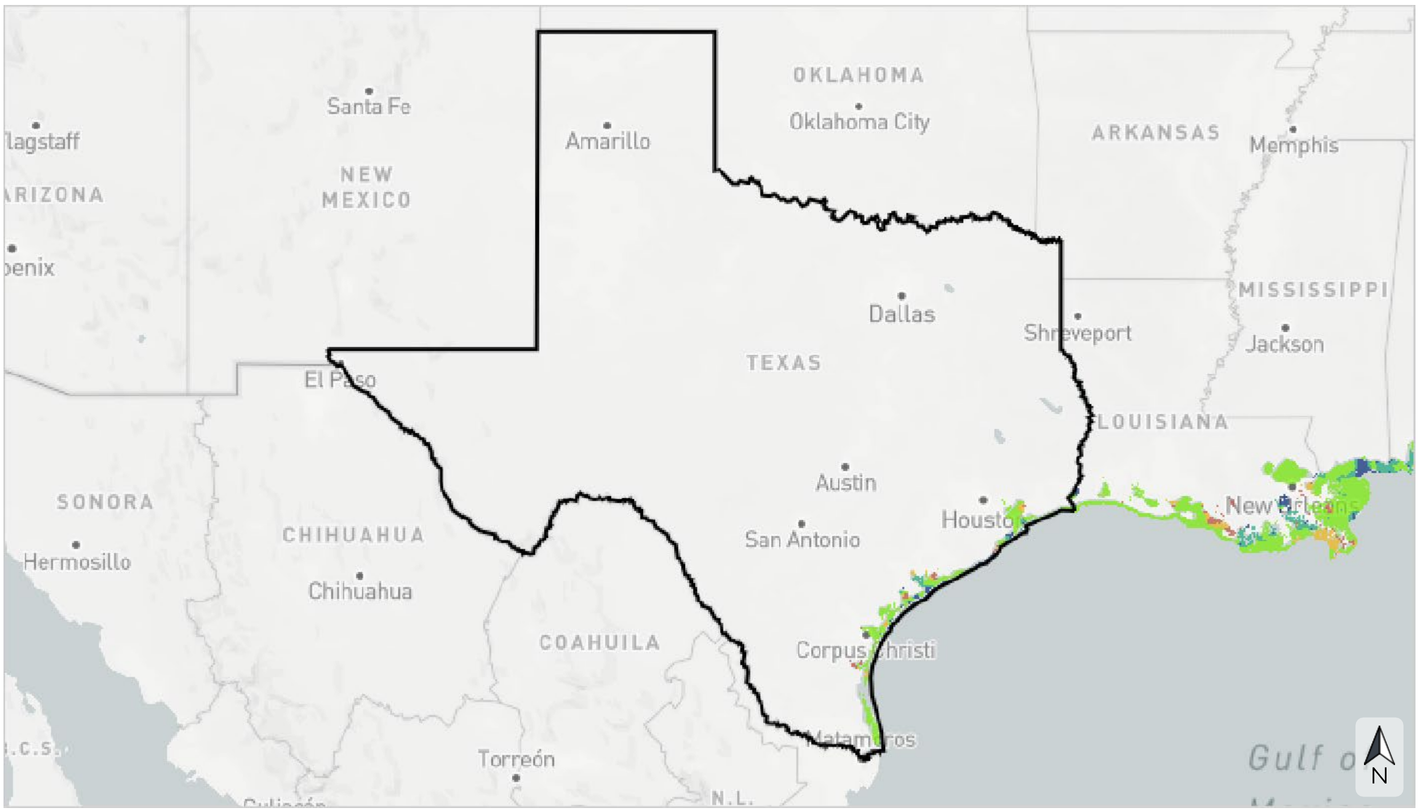
	Indicator Values	Acres	Percent of Area	
↑ High	Natural and harder to develop	30,548	<0.1%	
	Natural	60,776	<0.1%	↑ In good condition
	Partially armored and harder to develop	1,194	<0.1%	↓ Not in good condition
	Partially armored	4,908	<0.1%	
	Armored	15,595	<0.1%	
↓ Low	*Area not evaluated for this indicator*	*171,765,678*	*99.9%*	

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Coastal & marine

Estuarine coastal condition

This indicator combines measures of water quality, sediment quality, contaminants in fish tissue, and benthic community condition to create an overall index of coastal estuarine condition. Estuaries serve as important nursery habitat for wildlife, including many species of fish and shellfish eaten as seafood. They also improve water quality by filtering out sediments and pollutants, provide recreational opportunities, and support coastal economies. This indicator originates from the Environmental Protection Agency's National Coastal Condition Assessment data.



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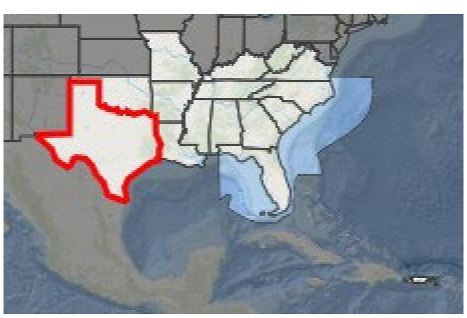

Good

Good to fair

Fair

Fair to poor

Poor

Table 22: Indicator values for estuarine coastal condition in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

	Indicator Values	Acres	Percent of Area	
↑ High	Good	304,555	0.2%	
	Good to fair	160,862	<0.1%	↑ In good condition
	Fair	1,136,252	0.7%	↓ Not in good condition
	Fair to poor	103,359	<0.1%	
↓ Low	Poor	78,889	<0.1%	
	Area not evaluated for this indicator	*170,094,782*	*98.9%*	

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Coastal & marine

Islands

This indicator represents important habitat for island-dependent species across the Southeast. Because the isolation of islands can make them ecologically unique and protect them from disturbance and mainland predators, they often serve as important habitat for many species of mammals, plants, and insects, as well as breeding coastal birds and sea turtles. The highest scores go to island critical habitat for six threatened and endangered animal and plant species: piping plover, loggerhead sea turtle, Cape Sable thoroughwort, Florida semaphore cactus, silver rice rat, and Bartram's hairstreak butterfly. This indicator originates from U.S. Fish and Wildlife Service critical habitat data and island boundaries from the U.S. Geological Survey and Esri.

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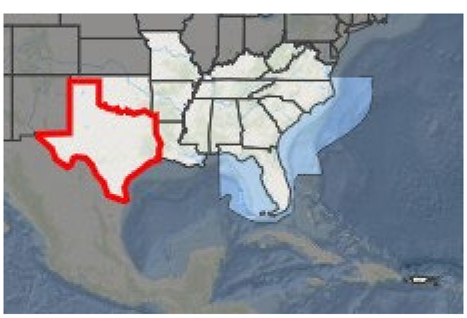


Island critical habitat for any of six threatened and endangered species (piping plover, loggerhead sea turtle, Cape Sable thoroughwort, Florida semaphore cactus, silver rice rat, or Bartram's hairstreak butterfly)

Island

Table 23: Indicator values for islands in this area. A good condition threshold is not yet defined for this indicator.

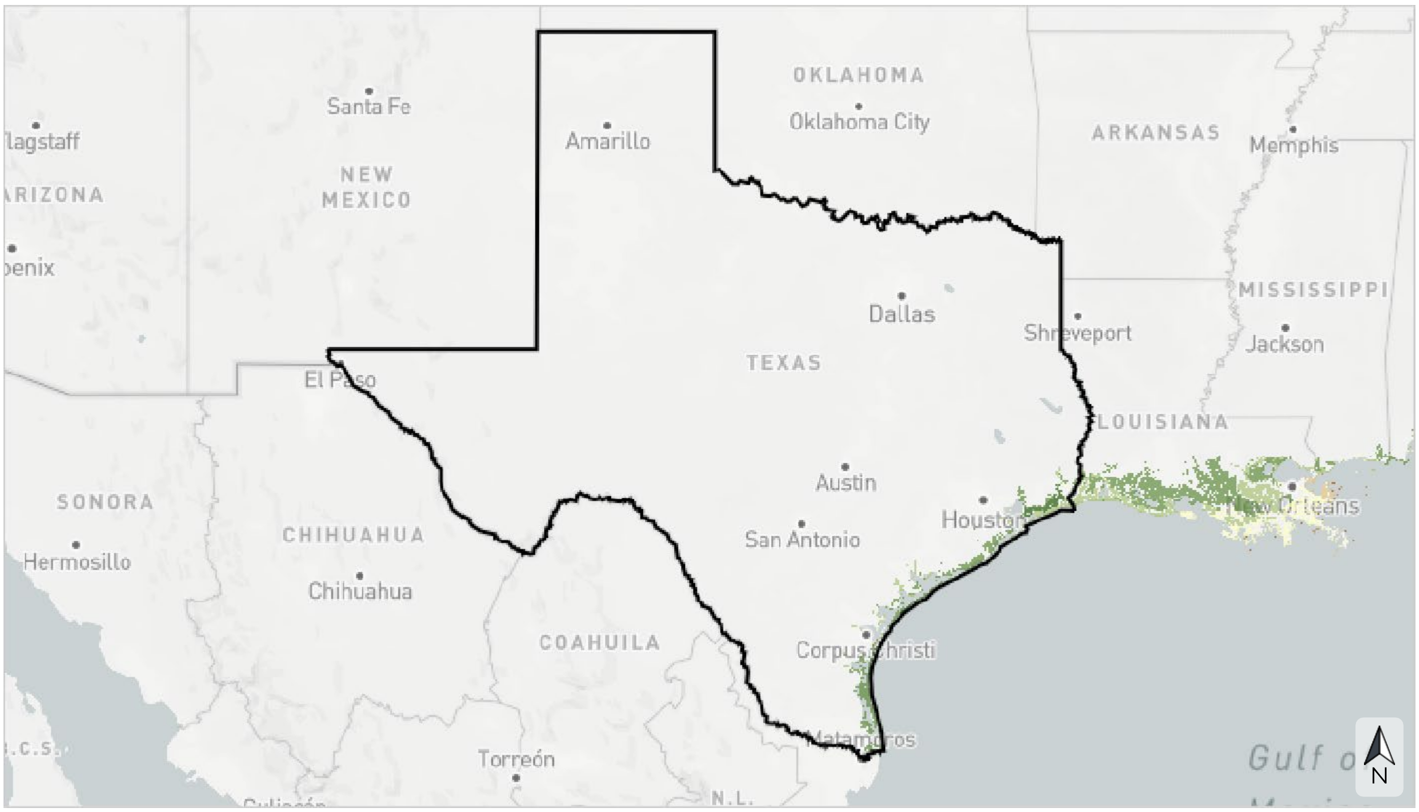
	Indicator Values	Acres	Percent of Area
↑ High	Island critical habitat for any of six threatened and endangered species (piping plover, loggerhead sea turtle, Cape Sable thoroughwort, Florida semaphore cactus, silver rice rat, or Bartram's hairstreak butterfly)	84,061	<0.1%
	Island	270,518	0.2%
↓ Low	*Area not evaluated for this indicator*	*171,524,120*	*99.8%*
	Outside Southeast Blueprint	*22,348*	*<0.1%*

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Coastal & marine

Resilient coastal sites

This indicator depicts the capacity of coastal habitats to migrate to adjacent lowlands in order to sustain biodiversity and natural services under increasing inundation from sea-level rise. It is based on the physical and condition characteristics of current tidal complexes, their predicted migration space, and surrounding buffer areas. These characteristics include marsh complex size, shared edge with migration space, sediment balance, water quality, natural landcover, landform diversity, and many others. This indicator originates from The Nature Conservancy's Resilient Coastal Sites project.



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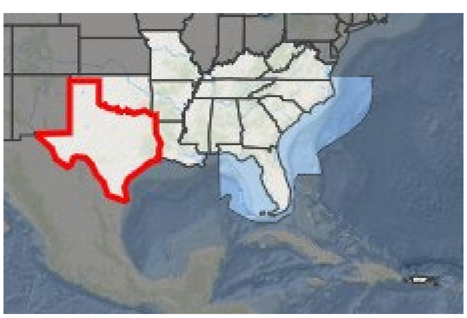

Most resilient
More resilient
Slightly more resilient
Average/median resilience
Slightly less resilient
Less resilient
Least resilient

Table 24: Indicator values for resilient coastal sites in this area. A good condition threshold is not yet defined for this indicator.

↑ High

Indicator Values	Acres	Percent of Area
Most resilient	237,679	0.1%
More resilient	1,186,577	0.7%
Slightly more resilient	377,286	0.2%
Average/median resilience	57,161	<0.1%
Slightly less resilient	2,327	<0.1%
Less resilient	787	<0.1%
Least resilient	1,951	<0.1%
Area not evaluated for this indicator	*170,014,932*	*98.9%*
Outside Southeast Blueprint	*22,348*	*<0.1%*

↓ Low

To learn more and explore the GIS data, [view this indicator in the SECAS Atlas](#).

Coastal & marine

Seagrasses

This indicator represents the presence of seagrass in the Atlantic Ocean and Gulf of Mexico. Seagrasses provide food and habitat for a range of marine and estuarine wildlife, including fish, sea turtles, shrimp, crabs, oysters, and more. They also produce oxygen, filter water, control erosion, and buffer storms. Seagrasses serve as an important indicator of the overall health of coastal ecosystems because they are sensitive to water quality and require sufficiently clear water for sunlight to penetrate. This indicator originates from the National Oceanic and Atmospheric Administration's Marine Cadastre.

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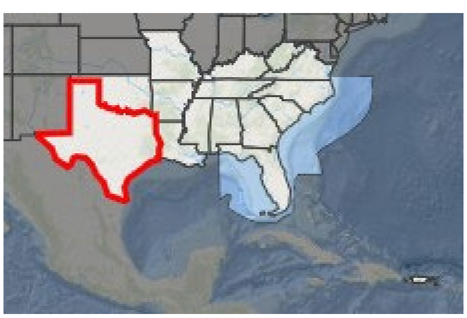


Seagrasses present

Table 25: Indicator values for seagrasses in this area. A good condition threshold is not yet defined for this indicator.

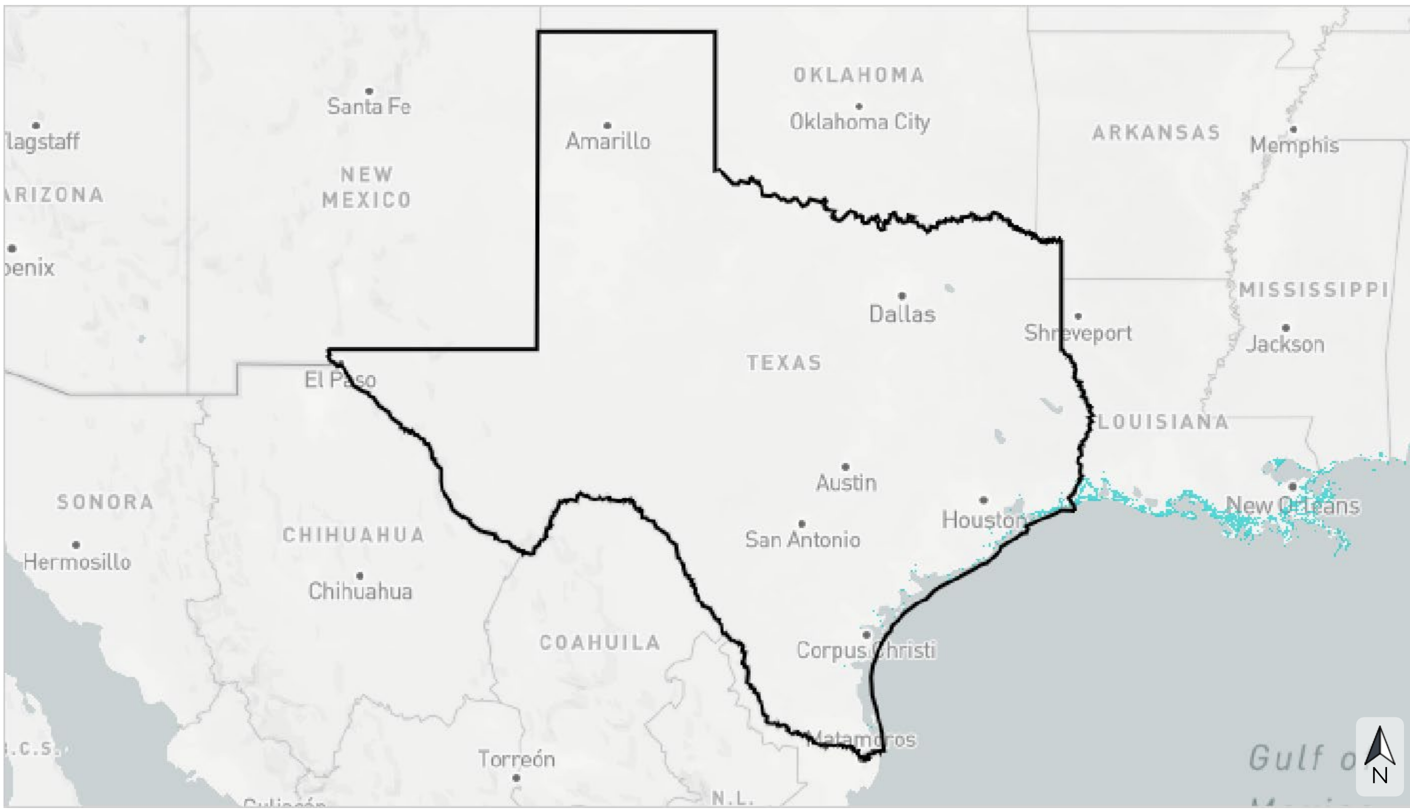
	Indicator Values	Acres	Percent of Area
↑ High	Seagrasses present	228,430	0.1%
	Area not evaluated for this indicator	*171,650,269*	*99.9%*
	Outside Southeast Blueprint	*22,348*	*<0.1%*

To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Stable coastal wetlands

This indicator uses remote sensing to calculate the unvegetated-vegetated ratio of tidal wetlands, which compares how much of a wetland is not covered by plants (e.g., sediment, rocks, open water) to how much is covered by plants. This ratio, and how it changes over time, is a good surrogate for salt marsh degradation processes like sediment loss and conversion to open water. It helps differentiate between stable marshes that are more resilient, and declining marshes that are more vulnerable to threats like sea-level rise, erosion, and coastal development.

This indicator originates from a U.S. Geological Survey project on an unvegetated to vegetated ratio for coastal wetlands.



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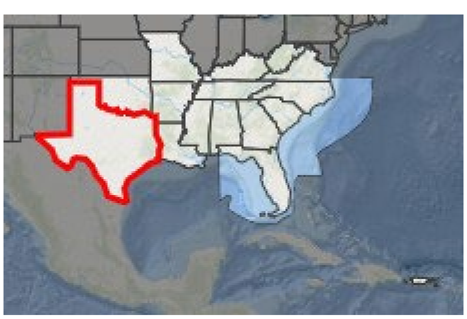


Stable coastal wetlands

Table 26: Indicator values for stable coastal wetlands in this area. Good condition thresholds reflect the range of indicator values that occur in healthy, functioning ecosystems.

	Indicator Values	Acres	Percent of Area	
↑ High	Stable coastal wetlands	301,041	0.2%	↑ In good condition
	Area not evaluated for this indicator	*171,577,659*	*99.8%*	
	Outside Southeast Blueprint	*22,348*	*<0.1%*	

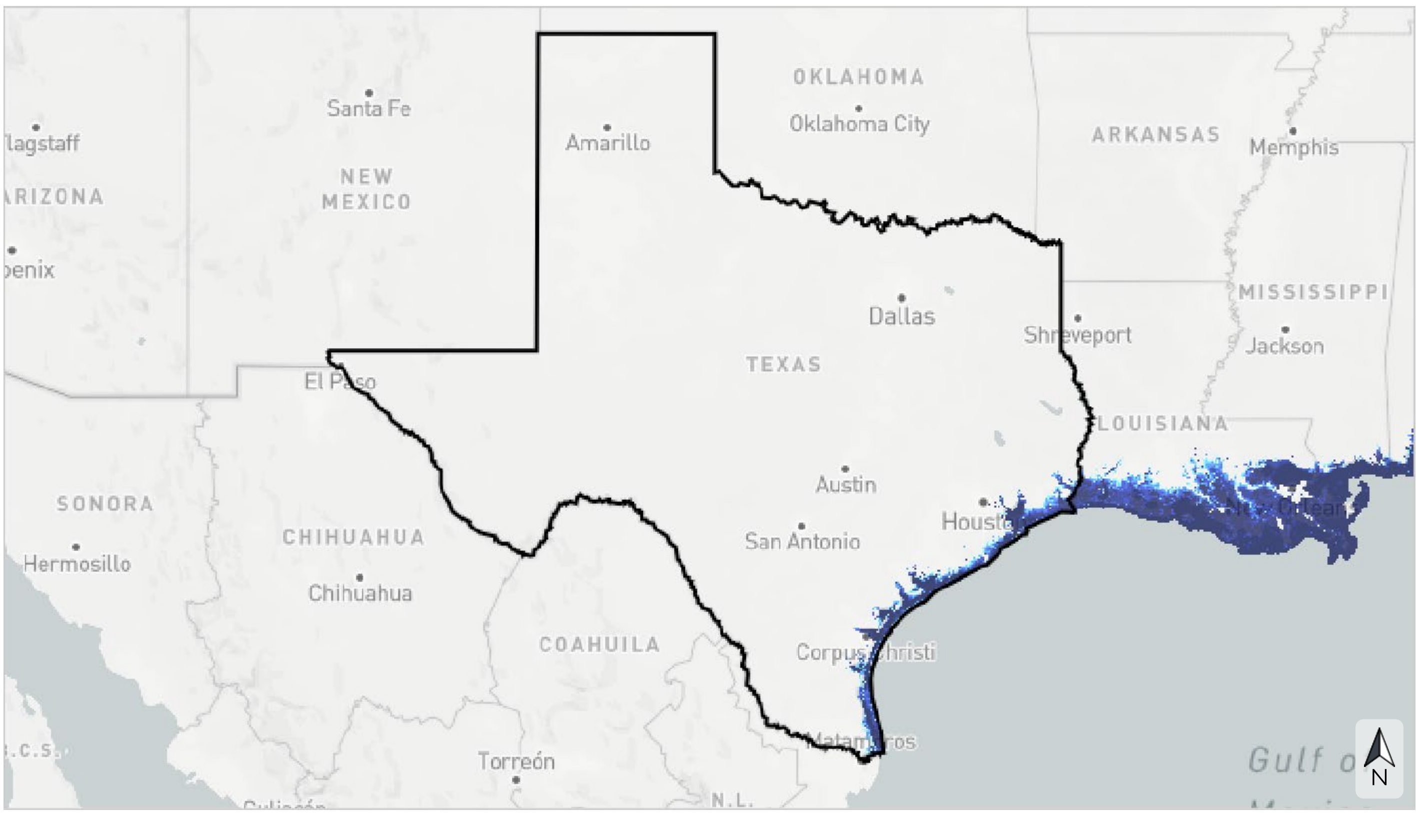
To learn more and explore the GIS data, view this indicator in the SECAS Atlas.

Threats

Sea-level rise

NOAA's sea-level rise (SLR) inundation models represent areas likely to experience flooding at high tide based on each foot of inundation depth above current levels. These inundation depth models are not linked to a future timeframe; see the projections below. NOAA calculates the inundation depth at "mean higher high water", or the average highest daily tide. The area covered by each inundation depth level includes areas projected to be inundated at lower levels. For example, areas inundated by 4 ft of SLR also includes areas inundated by 3 ft, 2 ft, 1 ft, and current inundation levels.

To explore additional SLR information, please see NOAA's [Sea Level Rise Viewer](#).



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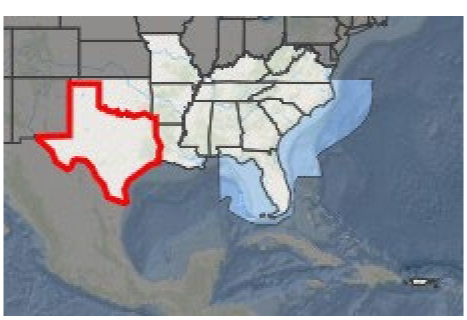


Flooding extent by projected sea-level rise (ft)

0 1 2 3 4 5 6 7 8 9 10

Table 27: Extent of flooding by projected average highest daily tide due to sea level rise in this area. Values from the [NOAA sea-level rise inundation data](#).

Feet of sea-level rise	Acres	Percent of Area
0 feet	2,464,661	1.4%
1 foot	2,795,750	1.6%
2 feet	3,093,251	1.8%
3 feet	3,302,607	1.9%
4 feet	3,469,355	2.0%
5 feet	3,616,314	2.1%
6 feet	3,768,572	2.2%
7 feet	3,936,500	2.3%
8 feet	4,097,934	2.4%
9 feet	4,260,008	2.5%
10 feet	4,419,417	2.6%
Not projected to be inundated by up to 10 feet	*10,372,350*	*6.0%*
Sea-level rise unlikely to be a threat (inland counties)	*156,958,824*	*91.3%*
Sea-level rise data unavailable	*128,108*	*<0.1%*
Outside Southeast Blueprint	*22,348*	*<0.1%*
Total area	**171,901,047**	**100%**

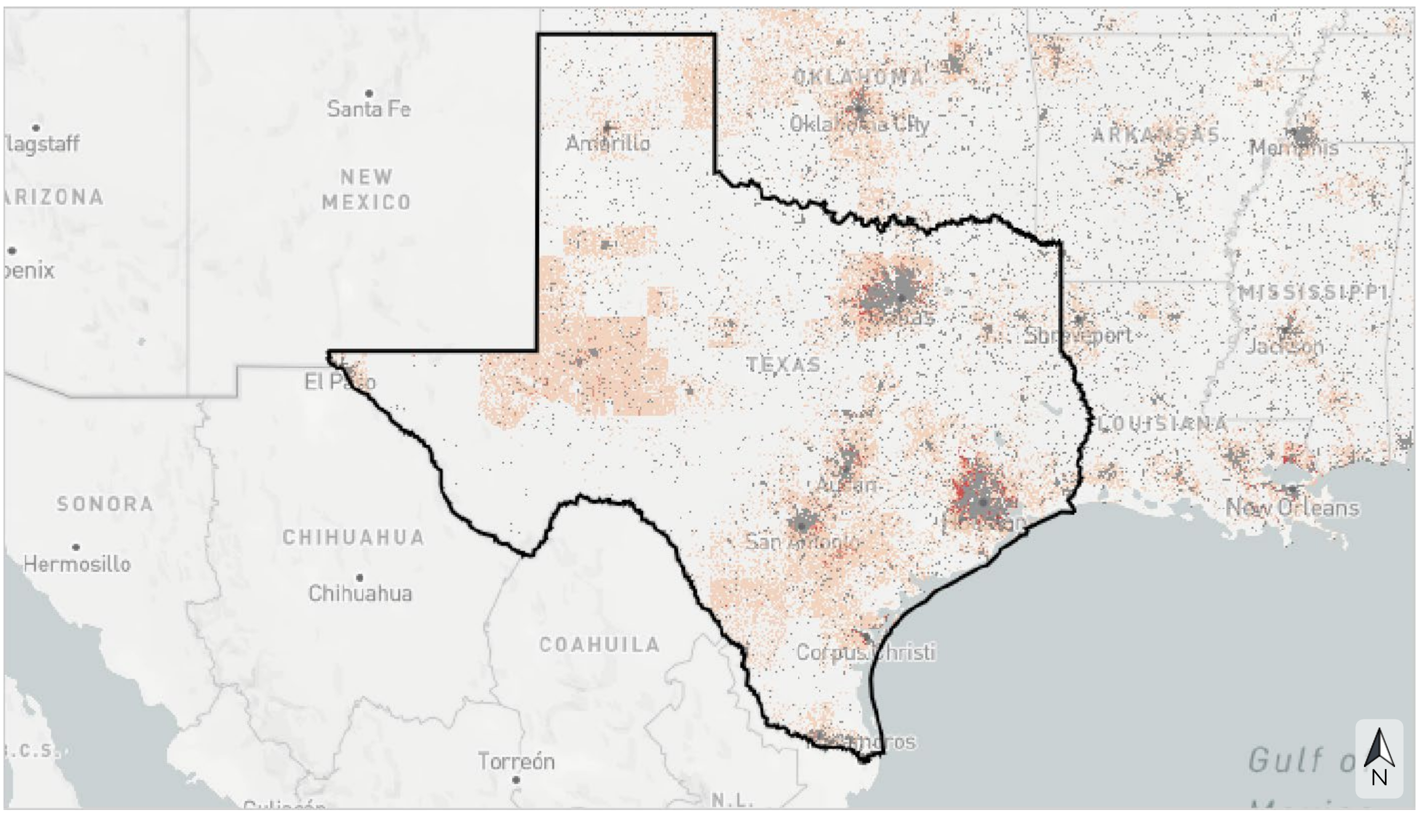
Table 28: Projected sea level rise by decade in this area. Values are based on area-weighted averages of decadal projections for 1-degree grid cells that overlap this area based on [NOAA's 2022 Sea Level Rise Report](). 2060 corresponds to the [SECAS goal](): a 10% or greater improvement in the health, function, and connectivity of Southeastern ecosystems by 2060.

SLR Scenario	2020 (ft)	2030 (ft)	2040 (ft)	2050 (ft)	2060 (ft)	2070 (ft)	2080 (ft)	2090 (ft)	2100 (ft)
Low	0.5	0.76	1	1.2	1.5	1.7	1.9	2	2.2
Intermediate-low	0.53	0.82	1.1	1.4	1.7	2	2.3	2.6	2.9
Intermediate	0.54	0.85	1.1	1.5	1.9	2.4	2.9	3.6	4.4
Intermediate-high	0.55	0.87	1.2	1.7	2.3	3.1	4	4.9	5.9
High	0.55	0.9	1.3	1.9	2.7	3.8	5	6.3	7.6

Urban growth

The FUTURES urban growth model predicts the likelihood that an area will urbanize at every decade from 2020 to 2100. Developed areas from the 2019 National Landcover Database serve as the baseline for current urban areas. The model simulates landscape change based on trends in population growth, local development suitability factors, and an urban patch-growing algorithm. It considers environmental drivers like distance to floodplain, slope, and available infrastructure, and even socio-economic status.

The probability of urbanization for each area reflects how many times it urbanized out of 50 model runs.



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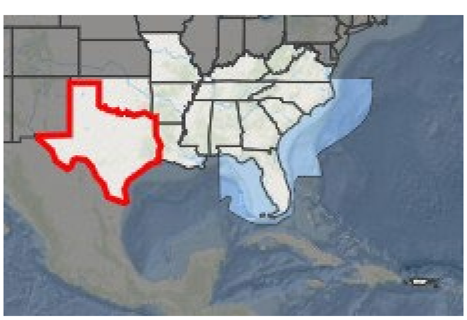

Probability of urbanization by 2060

Urban in 2019

Very high likelihood of urbanization (>50% probability)

High likelihood of urbanization (25 - 50% probability)

Moderate likelihood of urbanization (2 - 25% probability)

Not likely to urbanize

5.9% of this area is already urban in 2019, and an additional 19.5% has at least a moderate probability of urbanizing by 2060.

Table 29: Extent of projected urbanization by decade in this area. Values from the FUTURES urban growth model. Data provided by the [Center for Geospatial Analytics](), NC State University. 2060 corresponds to the [SECAS goal](): a 10% or greater improvement in the health, function, and connectivity of Southeastern ecosystems by 2060.

Decade	Acres	Percent of Area
Urban in 2019	10,142,244	5.9%
2020 projected extent	10,382,457	6.0%
2030 projected extent	11,024,558	6.4%
2040 projected extent	11,599,720	6.7%
2050 projected extent	12,101,245	7.0%
2060 projected extent	12,557,757	7.3%
2070 projected extent	12,935,652	7.5%
2080 projected extent	13,226,376	7.7%
2090 projected extent	13,430,376	7.8%
2100 projected extent	13,569,411	7.9%
Not projected to urbanize by 2100	*123,469,762*	*71.8%*
Outside Southeast Blueprint	*22,348*	*<0.1%*
Total area	**171,901,047**	**100%**

Ownership and Partners

Conserved lands ownership

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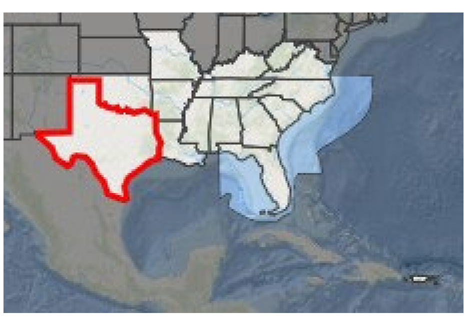

- Federal
- Joint
- State/province
- Private non-profit conserved lands
- Private conservation land
- Territorial
- Regional
- Local
- Tribal
- Designation
- Ownership unknown

Table 30: Extent of ownership class in this area. Protected areas are derived from the [Protected Areas Database of the United States](#) (PAD-US v3.0). Note: areas are based on the polygon boundary of this area compared to protected area polygons, rather than pixel-level analyses used elsewhere in this report.

Ownership	**Acres**	**Percent of Area**
Federal	2,609,391	1.5%
State/province	2,346,263	1.4%
Regional	47,379	<0.1%
Local	320,707	0.2%
Joint	260	<0.1%
Private non-profit conserved lands	142,002	<0.1%
Private conservation land	713,218	0.4%
Designation	2,420,333	1.4%
Ownership unknown	664,772	0.4%
Not conserved	*162,636,731*	*94.6%*
Total area	**171,901,058**	**100%**

Land protection status

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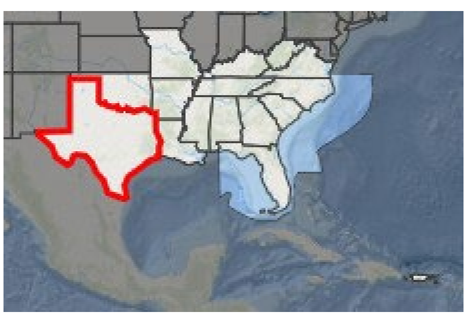

Managed for biodiversity (disturbance events proceed or are mimicked)

Managed for biodiversity (disturbance events suppressed)

Managed for multiple uses (subject to extractive uses such as mining or logging, or OHV use)

No known mandate for biodiversity protection

Table 31: Extent of land protection status in this area. Protected areas are derived from the Protected Areas Database of the United States (PAD-US v3.0). Note: areas are based on the polygon boundary of this area compared to protected area polygons, rather than pixel-level analyses used elsewhere in this report.

Land Protection Status	Acres	Percent of Area
Managed for biodiversity (disturbance events proceed or are mimicked)	1,778,778	1.0%
Managed for biodiversity (disturbance events suppressed)	2,699,280	1.6%
Managed for multiple uses (subject to extractive uses such as mining or logging, or OHV use)	2,856,732	1.7%
No known mandate for biodiversity protection	1,929,537	1.1%
Not conserved	*162,636,731*	*94.6%*
Total area	**171,901,058**	**100%**

Protected Areas

- Permanent University Fund (Texas General Land Office; 1,389,713 acres)
- BIBE (NPS; 784,706 acres)
- National Forests in Texas (USDA FOREST SERVICE; 677,734 acres)
- Big Bend (576,702 acres)
- Big Bend Ranch SP (Texas Parks and Wildlife Department; 313,391 acres)
- Fort Hood (219,325 acres)
- Mission-Aransas National Estuarine Research Reserve (Unknown; 185,674 acres)
- Padre Island National Seashore (Unknown; 131,161 acres)
- PAIS (NPS; 130,489 acres)
- Fort Bliss (123,320 acres)
- SAM RAYBURN (Unknown; 116,718 acres)
- Aransas National Wildlife Refuge (Unknown; 116,538 acres)
- Sam Rayburn Reservoir (113,190 acres)
- BITH (NPS; 108,722 acres)
- Black Gap WMA (Texas Parks and Wildlife Department; 104,659 acres)
- Lower Rio Grande Valley National Wildlife Refuge (Unknown; 98,081 acres)
- LAGUNA ATASCOSA NATIONAL WILDLIFE REFUGE (Fee; 95,359 acres)

- Laguna Atascosa National Wildlife Refuge (Unknown; 91,401 acres)
- ARANSAS NATIONAL WILDLIFE REFUGE (Fee; 90,764 acres)
- LOWER RIO GRANDE VALLEY NATIONAL WILDLIFE REFUGE (Fee; 88,232 acres)
- GUMO (NPS; 86,839 acres)
- WRIGHT PATMAN (Unknown; 81,011 acres)
- Cibola National Forest (USDA FOREST SERVICE; 79,349 acres)
- SAN BERNARD NATIONAL WILDLIFE REFUGE (Fee; 62,792 acres)
- San Bernard National Wildlife Refuge (Unknown; 62,098 acres)
- ... and 9,306 more protected areas ...

Nearby land trusts

Click here to search for land trusts within 500 miles of this area on the Land Trust Alliance website.

Credits

This report was generated by the Southeast Conservation Blueprint Explorer, which was developed by Astute Spruce, LLC in partnership with the U.S. Fish and Wildlife Service under the Southeast Conservation Adaptation Strategy.

Data credits

Urbanization data are derived from the FUTURES urban growth model. Data provided by the Center for Geospatial Analytics, NC State University (June 2022).

Sea level rise data are derived from the National Oceanic and Atmospheric Administration's Sea Level Rise Inundation Depth Data and the 2022 Sea Level Rise Technical Report.

Land ownership and conservation status is derived from the Protected Areas Database of the United States (PAD-US v3.0).

Supplement 4.2

Descriptions of Habitats and their Threats

This supplement is to be used with **Chapter 4** to gain a more regional-scale understanding of the health of habitats in Texas.

The following are descriptions of geographic communities in Texas along with the primary threats to the community's health, if known. While most of these systems have been mapped and described at a global scale, this report represents the first descriptions of systems in the context of the state of Texas. Habitats covered in this plan are directly related to SGCN and Rare Communities. These may include terrestrial and/or aquatic vegetation communities; a particular watershed, waterbody or stream segment; particular geologic substrates (e.g. limestone, granite, sands) or formations (e.g. karst, caves).

Preliminary estimates of the general condition, ecological health, and priority threats of each community were developed using NatureServe Explorer. The *SWAP: Texas* "**Potential Threats:**" are generally quoted directly from NatureServe Explorer, including citations, and all citations are included in the "References" section of the *SWAP: Texas*. Exceptions: location-specific threats outside of Texas (for example, "Dredging of the Mississippi River") were omitted, unless they added to the overall understanding of threats to a particular habitat. Also, some entries were edited for length or summarized by key points. Summaries of NatureServe entries do not include primary source citations.

In this Supplement, habitats are first sorted into coarse-scale categories that are commonly used and easily recognized. These habitat types and definitions used for coarse sorting are based on discussions with the Wildlife Habitat Policy Research Program working group (National Council for Science and the Environment 2010), the USFWS Wildlife and Sportfish Restoration Program TRACS development team (2010), National Fish Habitat Action Plan (Esselman et. al. 2010), state fish and wildlife management agencies, and conservation organizations. Within each coarse-scale category are a series of specific habitat types (Sayre, Comer, Warner, & Cress, 2009) identified as habitat critical to SGCN.

Some of Texas's SGCN populations and rare communities are located in small, fine-scale habitats (e.g. bogs, fens, sand hills, barren ground clearings) which are embedded in a larger-scale types (e.g. Riparian: Red River Large Floodplain Forest, Grassland: Western Great Plains Shortgrass Prairie, Riverine: Upper Brazos). When considering where to take action, prioritize attention in places where SGCN populations and rare communities occur and their needs are or could be well-met for the long term. These places in good to best condition would be the "desired ecological condition" – natural systems in "good working order." Places already in this condition are good candidates for protection actions; places with potential to be in this condition are good candidates for restoration actions.

Some fine-scale habitats (ecological systems) are suspected or historically present, but currently not geographically represented in Texas because of small size, combination with a dominant ecological system, or habitat loss. These systems are described here using the NatureServe Terrestrial Ecological Systems of the United States (NatureServe) summary and are noted as "Unmapped."

Plans for the 2025 State Wildlife Action Plan

A clear need for a more comprehensive atlas of communities with SGCN distributions and habitat suitability models, known habitat threats, and potential for conservation (AKA Conservation Opportunity

Area) is needed and is currently being prepared for the 2025 *SWAP: Texas.* A Conservation Opportunity Area (or Atlas) initial analysis is planned to be complete in October of 2024. This will allow TPWD, stakeholders, and partners to determine areas that have the greatest potential for significant positive conservation impact, and will allow for limited resources to be dedicated to research and conservation efforts in these locations.

Native Fish Conservation Areas

The Texas Native Fish Conservation Areas Network ("Texas NFCAs Network") was developed out of the need for an integrated and holistic approach to conservation of freshwater systems. The Texas NFCAs Network consists of springs, ciénegas, creeks, rivers, and associated watersheds uniquely valued in preservation of Texas fresh-water fish diversity. Twenty native fish conservation areas have been designated throughout the state. These were selected based on a spatial prioritization focused on identification of freshwater systems critically important to the long-term persistence of 91 freshwater fishes considered species of greatest conservation need (SGCN). Descriptions of these areas can be found in **Supplement 3.2 Texas Native Fish Conservation Areas and SGCN** and **4.4 Texas Native Fish Conservation Network**.

Barren/Sparse Vegetation

Barren/Sparse vegetation types in Texas may include but are not limited to desert playas, badlands, volcanic ash beds, talus slopes, cliff faces, rocky outcrops, and inland dunes. These habitats typically have low to no vegetation cover and may provide very specific environmental conditions for assemblages of rare or unique species. Priority habitats of this broadly defined type occur within the following Texas ecoregions: Arizona/New Mexico Mountains and Chihuahuan Deserts, High Plains, Southwestern Tablelands, Edwards Plateau, Cross Timbers, and Pineywoods.

It is important to note that playas are shallow, mostly ephemeral wetlands that may function as grassland habitat when dry, according to workshop biologists; if more often wet than dry, or if wetland vegetation or soil characteristics persist or are important to the ecological function, then habitat will be captured in wetland categories. Also, the broadly defined *Coastal habitat* type also includes similar vegetation types but will be discussed within that section.

Edwards Plateau Carbonate Glade and Barrens

These small patch systems occur on non-slope forming members of the Glen Rose formation, or areas of massive limestones such as Edwards Limestone. These openings can usually be found on level to gently sloping uplands on plateau tops, or level benches between slopes in stair step topography. Soils are very shallow, sometimes very little soil development over rocky substrates. This ecological system occurs at too fine of a resolution to be mapped within the Texas Ecological System Database. It is, however restricted to the Edwards Plateau and Cross Timbers ecoregions.

These are generally small patch occurrences with very sparse herbaceous cover, sometimes with occasional scattered shrubs. These sites generally co-occur with savannas, representing the shallowest soils sites, often on exposed or near-exposed limestone. They may occur as bands with adjacent grasslands, shrublands, or open woodlands. Herbaceous cover may include species such as *Chaetopappa bellidifolia* (hairy leastdaisy), *Evax prolifera* (rabbit's tobacco), *Croton monanthogynus* (prairie-tea), *Sedum nuttallianum* (yellow stonecrop), *Sedum pulchellum* (widowscross), *Sporobolus vaginiflorus* (poverty dropseed), *Centaurium texense* (Texas centaury), *Spermolepis inermis* (spreading scaleseed), *Chamaesyce serpens* (matted sandmat), *Heliotropium tenellum* (pasture heliotrope), *Lesquerella spp.* (bladderpod), and others.

A possible outlier (the system occurring well outside the ecoregion within which it is normally found) of this system consists of small patch occurrences of very sparse herbaceous cover found on very shallow soils over chalk outcrops in isolated locales of North Texas (Gober, Annona, Austin Chalk and Pecan Gap formation). Species include *Bouteloua rigidiseta* (Texas grama), *Sedum pulchellum* (Texas sedum), *Sporobolus vaginiflorus* (poverty dropseed), *Nostoc commune* (nostoc), *Penstemon cobaea* (white beardtongue), and *Lesquerella spp.* (bladderpod). Adjacent woodlands or savannas on thin-soiled chalk ridges may contain *Quercus shumardii* (Shumard oak), *Quercus muehlenbergii* (chinkapin oak), *Celtis spp.* (hackberry), *Cornus drummondii* (roughleaf dogweed), *Viburnum rufidulum* (rusty blackhaw), *Fraxinus texensis* (Texas ash), and others.

Potential Threats:

Drought and wind erosion are the major influences affecting this system.

Edwards Plateau Cliff

These priority habitats occur on hard-bedded limestone geologic formations. They are vertical or near vertical rock faces, sometimes alternating with slope forming limestone members. There is little to no soil development. Some soil accumulating on ledges and in crevices. These cliffs mainly occur withing the Edwards Plateau and Cross Timbers ecoregions, however, outliers can be found in the South Texas Plains, Southwestern Tablelands and Chihuahuan Deserts ecoregions. Some of these sites may be mesic, accumulating moisture from nearby slopes in crevices within the limestone substrate, and seeps may be present. They often occur as long narrow bands.

Composition and cover on these cliff faces is a function of aspect, canopy cover provided by surrounding systems, local climate, and moisture available from the underlying 51 geologic formation. Seeps and mesic sites may have fairly dense cover of *Adiantum capillus-veneris* (maiden-hair fern) with patches of *Thelypteris ovata* var. *lindheimeri* (Lindheimer's maidenfern) present. More xeric sites often have significant shrub cover, with species such as *Buddleja racemosa* (Texas butterflybush), *Ungnadia speciosa* (Mexican buckeye), *Diospyros texana* (Texas persimmon), *Ageratina havanensis* (shrubby boneset), *Garrya ovata* ssp. *lindheimeri* (Lindheimer's silktassel), *Bernardia myricifolia* (southwest bernardia), *Philadelphus* spp. (mock- orange), *Styrax* spp. (snowbell), and *Toxicodendron radicans* ssp. *eximium* (poison ivy).

Herbaceous species that may be present include *Salvia roemeriana* (cedar sage), *Penstemon baccharifolius (*baccharisleaf beardtongue), *Schoenus nigricans* (black sedge), *Chaetopappa bellidifolia* (least daisy), *Perityle* spp. (rockdaisy), and ferns in the genera *Asplenium*, *Astrolepis*, *Cheilanthes*, and *Pellaea*. Sparse grasses including *Bouteloua hirsuta* (hairy grama), *Bouteloua rigidiseta* (Texas grama), and *Aristida oligantha* (oldfield threeawn) may be present. These cliffs often serve as refugia from herbivores.

Potential Threats:

Community occupies steep slopes with little soil development and vulnerable to moisture changes. Climate change may significantly affect this system.

North American Warm Desert Active and Stabilized Dunes

These inland dune systems occur over Quaternary aeolian sand deposits associated with the Hueco Bolson and the Salt Basin. They can vary from rolling dunes to sandy level plains. Soil types include Sand Hills and Deep Sand Ecological Sites (SSURGO soils.) This ecological system occurs in Chihuahua Desert ecoregion in West Texas and is shared with neighboring New Mexico and internationally with Mexico.

This system occupies the deep sands adjacent to the Salt Basin west of the Guadalupe Mountains, and the Hueco Basin along the Rio Grande. These sands are characterized by sparsely vegetated active dunes as well as stabilized dunes colonized by species such as *Sporobolus giganteus* (giant dropseed), *Sporobolus flexuosus* (mesa dropseed), *Sporobolus cryptandrus* (sand dropseed), *Sporobolus contractus* (spike dropseed), *Bouteloua eriopoda* (black grama), *Schizachyrium scoparium* (little bluestem), *Aristida purpurea* (purple threeawn), *Prosopis glandulosa* (honey mesquite), *Psorothamnus scoparius* (broom pea), *Artemisia filifolia* (sand sage), *Yucca elata* (soaptree yucca), *Croton dioicus* (grassland croton), *Dimorphocarpa wislizeni* (spectaclepod), *Helianthus petiolaris* (plains sunflower), *Palafoxia sphacelata* (rayed palafoxia), *Heliotropium convolvulaceum* (bindweed heliotrope), *Eriogonum annuum* (annual wildbuckwheat), *Tripterocalyx carneus* (winged sandpuffs), *Amsonia tomentosa* var. *stenophylla* (wooly bluestar), *Proboscidea althaeifolia* (devilshorn), and *Ipomopsis wrightii* (leafy skyrocket).

Potential Threats:

Invasion by introduced annual vegetation such as *Bromus rubens* and *Salsola tragus* can alter dune processes by stabilizing dunes and depleting soil moisture.

Urbanization impacts, which may be direct as vegetation is removed for building sites or more indirectly through natural fire regime alteration, and/or the introduction of invasive species. Mining operations can drastically impact natural vegetation. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species.

North American Warm Desert Badland

Shale and mudstone geology commonly provide parent material for these harsh and almost completely barren habitats. They have Rolling topography with some abrupt erosional scarps and gullies. Soils are clays, often forming clay hills in hot desert environments. This ecological system occurs in Chihuahua Desert ecoregion in West Texas and is shared with neighboring New Mexico and internationally with Mexico.

This system is sparsely vegetated to unvegetated on fine-textured soils where high rates of erosion, high temperatures and evaporation, and low precipitation preclude the development of significant vegetative cover. These sites are highly erosional and occupy rolling landscapes frequently cut by drainages.

Potential Threats:

Invasion by introduced annuals such as *Brassica tournefortii* and *Bromus rubens* increases the risk of fire (Sawyer et al. 2009).

Human development has impacted many locations throughout the ecoregion. High- and low-density urban and industrial developments also have large impacts. For example, residential development has significantly impacted locations within commuting distance to urban areas. Impacts may be direct as vegetation is removed for building sites or more indirectly through natural fire regime alteration, and/or the introduction of invasive species. Mining operations can drastically impact natural vegetation. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species.

North American Warm Desert Bedrock Cliff and Outcrop

This system is well-developed on massive Cretaceous and Permian limestones, but also occupies igneous and sandstone formations. On steep rock faces with slopes greater than 80% causing very little to no soil development. This ecological system occurs within Chihuahua Desert ecoregion in West Texas and is shared with neighboring New Mexico and internationally with Mexico.

This sparsely vegetated system occupies steep rock faces of the massive limestones and other substrates of the region. Some of these cliffs may be 100's of feet tall. Vegetation is typically restricted to crevices, although crustose lichens may be well-represented.

Potential Threats:

Introduced annuals may invade the limited growing sites and deplete soil moisture from native species.

Human development has impacted many locations throughout the ecoregion. High- and low-density urban and industrial developments also have large impacts. For example, residential development has significantly impacted locations within commuting distance to urban areas. Impacts may be direct as vegetation is removed for building sites or more indirectly through natural fire regime alteration, and/or the introduction of invasive species. Mining operations can drastically impact natural vegetation. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species.

North American Warm Desert Pavement

These priority habitats often occur on Quaternary alluvium and colluvium geology. They have a level to gently rolling landform. The soils are described as gravelly sites. This ecological system occurs in Chihuahua Desert ecoregion in West Texas and is shared with neighboring New Mexico and internationally with Mexico.

Unvegetated to very sparsely vegetated sites on level to gently rolling, gravelly landscapes. These sites are often characterized by harsh, high temperature conditions often leading to the development of gravels coated with "desert varnish." This system may occur on alluvial flats or the level portions of bajada fans at low elevations. *Larrea tridentata* (creosotebush) often occurs as widely scattered shrubs.

Potential Threats

Mechanical disturbance of pavement exposes subsurface layers and likely results in increased soil erosion. After extremely wet winters/springs, flushes of introduced annuals such as *Bromus rubens* may increase the risk of fire.

Human development has impacted many locations throughout the ecoregion. High- and low-density urban and industrial developments also have large impacts. For example, residential development has significantly impacted locations within commuting distance to urban areas. Impacts may be direct as vegetation is removed for building sites or more indirectly through natural fire regime alteration, and/or the introduction of invasive species. Mining operations can drastically impact natural vegetation. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species.

North American Warm Desert Playa

These playas occur on Quaternary alluvial, playa, and caliche deposits. They are Internally draining, somewhat circular basins. The soil substrate for these systems in Texas is Verhalen clay. This ecological system occurs in Chihuahua Desert ecoregion in West Texas and is shared with neighboring New Mexico and internationally with Mexico.

This system forms in alternately wet and dry, internally draining, often clay-lined basins, sometimes over caliche. They tend to be sparsely vegetated, sometimes with open water, or herbaceous vegetation. High evaporation rates leads to high salinity and halophytic species may be common. Species that may be present include *Distichlis spicata* (saltgrass), *Allenrolfea occidentalis* (pickle-weed), *Tiquilia canescens* (oreja de pero), *Suaeda* spp. (seablite), *Salsola* spp. (Russian thistle), and *Atriplex canescens* (four-wing saltbush).

Potential Threats

Land conversion from wetlands to agricultural use is common, as is dewatering. Threats to the ecosystem include changes in the hydrologic input can alter the marsh's pH level from alkaline to freshwater, leading to a reduction in wetland vegetation. Even minor changes in the water table depth or inundation duration can significantly affect soil salinity. Climate change impacts could exacerbate the situation by reducing high flows, causing a drop in the groundwater table, shrinking and drying the marsh, increasing fire frequency due to warmer temperatures and drier fuels, promoting invasive species, and increased competition for water from all users. This could add to the already overtaxed water allocation of California's agricultural system.

North American Warm Desert Volcanic Rockland

The geology of these priority habitats in Texas is tertiary extrusive igneous formations, including tuff, basalt, and rhyolite. These rocky sites are usually talus slopes, but also relatively level rocky and boulder sites. Soil is generally lacking or reduced to small pockets within the rock matrix.

This ecological system occurs in Chihuahua Desert ecoregion in West Texas and is shared with neighboring New Mexico and internationally with Mexico.

Very sparsely vegetated sites (<10% cover) on rocky or boulder strewn slopes and flats where the rock material is volcanic in origin. Scattered individuals of species such as *Larrea tridentata* (creosotebush), *Fouquieria splendens* (ocotillo), *Jatropha dioica* (leatherstem), *Prosopis glandulosa* (honey mesquite), *Yucca torreyi* (Torrey's yucca), and cacti such as *Echinocereus* spp. (hedgehog cacti) and *Opuntia rufida* (blind pricklypear) may be present.

Potential Threats

nvasion by introduced annual vegetation such as *Bromus rubens* and *Salsola tragus* can alter dune processes by stabilizing dunes and depleting soil moisture.

Human development has impacted many locations throughout the ecoregion. High- and low-density urban and industrial developments also have large impacts. For example, residential development has significantly impacted locations within commuting distance to urban areas. Impacts may be direct as vegetation is removed for building sites or more indirectly through natural fire regime alteration, and/or the introduction of invasive species. Mining operations can drastically impact natural vegetation. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species.

Rocky Mountain Cliff, Canyon and Massive Bedrock

Currently undescribed

Southeastern Coastal Plain Cliff

Currently undescribed

Western Great Plains Cliff and Outcrop

These systems occur on various geologic formations that tend to be less erodible, including limestone and sandstone. Like nearly all cliffs and rock outcrops, these are areas of high topographic relief, typically with slopes greater than 80%, including along river breaks and escarpments. There is very little soil development except on shelves and in cracks and crevices. These habitats most often occur along rivers within the Cross Timbers, East Central Texas Plains, and the Texas Blackland Prairie ecoregions. This ecological system can be found throughout most of the Western Great Plains from Texas to Canada including the neighboring states of Oklahoma and New Mexico.

Potential Threats

Drought and wind erosion are the major influences affecting this system.

Desert Scrub

Desert scrub landcover are characterized by woody-stemmed shrubs and succulents. In the western portion of the state this includes cool desert scrub, cool desert steppe, warm desert scrub, and warm desert steppe. While in the southern portion of the state this landcover type has been expanded to include the more densely vegetated thornscrub.

Priority habitats of this broadly defined type occur within the following Texas ecoregions: Arizona/New Mexico Mountains and Chihuahuan Deserts, High Plains, Southwestern Tablelands, Edwards Plateau, South Texas Plains, East Central Texas Plains, Gulf Coast Prairies and Marshes, and Texas Blackland Prairie.

Apacherian-Chihuahuan Mesquite Upland Scrub

This system is often considered a native invasive, upland shrub community occurring within the Chihuahuan Deserts grasslands in foothills and piedmonts of West Texas. Substrates are typically derived from alluvium, often gravelly without a well-developed argillic or calcic soil horizon that would limit infiltration and storage of winter precipitation in deeper soil layers. The land area of system has expanded over the last century due to increased grazing, decrease in fire frequency and more frequent/severe periods of drought. Naturally occurring vegetation cover is dominated by *Prosopis glandulosa* (honey mesquite), *Flourensia cernua* (tarbush), *Larrea tridenta* (creosotebush) and various succulents. Other species such as *Parthenium incanum* (mariola), *Acacia constricta* (whitethorn acacia), and *Atriplex canescens* (four-wing saltbush) are commonly encountered. Herbaceous cover is often low and comprised of *Dasyochloa pulchella* (fluffgrass)*, Mulhlenbergia porter* (bush muhly), and *Pleuraphis mutica* (toboasa).

Potential Threats:

During the last century, the area occupied by this system has increased through conversion of desert grasslands as a result of drought, overgrazing and *Prosopis glandulosa* seed dispersion by livestock, and/or decreases in fire frequency (Buffington and Herbel 1965, Brown and Archer 1987). It is believed that this system formerly occurred in relatively minor amounts and was largely confined to drainages until cattle distributed seed upland from the bosques into desert grasslands (Brown and Archer 1987, 1989). Shrublands dominated by *Prosopis* spp. have replaced large areas of desert grasslands, especially those formerly dominated by *Bouteloua eriopoda*, in Trans Pecos Texas, southern New Mexico and southeastern Arizona (York and Dick-Peddie 1969, Hennessy et al. 1983). Studies on the Jornada Experimental Range suggest that combinations of drought, overgrazing by livestock, wind and water erosion, seed dispersal by livestock, fire suppression, shifting dunes, and changes in the seasonal distribution of precipitation have caused this recent, dramatic shift in vegetation physiognomy (Buffington and Herbel 1965, Herbel et al. 1972, Humphrey 1974, McLaughlin and Bowers 1982, Gibbens et al. 1983, Hennessy et al. 1983, Schlesinger et al. 1990, McPherson 1995).

Historical natural-ignition fires were relatively small, probably 10-15 acres in size. Repeated fire is thought to help maintain a general mosaic pattern between open grassland and shrub-dominated areas (Johnston 1963). Wright et al. (1976) found that *Prosopis glandulosa* is very fire-tolerant when only 3 years old. Most plants resprout after being top-killed by fire. Thus, prior to livestock grazing reducing fire frequency, repeated grassland fires probably maintained lower stature of shrubs and prevented new establishment by killing seedlings.

Drought is a relatively common occurrence in this desert scrub, generally occurring every 10-15 years and lasting 2-3 years with occasional long-term drought periods (10-15 years duration). *Prosopis* spp. and other shrubs have extensive root systems that allow them to exploit deep-soil water that is unavailable to shallower rooted grasses and cacti (Burgess 1995). This strategy works well, especially during drought. However, on sites that have well-developed argillic or calcic soil horizons that limit infiltration and storage of winter moisture in the deeper soil layers, *Prosopis* spp. invasion can be limited to a few, small individuals (McAuliffe 1995). This has implications in plant geography and desert grassland restoration work in the southwestern United States.

Chihuahuan Creosote Bush Desert Scrub

This system occurs on alluvial/colluvial gravel flats. Landforms are flat to gently rolling and occupy outwash plains and basins between mountain ranges. This desert scrub type often occurs on gravelly soils.*Larrea tridentata* (creosotebush) is usually the clear dominant, though species such as *Parthenium incanum* (mariola), *Acacia constricta* (whitethorn acacia), *Flourensia cernua* (tarbush), and/or *Prosopis glandulosa* (honey mesquite) may be present. On some sites, particularly hot desert sites at low elevations, succulents such as *Fouquieria splendens* (ocotillo), *Agave lechuguilla* (lechuguilla), *Yucca torreyi* (Torrey's yucca), *Opuntia* spp. (pricklypears), and *Echinocereus* spp. (hedgehog cacti) may be conspicuous.

Potential Threats:

Not documented.

Chihuahuan Mixed Desert and Thornscrub

In the Chihuahuan Deserts of Texas, this ecological system is widely distributed and often occupies footslopes and hilly landforms of limestones, sandstones, and igneous strata, though it is best developed on limestones. The substrate includes rocky soils.

This shrubland can occur in proximity to Apacherian – Chihuahuan Semi-Desert Grassland and Steppe, Chihuahuan Creosote bush Desert Scrub, and/or Chihuahuan Succulent Desert Scrub. *Larrea tridentata* (creosote bush), *Parthenium incanum* (mariola), *Condalia ericoides* (javelina bush), *Mimosa aculeaticarpa* var. *biuncifera* (catclaw mimosa), *Yucca torreyi* (Torrey's yucca), *Acacia constricta* (whitethorn acacia), *Agave lechuguilla* (lechuguilla), *Dasylirion leiophyllum* (smooth sotol), *Viguiera stenoloba* (skeleton-leaf golden eye), *Leucophyllum* spp. (cenizo), and *Prosopis glandulosa* (honey mesquite) are often present to dominant, but numerous shrub species may be present. It differs from Chihuahuan Creosote bush Desert Scrub in having a diversity of shrub species present and is not a nearly monotypic stand of *Larrea tridentata* (creosote bush). Herbaceous cover is generally low with species such as *Bouteloua eriopoda* (black grama), *Bouteloua ramosa* (chino grama), *Bouteloua curtipendula* (sideoats grama), *Bouteloua trifida* (red grama), *Aristida purpurea* (purple threeawn), *Dasyochloa pulchella* (fluffgrass), and *Muhlenbergia setifolia* (curlyleaf muhly).

Potential Threats:

Although thornscrub occurring on limestone rock outcrops is stable, other stands may be sensitive to altered fire regimes caused by invasive species, as well as anthropogenic disturbance such as mechanical/chemical shrub removal. Altered (uncharacteristic) fire regimes greatly influence ecosystem processes.

The historical desert scrub has a very long fire-return interval (FRI) ranging from 300-1000 years (500 years on average) (from LANDFIRE BpS Model 2510740). *Larrea tridentata* and other desert scrub plant species did not evolve with fire and are sensitive to burning; most of them do not resprout after burning and are slow to recover, and therefore fires should be rare events to be avoided. Invasion of non-native grasses provides fine fuels that can increased fire frequency, intensity and severity. Fires in desert scrub are becoming more common, especially after a series of wet years when fine fuels from non-native herbaceous species build up enough to carry fire.

The impact of livestock grazing to the historical stands of desert scrub is expected to be relatively small because there is little forage available for them in this type, but where livestock grazing or other anthropomorphic disturbance occurs there may be increased soil erosion (Milchunas 2006).

Human development has impacted many locations throughout the ecoregion. These sites represent a poor-condition/non-functioning ecosystem that is highly fragmented, or much reduced in size from its historical extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or disturbed by off-road vehicles; the biotic condition is at the limit or beyond natural range of variation, e.g., vegetation composition is altered and is not dominated by native shrubs such as *Larrea tridentata* and *Flourensia cernua*. Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator-to-prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub horizons. Non-native grass invasion provides fine fuels that may increase fire frequency, intensity and severity.

Chihuahuan Mixed Salt Desert Scrub

This system usually occurs as an open-canopied shrubland surrounding saline basins, alluvial fans, and the salty bottomlands along the Pecos River. Substrates are fine-textured, alluvial, and saline.

Species making up the often relatively sparse vegetative cover include *Atriplex canescens* (four- wing saltbush), *Allenrolfea occidentalis* (pickle-weed), *Suaeda suffrutescens* (desert seepweed), *Cylindropuntia leptocaulis* (tasajillo), *Prosopis glandulosa* var. *torreyana* (western honey mesquite), *Isocoma pluriflora* (southern Jimmy-weed), *Sesuvium verrucosum* (winged sea purslane), *Koeberlinia spinosa* (allthorn), *Atriplex acanthocarpa* (tubercled saltbush), *Flourensia cernua* (tarbush), and *Ziziphus obtusifolia* (lotebush). Non-native halophiles such as *Salsola tragus* (prickly Russian thistle), *Alhagi maurorum* (camelthorn), *Peganum harmala* (African rue), and *Tamarix* spp. (saltcedars) are commonly encountered to dominant. Grass-like plants commonly found, and sometimes constituting significant cover, include *Sporobolus airoides* (alkali sacaton), *Sporobolus wrightii* (big sacaton), *Distichlis spicata* (saltgrass), *Trichloris crinita* (false Rhodes grass), *Pappophorum bicolor* (pink pappusgrass), *Pleuraphis mutica* (tobosa), and *Scleropogon brevifolius* (burrograss).

Potential Threats:

Not documented.

Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub

This system includes shrubby sites on fixed sand dunes associated with wind-formed sand geologic formations of the Trans-Pecos, often resulting from degradation of grasslands of the *North American Warm Desert Active and Stabilized Dunes* or the *Chihuahuan Sandy Plains Semi- Desert Grassland*. The landforms are rolling sand hills and sandy flats covered in small mounds (hummocks). The substrate is often deep sands.

Prosopis glandulosa (honey mesquite) and *Artemisia filifolia* (sand sage) are the most common dominants, but other woody species include *Yucca elata* (soaptree yucca), *Cylindropuntia imbricata* (tree cholla), *Atriplex canescens* (four-wing saltbush), and *Ephedra* spp. (mormon-tea). Herbaceous species of the adjacent grasslands are common.

Potential Threats:

Not documented.

Chihuahuan Succulent Desert Scrub

G4: Apparently Secure

This system typically occupies dry slopes with significant exposed rock, typically limestone or gravel, but may be found on igneous and sandstone substrates. The soils are often rocky or gravelly sites.

Shrub species such as *Larrea tridentata* (creosotebush), *Parthenium incanum* (mariola), *Viguiera stenoloba* (skeleton-leaf golden eye) (agarito), and *Forestiera angustifolia* (desert olive) may be present, but succulents such as *Yucca torreyi* (Torrey's yucca), *Dasylirion texanum* (Texas sotol), *Agave lechuguilla* (lechuguilla), *Fouquieria splendens* (ocotillo), *Dasylirion leiophyllum* (smooth sotol), *Euphorbia antisyphilitica* (candelilla), and *Opuntia* spp. (pricklypears) are conspicuous and are the aspect dominants. Overall cover is generally low and bare rock is easily visible in most occurrences. Herbaceous cover is low with grasses such as *Bouteloua eriopoda* (black grama), *Bouteloua ramosa* (chino grama), and *Bouteloua curtipendula* (sideoats grama) sometimes present. Fern and fern allies such as *Astrolepis* spp. (cloakferns), *Cheilanthes* spp. (lipferns) and *Selaginella lepidophylla* (resurrection plant) are often common.

Tamaulipan Calcareous Thornscrub

This shrubland typically occupies xeric, rocky uplands on calcareous substrates including limestone, caliche (such as those of the Goliad Formation), calcareous gravels, and calcareous sandstone of south Texas and northeastern Mexico. Soils are usually thin, and sites are most frequently dominated by shrubs between 0.5 and 2 m in height. Shrub canopy can be dense (to about 90%), or sparser where rocky exposures reduce substrate for rooting.

A sparse overstory, usually <4 m in height, may be present and composed of species such as *Prosopis glandulosa* (honey mesquite) and, in the south, *Ebenopsis ebano* (Texas ebony), *Cordia boissieri* (anacahuita), and/or *Helietta parvifolia* (baretta). *Quercus fusiformis* (plateau live oak) may form a relatively open canopy in areas in the northeastern part of the South Texas Plains. The shrub layer may be heavily dominated by *Leucophyllum frutescens* (cenizo), *Acacia berlandieri* (guajillo), and/or *Acacia rigidula* (blackbrush). More commonly, a diverse array of shrubs is present, including these three in addition to several of the following species: *Salvia ballotiflora* (shrubby blue sage), *Eysenhardtia texana* (Texas kidneywood), *Guaiacum angustifolium* (guayacan), *Sophora secundiflora* (Texas mountain-laurel), *Mahonia trifoliolata* (agarito), *Ephedra antisyphilitica* (joint-fir), *Sideroxylon celastrinum* (la coma), *Jatropha dioica* (leatherstem), *Bernardia myricifolia* (oreja de raton), *Karwinskia humboldtiana* (coyotillo), *Aloysia macrostachya* (vara dulce), *Condalia spathulata* (knifeleaf condalia), *Croton incanus* (Torrey croton), *Koeberlinia spinosa* (allthorn), *Acacia schaffneri* (huisachillo), *Forestiera angustifolia* (desert olive), *Celtis ehrenbergiana* (granjeno), *Diospyros texana* (Texas persimmon), *Cylindropuntia leptocaulis* (tasajillo), *Krameria ramosissima* (calderona), *Yucca treculeana* (Spanish dagger), and others. More southerly occurrences may also contain *Lippia graveolens* (redbrush lippia), *Helietta parvifolia* (baretta), *Gochnatia hypoleuca* (chomonque), *Croton humilis* (low croton), *Ebenopsis ebano* (Texas ebony), and/or *Mortonia greggii* (afinador). The herbaceous layer may be somewhat well-developed, but often bare rock is easily visible through the layer. Many sites are now dominated by non-native grasses, particularly *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem) and/or *Pennisetum ciliare* (buffelgrass). Other grasses are often shortgrasses, with species such as *Bouteloua rigidiseta* (Texas grama), *Bouteloua hirsuta* (hairy grama), *Bouteloua dactyloides* (buffalograss), *Hilaria belangeri* (curlymesquite), *Aristida purpurea* (purple threeawn), *Bouteloua curtipendula* (sideoats grama), and *Setaria leucopila* (plains bristlegrass) present. Forbs and subshrubs are conspicuous in the herbaceous layer and include species such as *Tiquilia canescens* (oreja de perro), *Thamnosma texana* (Texas desert-rue), *Galphimia angustifolia* (narrowleaf thryallis), *Polygala alba* (white milkwort), *Cordia podocephala* (cluster cordial), *Acourtia runcinata* (peonia), *Dalea aurea* (golden dalea), *Calliandra conferta* (Rio Grande stickpea), *Chamaecrista greggii* (Gregg's senna), *Heliotropium torreyi* (Torrey heliotrope), *Melampodium cinereum* (blackfoot daisy), *Hymenopappus scabiosaeus* (old plainsman), *Desmanthus velutinus* (velvet bundleflower), *Calylophus hartwegii* (Hartweg evening primrose), *Simsia calva* (awnless bush sunflower), *Hermannia texana* (Mexican mallow), *Macrosiphonia lanuginosa* var. *macrosiphon* (plateau rocktrumpet), *Viguiera stenoloba* (skeletonleaf goldeneye), *Stenaria nigricans* (prairie bluets), *Thymophylla pentachaeta* (fire-hair dogweed), *Wedelia hispida* (hairy zexmania), and *Meximalva filipes* (violet sida). Down slope from these sites, soil development increases, soils tend to be tight, a more well-developed overstory of *Prosopis glandulosa* (honey mesquite) becomes prominent, and species such as *Castela erecta* (amargosa) and *Ziziphus obtusifolia* (lotebush) increase in cover relative to other species.

Potential Threats:

Threats from development, including overgrazing by livestock, mining, and energy development, continue to convert or degrade existing stands. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species. Persistent drought may result in loss of key species. Conversion of this type has commonly come from effective brush eradication using mechanical, chemical or prescribed burning method. Common stressors and threats include fragmentation from roads, non-native species invasion (Landfire 2007a), and development, mining, agriculture. Other stressors and threats include overgrazing/browsing by livestock, and possibly loss of pollinators.

According to Climate Wizard in 2050 global climate change model (using Medium A1B emission scenario and Ensemble Average general circulation model), the average annual temperature is predicted to rise approximately 5°F and average annual precipitation will not significantly change (TNC 2013). Seasonal shifts in precipitation predict increased fall (monsoon) moisture with similar levels of precipitation to current in the rest of the year (TNC 2013). Potential climate change effects on vegetation could include a shift to species adapted to a hotter, generally drier environment. While average precipitation amounts may remain similar or slightly decrease during the winter, spring and summer months, that, along with increased temperatures, may cause vegetation to experience less effective precipitation and more soil moisture deficit during much of the growing season reducing plant growth and increasing mortality from extreme events including exceptional drought. If the increased fall precipitation is from intense storms such as hurricanes, we can expect more disturbances from flooding and water erosion.

Tamaulipan Mixed Deciduous Thornscrub

This shrubland is differentiated from Tamaulipan Savanna Grassland as it occupies tighter soils, as opposed to the sandier soils of the savanna grassland. The sites are often lower in the landscape compared to nearby savanna grassland or Tamaulipan Calcareous Shrubland but would be considered uplands as they are distant from bottomland soils and drainages, and are not well-developed woodlands typical of the lowest landscape positions. To a large degree, all of these systems share numerous shrub species, but show subtle differences in relative dominance. However, this system generally occurs as a closed shrubland or low woodland, usually lacking a purely open herbaceous component. Soils are clays, clay loams, and clay flats and are often calcareous or alkaline to varying degrees. Some sites are highly saline, and these sites are occupied by Tamaulipan Saline Shrubland, but transitions between the systems may be subtle.

Prosopis glandulosa (honey mesquite) is very often a conspicuous component of the canopy, sometimes reaching to 6 m in height. This canopy may be dense, but given the open nature of the canopy of individual *P. glandulosa* (honey mesquite), significant solar radiation reaches the lower strata. *Acacia farnesiana* (huisache), *Celtis ehrenbergiana* (granjeno), *Ebenopsis ebano* (Texas ebony), and *Celtis laevigata* (sugar hackberry) may also be components of the canopy, but *P. glandulosa* (honey mesquite) usually dominates. The overstory canopy may be open with only scattered emergent trees over a dense shrub layer at 1 to 3 m in height. Depending on land use history, the shrub understory may be limited to a few species such as *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear), *Ziziphus obtusifolia* (lotebush), or *Celtis ehrenbergiana* (granjeno) on relatively recently cleared sites. On more mature sites, a diverse assemblage of species such as *Acacia rigidula* (blackbrush), *Castela erecta* (amargosa), *Malpighia glabra* (Barbados cherry), *O. engelmannii* var. *lindheimeri* (Lindheimer pricklypear), *Cylindropuntia leptocaulis* (tasajillo), *Ziziphus obtusifolia* (lotebush), *Celtis ehrenbergiana* (granjeno), *Lycium berlandieri* (Berlandier wolfberry), *Forestiera angustifolia* (desert olive), *Guaiacum angustifolium* (guayacan), *Diospyros texana* (Texas persimmon), *Amyris texana* (Texas torchwood), *Karwinskia humboldtiana* (coyotillo), *Havardia pallens* (tenaza), *Phaulothamnus spinescens* (snake-eyes), *Schaefferia cuneifolia* (desert yaupon), *Condalia hookeri* (brasil), and *Zanthoxylum fagara* (colima) may occur. *Leucophyllum frutescens* (cenizo) and *Acacia berlandieri* (guajillo) may be present, but occur as scattered individuals as opposed to dominating the aspect of the community as they sometimes do on some shallow-soiled calcareous sites. However, like some shallow-soiled calcareous sites, *Acacia rigidula* (blackbrush) is the aspect dominant of the shrub layer. The herbaceous layer is usually fairly sparse. Currently, the herbaceous layer may actually be dense with the non-native grass *Urochloa maximum* (guineagrass). Other non-native species, such as *Pennisetum ciliare* (buffelgrass), *Cynodon dactylon* (bermudagrass), *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem), and *Dichanthelium annulatum* (Kleberg bluestem), may also be present to dominant. Native grasses, such as *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Trichloris* spp. (false Rhodes grasses), and *Pappophorum bicolor* (pink pappusgrass), may be present.

Potential Threats:

Much of this system was decimated by development for agriculture early in the twentieth century (Crosswhite 1980). Grazing pressure removing native grasses, increase in invasive (introduced) grasses, and lack of fire threaten this system. Currently, the non-native grasses *Pennisetum ciliare* and *Urochloa maxima* can serve as ladder fuel which increases the potential for fire in this system. Threats from development, including development for agriculture, overgrazing by livestock, and possibly energy development, continue to convert or degrade existing stands. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species. Persistent drought may result in loss of key species. Conversion of this type has commonly come from agricultural practices. Common stressors and threats include fragmentation from roads, agriculture and development, and non-native species invasion. Other stressors and threats include overgrazing/browsing by livestock, and possibly loss of pollinators.

According to Climate Wizard in 2050 global climate change model (using Medium A1B emission scenario and Ensemble Average general circulation model), the average annual temperature is predicted to rise approximately 5°F and average annual precipitation will not significantly change (TNC 2013). Seasonal shifts in precipitation predict increased fall (monsoon) moisture with similar levels of precipitation to current in the rest of the year (TNC 2013). Potential climate change effects on vegetation could include a shift to species adapted to a hotter, generally drier environment. While average precipitation amounts may remain similar or slightly decrease during the winter, spring and summer months, that, along with increased temperatures, may cause vegetation to experience less effective precipitation and more soil moisture deficit during much of the growing season reducing plant growth and increasing mortality from extreme events including exceptional drought. If the increased fall precipitation is from intense storms such as hurricanes, we can expect more disturbances from flooding and water erosion.

Grasslands

Grasslands as defined for this document include prairies, temperate grasslands, montane grasslands, and open meadows. Grasslands also make up a great portion Texas' landscape (Figure 1) and are one of most altered and endangered ecosystems on Earth (Sampson and Knoppf, 1996 & USFWS, 2012, Preat 2009). In Texas native grasslands not only provide habitat to a diverse array of plant and animal species but are also an ecologically significant source of energy for herbivores, important for nutrient cycling, carbon storage, and contribute to water quality.

Apacherian-Chihuahuan Semi-Desert Grassland and Steppe

These arid grasslands occur on various geologic substrates, typically not occupying fine alluvium, but may occur on alluvial outwash slopes. This system may occur on igneous, limestone, and sandstone. These are grasslands occurring at lower elevations on mountain slopes and continuing onto lower bajadas. Soils are typically on rocky and derived from limestone, igneous, and sandstone substrates.

This grassland system sometimes occurs in association with Chihuahuan Mixed Desert and Thornscrub and may have shrubs of that system present. The herbaceous layer may be dense, but typically much bare ground or rock is visible. Graminoids dominate the layer with species such as *Bouteloua eriopoda* (black grama), *Bouteloua curtipendula* (sideoats grama), *Muhlenbergia setifolia* (curlyleaf muhly), *Bouteloua ramosa* (chino grama), *Muhlenbergia porteri* (bush muhly), *Bouteloua barbata* (sixweeks grama), *Dasyochloa pulchella* (fluffgrass), *Digitaria californica* (Arizona cottontop), and *Aristida* spp. (threeawns). On some slopes, species such as *Dasylirion leiophyllum* (smooth sotol), *Nolina texana* (Texas sacahuista), *Opuntia engelmannii* (Engelmann pricklypear), *Agave lechuguilla* (lechuguilla), *Yucca torreyi* (Torrey's yucca) and/or *Fouquieria splendens* (ocotillo) may be conspicuous, though scattered elements. *Nolina* spp. (sacahuista) and *Dasylirion* spp. (sotol) may dominate some sites, especially on limestone slopes. If significant areas dominated by shrubs are encountered, these sites are likely mapped as Chihuahuan Mixed Desert and Thornscrub, Chihuahuan Succulent Desert Scrub, or Chihuahuan Creosotebush Desert Scrub depending on composition. Shrub species that may be encountered in these grasslands include *Larrea tridentata* (creosotebush), *Parthenium incanum* (mariola), *Viguiera stenoloba* (skeleton-leaf golden eye), *Acacia constricta* (whitethorn acacia), *Mimosa aculeaticarpa* var. *biuncifera* (catclaw mimosa), *Condalia ericoides* (javelina bush), and many others.

Potential Threats:

- Desert grasslands and steppe have decreased due to drought, overgrazing, and urban development.
- Prosopis glandulosa seed dispersion by livestock led to conversion of grasslands.
- Fire suppression allowed succession and conversion to shrublands, desert scrub, and woodlands.
- Mesquite was largely confined to drainages until cattle distributed seed upland into desert grasslands.
- Combination of drought, overgrazing, wind and water erosion, seed dispersal by livestock, fire suppression, shifting dunes, and changes in the seasonal distribution of precipitation have caused a recent, dramatic shift in vegetation physiognomy.
- Grazing and fire-return intervals can affect the rate of shrub increase.

- Hydrological alterations occurred in many semi-desert grasslands during early Anglo-American settlement time.
- The introduction of invasive non-native, perennial grasses Eragrostis lehmanniana and Eragrostis curvula has greatly impacted many semi-desert grasslands in this ecoregion.
- Common stressors and threats include fragmentation, altered fire regime, introduction of invasive non-native species, and overgrazing by livestock.

Texas Coast Dune and Coastal Grassland

The geology of these grasslands includes Eolian deep sands and Pleistocene barrier island and beach deposits of the Beaumont formation. This also includes deep sands well inland on the South Texas Sand Sheet. This habitat occurs on primary and secondary dunes, as well as relatively level areas, on the mainland where deep sands are deposited. Significant local topography, in the form of swales and pothole wetlands, may be present but are excluded from this system. But significant surface drainages are generally scarce. The soils are deep or coastal sands.

This system includes upland, grass-dominated vegetation on deep sands. Dunes are often dominated by *Uniola paniculata* (sea oats), with other species such as *Croton punctatus* (Gulf croton), *Panicum amarum* (bitter panicum), *Ipomoea pescaprae* (goat-foot morning-glory), *Ipomoea imperati* (beach morning-glory), *Tidestromia lanuginosa* (wooly tidestromia), *Cakile* spp. (searocket), and *Sesuvium portulacastrum* (shoreline seapurslane) also present. Upland grasslands are often dominated by *Schizachyrium littorale* (seacoast bluestem) and *Paspalum monostachyum* (gulfdune paspalum). Numerous other species, such as *Sorghastrum nutans* (Indiangrass), *Paspalum plicatulum* (brownseed paspalum), *Muhlenbergia capillaris* (Gulf muhly), *Cenchrus spinifex* (common sandbur), *Elionurus tripsacoides* (Pan American balsamscale), *Eragrostis secundiflora* (red lovegrass), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Heteropogon contortus* (tanglehead), *Andropogon glomeratus* (bushy bluestem), *Spartina patens* (marshhay cordgrass), and *Dichanthelium* spp. (rosette grasses) may also be common. Numerous forbs, including such species as *Heterotheca subaxillaris* (camphor weed), *Croton* spp. (crotons), *Chamaecrista fasciculata* (partridge pea), *Rayjacksonia phyllocephala* (camphor daisy), *Physalis* spp. (groundcherries), *Helianthus argophyllus* (silverleaf sunflower), *Gaillardia pulchella* (Indian blanket), *Solidago sempervirens* (seaside goldenrod), *Baptisia* spp. (wild-indigos), *Indigofera miniata* (scarlet-pea), *Eriogonum multiflorum* (heartsepal wildbuckwheat), *Conoclinium betonicifolium* (betonyleaf thoroughwort), and *Rudbeckia hirta* (blackeyed Susan) are also commonly encountered. Some woody species are found in the system, but typically make up very little cover. Cover of woody species is limited, but may include *Baccharis* spp. (baccharis), *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear), *Morella cerifera* (wax-myrtle), *Quercus fusiformis* (plateau live oak), *Quercus virginiana* (coastal live oak), and stunted *Prosopis glandulosa* (honey mesquite). Non-native woody species such as *Tamarix* spp. (salt cedars), *Schinus terebinthifolius* (Brazilian peppertree), and *Triadica sebifera* (Chinese tallow) may be present to dominant. Small areas may have sufficient woody cover to be mapped as a shrubland.

Potential Threats:

In some areas this system has been virtually eliminated due to conversion to tame pasture, cropland, urban and recreational development, dominance by invasive species, or due to woody plant encroachment because of lack of burning. Threats include habitat conversion, alteration of natural fire regime, sea-level rise, coastal development, habitat degradation from recreational vehicles, and coastal engineering that interferes with sand movement and shoreline migration (Defeo et al. 2009). Increasing sea-level rise associated with global climate change will lead to more loss of coastal grasslands, especially in developed areas where development restricts the potential for inland migration of the grasslands. Invasive plant threats include exotic pasture grasses (such as *Bothriochloa ischaemum* var. *songarica*, *Dichanthium annulatum*, and *Urochloa maxima* (= *Panicum maximum*)), *Triadica sebifera*, and off-site native shrubs such as *Baccharis* spp. Invasive animals such as imported red fire ants (*Solenopsis invicta*) and feral hogs (*Sus scrofa*) prey on the eggs of various animals (Defeo et al. 2009). Feral house cats, dogs, and coyotes are a threat to nesting birds and other small animals which occur in coastal habitats. The recent increase in prevalence of the native grass *Heteropogon contortus* has raised some concern (Bielfelt 2013).

Central Mixedgrass Prairie

G3: Vulnerable

The geology of these grasslands are typical of various sedimentary formations of the Rolling Plains. These grasslands are gently rolling uplands. They occur generally soils comprised of loams and clay loams.

Central Mixedgrass Prairie represents the common prairie type in the Rolling Plains. This prairie often has *Schizachyrium scoparium* (little bluestem) as a dominant, with *Nassella leucotricha* (Texas wintergrass), *Bouteloua curtipendula* (sideoats grama), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Bouteloua hirsuta* (hairy grama), *Bouteloua gracilis* (blue grama), *Bouteloua dactyloides* (buffalograss), *Andropogon gerardii* (big bluestem), *Pascopyrum smithii* (western wheatgrass), *Aristida purpurea* (purple threeawn), *Sporobolus cryptandrus* (sand dropseed), and *Pleuraphis mutica* (tobosa) also commonly encountered. Grazing tends to favor shortgrass species such as *Bouteloua dactyloides* (buffalograss) and *Bouteloua gracilis* (blue grama). Sandy soils may be similar, but typically have greater cover of *Sporobolus cryptandrus* (sand dropseed) and forbs such as *Eriogonum annuum* (annual wildbuckwheat), *Heterotheca canescens* (gray goldaster), *Dimorphocarpa candicans* (Palmer's spectaclepod), and *Gaillardia pulchella* (Indian blanket). This system is frequently invaded by juniper (primarily *Juniperus pinchotii* (redberry juniper)), *Ziziphus obtusifolia* (lotebush), and *Prosopis glandulosa* (mesquite), and sandier sites may contain some *Artemisia filifolia* (sand sage) and *Quercus havardii* (Havard's shin oak).

Potential Threats:

Grazing and fire are important dynamic processes in this group, and overgrazing and fire suppression are major factors of habitat decline. The relative dominance of the various grass and forb species within different associations in the group also can strongly depend on the degree of natural or human disturbance. Conversion of this community to agriculture and urbanization contributes to large-scale habitat losss.

The suppression of fire within the region has enabled the invasion of both exotics and some shrub species such as *Juniperus virginiana* and also allowed for the establishment of *Pinus ponderosa* in the northwestern parts of the range.

Chihuahuan Gypsophilous Grassland and Steppe

Extensive occurrences this grassland are associated with the Permian Castile Formation and alluvium within evaporative bolsons. The system also occupies scattered occurrences of exposed gypsite and alluvium of evaporative ponds and swales receiving deposition from eroding gypsiferous formations.

These are rolling uplands with minor erosional scarps as well as level basins and drainages. The soils are all gypsum derived.

Occurrences may be sparsely vegetated, grassy, or shrublands. Also included here are the gypsum dunes. Sites occupied by this system may be rolling and erosional uplands, as well as alluvium of basins and drainages. Gypsophilous species are frequently encountered, including *Sporobolus nealleyi* (gypgrass), *Bouteloua breviseta* (gyp grama), *Tiquilia hispidissima* (rough coldenia), *Nama carnosum* (sand nama), *Sartwellia flaveriae* (threadleaf glowwort), *Gaillardia multiceps* (onion blanket-flower), *Anulocaulis* spp. (ringstems) and *Selinocarpus* spp. (moonpods). Other species that may be encountered include *Atriplex canescens* (four-wing saltbush), *Ephedra torreyana* (Torrey jointfir), *Calylophus hartwegii* (Hartweg evening primrose), *Poliomintha incana* (hoary rosemary-mint), *Yucca torreyi* (Torrey's yucca), *Sporobolus airoides* (alkali sacaton), *Scleropogon brevifolius* (burrograss), *Prosopis glandulosa* (honey mesquite), *Larrea tridentata* (creosotebush), *Condalia ericoides* (javelina bush), and *Sporobolus cryptandrus* (sand dropseed). This system includes the gypsum dunes which range from sparsely vegetated to scattered shrubs with patchy herbaceous cover. In addition to many of the species above, the composition of the dunes includes *Artemisia filifolia* (sand sage), *Psorothamnus scoparius* (broom pea), *Poliomintha incana* (hoary rosemary-mint), *Dalea lanata* (wooly dalea), *Andropogon hallii* (sand bluestem), *Sporobolus giganteus* (giant dropseed), *Dimorphocarpa wislizeni* (spectaclepod), *Tidestromia lanuginosa* (wooly tidestromia), *Krameria lanceolata* (trailing ratany), *Mentzelia* spp. (blazingstar), and *Yucca elata* (soaptree yucca).

Potential Threats:

- Desert grasslands and steppe are decreasing due to drought, overgrazing, and urban development.
- Livestock dispersion of seeds has led to conversion of grasslands, while fire suppression has allowed succession and conversion to shrublands, desert scrub, and woodlands.
- Mesquite has expanded into desert grasslands due to cattle distributing its seeds.
- A combination of factors has caused a recent shift in vegetation physiognomy, including drought, overgrazing, wind and water erosion, seed dispersal by livestock, fire suppression, shifting dunes, and changes in precipitation.
- Grazing and fire-return intervals affect the rate of shrub increase, while hydrological alterations occurred during early Anglo-American settlement time.
- The introduction of invasive non-native grasses has greatly impacted many semi-desert grasslands.
- Common stressors and threats include fragmentation, altered fire regime, introduction of invasive non-native species, and overgrazing by livestock.

Chihuahuan Loamy Plains Desert Grassland

These desert grassland ds occur primarily on Quaternary alluvium geology. Included in this system are also grasslands that occupy other formation at higher elevations of mountain foothills. These grasslands may occupy various sedimentary and igneous substrates. They range from level intermountain basins as well as level to gently rolling landforms on the foothills. The soils are considered loamy soil and foothill grasslands often occupy Shallow Ecological Sites over Perdiz Conglomerate, but may also occur on gravelly sites.

Currently this system includes two somewhat distinct grassland types. These grasslands occupy loams of the intermountain basins, and also represent foothill grasslands that occupy shallow soils at the basin edges. These types are often closely juxtaposed and share graminoid composition but differ in abiotic sites, aspect, and invading shrubs. The loamy grasslands are dominated by species such as *Bouteloua gracilis* (blue grama), *Bouteloua curtipendula* (sideoats grama), *Bouteloua eriopoda* (black grama), *Pleuraphis mutica* (tobosa), *Scleropogon brevifolius* (burrograss), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Bothriochloa barbinodis* (cane bluestem), and *Dasyochloa pulchella* (fluffgrass). These grasslands occur in extensive level plains with deep soils. *Prosopis glandulosa* (honey mesquite) is the common shrub invader.

Other shrubs present to dominant as invaders include *Larrea tridentata* (creosotebush), *Flourensia cernua* (tarbush), and *Mimosa aculeaticarpa* var. *biuncifera* (catclaw). The foothill grasslands are of similar composition with respect to grasses, but occupy rolling landscapes at slightly higher elevations and are on shallow soils. *Condalia ericoides* (javelina bush), *Juniperus* spp. (junipers), and *Acacia constricta* (whitethorn acacia) are common invaders.

Potential Threats:

- Native semi-desert grasslands are a dominant grassland type within this ecoregion, but they can convert to shrublands or woodlands over time without fire or other disturbance.
- Hydrological alterations also occurred in many semi-desert grasslands during early Anglo-American settlement time with a period of arroyo formation from 1865 to 1915.
- The introduction of invasive non-native, perennial grasses Eragrostis lehmanniana and Eragrostis curvula has greatly impacted many semi-desert grasslands in this ecoregion.
- Common stressors and threats include fragmentation from housing and water developments, altered fire regime, introduction of invasive non-native species, and overgrazing by livestock.
- Potential climate change effects could include a reduction in the current extent of the ecosystem and conversion to desert scrub or expanding woodlands.

Chihuahuan Sandy Plains Semi-Desert Grassland

G2: Imperiled

The geologic substrate of these grasslands includes Aeolian sand, sometimes as a thin veneer over surrounding formations, such as caliche, and sandstone. These grasslands are often level plains and mesas to gently rolling. The soils range from sandy, loamy sand, to shallow sandy loam soils.

This grassland or steppe occurs on sandy plains throughout the Trans-Pecos and into the arid southern portions of the High Plains. The herbaceous layer is often dominated by grasses such as *Bouteloua eriopoda* (black grama), *Sporobolus flexuosus* (mesa dropseed), *Sporobolus cryptandrus* (sand dropseed), *Muhlenbergia arenicola* (sand muhly), *Sporobolus airoides* (alkali sacaton), *Cenchrus spinifex* (common sandbur), and *Aristida purpurea* (purple threeawn).

Species such as *Prosopis glandulosa* (honey mesquite), *Yucca elata* (soaptree yucca), *Yucca campestris* (plains yucca), *Yucca torreyi* (Torrey's yucca), and *Larrea tridentata* (creosotebush) may occur as a scattered woody component. The non-native species *Eragrostis lehmanniana* (Lehmann lovegrass) and *Eragrostis barrelieri* (Mediterranean lovegrass) are frequently found in this system.

Potential Threats:

Not documented.

Chihuahuan-Sonoran Desert Bottomland and Swale Grassland

These grassland/wetland systems are described within the “freshwater wetland” section of this document. The upland grassland component of this system is considered a priority habitat as well as the wetland component.

East-Central Texas Plains Xeric Sandyland

These grasslands are associated with Eocene sand geologic formations, particularly Carrizo Sands, but also Queen City and Sparta Sands. They occur in high topographic positions, along with rapidly draining soils, resulting in conditions that only briefly retain surface moisture. Deep sands soils typify this system.

This small patch system is typically an open, herbaceous-dominated sand "prairie,” sometimes with open, oak-dominated woodlands. Species such as *Quercus incana* (bluejack oak), *Quercus margarettae* (sand post oak), *Quercus stellata* (post oak), and *Carya texana* (black hickory) (often stunted) occur in the usually sparse overstory. Invasion by *Ilex vomitoria* (yaupon) is frequent in the absence of fire. Other woody plants that may be encountered include *Juniperus virginiana* (eastern redcedar), *Rhus aromatica* (fragrant sumac), *Vaccinium arboreum* (farkleberry), *Viburnum rufidulum* (rusty blackhaw), *Rhus copallinum* (flameleaf sumac), and *Cornus florida* (flowering dogwood). The herbaceous layer may be sparse, often with exposed sand, *Cladonia* spp. (foliose lichens), and species such as *Aristida desmantha* (curly threeawn), *Brazoria truncata* (bluntsepal brazoria), *Cnidoscolus texanus* (Texas bull-nettle), *Dichanthelium* spp. (rosette grass), *Sporobolus junceus* (pineywoods dropseed), *Froelichia floridana* (Florida snake-cotton), *Hymenopappus artemisiifolius* (old plainsman), *Lechea* spp. (pinweed), *Loeflingia squarrosa* (spreading loeflingia), *Opuntia humifusa* (eastern pricklypear), *Paronychia drummondii* (Drummond nailwort), *Polanisia erosa* (large clammyweed), *Schizachyrium scoparium* (little bluestem), *Monarda punctata* (spotted beebalm), *Senecio ampullaceus* (Texas groundsel), *Sorghastrum elliottii* (slender Indiangrass), *Stylisma pickeringii* (bigpod bonamia), *Tetragonotheca* spp. (nerve-ray), *Gaillardia amblyodon* (maroon gaillardia), *Rhynchosia americana* (American snoutbean), *Zornia bracteata* (bracted zornia), and *Triplasis purpurea* (purple sandgrass). Species such as *Cyperus grayoides* (Illinois flatsedge), *Penstemon murrayanus* (cupleaf penstemon), *Selaginella arenicola* ssp. *riddellii* (sand spikemoss), *Tradescantia reverchonii* (Reverchon spiderwort), and *Yucca louisianensis* (Gulf Coast yucca) may be present, but primarily to the east, while *Tephrosia lindheimeri* (Lindheimer goat-rue) and *Rhynchosia americana* (American snoutbean) are frequently encountered to the south. Texas endemics, such as *Brazoria truncata* var. *pulcherrima* (Centerville brazos-mint), *Rhododon ciliatus* (Texas sandmint), and *Hymenopappus carrizoanus* (Carrizo Sands woollywhite), may be found in this system.

Potential Threats:

The primary threat to this system is loss of habitat through conversion to developed land uses. Very little of this system is under conservation ownership (Bezanson 2000). The cessation of a natural fire cycle may lead to conversion to shrub-dominated sites.

Llano Uplift Acidic Forest, Woodland and Glade

These unique glades and woodlands occur over intrusive igneous bedrock of Precambrian age. This habitat is comprised granite hills rising from a gently rolling landscape that is moderately dissected by drainages. The substrates are generally sandy loams, with gravelly soils common. Soils are generally acidic and coarse, resulting from weathering of the underlying granite. Many areas of exposed bedrock are present.

It comprises a mosaic of vegetation types, including closed-canopy forests, open woodlands, savannas and sparsely vegetated rock outcrops. Common trees include *Quercus marilandica* (blackjack oak), *Quercus fusiformis* (plateau live oak), *Quercus stellata* (post oak), *Carya texana* (black hickory), *Ulmus crassifolia* (cedar elm), and *Prosopis glandulosa* (mesquite). *Juniperus ashei* (Ashe juniper) may be present, but is much less common than in the surrounding landscape. Subcanopy species may include *Diospyros texana* (Texas persimmon), *Aloysia gratissima* (whitebrush), *Ungnadia speciosa* (Mexican buckeye), *Ziziphus obtusifolia* (lotebush), *Eysenhardtia texana* (Texas kidneywood), *Aesculus glabra* var. *arguta* (Ohio buckeye), *Opuntia engelmannii* (prickly pear), *Yucca elata* (palmilla), *Nolina texana* (sacahuista), and *Opuntia leptocaulis* (tasajillo). Grasslands may be dominated by *Schizachyrium scoparium* (little bluestem), *Sorghastrum nutans* (Indiangrass), *Panicum virgatum* (switchgrass), *Bouteloua hirsuta* (hairy grama), *Bouteloua curtipendula* (sideoats grama), *Nassella leucotricha* (Texas wintergrass), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), and *Plantago wrightiana* (Wright plantain). Granitic glades and barrens are sparsely vegetated by crustose and foliose lichens, several ferns and fern allies, and cacti. This system also includes small (up to 16 m in diameter) shallow depressions that hold rainwater and support wetland flora including the Texas endemic, *Isoetes lithophila* (rock quillwort).

Potential Threats:

This ecological system is a complex of vegetation types and is restricted to the Llano Uplift region of Texas. The distinct physical features of an area are maintained through the interplay of site conditions and the patterns of disturbance. The forest patches, woodlands, savannas and grasslands are thought to have been maintained historically by various fire frequencies and intensities. In the absence of natural or prescribed fire, increased cover of woody vegetation has increased in some occurrences. Native grazing may have also played a role in preventing woody encroachment though the rough terrain of much of this system would have limited the extent of native grazers.

Southeastern Great Plains Tallgrass Prairie

These prairies occur over lower Cretaceous geologic formations, including various limestones, sands (such as from the Paluxy and Antlers formations), and clays (such as from the Walnut formation). In contrast to Blackland Prairie, surfaces are flat rather than undulating, and valley slopes are angular rather than rounded. The “cuesta” landforms with gentle slopes leading up to relatively abrupt escarpments are characteristic of this portion of the Southeastern Great Plains Tallgrass Prairie. Soils of the Southeastern Great Plains Tallgrass Prairie in Texas differ from those of the Southern Blackland Prairie in being browner in color and containing more rock fragments, though much of the region occupied by this prairie is included in the Blackland Ecological Site. Soils of this area are more frequently characterized as Mollisols, as opposed to the Vertisols more characteristic of the Blackland Prairie. Calcareous clays are commonly encountered.

Schizachyrium scoparium (little bluestem) tends to dominate sites of this system, with *Bouteloua curtipendula* (sideoats grama) as another significant component. Other grasses that are frequently present include *Nassella leucotricha* (Texas wintergrass), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Aristida* spp. (threeawn), *Andropogon gerardii* (big bluestem), *Bouteloua dactyloides* (buffalograss), *Sporobolus compositus* (tall dropseed), *Bouteloua hirsuta* (hairy grama), *Sorghastrum nutans* (Indiangrass), *Muhlenbergia reverchonii* (seep muhly), *Chloris verticillata* (tumble windmillgrass), and *Erioneuron pilosum* (hairy tridens). Forbs species such as *Symphyotrichum ericoides* (heath aster), *Ambrosia psilostachya* (western ragweed), *Tragia ramosa* (catnip noseburn), *Amphiachyris dracunculoides* (common broomweed), *Dyschoriste linearis* (narrowleaf dyschoriste), *Salvia texana* (Texas sage), *Oenothera* spp. (evening primrose), *Stenaria nigricans* var. *nigricans* (prairie bluets), *Lindheimera texana* (Texas star), *Thelesperma* spp. (greenthread), *Dalea* spp. (prairie clover), and *Psoralidium* spp. (scurfpea) may be encountered. Occurrences often contain and are sometimes dominated by the non-native grass *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem) and/or *Cynodon dactylon* (bermudagrass). Significant areas of this system remain within the Grand Prairie of Texas.

Potential Threats:

Habitat loss, suppression of fire, invasive species encroachment.

Southern Rocky Mountain Montane-Subalpine Grassland

G4: Apparently Secure

The tertiary volcanic formations of the Davis Mountains and Permian limestone of the Guadalupe Mountains make up the geologic formation underlying these grasslands in Texas. Landform: Limited in distribution to high elevation side slopes and local level plains.

Loams of high mountains. Description: The occurrences of this system in Texas represent southern outliers of this system and are small patches in high elevations of the Guadalupe, Chisos, and Davis Mountains. These occurrences may be dominated by *Festuca arizonica* (Arizona fescue), *Bouteloua gracilis* (blue grama), and *Blepharoneuron tricholepis* (pine dropseed). *Muhlenbergia montana* (mountain muhly), *Koeleria micrantha* (junegrass), *Allium cernuum* (nodding onion), *Silene laciniata* ssp. *greggii* (Gregg's campion), *Commelina dianthifolia* (birdbill dayflower) may be present.

Potential Threats:

The primary land uses that alter the natural processes of these communities are associated with livestock grazing. Excessive grazing stresses the system through soil disturbance, altering the composition of perennial species, and increasing the establishment of native disturbance-increasers and invasive exotic species, particularly *Bromus inermis, Cardaria draba, Cirsium vulgare, Leucanthemum vulgare, Linaria dalmatica*, and *Poa pratensis*. Other concerns are fragmentation from roads and Off Road Vehicles (ORVs), altered fire or altered hydrological regimes.

Tamaulipan Caliche Grassland

This system occurs on sites that have a relatively thin veneer of eolian sand over caliche geologic substrate. Such sites occur on the edge of the South Texas Sand Sheet where it overlies caliche of the Goliad Formation. These grasslands occur on relatively level sites atop the Goliad formation. Shallow sands and sandy loams, sometimes red sandy loams, over caliche substrate.

This system is described from the vicinity of Loreto in Tamaulipas, Mexico, but the conditions of sand veneer over caliche outcrop may also be present on the edge of the sandsheet where it passes over the Goliad Formation in northern Hidalgo and Starr Counties. Soils are a reddish sandy loam about 0.3 m in depth or less. Such sites may currently be occupied by nonnative grasses such as Pennisetum ciliare (buffelgrass) and *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem), though invasion by these species is not observed in Mexican occurrences (Chris Best, pers. obs.). These grasslands are known to occur within a mosaic of calcareous shrublands. Johnston (1963) describes them as grassland patches (the largest of which are 50 to 100 acres in extent) within a matrix of shrubland. Grasses often dominate sites, including species such as *Schizachyrium littorale* (seacoast bluestem), *Aristida purpurea* (purple threeawn), *Bouteloua hirsuta* (hairy grama), *Elionurus tripsacoides* (Pan American balsamscale), *Trachypogon spicatus* (crinkleawn), *Heteropogon contortus* (tanglehead), *Bouteloua curtipendula* (sideoats grama), *Tridens texanus* (Texas tridens), and *Tridens muticus* (slim tridens). *Brachiaria ophryodes* and *Bouteloua radicosa* (purple grama) are also noted from occurrences in Mexico. Shrubs and sub-shrubs are scattered and sometimes coalesce into larger areas, and include species such as *Calliandra conferta* (Rio Grande stickpea), *Krameria ramosissima* (calderona), *Calliandra biflora* (twoflower stickpea), *Chamaecrista greggii* (Gregg's senna), and *Macrosiphonia lanuginosa* (plateau rocktrumpet). Perennial forbs are conspicuous and include species such as *Heliotropium confertifolium* (leafy heliotrope), *Melampodium cinereum* (blackfoot daisy), *Simsia calva* (awnless bush sunflower), *Acalypha radians* (cardinal's feather), *Cnidoscolus texanus* (Texas bull-nettle), *Galphimia angustifolia* (narrowleaf thryallis), *Hermannia texana* (Mexican mallow), *Croton capitatus* (hog croton), *Rhynchosia americana* (American snoutbean), and *Dalea nana* (dwarf dalea). Scattered shrubs that may be present include *Prosopis glandulosa* (honey mesquite), *Zanthoxylum fagara* (colima), *Cordia boissieri* (anacahuita), and *Condalia hookeri* (brasil).

Potential Threats:

The keys threats are conversion to agriculture and brush encroachment. Brush invasion is caused by altered fire regime from active fire suppression and passive suppression from heavy grazing by livestock that removes fine fuels that carry fire. Other threats from development, invasive species, and energy development continue to convert or degrade existing stands. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species. Persistent drought may result in loss of key species. Conversion of this type has commonly come from agriculture (Johnston 1955) and invasion by brush (Landfire 2007a). Common stressors and threats include conversion to cropland, invasion by brush, altered fire regime, overgrazing by livestock (Landfire 2007a), and development. Other stressors and threats include fragmentation from roads and invasion non-native species.

According to Climate Wizard in 2050 global climate change model (using Medium A1B emission scenario and Ensemble Average general circulation model), the average annual temperature is predicted to rise approximately 5°F and average annual precipitation will not significantly change (TNC 2013). Seasonal shifts in precipitation predict increased fall (monsoon) moisture with similar levels of precipitation to current in the rest of the year (TNC 2013). Potential climate change effects on vegetation could include a shift to species adapted to a hotter, generally drier environment. While average precipitation amounts may remain similar or slightly decrease during the winter, spring and summer months, that, along with increased temperatures, may cause vegetation to experience less effective precipitation and more soil moisture deficit during much of the growing season reducing plant growth and increasing mortality from extreme events including exceptional drought. If the increased fall precipitation is from intense storms such as hurricanes, we can expect more disturbances from flooding and water erosion.

Tamaulipan Clay Grassland. Unmapped.

This Tamaulipan ecological system occurs on clay prairies near the Gulf Coast and drier sites further inland. Substrates are fine calcareous clays and clay loam. Occasional fires and root pruning from montmorillonitic clay limit shrub invasion, if the grassland is not overgrazed. If overgrazed the land will convert to stable thornscrub dominated by *Prosopis glandulosa* and *Celtis ehrenbergiana (= Celtis pallida)*. Vegetation is dominated by perennial mid and short grasses such as *Schizachyrium scoparium, Paspalum* spp., *Trichloris pluriflora (= Chloris pluriflora), Bouteloua dactyloides (= Buchloe dactyloides)*, with other grasses such as *Bothriochloa saccharoides, Bouteloua curtipendula, Chloris andropogonoides, Nassella leucotricha, Schedonnardus paniculatus, Setaria leucopila*, and clumps of *Andropogon gerardii* on less clayey sites. *Prosopis glandulosa* or *Quercus fusiformis* are often present as scattered mottes or are restricted to drainages. *Opuntia engelmannii var. lindheimeri* is often present.

Potential Threats:

Not documented.

Tamaulipan Savanna Grassland

These grasslands occur on thinner eolian sands on the western side of the South Texas Sand Sheet, and other sandy sites such as those of the Eocene sands of the Carrizo, Queen City, and Sparta Formations. Also found associated with other formations, such as Oakville Sandstone and other formations producing sandy residuum. They are level to gently rolling sites. The soils are sandy to sandy loam sites.

It is typically dominated by *Prosopis glandulosa* (honey mesquite) in the overstory, and the overstory may be sparse, giving the aspect of an open grassland, with scattered trees and shrubs. Or, more commonly, the system occurs as shrub-dominated patches within a grassy matrix, with an emergent canopy to about 6 or more meters in height of *Prosopis glandulosa* (honey mesquite) and sometimes other species, such as *Ebenopsis ebano* (Texas ebony) or *Celtis ehrenbergiana* (granjeno). Sometimes the overstory canopy is well-developed and would be considered woodland. These patches often coalesce to form significant expanses of shrubland. Sites with somewhat tighter soils tend to have a denser shrub stratum, while deep sands and sandy sites tend to be more open, often with sizeable areas lacking significant shrub cover and dominated by a primarily graminoid herbaceous layer. The shrub component of woody patches or shrublands is commonly dominated by species such as *Zanthoxylum fagara* (Colima), *Condalia hookeri* (brasil), *Celtis ehrenbergiana* (granjeno), *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear), *Diospyros texana* (Texas persimmon), *Colubrina texensis* (Texas hogplum), *Cylindropuntia leptocaulis* (tasajillo), and *Acacia farnesiana* (huisache). *Prosopis glandulosa* (honey mesquite) is almost always present, and is often dominant to co-dominant and occupies the highest canopy position (sometimes sharing that position with few other species), sometimes to 6 m in height. Numerous other species may also occur in the shrub layer, including but not limited to *Schaefferia cuneifolia* (desert yaupon), *Mahonia trifoliolata* (agarito), *Forestiera angustifolia* (desert olive), *Lycium berlandieri* (Berlandier wolfberry), *Aloysia gratissima* (whitebrush), *Salvia ballotiflora* (shrubby blue sage), and *Ziziphus obtusifolia* (lotebush). The diversity of the shrub layer is significantly influenced by land use history, with recently cleared areas sometimes being represented by a near monoculture of *Prosopis glandulosa* (honey mesquite) in the overstory, *Pennisetum ciliare* (buffelgrass) in the herbaceous layer, and *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear) as the most conspicuous component of the shrub layer. The herbaceous layer is typically dominated by graminoids and may be quite dense (60 to 100% cover). Grasses, such as *Schizachyrium scoparium* (little bluestem), *Schizachyrium littorale* (seacoast bluestem), *Chloris cucullata* (hooded windmillgrass), *Paspalum monostachyum* (gulfdune paspalum), *Paspalum plicatulum* (brownseed paspalum), *Elionurus tripsacoides* (Pan American balsamscale), *Bouteloua rigidiseta* (Texas grama), *Urochloa ciliatissima* (fringed signalgrass), *Heteropogon contortus* (tanglehead), *Eragrostis secundiflora* (red lovegrass), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Trichloris pluriflora* (multiflower false Rhodes grass), *Aristida* spp. (threeawns), *Sporobolus cryptandrus* (sand dropseed), and/or *Dichanthelium* spp. (rosette grasses) commonly dominate or co-dominate the herbaceous layer. Forbs are also common, including species such as *Gaillardia pulchella* (Indian blanket), *Eriogonum multiflorum* (heartsepal wildbuckwheat), *Croton* spp. (croton), *Cnidoscolus texana* (Texas bull-nettle), *Aphanostephus skirrhobasis* (lazy daisy), *Rudbeckia hirta* (blackeyed Susan), *Verbesina encelioides* (cowpen daisy), *Clematis drummondii* (old man's beard), *Cynanchum barbigerum* bearded shallow-wort), *Thymophylla pentachaeta* (parralena), *Justicia pilosella* (hairy tubetongue), *Nama jamaicense* (fiddleleaf nama), *Monarda punctata* (spotted beebalm), *Palafoxia texana* (Texas palafoxia), *Florestina tripteris* (white palafoxia), *Zornia bracteata* (bracted zornia), *Croptilon divaricatum* (scratch-daisy), *Rhynchosia americana* (American snoutbean), and *Wedelia texana* (hairy zexmania), though some of these species are restricted to the sandiest sites.

Potential Threats:

The natural range of variation in disturbance within this vegetation is difficult to assess currently, because of dramatic changes resulting from severe overgrazing and the resultant changes in vegetation dynamics in the region which occurred in the early to mid-1800s. While most experts agree that this was a major habitat type of the region, the historic extent of mesquite savanna is arguable. Periodic fire, probably resulting from human sources of ignition, likely maintained the habitats as an open savanna. The average fire-return interval is 6 years. Periods of overgrazing apparently led to an alternative stable state in which fire does not play a significant role, and the habitat has become a closed shrubland community with little to no opportunity for reverting to mesquite savanna (Landfire 2007a). Many sites are currently occupied by denser shrub cover than historical condition (Landfire 2007a).

Threats from development, including development for agriculture and overgrazing by livestock, continue to convert or degrade existing stands. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species. Persistent drought may result in loss of key species. Conversion of this type has commonly come from agricultural practices. Common stressors and threats include fragmentation from roads, agriculture and development, and non-native species invasion. Other stressors and threats include overgrazing/browsing by livestock, and possibly loss of pollinators.

According to Climate Wizard (TNC 2013), in 2050 global climate change model (using Medium A1B emission scenario and Ensemble Average general circulation model), the average annual temperature is predicted to rise approximately 5°F and average annual precipitation will not significantly change (TNC 2013). Seasonal shifts in precipitation predict increased fall (monsoon) moisture with similar levels of precipitation to current in the rest of the year (TNC 2013). Potential climate change effects on vegetation could include a shift to species adapted to a hotter, generally drier environment. While average precipitation amounts may remain similar or slightly decrease during the winter, spring and summer months, that, along with increased temperatures, may cause vegetation to experience less effective precipitation and more soil moisture deficit during much of the growing season reducing plant growth and increasing mortality from extreme events including exceptional drought. If the increased fall precipitation is from intense storms such as hurricanes, we can expect more disturbances from flooding and water erosion.

Texas Blackland Tallgrass Prairie

The geology underlying these praire systems include cretaceous shales, marls and limestones, such as those of the Pecan Gap Chalk, Marlbrook Marl, Eagle Ford, Gober Chalk, and Austin Chalk Formations, and Taylor, and Navarro Groups, as well as portions of the Eocene Midway Group and Wilcox formation. Also, Miocene formations (Fleming and Oakville Sandstone formations) underlie the southern outlier of Blackland prairie recognized as the Fayette Prairie. They are flat to gently rolling and dissected by drainages, with the most significant ridges associated with harder chalk formations. The soils are typically Vertisols, but this system may occupy Mollisols or Alfisols in limited parts of its distribution. The system generally occurs on calcareous clays, but may also occur on loams, clay loams, or even sandy clay loams.

Currently, only remnants of this system exist, with most of the historical distribution replaced by crop production or improved pasture. *Schizachyrium scoparium* (little bluestem) is the most ubiquitous component of occurrences of this system. *Andropogon gerardii* (big bluestem) and *Sorghastrum nutans* (Indiangrass) are also common dominants. Other species commonly encountered include *Bouteloua curtipendula* (sideoats grama), *Carex microdonta* (smalltooth sedge), *Sporobolus compositus* (tall dropseed), *Nassella leucotricha* (Texas wintergrass), *Bothriochloa laguroides* spp. *torreyana* (silver bluestem), *Eriochloa sericea* (silky cupgrass), *Paspalum floridanum* (Florida paspalum), and *Tridens strictus* (longspike tridens). Forbs commonly encountered in this system include *Symphyotrichum ericoides* (heath aster), *Stenaria nigricans* var. *nigricans* (prairie bluets), *Helianthus maximiliani* (Maximilian sunflower), *Rudbeckia hirta* (blackeyed Susan), *Bifora americana* (prairie bishop), *Acacia angustissima* var. *hirta* (prairie acacia), *Desmanthus illinoensis* (Illinois bundleflower), and many more. Perhaps more commonly encountered species include *Croton monanthogynus* (doveweed), *Amphiachyris dracunculoides* (annual broomweed), and *Asclepias* spp. (milkweeds). Lowland sites and swales are often dominated by *Tripsacum dactyloides* (eastern gamagrass) and *Panicum virgatum* (switchgrass).

Potential Threats:

Historic descriptions of the Blackland Prairie region by early travelers indicate the region was dominated by a tallgrass prairie. Forests were limited to stream valleys, and trees and shrubs sometimes occurred as scattered individuals and clumps in a vast sea of grasses and wildflowers (Diggs et al. 1999). Today, only small remnants (occupying <1% of the original extent) remain (Riskind and Collins 1975, Diggs et al. 1999, Eidson and Smeins 1999). Threats to the remaining remnants include elimination of the landscape-level processes that maintained the system such as fire and native grazers, introduction of exotic species (*Bothriochloa ischaemum, Dichanthium sericeum, Lolium arundinaceum* (= *Schedonorus arundinaceus*)), woody plant encroachment, overgrazing by livestock, urban and rural development, and infrastructure development (Eidson and Smeins 1999).

Texas-Louisiana Coastal Prairie

This system is generally coincident with the distribution of the Pleistocene Beaumont and Lissie Geologic Formations. It is usually on level to gently rolling landscapes, with slopes generally less than 5%.

Microtopography plays an important role in local variation in the system, with ridges, swales, mounds, depressions, mima (or pimple) mounds, and gilgai leading to a mosaic of drier and wetter plant communities. The soils are non-saline Vertisols, Alfisols, and (less extensively)

Mollisols. Vertisols are often characterized by gilgai, resulting from shrink-swell attributes of the montmorillonitic clays of which they are composed. The Alfisols have a loamy surface with clayey subsoils.

It is dominated by graminoid species, such as *Schizachyrium scoparium* (little bluestem), *Sorghastrum nutans* (Indiangrass), *Paspalum plicatulum* (brownseed paspalum), *Panicum virgatum* (switchgrass), *Andropogon gerardii* (big bluestem), *Sporobolus compositus* (tall dropseed), *Paspalum setaceum* (thin paspalum), *Fimbristylis puberula* (hairy fimbry), *Dichanthelium oligosanthes* (fewflower panicgrass), *Rhynchospora* spp. (beaksedges), *Paspalum floridanum* (Florida paspalum), *Muhlenbergia capillaris* (Gulf muhly), *Tridens strictus* (longspike tridens), *Bouteloua curtipendula* (sideoats grama), *Andropogon glomeratus* (bushy bluestem), and *Tripsacum dactyloides* (eastern gamagrass). *Axonopus* spp. (carpetgrasses), *Sporobolus indicus* (rat-tail smutgrass), *Andropogon virginicus* (broomsedge bluestem), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), and *Nassella leucotricha* (Texas wintergrass) may be particularly noticeable on over-grazed sites. Non-native graminoids that may be conspicuous to dominant components include *Cynodon dactylon* (bermudagrass), *Cyperus entrerianus* (deep- rooted sedge), *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem), *Dichanthium* spp. (old world bluestems), *Lolium perenne* (Italian ryegrass), *Schedonorus phoenix* (tall fescue), *Paspalum notatum* (bahiagrass), and *Paspalum dilatatum* (dallisgrass). Forbs that may often be encountered include *Liatris* spp. (gayfeathers), *Sabatia campestris* (meadow pink), *Ambrosia psilostachya* (western ragweed), *Euphorbia bicolor* (snow-on-the-prairie), *Solidago* spp. (goldenrods), *Rudbeckia hirta* (blackeyed Susan), *Ruellia humilis* (low wild petunia), *Asclepias viridis* (green milkweed), *Chamaecrista fasciculata* (partridge pea), *Helianthus angustifolius* (narrowleaf sunflower), *Euthamia* spp. (goldentops), *Ratibida columnifera* (Mexican hat), *Symphyotrichum ericoides* (heath aster), *Silphium laciniatum* (compassplant), *Baptisia* spp. (wild indigos), *Iva angustifolia* (narrowleaf sumpweed), *Eryngium yuccifolium* (button snakeroot), *Boltonia diffusa* (smallhead doll's daisy), and *Neptunia lutea* (yellow neptunia). Woody species may invade this typically herbaceous vegetation, including *Rosa bracteata* (Macartney rose), *Acacia farnesiana* (huisache), *Triadica sebifera* (Chinese tallow), *Baccharis halimifolia* (baccharis), *Celtis laevigata* (sugar hackberry), and *Prosopis glandulosa* (honey mesquite).

Potential Threats:

This prairie system once covered as much as 9 million acres and less than 1% is thought to remain (Smeins et al. 1992, Bergan 1999, USFWS and USGS 1999, Grace et al. 2000, LDWF 2005, USGS 2013). This loss was caused by conversion to other land uses (primarily rice and sugarcane farming, pasture, and residential and commercial development) and environmental degradation due to the interruption of important ecological processes, such as fire, needed to maintain this system. In the absence of regular fire, this system will be invaded by woody shrubs and trees. Remaining occurrences continue to be threatened by conversion to other land uses (agriculture, pasture, and residential and commercial development), overgrazing, and loss of landscape level natural processes (Smeins et al. 1992, Bergan 1999, USFWS and USGS 1999, Grace et al. 2000, LDWF 2005, USGS 2013). Fire suppression and overgrazing have allowed native and non-native woody species to invade. If changes in regional climate bring about an increase in precipitation, this could lead to an increase in woody encroachment; a decrease in precipitation could lead to loss of the wet prairie components of this system. Due to its proximity to the coast and coastal marshes, sea-level rise could further impact this system by saltwater inundation and increased salinity.

West Gulf Coastal Plain Southern Calcareous Prairie

These grasslands are primarily associated with the Fleming Formation, a calcareous clay/sandstone geology of Miocene age. The Cook Mountain Formation, a marly Eocene formation, may also give rise to clays that support this system. It occurs on upper slopes and broad uplands in gently undulating landscapes. The soils are circumneutral to moderately alkaline, vertic soils such as Ferris, Houston Black, or Wiergate clays.

This graminoid-dominated system occurs within a landscape generally dominated by forest and woodland. It occupies deep vertic soils with circumneutral surface pH, a condition uncommon in the landscape of predominantly acidic, forested soils. Occurrences may reflect a relationship to the blackland prairie further to the west, within the Fayette Prairie, and some consider these small patch prairies to be outliers of the Blackland Tallgrass Prairie. The system may be dominated by species such as *Schizachyrium scoparium* (little bluestem), *Sorghastrum nutans* (Indiangrass), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Bouteloua curtipendula* (sideoats grama), *Andropogon gerardii* (big bluestem), *Nassella leucotricha* (Texas wintergrass), *Paspalum pubiflorum* (hairyseed paspalum), and *Panicum virgatum* (switchgrass). Non-native grasses such as *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem), *Bromus arvensis* (Japanese brome), *Cynodon dactylon* (bermudagrass), and/or *Lolium perenne* (Italian ryegrass) may be conspicuous to dominant. Other herbaceous species that may be encountered include *Acacia angustissima* (prairie acacia), *Carex cherokeensis* (Cherokee sedge), *Croton monanthogynus* (doveweed), *Neptunia* sp. (neptunia), *Carex microdonta* (smalltooth sedge), *Grindelia lanceolata* (Gulf gumweed), *Rudbeckia missouriensis* (Missouri coneflower), *Rudbeckia hirta* (blackeyed susan), *Indigofera miniata* (scarlet-pea), *Arnoglossum plantagineum* (groovestem Indian plantain), *Euphorbia bicolor* (snow-on-the-prairie), *Dalea* spp. (prairieclovers), *Coreopsis tinctoria* (plains coreopsis), *Eustoma exaltatum* (tall prairie gentian), and *Symphyotrichum* spp. (asters). Various woody species from the surrounding landscape, including *Pinus taeda* (loblolly pine), *Ulmus alata* (winged elm), *Liquidambar styraciflua* (sweetgum), *Juniperus virginiana* (eastern redcedar), *Crataegus spathulata* (littlehip hawthorn), *Crataegus crus-galli* (cockspur hawthorn), *Sideroxylon lanuginosum* (gum bumelia), and others, may invade these prairies. Non-native woody species, such as *Rosa bracteata* (Macartney rose), may also invade. This may be a result of long-term fire suppression.

Potential Threats:

To date, habitat conversion to other land uses may have resulted in the biggest loss of this ecosystem. In Louisiana, only 5-10% of the historic extent is thought to remain today (Smith 1993). What remains is highly threatened by disruption of fire regimes necessary for maintenance of vegetation composition and structure. Vegetation composition and structure are threatened by native and non-native invasive species. Louisiana's Keiffer Prairie (an example of this system) saw a 50% decrease in size of prairie patches from 1935 to 1995. The Tanock Prairie was mapped in early survey records as occupying more than 1000 acres, but today it is a series of 5- to 10-acre remnants (Landfire 2007a). If changes in regional climate bring about an increase in precipitation, this could lead to an increase in woody encroachment.

Western Great Plains Sand Prairie

The geologic substrate of these prairies is comprised of aeolian sands. They range from rolling dunes to level sandy plains. The soils include deep sands, sand hills, and adjacent sandy soils.

This represents far southern outliers of this system which is best developed in Nebraska and South Dakota, and may in fact be a different system. These grasslands occupy deep sands and sandhills and are dominated by species such as *Sporobolus giganteus* (giant dropseed), *Sporobolus cryptandrus* (sand dropseed), *Andropogon hallii* (sand bluestem), *Andropogon gerardii* (big bluestem), *Schizachyrium scoparium* (little bluestem), *Paspalum setaceum* (thin paspalum), *Calamovilfa gigantea* (big sandreed), and *Cenchrus spinifex* (common sandbur).

Some woody species may be present, including *Artemisia filifolia* (sand sage) and *Quercus havardii* (Havard's shin oak).

Potential Threats:

Conversion to agriculture can impact this system, and its range has decreased from human activities. Impacts from energy extraction in oil and gas fields in have recently fragmented larges areas with road networks to well pads and pipelines. Overgrazing by livestock grazing and fires can remove vegetation cover and promote blowouts.

The dominant species are adapted to frequent fires, sprouting from rhizomes post-fire. Fire suppression and moderate grazing have caused unevenness in structure and favored invasion of introduced grasses *Poa pratensis* and *Bromus inermis* across the sandhills (Sims 1988, Hauser 2005). A variety of seral stages are desirable to provide habitat for all phases of the lesser or greater prairie-chicken life cycle. The vegetation ideally exhibits a diversity of native short to tall grasses and native forbs interspersed with sparse to somewhat dense low-growing shrubby cover which includes sufficient cover for nesting and brood-rearing, as well as open areas suitable for leks.

Western Great Plains Shortgrass Prairie

This system occurs in multiple ecoregions within the state of Texas and on various geologic formations. They are often on level to gently rolling uplands.

Bouteloua dactyloides (buffalograss) and *Bouteloua gracilis* (blue grama) are common dominants. Other species that may be present include *Aristida purpurea* (purple threeawn), *Bouteloua curtipendula* (sideoats grama), *B. hirsuta* (hairy grama), *B. rigidiseta* (Texas grama), *Erioneuron pilosum* (fluffgrass), *Hilaria belangeri* (curlymesquite), and *Pascopyrum smithii* (western wheatgrass). Shrub cover is generally low, but may include species such as *Acacia greggii* (catclaw), *Rhus microphylla* (littleleaf sumac), *Rhus trilobata* (skunkbush sumac), *Dalea formosa* (feather dalea), *Mahonia trifoliolata* (agarito), *Juniperus* sp. (juniper), and *Prosopis glandulosa* (mesquite). Forbs such as *Calylophus* sp. (sundrops), *Melampodium leucanthum* (plains blackfoot), *Krameria lanceolata* (trailing ratany), and others are often present.

Gutierrezia sarothrae (broom snakeweed) may be present with significant cover, especially on sites with intense and continuous grazing. In this, the southeastern most expression of the system, it tends to occur on sites with soils providing relatively dry conditions such as Shallow Clay, Very Shallow, and Very Shallow Clay Ecological Sites.

Potential Threats:

Historically, fires were often very expansive, especially after a series of years with above-average precipitation when litter/fine fuels built up. Currently, fire suppression, fragmentation of landscapes, and more extensive grazing in the region have likely decreased the fire frequency even more, and it is unlikely that these processes could occur at a natural scale. Heavy continuous livestock grazing, military training, invasive non-native species, altered fire regime (fire suppression), conversion to agriculture, fragmentation from roads and development such as exurban and urban development, and more recently gas and oil exploration and extraction stress the shortgrass prairie ecosystem. Of these, altered grazing and fire regimes stressors are prevalent throughout the range. Cultivation for row crop agriculture has been widespread and extensive in the higher precipitation parts of the range, where more conducive soil moisture conditions exist, or where irrigation is possible. Habitat fragmentation from roads is common throughout the range, probably less in the drier parts of the range where large ranches are more common, but none the less, still at levels limiting natural fire regimes through the range. Stressors related to urban and suburban development and military training affect a relatively small proportion of the range of this system, but where they occur, impacts are often severe.

Conversion to agriculture and pastureland with subsequent irrigation has degraded and extirpated this system in approximately 40% of its range (Samson and Knopf 1994). Conversion of this type has commonly come from dryland wheat cultivation in the less xeric portion in eastern Colorado and western Kansas and from all types of irrigated agriculture typically near rivers such as the Platte and Arkansas basins. Historically, areas of the central and western range have been impacted by the unsuccessful attempts to develop dryland cultivation during the Dust Bowl of the 1930s (CNHP 2010). Urban and exurban development along the Front Range and water developments/reservoirs are also significant. Locally, mechanical disturbance (roads, mechanized military training, ORVs, sacrifice areas surrounding livestock tanks, etc.) may eliminate cover of blue grama and other grasses that are slow to recover. Conversion to invasive non-native species is generally not a widespread or significant problem on dry upland sites. Invasion and conversion to woodlands by native trees *Juniperus* spp. and *Prosopis glandulosa* (in southern extent) is an issue where alteration of natural fire regime has permitted woodland expansion into former grasslands.

Common stressors and threats include fragmentation, altered fire regime, overgrazing by livestock, and invasive species (in the less xeric regions). Fire suppression and certain grazing patterns such as continuous heavy grazing in the region have likely decreased the fire frequency even more, and it is unlikely that these processes could occur at a natural scale. The short grasses that dominate this system are extremely drought- and grazing-tolerant although continuous heavy grazing and extended drought (3-4 years) will reduce cover of dominant species.

Western Great Plains Tallgrass Prairie. Unmapped.

This system can be found throughout the Western Great Plains Division. It is found primarily in areas where soil characteristics allow for mesic conditions more typical of the Eastern Great Plains Division and thus are able to sustain tallgrass species. This system may be small patches interspersed within Northwestern Great Plains Mixedgrass Prairie (CES303.674) or Western Great Plains Shortgrass Prairie (CES303.672) and may also be associated with upland terraces above a floodplain system where these more mesic conditions persist. Soils are primarily loamy Mollisols that are moderately deep and rich. Those areas that contain more sandy soils should be considered part of Western Great Plains Sand Prairie (CES303.670). This system is dominated primarily by Andropogon gerardii and may also include

Sorghastrum nutans, *Schizachyrium scoparium*, *Pascopyrum smithii*, *Hesperostipa spartea*, and *Sporobolus heterolepis*. *Andropogon gerardii* often dominates the lowland regions, although *Pascopyrum smithii* can be prolific if conditions are favorable. Forbs in varying density may also be present. The primary dynamics for this system include fire, climate and grazing. Fire suppression in these areas has allowed for the invasion of woody species such as Juniperus virginiana and Prunus spp. Grazing also has contributed to these changes and likewise led to a decrease of this system as overgrazing favors shortgrass and mixedgrass systems. Conversion to agriculture likewise has probably decreased the range of this system. Thus, this system likely only occurs in small patches and in scattered locations throughout the division. Large-patch occurrences are mostly isolated to slopes and swales of rolling uplands where either grazing or cultivation are more problematic.

Shrubland

Shrubland vegetation includes temperate chaparral, shrubland and shrub steppe, and successional herbaceous/shrubland.

Chihuahuan Mixed Desert and Thornscrub

These shrublands s are described within the "desert scrub" section of this document.

Edwards Plateau Limestone Shrubland

This vegetation system often occurs on massive limestone such as Edwards or related formations. This system may occur on plateaus, or slopes, and may often form a discontinuous band around a plateau edge as it breaks into the adjacent slope. This system sols are characterized by Shallow or Very Shallow Ecological Sites, but may also be found on Low Stony Hill Ecological Sites. This system occurs in the Central Great Plains, Chihuahuan Deserts, East Central Plains, Edwards Plateau, High Plains, Southwestern Tablelands, and Texas Blackland Prairies ecoregions in Texas.

This vegetation system may be represented by extensive continuous shrub cover, or occur as a discontinuous shrubland, often with scattered emergent overstory trees. *Quercus sinuata* var. *breviloba* (white shin oak), *Quercus fusiformis* (plateau live oak), and/or *Juniperus ashei* (Ashe juniper) may be important components of the system. In the west, *Pinus remota* (paper-shell pinyon) may also contribute to a scattered emergent overstory. Shrub cover may be dominated by these species, or may be represented as an assemblage of a rather diverse array of species including *Rhus virens* (evergreen sumac), *Rhus lanceolata* (prairie sumac), *Cercis canadensis* var. *texensis* (Texas redbud), *Forestiera pubescens* (elbowbush), *Forestiera reticulata* (netleaf forestiera), *Ungnadia speciosa* (Mexican buckeye), *Sophora secundiflora* (Texas mountain- laurel), *Diospyros texana* (Texas persimmon), *Salvia ballotiflora* (mejorana), *Mimosa borealis* (fragrant mimosa), *Condalia hookeri* (brasil), *Rhus trilobata* (skunkbush sumac), *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear), and *Mahonia trifoliolata* (agarito). This system also includes *Quercus mohriana* (Mohr's shin oak) or *Quercus vaseyana* (Vasey shin oak) dominated shrublands that are more common to the west. Herbaceous cover may be patchy and is generally graminoid with species including *Schizachyrium scoparium* (little bluestem), *Bouteloua curtipendula* (sideoats grama), *Bouteloua rigidiseta* (Texas grama), *Bouteloua trifida* (red grama), *Hilaria belangeri* (curlymesquite), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Nassella leucotricha* (Texas wintergrass), *Erioneuron pilosum* (hairy tridens), *Aristida* spp. (threeawn), and others. Disturbances such as fire may be important processes maintaining this system. However, it appears to persist on thin-soiled sites. To the west, semi-arid conditions result in the replacement of upland woodlands with shrublands. *Juniperus pinchotii* (redberry juniper) increasingly replaces *Juniperus ashei*

(Ashe juniper) in this semi-arid region, and shrubs such as *Prosopis glandulosa* (honey mesquite), *Leucophyllum frutescens* (cenizo), *Acacia berlandieri* (guajillo), *Mimosa aculeaticarpa* var. *biuncifera* (catclaw mimosa), and *Condalia viridis* (green condalia) become increasingly common. Succulents such as *Dasylirion texanum* (Texas sotol), *Nolina texana* (Texas sacahuista), and *Agave lechuguilla* (lechuguilla) also become increasingly common. In these situations, sometimes large patches are dominated by grasses such as *Bouteloua trifida* (red grama), *Bouteloua curtipendula* (sideoats grama), *Hilaria belangeri* (curlymesquite), *Eroneuron pilosum* (hairy tridens), *Tridens muticus* (slim tridens), and *Nassella leucotricha* (Texas wintergrass). Interestingly, non-native grasses such as *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem) are less frequently encountered as dominants of occurrences in the semi-arid west, than in less xeric sites to the east. As conditions become more xeric to the west, this system transitions to shrublands more characteristic of the Chihuahuan Deserts region, often with conspicuous increases in succulents such as *Dasylirion texanum* (Texas sotol), *Nolina texana* (Texas sacahuista), *Agave lechuguilla* (lechuguilla), and even *Fouquieria splendens* (ocotillo). To the south, the system transitions to the shrublands of shallow soils characteristic of the South Texas Plains, with shrubs such as *Leucophyllum frutescens* (cenizo), *Acacia berlandieri* (guajillo), and *Acacia rigidula* (blackbrush). Southern Val Verde County represents a particularly confusing mosaic of these three types.

Potential Threats:

Not documented.

Madrean Oriental Chaparral

This vegetation system includes various formations at higher elevations of the mountains of West Texas, including the Permian limestones of the Guadalupe Mountain region, Tertiary igneous formations, and sedimentary formations including limestone and sandstone elsewhere. This system lies on montane slopes. The soils of this system are Rocky and gravelly slopes, often with little soil development. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregions of Texas.

This vegetation system occurs at elevations above desert shrublands on dry rocky habitats of foothills, mountains, and canyons. It often occurs at elevations coincident with the occurrence of Madrean Encinal and Madrean coniferous woodlands, but typically occupies more xeric sites, often with steeper slopes and less soil development. Shrub cover is typically moderate to dense. Oak species such as *Quercus grisea* (gray oak), *Quercus vaseyana* (Vasey shin oak), *Quercus pungens* (sandpaper oak), *Quercus x pauciloba* (wavyleaf oak), *Quercus turbinella* (scrub oak), *Quercus mohriana* (Mohr's shin oak), and *Quercus gambelii* (Gambel oak) occurring as shrubs may be present to dominant making distinguishing this system from Madrean Encinal sometimes difficult. Other shrub species that are commonly encountered to dominant, include *Cercocarpus montanus* (mountain mahogany), *Pinus cembroides* (Mexican pinyon pine) or *Pinus edulis* (pinyon pine, in the Guadalupe Mountain region), *Ceanothus greggii* (desert ceanothus), *Fallugia paradoxa* (Apache plume), *Rhus virens* (evergreen sumac), *Garrya wrightii* (Wright's silktassel), *Aloysia wrightii* (Wright's beebrush), *Juniperus pinchotii* (redberry juniper), *Chrysactinia mexicana* (damianita), *Fraxinus greggii* (little-leaf ash), and *Viguiera stenoloba* (skeleton-leaf golden eye). *Dasylirion leiophyllum* (smooth sotol), *Nolina texana* (Texas sacahuista), *Agave lechuguilla* (lechuguilla), and *Opuntia engelmannii* var. *engelmannii* (Engelmann pricklypear) are frequently encountered. Herbaceous cover is patchy and bare rock is frequently visible. Graminoids dominate the herbaceous layer with species such as *Bouteloua curtipendula* (sideoats grama), *Bouteloua hirsuta* (hairy grama), *Muhlenbergia emersleyi* (bull muhly), *Muhlenbergia pauciflora* (New Mexican muhly), *Muhlenbergia setifolia* (curlyleaf muhly), *Achnatherum lobatum* (littleawn needlegrass), *Muhlenbergia dubia* (pine muhly), and *Heteropogon contortus* (tanglehead).

Potential threats:

Not documented.

Rocky Mountain Gambel Oak-Mixed Montane Shrubland

This vegetation system is primarily limestone formations of the mountains. This system occurs on slopes and rolling landforms of the Trans-Pecos mountains. This system soils include Limestone Hill and Mountain and High Montane Conifer Ecological Sites. This system occurs in the Chihuahuan Deserts ecoregion of Texas.

High mountain shrublands dominated by the deciduous oak species *Quercus gambelii* (Gambel oak). This species often forms nearly monotypic shrublands, but other species present may include *Cercocarpus montanus* (mountain mahogany), *Robinia neomexicana* (New Mexico locust), *Symphoricarpos oreophilus* (mountain snowberry), and *Rhus trilobata* (skunkbush sumac). These shrubland patches represent southern outliers of the extensive and diverse system further north.

Potential Threats:

Threats and stressors to this shrubland system include altered fire regime, fragmentation from roads and development near urban areas, mining, invasive species, livestock grazing disturbance or other human disturbances (CNHP 2010). These disturbances can cause significant soil loss/erosion and negatively impact the water quality within the immediate watershed. Invasive exotic species such as *Bromus tectorum* can become abundant in disturbed areas and alter floristic composition and provide fine fuels that many increase fire frequency and severity beyond the natural range of variation.

Rocky Mountain Lower Montane-Foothill Shrubland

This ecological system is found in the foothills, canyon slopes and lower mountains of the Rocky Mountains and on outcrops and canyon slopes in the western Great Plains. It ranges from southern New Mexico and west Texas extending north into Wyoming, and west into the Intermountain West region. These shrublands occur between 1500 and 2900 m elevation and are usually associated with exposed sites, rocky substrates, and dry conditions, which limit tree growth. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregions of Texas.

This system is generally drier than Rocky Mountain Gambel Oak-Mixed Montane Shrubland but may include mesic montane shrublands where *Quercus gambelii* does not occur. Scattered trees or inclusions of grassland patches or steppe may be present, but the vegetation is typically dominated by a variety of shrubs, including *Amelanchier utahensis, Cercocarpus montanus, Purshia tridentata, Rhus trilobata, Ribes cereum, Symphoricarpos oreophilus*, or *Yucca glauca*.

Grasses are represented as species of *Muhlenbergia, Bouteloua, Hesperostipa*, and *Pseudoroegneria spicata*. Fires play an important role in this system as the dominant shrubs usually have a severe die-back, although some plants will stump sprout. *Cercocarpus montanus* requires a disturbance such as fire to reproduce, either by seed sprout or root-crown sprouting. Fire suppression may have allowed an invasion of trees into some of these shrublands, but in many cases sites are too xeric for tree growth.

Potential Threats:

Threats and stressors to this shrubland system include altered fire regime, fragmentation from roads and development near urban areas, mining, invasive species, livestock grazing disturbance or other human disturbances (CNHP 2010). These disturbances can cause significant soil loss/erosion and negatively impact the water quality within the immediate watershed. Invasive exotic species such as *Bromus tectorum* can become abundant in disturbed areas and alter floristic composition and provide fine fuels that many increase fire frequency and severity beyond the natural range of variation.

South Texas Lomas

This vegetation system occurs on Quaternary windblown deposits identified as clay dunes (Qcd). This system lies along round, elliptic, or crescent-shaped topographic highs, often within a matrix of low flats influenced by wind-driven tides. This system soils are often associated with the Coastal Ridge Ecological Site, such as Point Isabel clay loam and Lalinda fine sandy loam. This system occurs in the Gulf Coastal Prairie and Marshes ecoregion of Texas.

This system occupies clay dunes (lomas) along the lower Texas coast (and somewhat inland) and adjacent Mexico. These often develop from deposition of windblown fine sediments, resulting in elevated landforms within a matrix of tidal flats. These are typically fairly dense to extremely dense shrublands, often 2-4 meters in height, and dominated by species such as *Ebenopsis ebano* (Texas ebony), *Citharexylum berlandieri* (negrito), *Leucophyllum frutescens* (cenizo), *Yucca treculeana* (Spanish dagger), *Jatropha dioica* (leatherstem), *Acacia rigidula* (blackbrush), *Opuntia engelmannii* var. *lindheimeri* (Lindheimer prickly pear), *Prosopis glandulosa* (honey mesquite), *Sideroxylon celastrinum* (la coma), *Forestiera angustifolia* (desert olive), *Celtis ehrenbergiana* (granjeno), *Guaiacum angustifolium* (guayacan), *Karwinskia humboldtiana* (coyotillo), *Castela erecta* (amargosa), *Zanthoxylum fagara* (colima), *Phaulothamnus spinescens* (snake-eyes), and *Ziziphus obtusifolia* (lotebush). There may be scattered emergent trees of *Ebenopsis ebano* (Texas ebony) and *Prosopis glandulosa* (honey mesquite) forming a sparse woodland. Within these shrublands, the herbaceous layer is typically not well-developed, however the non-native *Urochloa maximum* (guineagrass), may be conspicuous. A grassland, often dominated by *Sporobolus wrightii* (big sacaton), occupies the margins of these clay dunes, as they grade downslope into the surrounding salty flats. These margins may also contain *Sporobolus pyramidatus* (whorled dropseed), *Monanthochloe littoralis* (shoregrass), and *Spartina spartinae* (Gulf cordgrass). Other somewhat halophytic species, such as *Maytenus phyllanthoides* (gutta-percha) and *Prosopis reptans* (tornillo) may also occupy these dunes. The proximity of many of these dunes to active tidal fluctuations and salt spray also influences species composition at these sites.

Potential Threats:

Not documented.

Tamaulipan Calcareous Thornscrub

This vegetation system Ridge or plateau forming hard calcareous substrates such as caliche of the Goliad Formation or Uvalde Gravel. This vegetation lies typically ridges high on the landscape, sometimes rolling or relatively level plateaus. This system soils occur along Shallow, Shallow Ridge or Gravelly Ridge Ecological Sites. This system occurs in the Gulf Coastal Prairie and Marshes ecoregion of Texas. This system occurs in the South Texas Plains ecoregion of Texas.

This shrubland typically occupies xeric, rocky uplands on calcareous substrates including limestone, caliche (such as those of the Goliad Formation), calcareous gravels, and calcareous sandstone of south

Texas and northeastern Mexico. Soils are usually thin, and sites are most frequently dominated by shrubs between 0.5 and 2 m in height. Shrub canopy can be dense (to about 90%), or sparser where rocky exposures reduce substrate for rooting. A sparse overstory, usually <4 m in height, may be present and composed of species such as *Prosopis glandulosa* (honey mesquite) and, in the south, *Ebenopsis ebano* (Texas ebony)*, Cordia boissieri* (anacahuita), and/or *Helietta parvifolia* (baretta). *Quercus fusiformis* (plateau live oak) may form a relatively open canopy in areas in the northeastern part of the South Texas Plains. The shrub layer may be heavily dominated by *Leucophyllum frutescens* (cenizo)*, Acacia berlandieri* (guajillo)*,* and/or *Acacia rigidula* (blackbrush)*.* More commonly, a diverse array of shrubs is present, including these three in addition to several of the following species: *Salvia ballotiflora* (shrubby blue sage)*, Eysenhardtia texana* (Texas kidneywood)*, Guaiacum angustifolium* (guayacan)*, Sophora secundiflora* (Texas mountain-laurel)*, Mahonia trifoliolata* (agarito)*, Ephedra antisyphilitica* (joint-fir)*, Sideroxylon celastrinum* (la coma)*, Jatropha dioica* (leatherstem)*, Bernardia myricifolia* (oreja de raton)*, Karwinskia humboldtiana* (coyotillo)*, Aloysia macrostachya* (vara dulce)*, Condalia spathulata* (knifeleaf condalia)*, Croton incanus* (Torrey croton)*, Koeberlinia spinosa* (allthorn)*, Acacia schaffneri* (huisachillo)*, Forestiera angustifolia* (desert olive)*, Celtis ehrenbergiana* (granjeno)*, Diospyros texana* (Texas persimmon)*, Cylindropuntia leptocaulis* (tasajillo)*, Krameria ramosissima* (calderona)*, Yucca treculeana* (Spanish dagger)*,* and others. More southerly occurrences may also contain *Lippia graveolens* (redbrush lippia)*, Helietta parvifolia* (baretta)*, Gochnatia hypoleuca* (chomonque)*, Croton humilis* (low croton)*, Ebenopsis ebano* (Texas ebony), and/or *Mortonia greggii* (afinador)*.*

The herbaceous layer may be somewhat well-developed, but often bare rock is easily visible through the layer. Many sites are now dominated by non-native grasses, particularly *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem) and/or *Pennisetum ciliare* (buffelgrass)*.* Other grasses are often shortgrasses, with species such as *Bouteloua rigidiseta* (Texas grama)*, Bouteloua hirsuta* (hairy grama)*, Bouteloua dactyloides* (buffalograss)*, Hilaria belangeri* (curlymesquite)*, Aristida purpurea* (purple threeawn)*, Bouteloua curtipendula* (sideoats grama)*,* and *Setaria leucopila* (plains bristlegrass) present. Forbs and subshrubs are conspicuous in the herbaceous layer and include species such as *Tiquilia canescens* (oreja de perro)*, Thamnosma texana* (Texas desert-rue)*, Galphimia angustifolia* (narrowleaf thryallis)*, Polygala alba* (white milkwort)*, Cordia podocephala* (cluster cordial) *, Acourtia runcinata* (peonia)*, Dalea aurea* (golden dalea)*, Calliandra conferta* (Rio Grande stickpea)*, Chamaecrista greggii* (Gregg's senna)*, Heliotropium torreyi* (Torrey heliotrope)*, Melampodium cinereum* (blackfoot daisy)*, Hymenopappus scabiosaeus* (old plainsman)*, Desmanthus velutinus* (velvet bundleflower)*, Calylophus hartwegii* (Hartweg evening primrose)*, Simsia calva* (awnless bush sunflower)*, Hermannia texana* (Mexican mallow)*, Macrosiphonia lanuginosa* var. *macrosiphon* (plateau rocktrumpet)*, Viguiera stenoloba* (skeletonleaf goldeneye)*, Stenaria nigricans* (prairie bluets)*, Thymophylla pentachaeta* (fire-hair dogweed)*, Wedelia hispida* (hairy zexmania)*,* and *Meximalva filipes* (violet sida)*.* Down slope from these sites, soil development increases, soils tend to be tight, a more well-developed overstory of *Prosopis glandulosa* (honey mesquite) becomes prominent, and species such as *Castela erecta* (amargosa) and *Ziziphus obtusifolia* (lotebush) increase in cover relative to other species.

Potential Threats:

Threats from development, including overgrazing by livestock, mining, and energy development, continue to convert or degrade existing stands. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species. Persistent drought may result in loss of key species. Conversion of this type has commonly come from effective brush eradication using mechanical, chemical or prescribed burning method. Common stressors and threats include fragmentation from roads, non-native species invasion (Landfire 2007a), and development, mining, agriculture. Other stressors and threats include overgrazing/browsing by livestock, and possibly loss of pollinators.

According to Climate Wizard in 2050 global climate change model (using Medium A1B emission scenario and Ensemble Average general circulation model), the average annual temperature is predicted to rise approximately 5°F and average annual precipitation will not significantly change (TNC 2013). Seasonal shifts in precipitation predict increased fall (monsoon) moisture with similar levels of precipitation to current in the rest of the year (TNC 2013). Potential climate change effects on vegetation could include a shift to species adapted to a hotter, generally drier environment. While average precipitation amounts may remain similar or slightly decrease during the winter, spring and summer months, that, along with increased temperatures, may cause vegetation to experience less effective precipitation and more soil moisture deficit during much of the growing season reducing plant growth and increasing mortality from extreme events including exceptional drought. If the increased fall precipitation is from intense storms such as hurricanes, we can expect more disturbances from flooding and water erosion.

Tamaulipan Mixed Deciduous Thornscrub

This system is well-represented on the Eocene Claiborne and Jackson Groups and the Pleistocene Beaumont Formation, but also found on various other formations. This system lies along gently rolling to nearly level sites, sometime interdigitated with calcareous ridges and low lying drainages and bottomlands. This system soils include Clay, Clay Flat, and Clay Loam Ecological Sites are the typical soils for this system, though it may occur on a variety of other tight soils. This system occurs in the South Texas Plains ecoregion of Texas.

This shrubland is differentiated from Tamaulipan Savanna Grassland as it occupies tighter soils, as opposed to the sandier soils of the savanna grassland. The sites are often lower in the landscape compared to nearby savanna grassland or Tamaulipan Calcareous Shrubland, but would be considered uplands as they are distant from bottomland soils and drainages, and are not well-developed woodlands typical of the lowest landscape positions. To a large degree, all of these systems share numerous shrub species, but show subtle differences in relative dominance. However, this system generally occurs as a closed shrubland or low woodland, usually lacking a purely open herbaceous component. Soils are clays, clay loams, and clay flats and are often calcareous or alkaline to varying degrees. Some sites are highly saline, and these sites are occupied by Tamaulipan Saline Shrubland, but transitions between the systems may be subtle. *Prosopis glandulosa* (honey mesquite) is very often a conspicuous component of the canopy, sometimes reaching to 6 m in height. This canopy may be dense, but given the open nature of the canopy of individual *Prosopis glandulosa* (honey mesquite), significant solar radiation reaches the lower strata. *Acacia farnesiana* (huisache), *Celtis ehrenbergiana* (granjeno), *Ebenopsis ebano* (Texas ebony), and *Celtis laevigata* (sugar hackberry) may also be components of the canopy, but *Prosopis glandulosa* (honey mesquite) usually dominates. The overstory canopy may be open with only scattered emergent trees over a dense shrub layer at 1 to 3 m in height. Depending on land use history, the shrub understory may be limited to a few species such as *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear), *Ziziphus obtusifolia* (lotebush), or *Celtis ehrenbergiana* (granjeno) on relatively recently cleared sites. On more mature sites, a diverse assemblage of species such as *Acacia rigidula* (blackbrush), *Castela erecta* (amargosa), *Malpighia glabra* (Barbados cherry), *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear), *Cylindropuntia leptocaulis* (tasajillo), *Ziziphus obtusifolia* (lotebush), *Celtis ehrenbergiana* (granjeno)*, Lycium berlandieri* (Berlandier wolfberry)*, Forestiera angustifolia* (desert olive)*, Guaiacum angustifolium* (guayacan)*, Diospyros texana* (Texas persimmon)*, Amyris texana* (Texas torchwood)*, Karwinskia humboldtiana* (coyotillo)*, Havardia pallens* (tenaza)*, Phaulothamnus spinescens* (snake-eyes)*, Schaefferia cuneifolia* (desert yaupon)*, Condalia hookeri* (brasil)*,* and *Zanthoxylum fagara* (colima) may occur*. Leucophyllum frutescens* (cenizo) and *Acacia berlandieri* (guajillo) may be present, but occur as scattered individuals as opposed to dominating the aspect of the community as they sometimes do on some shallow- soiled calcareous sites. However, like some shallow-soiled calcareous sites, *Acacia rigidula* (blackbrush) is the aspect dominant of the shrub layer. The herbaceous layer is usually fairly sparse. Currently, the herbaceous layer may actually be dense with the non-native grass *Urochloa maximum* (guineagrass)*.* Other non-native species, such as *Pennisetum ciliare* (buffelgrass)*, Cynodon dactylon* (bermudagrass)*, Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem)*,* and *Dichanthelium annulatum* (Kleberg bluestem), may also be present to dominant. Native grasses, such as *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem)*, Trichloris* spp. (false Rhodes grasses), and *Pappophorum bicolor* (pink pappusgrass), may be present*.*

Potential Threats:

Much of this system was decimated by development for agriculture early in the twentieth century (Crosswhite 1980). Grazing pressure removing native grasses, increase in invasive (introduced) grasses, and lack of fire threaten this system. Currently the non-native grasses *Pennisetum ciliare* and *Urochloa maxima* can serve as ladder fuel which increases the potential for fire in this system. Threats from development, including development for agriculture, overgrazing by livestock, and possibly energy development, continue to convert or degrade existing stands. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species. Persistent drought may result in loss of key species. Conversion of this type has commonly come from agricultural practices. Common stressors and threats include fragmentation from roads, agriculture and development, and non-native species invasion. Other stressors and threats include overgrazing/browsing by livestock, and possibly loss of pollinators.

According to Climate Wizard in 2050 global climate change model (using Medium A1B emission scenario and Ensemble Average general circulation model), the average annual temperature is predicted to rise approximately 5°F and average annual precipitation will not significantly change (TNC 2013). Seasonal shifts in precipitation predict increased fall (monsoon) moisture with similar levels of precipitation to current in the rest of the year (TNC 2013). Potential climate change effects on vegetation could include a shift to species adapted to a hotter, generally drier environment. While average precipitation amounts may remain similar or slightly decrease during the winter, spring and summer months, that, along with increased temperatures, may cause vegetation to experience less effective precipitation and more soil moisture deficit during much of the growing season reducing plant growth and increasing mortality from extreme events including exceptional drought. If the increased fall precipitation is from intense storms such as hurricanes, we can expect more disturbances from flooding and water erosion.

Western Great Plains Mesquite Woodland and Shrubland

This vegetation system occupies areas of alluvial deposition. This system is lies along drainages and on floodplains. This system soils are located on bottomlands and soils along drainages. The system is in the High Plain and Southwestern Tableland ecoregions in Texas.

Because *Prosopis glandulosa* (honey mesquite) is the characteristic dominant of this system, and that species can occupy various sites and is thought to have expanded on the landscape as a result of land-use, it is difficult to distinguish this system from areas where *Prosopis glandulosa* (honey mesquite) has invaded. The system is only mapped on bottomland soils and along drainages, while other shrublands dominated by the species are mapped as Native Invasive: Mesquite Shrubland. *Prosopis glandulosa* (honey mesquite) typically dominate the sites, sometimes occurring in the overstory canopy. Other overstory species may include species of the Western Great Plains Floodplain (CES303.678) or Western Great Plains Riparian (CES303.956) systems, such as *Celtis laevigata* var. *reticulata* (netleaf hackberry), *Sapindus saponaria* var. *drummondii* (western soapberry), *Populus deltoides* (eastern cottonwood), and *Salix nigra* (black willow). *Prosopis glandulosa* (honey mesquite) is dominant in the shrub layer, but other shrub species encountered include small representatives of the overstory, *Ziziphus obtusifolia* (lotebush), *Prunus angustifolia* (Chickasaw plum), and *Baccharis* spp. (baccharis).

Herbaceous species present in the understory may include *Panicum virgatum* (switchgrass), *Bothriochloa laguroides* var. *torreyana* (silver bluestem), *Nassella leucotricha* (Texas wintergrass), and *Schizachyrium scoparium* (little bluestem). Non-native species such as *Cynodon dactylon* (bermudagrass), *Bromus catharticus* (rescuegrass), *Sorghum halepense* (Johnsongrass), and *Bromus arvensis* (Japanese brome) are also commonly present and may be dominant.

Potential Threats:

With fire suppression and grazing, *Prosopis glandulosa* has been able to extend its range and become dense in examples of Western Great Plains Shortgrass Prairie (CES303.672) or Central Mixedgrass Prairie (CES303.659). Those areas should still be considered part of the prairie system. In Landfire mapzone 26 BpS modeling workshops, this was modeled in its limited extent along drainages rather than as the pervasive existing vegetation type (EVT). Because *Prosopis glandulosa* is the characteristic dominant of this system, and that species can occupy various sites and is thought to have expanded on the landscape as a result of land use, it is difficult to distinguish this system from areas where *Prosopis glandulosa* has invaded.

Western Great Plains Sandhill Steppe

The system vegetation within the Phase 1 area, this system is apparently restricted to thick sandy deposits in the Seymour Formation (a Pleistocene formation formed from ancient channel deposits of the Clear Fork of the Brazos River). This system lies along rolling to level uplands. This system soils are restricted to Deep Sand, Sand Hills or Sandy ecological site. The system is located in the Central Great Plains. Edwards Plateau, High Plain and Southwestern Tableland ecoregions in Texas.

Shrub cover may be variable, ranging from about 15 to 90% canopy cover. *Artemisia filifolia* (sand sage) or *Quercus havardii* (Havard's shin oak) may dominate or co-dominate the shrub layer, but *Prosopis glandulosa* (mesquite), *Rhus trilobata* (skunkbush sumac), or *Prunus angustifolia* (Chickasaw plum) may also be conspicuous. Shrub cover may sometimes be sufficient to greatly reduce the cover of herbaceous species in the understory. At some sites, shrub cover may be low and herbaceous cover is typically dominated by grass species such *Schizachyrium scoparium* (little bluestem) and *Sporobolus cryptandrus* (sand dropseed).

Key Ecological Processes:

Fire and grazing constitute the most important processes impacting this system. Burning shrublands reduces cover of *Artemisia filifolia* for several years resulting in grassland patches that form a mosaic pattern with shrublands. Composition of grasslands depends on precipitation and management. Drought stress can also influence this system in some areas. In the southern range of this system, *Quercus havardii* may also be present to dominant and represents one succession pathway that develops over time following a disturbance. *Quercus havardii* is able to resprout following a fire and thus may persist for long periods of time once established, forming extensive clones. Edaphic and climatic factors are the most important dynamic processes for this type, with drought and extreme winds impacting this system significantly in some areas. Because *Quercus havardii* is able to resprout rapidly following fire, fire tends to cause structural changes in the vegetation, and compositional shifts are less significant in most cases. Overgrazing can lead to decreasing dominance of some of the grass species such as *Andropogon hallii, Calamovilfa gigantea*, and *Schizachyrium scoparium*. In the western extent of this system in the shortgrass prairie, more xeric mid- and shortgrass species such as *Hesperostipa comata, Sporobolus cryptandrus* and *Bouteloua gracilis* often dominate the herbaceous layer.

Savanna/Open Woodland

Savanna/Open Woodland vegetation is open to broadly open tree canopy with a grass dominated understory, and can contain deciduous, evergreen or mixed overstory trees.

East-Central Texas Plains Post Oak Savanna and Woodland

This vegetation system typically is on sedimentary formations of Tertiary age, including Eocene sands such the Queen City, Sparta, and Carrizo Sands, as well as the Wilcox and Claiborne groups. The system also occupies other Teritary formations such as the Goliad and Willis, as well as portions of the Quaternary Willis Formation. This system occupies gently rolling to hilly topography. It is moderately dissected by drainages. The soils of this system usually occurs on sandy to sandy loam soils, often with a marked clay subsurface horizon. Soils of this system are generally Alfisols, and are typically acidic to neutral. Typical Ecological Sites include Claypan Savannah, Claypan Prairie, Sandy Loam, Sandy, and Deep Sand. This system occurs in the East Central Plains, Gulf Coast Prairies and Marshes and West Gulf Coastal Plain Ecoregions in Texas.

This system represents a transition from the woodlands and forests of East Texas to the prairies to the west, specifically the Blackland Prairie. Savannas and woodlands are typically dominated by *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), and *Carya texana* (black hickory). Large areas of woodland, particularly in the south and east, are dominated or co- dominated by *Quercus fusiformis* (plateau live oak) or *Quercus virginiana* (coastal live oak, east of the Brazos River). Other species, such as *Quercus incana* (bluejack oak) (on more xeric sites), *Ulmus alata* (winged elm), *Ulmus crassifolia* (cedar elm), *Quercus nigra* (water oak), *Juniperus virginiana* (eastern redcedar), *Celtis laevigata* (sugar hackberry), and *Prosopis glandulosa* (mesquite), can also be present in the overstory. To the east, *Quercus falcata* (southern red oak), *Quercus nigra* (water oak), *Liquidambar styraciflua* (sweetgum), *Pinus echinata* (shortleaf pine), *Pinus taeda* (loblolly pine), and *Carya alba* (mockernut hickory) may be conspicuous in the overstory. Shrubs may attain significant cover in the understory, with species including *Ilex vomitoria* (yaupon) (often dominant), *Callicarpa americana* (American beautyberry), *Sideroxylon lanuginosum* (gum bumelia), *Crataegus* spp. (hawthorn), *Ilex decidua* (possumhaw), *Toxicodendron radicans* (poison ivy), *Smilax bona-nox* (saw greenbrier), *Juniperus virginiana* (eastern redcedar), and *Symphoricarpos orbiculatus* (coral-berry). To the south, this system grades into vegetation more characteristic of south Texas, with *Quercus fusiformis* (plateau live oak) and *Prosopis glandulosa* (honey mesquite) becoming the primary overstory components, and shrubs of south Texas such as *Acacia rigidula* (blackbrush), *Forestiera angustifolia* (desert olive), *Condalia hookeri* (brasil), *Colubrina texensis* (Texas hogplum), *Eysenhardtia texana* (Texas kidneywood), *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear), and *Diospyros texana* (Texas persimmon) becoming increasingly conspicuous understory components. To the east, *Vaccinium arboreum* (farkleberry), *Morella cerifera* (wax-myrtle), *Diospyros virginiana* (common persimmon), and *Cornus florida* (flowering dogwood) may be common components of the understory. On some sites, *Ilex vomitoria* (yaupon) can form nearly continuous, sometimes impenetrable, dense shrub layer. Mid- and tallgrass species including *Schizachyrium scoparium* (little bluestem), *Sorghastrum nutans* (Indiangrass), and *Panicum virgatum* (switchgrass) are frequent in the understory where light penetration supports herbaceous cover, and also form prairie patches within the savanna, particularly on tighter soils. Other grasses present include *Andropogon gerardii* (big bluestem), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Paspalum plicatulum* (brownseed paspalum) (to the south), *Nassella leucotricha* (Texas wintergrass), *Dichanthelium* spp. (rosette grasses), *Aristida* spp. (threeawn), and *Sporobolus cryptandrus* (sand dropseed). Non-native grass species such as *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem), *Paspalum notatum* (bahiagrass), and *Cynodon dactylon* (bermudagrass) may dominate some sites. Forbs are often conspicuous, and may include species such as *Croton capitatus* (hog croton), *Gaillardia pulchella* (Indian blanket), *Monarda punctata* (spotted beebalm), *Rudbeckia hirta* (blackeyed Susan), *Phlox drummondii* (Drummond phlox), *Commelina erecta* (erect dayflower), *Acalypha radians* (cardinal's feather), *Verbesina virginica* (frostweed), *Aphanostephus skirrhobasis* (lazy daisy), *Froelichia gracilis* (slender snake cotton), *Cnidoscolus texanus* (Texas bull-nettle), and many others.

Drought, grazing, and fire are the primary natural processes that affect this system. Much of this system has been impacted by conversion to improved pasture or crop production. Overgrazing and fire suppression have led to increased woody cover on most extant occurrences and the invasion of some areas by problematic brush species such as *Juniperus virginiana* (eastern redcedar) (to the north) and *Prosopis glandulosa* (honey mesquite) (to the south).

Potential Threats:

Overgrazing and fire suppression have led to increased woody cover on most extant occurrences and the invasion of some areas by problematic brush species such as *Juniperus virginiana var. virginiana* and *Prosopis glandulosa* in the southern part of the system's range. These factors have also led to decreases in native grass cover allowing for annual grasses and forbs to invade. Early land uses, including grazing, then farming, and today urban and rural development, infrastructure development, and lignite coal mining, have resulted in the clearing of vast areas. Other threats include fragmentation and erosion.

Edwards Plateau Limestone Savanna and Woodland

This vegetation system is primarily found on Cretaceous limestones of the Edwards Plateau and Limestone (also referred to as Lampasas) Cutplain, but also associated with Pennsylvanian limestones of the Palo Pinto Formation and Winchell, Ranger, Home Creek Limestone in the vicinity of Palo Pinto County, as well as on Cretaceous chalk formations in the Northern Blackland Prairie and Cretaceous limestones of the Western Crosstimbers and Rolling Plains. This system occurs on rolling to level topography, often on plateau tops, but also on gentle slopes. The soils of this system are generally loams, clay loams, or clays, often with limestone parent material apparent. Low Stony Hill, Adobe, Clay Loam, and Shallow Ecological Sites are commonly associated with this system. This system occurs in the East Central Plains, Cross Timbers, Edwards Plateau, South Texas Plains, and Texas Blackland Prairie Ecoregions in Texas.

This upland system forms the matrix vegetation type of the Edwards Plateau. It is typified by a mosaic of evergreen oak and juniper forests, woodlands and savannas over shallow soils of rolling uplands and adjacent upper slopes within the Edwards Plateau and some adjacent ecoregions where limestone is present. Significant open areas dominated by grasses may resemble prairies, and such open occurrences may grade into prairie types to the west (shortgrass prairie), northwest (Central mixedgrass), north (Southeastern Great Plains tallgrass), and east (Blackland). Species such as *Quercus fusiformis* (plateau live oak) or *Juniperus ashei* (Ashe juniper) often dominate the canopy of this system. Other canopy species may include *Quercus buckleyi* (Texas oak), *Quercus laceyi* (Lacey oak, in the southwestern part of the Edwards Plateau), *Ulmus crassifolia* (cedar elm), *Fraxinus texensis* (Texas ash), *Quercus sinuata* var. *breviloba* (white shin oak), and *Quercus vaseyana* (Vasey shin oak) (especially in the western part of the region). *Pinus remota* (paper-shell pinyon) and *Juniperus pinchotii* (redberry juniper) may dominate or be a component of the canopy to the southwest and west of the region. The shrub layer may be fairly well-developed, containing overstory species, as well as species such as *Diospyros texana* (Texas persimmon), *Mahonia trifoliolata* (agarito), *Sophora secundiflora* (Texas mountain-laurel), *Prosopis glandulosa* (honey mesquite), *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear), and *Cylindropuntia leptocaulis* (tasajillo). Many uplands have mottes of *Quercus fusiformis* (plateau live oak) punctuating a generally grass dominated landscape, forming what has been referred to as a motte-savanna. The understory can contain various graminoid species, including *Schizachyrium scoparium* (little bluestem), *Bouteloua curtipendula* (sideoats grama), *Bothriochloa barbinodis* (cane bluestem), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Nassella leucotricha* (Texas wintergrass), *Sorghastrum nutans* (Indiangrass), *Hilaria belangeri* (curlymesquite), *Bouteloua dactyloides* (buffalograss), *Andropogon gerardii* (big bluestem), *Bouteloua hirsuta* (hairy grama), *Bouteloua rigidiseta* (Texas grama), *Muhlenbergia reverchonii* (seep muhly), *Muhlenbergia lindheimeri* (Lindheimer muhly), *Aristida purpurea* (purple threeawn), and/or *Carex planostachys* (cedar sedge). The composition of the grassland component is driven by grazing, fire, and climate. Shortgrass species such as *Bouteloua dactyloides* (buffalograss) and *Hilaria belangeri* (curly mesquite) are favored under heavy continuous grazing and/or dry climate (to the west), while mid- and tallgrasses are favored under more mesic conditions, more well-developed soils, and well- managed grazing. The herbaceous stratum is often dominated by non-native grass species, especially *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem). Some disturbed areas on hard-bedded limestone of the western plateau are now dominated by mesquite woodland. Natural mesquite woodlands are believed to have occurred on the deeper soils of adjacent riparian systems.

Potential threats:

Range-restricted. This system is found primarily within the Edwards Plateau ecoregion but can extend north into Oklahoma and into portions of the Southern Shortgrass region of Texas.

Madrean Juniper Savanna

This vegetation system is associated with various substrates including limestones, sandstones, igneous formations, and alluvial/colluvial surfaces. This system typically occupies foothills and lower slopes of mountains. Such situations may often be rolling landscapes, and are sometimes on gentle slopes to level surfaces. The soils occupied by the system vary from gravelly, to shallow to loamy soils. It may also occur on rocky slopes of limestone or igneous parent material. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregions of Texas.

This system often co-occurs with the Madrean Pinyon-Juniper Woodland, but often occupies slightly lower elevations. It is similar to that system but lacks pinyon as a dominant, though some pinyon species (*Pinus cembroides* (Mexican pinyon pine), *Pinus edulis* (pinyon pine), or *Pinus remota* (paper-shell pinyon pine)) may be present. One of several juniper species may be the dominant overstory, including *Juniperus monosperma* (one-seeded juniper), *Juniperus pinchotii* (redberry juniper), *Juniperus coahuilensis (rose-fruited juniper)*, or *Juniperus deppeana* (alligator juniper). The system may occur with junipers forming a shrubland, or as a closed woodland, or, more commonly, as an open woodland. *Nolina texana* (Texas sacahuista), *Dasylirion leiophyllum* (smooth sotol), and *Yucca* spp. (yuccas) are commonly encountered. This system typically gives way at lower elevations to grassland, with species such as *Bouteloua gracilis* (blue grama), *Bouteloua curtipendula* (sideoats grama), *Bouteloua eriopoda* (black grama), *Muhlenbergia emersleyi* (bull muhly), and *Muhlenbergia setifolia* (curlyleaf muhly) commonly encountered in the herbaceous layer.

Potential Threats:

Wildfire suppression, overgrazing, introduced invasive plant species, firewood collection.

South-Central Saline Glade

This vegetation system in some cases, this system may be associated with inland salt domes when the proximity of such a structure to the surface produces high salinity in the surface soils. Otherwise, surface geology of various formations may contain sufficient alkalinity such that leaching from particular members of these formations gives rise to such conditions.

These systems sites are often associated with streams or drainages, sometimes occurring on terraces. The soils of this system are characterized by high levels of exchangeable sodium and low permeability with reduced soil aeration. Some soils may be Glossic Natraqualfs. The system occurs in Gulf Coast Prairies and Marshes and West Gulf Coastal Plain ecoregions in Texas.

While apparently not well-represented in Texas, the search for *Geocarpon minima* (tinytim) has led investigators to identify some areas that may be characterized as this system. One area mapped as this system, near Grand Saline in Van Zandt County, may not be a good representative of this system. This site does have alkaline soils and is characterized by halophytic species, and generally lacks woody vegetation. The site appears to more closely resemble an inland salt marsh, with extensive areas dominated by *Distichlis spicata* (saltgrass) and lower, wetter areas dominated by *Schoenoplectus* sp. (bulrush). Shrubs that may occur in patches within this system include *Baccharis halimifolia* (baccharis), *Iva angustifolia* (narrowleaf sumpweed), and *Tamarix* sp. (salt cedar). Some sites may be relatively sparsely vegetated and intermixed as a mosaic with surrounding woodlands containing species such as *Quercus stellata* (post oak), *Quercus similis* (bottomland post oak), *Ulmus crassifolia* (cedar elm), *Quercus nigra* (water oak), and *Pinus taeda* (loblolly pine). Other herbaceous species that may be encountered include *Coreopsis tinctoria* (plains coreopsis), *Sporobolus vaginiflorus* (poverty dropseed), *Distichlis spicata* (saltgrass), *Diodia teres* (rough buttonweed), *Houstonia* spp. (bluets), *Isolepis carinata* (keeled bulrush), *Phemeranthus parviflorus* (prairie flameflower), *Plantago* spp. (plantains), *Krigia occidentalis* (western dwarf dandelion), and *Aristida* spp. (threeawns).

Potential Threats:

Not documented.

Southern Rocky Mountain Ponderosa Pine Savanna

In Texas this system is found predominantly in Guadalupe, Sierra Diablo, and Davis Mountains in the western portion of the state.

These savannas occur at the lower treeline/ecotone between grassland/or shrubland and more mesic coniferous forests typically in warm, dry, exposed sites. It is found on rolling plains, plateaus, or dry slopes usually on more southerly aspects.

This system is best described as a savanna that has widely spaced (<25% tree canopy cover) (>150 years old) *Pinus ponderosa* (primarily *var. scopulorum* and *var. brachyptera*) as the predominant conifer. It is maintained by a fire regime of frequent, low-intensity surface fires. A healthy occurrence often consists of open and park-like stands dominated by *Pinus ponderosa*. Understory vegetation in the true savanna occurrences is predominantly fire-resistant grasses and forbs that resprout following surface fires; shrubs, understory trees and downed logs are uncommon. Important and often dominant species include *Festuca arizonica, Koeleria macrantha, Muhlenbergia montana,* and *Pseudoroegneria spicata*. Other important grasses, such as *Andropogon gerardii, Bouteloua gracilis, Elymus elymoides,* and *Schizachyrium scoparium*, dominate less frequently. A century of anthropogenic disturbance and fire suppression has resulted in a higher density of *Pinus ponderosa* trees, altering the fire regime and species composition.

Potential Threats:

With settlement and a century of anthropogenic disturbance and fire suppression, stands now have a higher density of *Pinus ponderosa* trees, altering the fire regime and species composition. Presently, many stands contain understories of more shade-tolerant species, such as *Pseudotsuga menziesii* and/or *Abies* spp., as well as younger cohorts of *Pinus ponderosa*. These altered structures have affected fuel loads and fire regimes. Presettlement fire regimes were primarily frequent (5- to 15-year return intervals), low-intensity ground fires triggered by lightning strikes or deliberately set by Native Americans. With fire suppression and increased fuel loads, fire regimes are now less frequent and often become intense crown fires, which can kill mature *Pinus ponderosa* (Reid et al. 1999).

Conversion of this type has commonly come from urban and exurban development especially along the Front Range, water developments and reservoirs. With long-term fire suppression, stands have converted through succession to Southern Rocky Mountain Ponderosa Pine Woodland (CES306.648) or Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland (CES306.823). Restoration to savanna is difficult or impossible when adjacent to housing development.

Common stressors and threats include fragmentation from housing and water developments, altered fire regime from fire suppression and indirectly from livestock grazing and fragmentation, and introduction of invasive non-native species (CNHP 2010b). Potential climate change effects could include a change in the current extent of this ecosystem with tree mortality in lower elevation stands converting to Western Great Plains Foothill and Piedmont Grassland (CES303.817), if climate change has the predicted effect of less effective moisture with increasing mean temperature (TNC 2013).

West Gulf Coastal Plain Catahoula Barrens

This system vegetation is restricted to surface outcrops of the Oligocene Catahoula geologic formation, an often tuffaceous sandstone. This systems landform is generally level to gently undulating (but sometimes steep), with surface or near surface exposure of the underlying sandstone bedrock. The soils of this system are shallow loams, such as Browndell –Rock outcrop. Soils may contain montmorillonitic clays. These thin soils can be extremely xeric during dry periods, but can also be saturated during wetter months. The system is confined to the West Gulf Coastal Plain ecoregion in Texas.

Vegetation associated with thin soils over the tuffaceous sandstone of the Catahoula formation is primarily herbaceous. But where the soil is deeper, or fire is excluded for long periods, it can display significant woody cover, with usually stunted representatives of species such as *Pinus palustris* (longleaf pine), *Pinus taeda* (loblolly pine), *Pinus echinata* (shortleaf pine), *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), and *Carya texana* (black hickory) dominating the canopy. Shrubs may form a patchy, discontinuous layer with species such as *Ilex vomitoria* (yaupon), *Morella cerifera* (wax-myrtle), *Vaccinium arboreum* (farkleberry), *Forestiera ligustrina* (elbowbush), *Gelsemium sempervirens* (Carolina jessamine), and *Crataegus* spp. (hawthorns) commonly encountered. Maintenance of fire in the landscape will reduce woody cover in these sites, with herbaceous dominated sites displaying increased species richness. On open sites, there may be exposed patches of bedrock or mineral soils, or areas of patchy cover of foliose and/or fruticose lichens. Open sites may have significant herbaceous cover, usually dominated by graminoid species such as *Schizachyrium scoparium* (little bluestem), *Sporobolus clandestinus* (rough dropseed), *Sporobolus silveanus* (Silveus' dropseed), *Schizachyrium tenerum* (slender bluestem), *Tridens strictus* (longspike tridens), *Scleria* spp. (nutrush), and/or *Aristida* spp. (threeawns). *Bigelowia nuttallii* (Nuttall's rayless golden-rod), *Plantago* spp. (plantains), *Minuartia drummondii* (Drummond sandwort), *Chaetopappa asteroides* (common leastdaisy), *Lechea san-sabeana* (San Saba pinweed), *Sabatia campestris* (meadow pink), *Croton michauxii* (narrowleaf rushfoil), *Croton monanthogynus* (doveweed), *Krameria lanceolata* (trailing ratany), *Selaginella arenicola* ssp. *riddellii* (Riddell's spikemoss), *Phemeranthus parviflorus* (prairie flameflower), and a variety of other herbaceous species may also be present. Several sensitive species are associated with this system, including *Schoenolirion wrightii* (Texas sunnybell), *Spiranthes parksii* (Navasota ladies'-tresses), and *Liatris tenuis* (slender gayfeather). This system typically occurs as small patches and many occurrences were likely missed by the current mapping effort.

Potential Threats:

The primary threats to this system are conversion and degradation of abiotic and biotic components through fire suppression, tree farming, recreational vehicle use, and livestock. These incompatible land uses result in an increase in woody cover, invasive species (e.g., *Sorghum halepense*), and erosion and loss of soil. Threats include fragmentation and disruption of ecological processes, and the resulting alteration of species composition and structure

West Gulf Coastal Plain Pine-Hardwood Flatwoods (mixed upland and wetland)

This system vegetation includes the West Gulf Coastal Plain Pine – Hardwood Flatwoods, this system is associated with high Pleistocene terraces, of the Lissie and upper Beaumont Formations, as well as the Quaternary Fluviatile Terrace Deposits to the north. This system represents the lowest topographic position within the level to very gently undulating terraces occupied by flatwoods. Hydrology is controlled by local rainfall, not overbank flooding of nearby streams. The soils of this system are fine-textured, with an impermeable subsurface horizon, which leads to a perched water table. Because of the lower topographic position of these flatwoods, saturated soil conditions tend to occur over extended periods of the year. The system is confined to the West Gulf Coastal Plain Ecoregions in Texas. The system is confined to the West Gulf Coastal Plain ecoregion in Texas. This system represents the wetter end of the wooded toposequence of the flatwoods and occurs within low positions of swales and other wet circumstances. The canopy is often dominated by *Quercus phellos* (willow oak), *Quercus laurifolia* (laurel oak), *Quercus lyrata* (overcup oak), *Quercus nigra* (water oak), *Quercus michauxii* (swamp chestnut oak), *Ulmus alata* (winged elm), and *Liquidambar styraciflua* (sweetgum). *Pinus taeda* (loblolly pine) may be present in the canopy. *Triadica sebifera* (Chinese tallow) is a commonly encountered non-native species invading this system. The understory and herbaceous layers of this system are not well- developed, as the canopy tends to be closed.

Potential Threats:

Not documented.

West Gulf Coastal Plain Stream Terrace Sandyland Longleaf Pine Woodland (not mapped)

This system is associated with coarse, Quaternary alluvial deposits, in the vicinity of Pleistocene surfaces. This system occurs on terraces adjacent to creeks and rivers where thick sand deposits develop. This system soils are deep to very deep sands occurring on stream terraces. This may include psamments or psammentic soils such as the Bienville, Alaga, Turkey, or Tonkawa when they occur on the appropriate landform. The system is confined to the West Gulf Coastal Plain Ecoregions in Texas. The system is confined to the West Gulf Coastal Plain ecoregion in Texas. This system is relatively xeric vegetation, even though it occurs on terraces adjacent to, or within, floodplains. This is the case because the soils are deep and well-drained sands (often alluvial deposits), with low moisture retention and high permeability. *Pinus palustris* (longleaf pine) may form a discontinuous and sparse overstory, along with species such *Quercus incana* (bluejack oak), *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), *Pinus echinata* (shortleaf pine), and *Carya texana* (black hickory). Where fire is excluded, the oaks become denser. *Pinus palustris* (longleaf pine) is absent from some instances. *Pinus elliottii* (slash pine) and *Pinus taeda* (loblolly pine) may be present to common in the current landscape. Depending on fire history, the shrub layer may be somewhat well-developed with species such as *Vaccinium arboreum* (farkleberry), *Sideroxylon lanuginosa* (gum bumelia), *Persea borbonia* (redbay), and *Ilex vomitoria* (yaupon). The herbaceous layer is usually sparse, with exposed sand and foliose lichens dominating the aspect of the sites. Species such as *Aristida desmantha* (curly threeawn), *Bulbostylis ciliatifolia* (capillary hairsedge), *Carex tenax* (wire sedge), *Cnidoscolus texanus* (Texas bull-nettle), *Cyperus grayoides* (Illinois flatsedge), *Dichanthelium dichotomum* (cypress panicgrass), *Froelichia floridana* (Florida snake-cotton), *Opuntia humifusa* (eastern pricklypear), *Polanisia erosa* (large clammyweed), *Schizachyrium scoparium* (little bluestem), and *Yucca louisianensis* (Gulf Coast yucca) may be present in the herbaceous layer. *Phlox nivalis* ssp. *texensis* (Texas trailing phlox) and *Gaillardia aestivalis* var. *winkleri* (Winkler's firewheel) are two rare taxa associated with this system. This system is floristically similar to other sandhill longleaf pine systems, but the landform of occurrences makes this system unique.

Potential Threats:

A primary threat to this ecological system is alteration of the natural fire regime. With longer fire-return intervals, this system can become invaded by fire-sensitive woody species common in the nearby forest systems. An increase in cover of off-site woody species can suppress the regeneration and growth of species typical of this system in its natural state. Threats also include the loss of habitat from commercial and residential development, and fragmentation of habitat by roads. These threats limit prescribed burning due to urban interface, safety and smoke management concerns. *Pinus palustris* woodlands have also declined due to conversion to intensively managed pine plantations. Longleaf pine forests were among the most valuable economic resources in the region at the turn of the twentieth century (Bray 1906). Overall losses of longleaf pine in Texas have exceeded those of all other southern states (Outcalt 1997); less than 16,200 hectares of mostly second-growth stands remain (McWilliams and Lord 1988). Land-use practices continue to degrade remaining examples of longleaf pine communities (Bridges and Orzell 1989a).

West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland (not mapped)

This system is found on sedimentary Pleistocene formations (particularly the Bentley formation), to formations of the Tertiary period (particularly the Catahoula and Wilcox formations).

Historically, this system was more widely distributed on older, more inland formations of the Eocene and Paleocene epochs. This system occupies topography ranging from rolling uplands, to hills and ridges such as those associated with the Kisatchie Wold (or Kisatche Cuesta) and the Sabine Uplift. This system soils are usually associated with coarse textured, well-drained, ultisols and alfisols, including loams, sandy loams, loamy sands, and sands, though occurrences may also be found to lesser extent on tighter soils such as clay loams. The system is confined to the West Gulf Coastal Plain ecoregion in Texas.

This system once occupied extensive areas of east Texas, but is presently limited in extent and difficult to map using remote-sensing. Small remnants of this once extensive forest type are encountered in Angelina, Jasper, Newton, and other nearby counties in Texas. We did not attempt to map it, and chose to include any occurrences of this system in the West Gulf Coastal Plain Pine-Hardwood Forest. It was characterized by relatively open-canopied woodlands dominated by *Pinus palustris* (longleaf pine) with an herbaceous layer often dominated by graminoids. It often occupied gently rolling uplands with coarse-textured, well-drained soils.

Pinus echinata (shortleaf pine) may be a significant component of some of the stands. *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), *Quercus incana* (bluejack oak), *Pinus taeda* (loblolly pine), *Liquidambar styraciflua* (sweetgum), and *Nyssa sylvatica* (blackgum) may also be common components of the canopy or subcanopy. Occurrences that are less frequently burned may develop a significant shrub layer with species including *Callicarpa americana* (American beautyberry), *Vaccinium arboreum* (farkleberry), *Vaccinium stamineum* (deerberry), *Morella cerifera* (wax-myrtle), *Ilex vomitoria* (yaupon), *Rhus copallinum* (flameleaf sumac), and *Toxicodendron radicans* (poison ivy). Instances with a more optimal fire return interval will retain a more open understory with a grassy aspect. The herbaceous layer is often dominated by grass species such as *Schizachyrium scoparium* (little bluestem), *Schizachyrium tenerum* (slender bluestem), *Sporobolus junceus* (pineywoods dropseed), *Nassella leucotricha* (Texas wintergrass), *Andropogon ternarius* (splitbeard bluestem), *Dichanthelium* spp. (rosette grasses), *Andropogon virginicus* (broomsedge bluestem). *Pteridium aquilinum* (brackenfern) may be locally abundant, forming a continuous ground cover. Forbs may be diverse in the herbaceous layer, including species such as *Pityopsis graminifolia* (narrowleaf silkgrass), *Solidago odora* (fragrant goldenrod), *Tephrosia* spp. (tephrosias), *Euphorbia corollata* (flowering spurge), *Croton argyranthemus* (silverleaf croton), *Vernonia texana* (Texas ironweed), *Alophia drummondii* (celestials), *Lespedeza* *virginica* (slender lespedeza), *Aristolochia reticulata* (netleaf pipevine), *Rhynchosia reniformis* (kidneyleaf snoutbean), *Stylosanthes biflora* (pencilflower), *Liatris elegans* (pink-scale gayfeather). With prolonged absence of fire, hardwoods and *Pinus taeda* (loblolly pine) may come to dominate the system.

Potential Threats:

This ecological system is much reduced form its original extent. Today, only 10 to 25% of this system remains in Louisiana (Smith 1993). The primary historic threat was conversion to other forest types or agriculture including forest plantations (LDWF 2005). A primary threat to current occurrences of this ecological system is alteration of the natural fire regime. With longer fire-return intervals, this system quickly becomes invaded by fire-sensitive woody species common in the nearby forest systems. An increase in cover of off-site woody species can suppress the regeneration and growth of species typical of this system in its natural state. Threats also include the loss of habitat from commercial and residential development, and fragmentation of habitat by roads. These threats limit prescribed burning due to urban interface, safety and smoke management concerns. *Pinus palustris* woodlands have also declined due to conversion to intensively managed pine plantations. Longleaf pine forests were among the most valuable economic resources in the region at the turn of the twentieth century (Bray 1906). Overall losses of longleaf pine in Texas have exceeded those of all other southern states (Outcalt 1997); less than 16,200 hectares of mostly second-growth stands remain (McWilliams and Lord 1988). Land use practices continue to degrade remaining examples of longleaf pine communities (Bridges and Orzell 1989a).

West Gulf Coastal Plain Weches Glade

This vegetation system is associated with outcrops of glauconitic shales of the Eocene Weches Formation. This system Occupies slopes on rolling to relatively steep uplands, sometimes on minor scarp slopes of outcrops. This system soils are frequently associated with the Trawick-Bub complex. The system is confined to the West Gulf Coastal Plain ecoregion in Texas.

Vegetation restricted to outcrops of the Weches Formation in San Augustine, Sabine, and Nacogdoches counties, where it occupies generally shallow soils that oscillate between very dry and saturated (during winter and early spring). These are small patch occurrences and are therefore difficult to map using our methodology. Edaphic constraints tend to restrict the growth of woody species, though as soil depth increases, so does woody plant development.

Outcrops may be exposed because of natural erosion on slopes or may be a result of human- induced openings. This primarily herbaceous system is characterized by species such as *Sedum pulchellum* (yellow stonecrop), *Clinopodium arkansanum* (Ozark savory), *Minuartia patula* (Pitcher's sandwort), *Minuartia drummondii* (Drummond sandwort), *Valerianella radiata* (beaked cornsalad), *Isoetes butleri* (Butler's quillwort), and *Allium drummondii* (Drummond wild- garlic). Other herbaceous species that may be present include *Erigeron* sp. (fleabane), *Desmanthus illinoensis* (Illinois bundleflower), *Croton monanthogynus* (doveweed), *Dalea* sp. (prairie clover), *Houstonia* spp. (bluets), *Nassella leucotricha* (Texas wintergrass), *Bouteloua curtipendula* (sideoats grama), *Eleocharis* spp. (spikerushes), *Sporobolus vaginiflorus* (poverty dropseed), *Thelesperma filifolium* (slender greenthread), and *Arnoglossum plantagineum* (groovestem Indian plantain). Sites may contain non-native species, including *Cynodon dactylon* (bermudagrass), *Lolium perenne* (Italian ryegrass), *Schedonorus phoenix* (tall fescue), *Lonicera japonica* (Japanese honeysuckle), and *Trifolium* spp. (clovers). Some woody species that may be present include *Juniperus virginiana* (eastern redcedar), *Pinus taeda* (loblolly pine), *Liquidambar styraciflua* (sweetgum), *Ligustrum sinense* (Chinese privet), *Rosa bracteata* (Macartney rose), *Cornus drummondii* (roughleaf dogwood), *Sideroxylon lanuginosum (*gum bumelia), and other species common to the surrounding landscape. Two rare species, *Lesquerella pallida* (white bladderpod) and *Leavenworthia aurea* var. *texana* (Texas golden gladecress), are associated with this system.

Potential Threats:

This ecological system faces significant threats from loss or degradation of habitat through incompatible land uses such as glauconite quarrying, infrastructure development (the Weches Formation follows a major highway in east Texas), residential development, herbicide application, grazing by livestock, tree planting, recreation vehicle use, and activities related to the exploration, production and distribution of natural gas and oil. Other threats include fragmentation and disruption of ecological processes and the resulting alteration of species composition and structure. For example, seasonal saturation and drying provided by surface water and shallow groundwater maintain aspects of this system. Alteration of hydrological processes through watershed degradation or climate change that results in drying of this system could threaten the species composition and structure dependent on seasonal saturation and drought. The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural ecosystems. This woodland-glade system was once more extensive on the landscape, but has now been reduced to scattered and isolated remnant patches, presenting conservation and management challenges. Close proximity of occurrences of this glade system may facilitate seed dispersal and cross pollination of glade species (USFWS 2013b). Non-native invasive species that impact this system include *Rosa bracteata, Lonicera japonica, Bromus japonicus, Cynodon dactylon, Kummerowia striata*, and *Trifolium dubium* (TNC 2003a).

Fire plays a critical role in the maintenance of this system and the woodlands which surround or interfinger with the rocky glades. In the absence of fire and appropriate disturbance in the landscape matrix, the areas with the shallowest soils (e.g., the glades) may be the only open areas persisting in a series of woody shrub thickets. Without fire or other disturbance, *Juniperus virginiana, Gleditsia triacanthos, Celtis laevigata, Fraxinus americana, Quercus muehlenbergii*, and *Pinus taeda* quickly regenerate, shading out the herbaceous plants, and leading to a shift in species diversity from the ground layer to the upper woody strata, resulting in a net loss of species diversity (Taft et al. 1995, J. Singhurst pers. comm. 2013). At sites with intermediate levels of woody encroachment, a signal of restoration potential is an inverse relationship between woody stem density and ground layer species richness (Taft 2009). The actual rocky or gravelly glades may not support sufficient fuel to consistently carry fire, but in the adjacent or interpenetrating perennial grasslands, occasional surface fire will retard woody plant encroachment and help maintain herbaceous diversity, as will, to an extent, grazing or mowing (Duffey et al. 1974). In addition to occasional fire, periodic drought is important in regulating woody plant encroachment. Native glade-grassland systems have evolved under a combined system of grazing, drought, and periodic fire (Duffey et al. 1974, Estes et al. 1979, Noss 2013).

Western Great Plains Mesquite Woodland and Shrubland

This vegetation system occupies areas of alluvial deposition. This system is lies along drainages and on floodplains. This system soils are located on bottomlands and soils along drainages. The system is in the High Plain and Southwestern Tableland ecoregion in Texas.Because *Prosopis glandulosa* (honey mesquite) is the characteristic dominant of this system, and that species can occupy various sites and is thought to have expanded on the landscape as a result of land-use, it is difficult to distinguish this system from areas where *Prosopis glandulosa* (honey mesquite) has invaded. The system is only mapped on bottomland soils and along drainages, while other shrublands dominated by the species are mapped as Native Invasive: Mesquite Shrubland. *Prosopis glandulosa* (honey mesquite) typically dominate the sites, sometimes occurring in the overstory canopy. Other overstory species may include species of the Western Great Plains Floodplain (CES303.678) or Western Great Plains Riparian (CES303.956) systems, such as *Celtis laevigata* var. *reticulata* (netleaf hackberry), *Sapindus saponaria* var. *drummondii* (western soapberry), *Populus deltoides* (eastern cottonwood), and *Salix nigra* (black willow). *Prosopis glandulosa* (honey mesquite) is dominant in the shrub layer, but other shrub species encountered include small representatives of the overstory, *Ziziphus obtusifolia* (lotebush), *Prunus angustifolia* (Chickasaw plum), and *Baccharis* spp. (baccharis).

Herbaceous species present in the understory may include *Panicum virgatum* (switchgrass), *Bothriochloa laguroides* var. *torreyana* (silver bluestem), *Nassella leucotricha* (Texas wintergrass), and *Schizachyrium scoparium* (little bluestem). Non-native species such as *Cynodon dactylon* (bermudagrass), *Bromus catharticus* (rescuegrass), *Sorghum halepense* (Johnsongrass), and *Bromus arvensis* (Japanese brome) are also commonly present and may be dominant.

Potential Threats:

Not documented.

Woodland

Woodland vegetation is variable, non-closed canopy; typically non-grass dominated understory; deciduous, evergreen or mixed.

Central and South Texas Coastal Fringe Forest and Woodland

This system occupies Holocene eolian sands of the South Texas Sand Sheet and sands of the Pleistocene Ingleside Barrier, which is mapped as Barrier Island and Beach Deposits of the Beaumont Formation. This system lies on generally level to gently rolling landscape. Some dunes to a height of more than 15 meters (50 feet) occur, adding significant relief to the regions. Low swales and round pothole wetlands typify low landscape positions, and significant drainage systems (in the form of streams) are generally lacking. This systems soils include sands, particularly deep sands typify this system. The system is located in the Gulf Coastal Prairies and Marshes ecoregion in Texas.

This *Quercus fusiformis* (plateau live oak) dominated system occupies deep sands resulting from eolian deposits of Holocene and Pleistocene age. Ridge and swale topography characterizes these sites, with some large (up to 15 m tall) vegetated dunes present. In addition to forest and woodland, open stands grading into surrounding grasslands occur, as well as dense shrublands dominated (almost to the exclusion of other species) by running clones of *Quercus fusiformis* (plateau live oak). Northern expressions, occurring on Ingleside Barrier sands from Calhoun to Kleberg County, differ somewhat from southern expressions, occurring on the South Texas Sand Sheet from southern Kleberg, Kenedy, and northern Willacy counties west to Brooks County.

These latitudinal expressions differ somewhat in composition, but the transition is subtle and the general character of the system remains relatively unchanged. The association CEGL007785 *Quercus fusiformis – Prosopis glandulosa* var. *glandulosa / Malvaviscus arboreus* var. *drummondii* Forest can be referred to the southern expression, while CEGL002117 *Quercus fusiformis – Persea borbonia* Forest represents the northern expression. The system occurs within a matrix of deep sand grasslands, but also as large patch forests and woodlands.

Depending on the overstory canopy and the development of the shrub layer, the herbaceous cover may resemble the surrounding grasslands, at least in composition. Herbaceous species present may include *Schizachyrium littorale* (seacoast bluestem), *Paspalum monostachyum* (gulfdune paspalum), *Paspalum plicatulum* (brownseed paspalum), *Andropogon gerardii* (big bluestem), *Sorghastrum nutans* (Indiangrass), *Elionurus tripsacoides* (Pan American balsamscale), *Trachypogon spicatus* (crinkleawn), *Acalypha radians* (cardinal's feather), *Argythamnia mercurialina* (tall wild-mercury), *Chamaecrista flexuosa* (partridge pea), *Cnidoscolus texanus* (Texas bull-nettle), *Croton argyranthemus* (silverleaf croton), *Froelichia floridana* (Florida snake-cotton), *Galactia canescens* (hoary milkpea), *Eriogonum multiflorum* (heartsepal wildbuckwheat), *Rhynchosia americana* (American snoutbean), *Stillingia sylvatica* (queen's delight), *Helianthemum georgianum* (Georgia sunrose), *Zornia bracteata* (bracted zornia), and *Thelesperma nuecense* (Nueces greenthread). In northern expressions, *Persea borbonia* (redbay) is a conspicuous component of the subcanopy, and may reach the canopy, along with *Quercus hemisphaerica* (coastal laurel oak), *Quercus marilandica* (blackjack oak), and *Celtis laevigata* (sugar hackberry). A relatively continuous shrubby understory may be dominated by species such as *Callicarpa americana* (American beautyberry), *Malvaviscus arboreus* (Turk's cap), and, in the north *Ilex vomitoria* (yaupon), or the shrub layer may not be well-developed. Other woody species in the understory may include *Zanthoxylum hirsutum* (tickle-tongue), *Condalia hookeri* (brasil), *Ziziphus obtusifolia* (lotebush), *Zanthoxylum fagara* (colima), *Forestiera angustifolia* (desert olive), *Diospyros texana* (Texas persimmon), and in the north, *Vaccinium arboreum* (farkleberry), *Erythrina herbacea* (coralbean), and *Morella cerifera* (wax-myrtle). The epiphytes *Tillandsia recurvata* (ballmoss) and *Tillandsia usneoides* (Spanish moss) are commonly encountered, with *Tillandsia bailey* (Bailey's ballmoss) less commonly found, and only in the south. *Vitis mustangensis* (mustang grape) is a conspicuous woody vine throughout, while northern expressions may also contain *Ampelopsis arborea* (peppervine), *Smilax bona-nox* (saw greenbrier), and *Toxicodendron radicans* (poison ivy). The southern occurrences of this deep sand live oak woodland and forest have some woody and herbaceous species more characteristic of the south Texas plains. Most conspicuously, live oak woodland margins in the south have an open overstory co-dominated by *Prosopis glandulosa* (honey mesquite). Mesquite occurs, but to a less conspicuous extent, in the northern portions of the system. Pothole ponds and swales accumulate water through percolation from adjacent sands, and are characterized by the presence of numerous sedges including *Cyperus* spp. (flatsedges), *Eleocharis* spp. (spikerushes), *Fimbristylis caroliniana* (Carolina fimbry), *Fuirena scirpoidea* (southern umbrellasedge), *Fuirena simplex* (western umbrellasedge), *Rhynchospora* spp. (beaksedges), *Schoenoplectus erectus* ssp. *raynalii* (sharp-scale bulrush), *Schoenoplectus saximontanus* (Rocky Mountain bulrush), and *Schoenoplectus pungens* var. *longispicatus* (common threesquare). Other species commonly encountered in these wetlands include *Andropogon glomeratus* (bushy bluestem), *Spartina patens* (marshhay cordgrass), *Echinodorus berteroi* (common burhead), *Hydrocotyle bonariensis* (largeleaf pennywort), *Juncus* spp. (rushes), *Mikania scandens* (climbing hemp-weed), *Nymphaea elegans* (tropical royalblue waterlily), *Phyla lanceolata* (lanceleaf frogfruit), *Sagittaria longiloba* (longlobe arrowhead), and *Typha domingensis* (southern cattail).

Potential Threats:

Not documented.

Crosstimbers Oak Forest and Woodland

The eastern occurrences of this system are associated with sandy members of the Cretaceous Woodbine Formation, while western occurrences occupy soils derived from the sands of the Cretaceous Trinity Group (such as Paluxy, Antler, and Twin Mountain-Travis Peak Sands). Further west, in the fringe of the Western Crosstimbers, the system occurs on more rugged, rocky and gravelly sites derived from Pennsylvanian formations. This system lies along gently rolling, moderately dissected uplands, and irregular plains becoming more rugged in the western fringe of the distribution of this system. This systems soils include sands or sandy loams, some with a claypan, are characteristic of this system. Ecological Sites typical of the eastern expressions include Sandy Loam, Tight Sandy Loam, Claypan Prairie, Sandstone Hill, and Sandy. Those more typical of the western expressions include Sandy Loam, Loamy Sand, Tight Sandy Loam, Sandy, Rocky Hill, and Clay Loam. The system is located in the Central Great Plains ecoregion in Texas.

This vegetation system is generally described as a savanna or woodland dominated by *Quercus stellata* (post oak) and/or *Quercus marilandica* (blackjack oak) and occurring in southwest- northeast trending bands separated by the Grand Prairie. Other species in the canopy may include *Ulmus crassifolia* (cedar elm), *Quercus fusiformis* (plateau live oak), *Celtis laevigata* (sugar hackberry), and *Juniperus virginiana* (eastern redcedar). The understory may have been historically dominated by *Schizachyrium scoparium* (little bluestem), but current understory composition may be largely determined by land use history and grazing pressure. In the east, where precipitation is greater, tallgrass species such as *Andropogon gerardii* (big bluestem) and *Sorghastrum nutans* (Indiangrass) may be important components of the understory, or occupy prairie patches. In the drier west, shortgrass species such as *Bouteloua dactyloides* (buffalograss) become more conspicuous. Other graminoid species that may be present include *Schizachyrium scoparium* (little bluestem), *Paspalum setaceum* (fringeleaf paspalum), *Sporobolus compositus* (tall dropseed), *Bouteloua curtipendula* (sideoats grama), *Bouteloua hirsuta* (hairy grama), *Bouteloua rigidiseta* (Texas grama), *Bothriochloa laguroides* ssp. *Torreyana* (silver bluestem), *Nassella leucotricha* (Texas wintergrass), and *Aristida* spp. (threeawn). Non- native species such as *Bromus catharticus* (rescuegrass), *Cynodon dactylon* (bermudagrass) and *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem) frequently dominate the herbaceous layer. With the disruption of a natural fire cycle, branching of overstory species may be continuous to near ground level, reducing light penetration and leading to reduced herbaceous cover. The shrub layer may contain species such as *Smilax bona-nox* (greenbrier), *Rhus glabra* (smooth sumac), *Rhus trilobata* (skunkbush sumac), *Crataegus* spp. (hawthorn), and *Symphoricarpos orbiculatus* (coral-berry). Sites dominated by *Prosopis glandulosa* (mesquite), sometimes with *Ziziphus obtusifolia* (lotebush) as a common shrub component, are particularly common to the west. Juniper (including *Juniperus virginiana* (eastern redcedar), *Juniperus ashei* (Ashe juniper), and *Juniperus pinchotii* (redberry juniper), depending on the site) dominated sites are also frequently encountered. Prairie openings and inclusions tend to occur on tighter soils.

The Eastern Crosstimbers occupy a relatively narrow band, approximately 20 miles wide running from McLennan County in the south to the Red River. The Western Crosstimbers is a broader belt, running from about Callahan County in the south, north and east to Montague County. The Western Crosstimbers can further be divided into the Main Belt which has developed on soils derived from the Cretaceous Trinity Group sands, and the more westerly Fringe which has developed on the more rugged and rocky/gravelly sites derived from Pennsylvanian formations.

Potential Threats:

Drought, grazing, and fire are the primary natural processes that affect this system. Overgrazing and conversion to agriculture, along with fire suppression, have led to the invasion of some areas by problematic brush species such as *Juniperus virginiana* and *Juniperus ashei* and *Prosopis glandulosa* farther south in Texas and Oklahoma. It has also led to decreases in native grass cover allowing for annual grasses and forbs to invade.

East-Central Texas Plains Post Oak Savanna and Woodland

This vegetation system opccurs tyypically on sedimentary formations of Tertiary age, including Eocene sands such the Queen City, Sparta, and Carrizo Sands, as well as the Wilcox and Claiborne groups. The system also occupies other Teritary formations such as the Goliad and Willis, as well as portions of the Quaternary Willis Formation. This system occupies gently rolling to hilly topography. It is moderately dissected by drainages. This system soils usually occurs on sandy to sandy loam soils, often with a marked clay subsurface horizon. Soils of this system are generally Alfisols, and are typically acidic to neutral. Typical Ecological Sites include Claypan Savannah, Claypan Prairie, Sandy Loam, Sandy, and Deep Sand. The system is in the Texas Blackland Prairie ecoregion in Texas.

This system represents a transition from the woodlands and forests of East Texas to the prairies to the west, specifically the Blackland Prairie. Savannas and woodlands are typically dominated by *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), and *Carya texana* (black hickory). Large areas of woodland, particularly in the south and east, are dominated or co- dominated by *Quercus fusiformis* (plateau live oak) or *Quercus virginiana* (coastal live oak, east of the Brazos River). Other species, such as *Quercus incana* (bluejack oak) (on more xeric sites), *Ulmus alata* (winged elm), *Ulmus crassifolia* (cedar elm), *Quercus nigra* (water oak), *Juniperus virginiana* (eastern redcedar), *Celtis laevigata* (sugar hackberry), and *Prosopis glandulosa* (mesquite), can also be present in the overstory. To the east, *Quercus falcata* (southern red oak), *Quercus nigra* (water oak), *Liquidambar styraciflua* (sweetgum), *Pinus echinata* (shortleaf pine), *Pinus taeda* (loblolly pine), and *Carya alba* (mockernut hickory) may be conspicuous in the overstory. Shrubs may attain significant cover in the understory, with species including *Ilex vomitoria* (yaupon) (often dominant), *Callicarpa americana* (American beautyberry), *Sideroxylon lanuginosum* (gum bumelia), *Crataegus* spp. (hawthorn), *Ilex decidua* (possumhaw), *Toxicodendron radicans* (poison ivy), *Smilax bona-nox* (saw greenbrier), *Juniperus virginiana* (eastern redcedar), and *Symphoricarpos orbiculatus* (coral-berry). To the south, this system grades into vegetation more characteristic of south Texas, with *Quercus fusiformis* (plateau live oak) and *Prosopis glandulosa* (honey mesquite) becoming the primary overstory components, and shrubs of south Texas such as *Acacia rigidula* (blackbrush), *Forestiera angustifolia* (desert olive), *Condalia hookeri* (brasil), *Colubrina texensis* (Texas hogplum), *Eysenhardtia texana* (Texas kidneywood), *Opuntia engelmannii* var. *lindheimeri* (Lindheimer pricklypear), and *Diospyros texana* (Texas persimmon) becoming increasingly conspicuous understory components. To the east, *Vaccinium arboreum* (farkleberry), *Morella cerifera* (wax-myrtle), *Diospyros virginiana* (common persimmon), and *Cornus florida* (flowering dogwood) may be common components of the understory. On some sites, *Ilex vomitoria* (yaupon) can form nearly continuous, sometimes impenetrable, dense shrub layer. Mid- and tallgrass species including *Schizachyrium scoparium* (little bluestem), *Sorghastrum nutans* (Indiangrass), and *Panicum virgatum* (switchgrass) are frequent in the understory where light penetration supports herbaceous cover, and also form prairie patches within the savanna, particularly on tighter soils. Other grasses present include *Andropogon gerardii* (big bluestem), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Paspalum plicatulum* (brownseed paspalum) (to the south), *Nassella leucotricha* (Texas wintergrass), *Dichanthelium* spp.

(rosette grasses), *Aristida* spp. (threeawn), and *Sporobolus cryptandrus* (sand dropseed). Non-native grass species such as *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem), *Paspalum notatum* (bahiagrass), and *Cynodon dactylon* (bermudagrass) may dominate some sites. Forbs are often conspicuous, and may include species such as *Croton capitatus* (hog croton), *Gaillardia pulchella* (Indian blanket), *Monarda punctata* (spotted beebalm), *Rudbeckia hirta* (blackeyed Susan), *Phlox drummondii* (Drummond phlox), *Commelina erecta* (erect dayflower), *Acalypha radians* (cardinal's feather), *Verbesina virginica* (frostweed), *Aphanostephus skirrhobasis* (lazy daisy), *Froelichia gracilis* (slender snake cotton), *Cnidoscolus texanus* (Texas bull-nettle), and many others.

Drought, grazing, and fire are the primary natural processes that affect this system. Much of this system has been impacted by conversion to improved pasture or crop production. Overgrazing and fire suppression have led to increased woody cover on most extant occurrences and the invasion of some areas by problematic brush species such as *Juniperus virginiana* (eastern redcedar) (to the north) and *Prosopis glandulosa* (honey mesquite) (to the south). The system is in the Central Geta Plains, Cross Timbers, Edwards Plateau, South Texas plains, and Texas Blackland Prairie ecoregions in Texas.

Potential Threats:

Though exact physiognomic condition of this ecological system during presettlement times is unknown, reconstruction of this history suggests that density of woody vegetation is higher today than historically (Campbell 1925, Tharp 1926, McBride 1933, Parmalee 1955, Midwood et al. 1998, Singhurst et al. 2004, Stambaugh et al. 2011b). Factors influencing the primary processes affecting this system, in particular, overgrazing and altered fire regimes, are likely responsible for this change in physiognomy, including invasion of some areas by problematic brush species such as *Juniperus virginiana var. virginiana* (to the north) and *Prosopis glandulosa* (to the south). These factors have also led to decreases in native grass cover allowing for annual grasses and forbs to invade. In addition, much of this system has been impacted by conversion to exotic pasture grasses *Cynodon dactylon* and *Paspalum notatum*. Other invasive species issues include *Ligustrum sinense, Melia azedarach, Triadica sebifera, Ailanthus altissima*, feral hogs, and red imported fire ants (TPWD 2012a). Early land uses, including grazing, then farming, and today urban and rural development, infrastructure development, and lignite coal mining, have resulted in the clearing of vast areas (Parmalee 1955, Bartlett 1995, Loucks 1999). Other threats include fragmentation and erosion (Bartlett 1995, Loucks 1999). Impacts of the altered composition and structure of vegetation regrowth since original land clearing are not well-studied and the vast majority of what remains is under private ownership. Less than 1% of the ecological system is under conservation management (Bezanson 2000).

Edwards Plateau Dry-Mesic Slope Forest and Woodland

This vegetation system is found on limestone (primarily Creatceous or Pennsylvanian) slopes within the Edwards Plateau and adjacent ecoregions, including the Carbonate Cross Timbers in the Palo Pinto County area and the Callahan Divide. Cuestas of cretaceous chalk in the Blackland Prairie and calcareous slopes of the Crosstimbers may also be occupied by this system. This system lies along slopes generally greater than 20 percent. This systems soils are comprised of Stones and boulders are conspicuous on the soil surface. Soils are generally dark clay to clay loam and shallow. Steep Rocky and Steep Adobe Ecological Sites may be associated with this system. The system is located in the Texas Blackland Prairie ecoregion in Texas.

This system occurs on dry to mesic, middle slopes of the rolling uplands and escarpments of the Edwards Plateau and similar sites. The canopy is typically dominated or co-dominated by deciduous trees, including *Quercus buckleyi* (Texas oak), *Quercus laceyi* (Lacey oak), *Quercus sinuata* var. *breviloba* (white shin oak), *Fraxinus texensis* (Texas ash), *Ulmus crassifolia* (cedar elm), *Prunus serotina* ssp. *eximia* (escarpment black cherry), *Juglans major* (Arizona walnut), and/or *Celtis laevigata* var. *reticulata* (netleaf hackberry). *Quercus fusiformis* (plateau live oak) and *Juniperus ashei* (Ashe juniper) are often present and are sometimes co-dominant with deciduous species of this system. Canopy closure is variable, and this system can be expressed as forests or woodlands. The shrub layer may be well-represented, especially where the overstory canopy is discontinuous. Species such as *Aesculus pavia* var. *flavescens* (red buckeye), *Cercis canadensis* var. *texensis* (Texas redbud), *Forestiera pubescens* (elbowbush), *Ungnadia speciosa* (Mexican buckeye), *Ceanothus herbaceus* (Jersey tea), *Frangula caroliniana* (Carolina buckthorn), *Sophora secundiflora* (Texas mountain-laurel), *Viburnum rufidulum* (rusty blackhaw), *Rhus* spp. (sumac), *Vitis* spp. (grape), and *Garrya ovata* (silktassel) may be present in the shrub layer. With the large amount of exposed rock, frequent accumulation of leaf litter, and significant canopy closure, herbaceous cover is generally sparse, with *Carex planostachys* (cedar sedge) often present. Woodland forbs such as *Tinantia anomala* (widowstears), *Chaptalia texana* (silver-puff), *Nemophila phacelioides* (baby blue-eyes), *Salvia roemeriana* (cedar sage), *Lespedeza texana* (Texas lespedeza), and various ferns may also be present, if patchy. Grasses such as *Schizachyrium scoparium* (little bluestem) and *Bouteloua* spp. (gramas) may occur, typically scattered and patchy.

Potential Threats:

Not documented.

Madrean Encinal

This vegetation system may occur on various substrates including Permian limestones of Guadalupe, Tertiary igneous formations, and sandstone formation, and even colluvial/alluvial substrates at middle elevations in mountainous areas of the Trans-Pecos. This system lies along mountain slopes and rolling uplands in mountainous areas. This system may occur on a wide range of soils, often rocky or gravelly, derived from limestone, sandstone, or igneous parent material. It may also occur on loams and alluvial surfaces. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregions of Texas. This system sometimes co-occurs with the Madrean Pinyon-Juniper Woodland and also grades into the Madrean Lower Montane Pine-Oak Forest and Woodland at higher elevations. It may replace the pinyon-juniper woodland at lower elevations and grade into desert grasslands, desert shrublands or montane chaparral. These lower elevation occurrences tend to be more open woodlands and savannas. Oak species typically dominate these woodlands with species such as *Quercus grisea* (gray oak), *Quercus emoryi* (Emory oak), *Quercus hypoleucoides* (silverleaf oak), *Quercus arizonica* (Arizona white oak), and/or *Quercus rugosa* (netleaf oak). On limestone, *Quercus mohriana* (Mohr's shin oak) may be common. Various pine and juniper species, such as *Juniperus deppeana* (alligator juniper), *Pinus cembroides* (Mexican pinyon pine), *Pinus edulis* (pinyon pine, in the Guadalupe Mountains region), may be conspicuous elements of the canopy. This system may be present as a shrubland, closed woodland, or open woodland. In addition to the oak, pine, and juniper species, other shrubs that may be encountered include *Mimosa aculeaticarpa* var. *biuncifera* (catclaw mimosa), *Mimosa dysocarpa* (velvetpod mimosa), *Rhus trilobata* (skunkbush sumac), and *Cercocarpus montanus* (mountain mahogany). *Viguiera stenoloba* (skeleton-leaf golden eye), *Parthenium incanum* (mariola), and other species common to the deserts of lower elevations may be present to common. *Nolina texana* (Texas sacahuista), *Dasylirion leiophyllum* (smooth sotol), *Opuntia imbricata* (tree cholla), and *Agave* spp. (agaves) are commonly encountered. The herbaceous layer is typically dominated by graminoids such as *Muhlenbergia emersleyi* (bull muhly), *Bouteloua curtipendula* (sideoats grama), *Bouteloua gracilis* (blue grama), *Bouteloua hirsuta* (hairy grama), *Bouteloua eriopoda* (black grama), *Piptochaetium fimbriatum* (pinyon ricegrass), and *Heteropogon contortus* (tanglehead), but this layer may be sparse.

Potential Threats:

Wildfire suppression, overgrazing, introduced invasive plant species, firewood collection.

Madrean Lower Montane Pine-Oak Forest and Woodland

These woodlands are described within the "forest" section of this document. Due to the arid nature of these systems many examples of this habitat type have a more open canopy and would be considered a woodland.

Potential Threats:

Not documented.

Madrean Pinyon-Juniper Woodland

This vegetation system mainly occupies tertiary igneous substrates, including rhyolitic and tuff formations, as well as Permian and Cretaceous limestones. This systems other substrates such as sandstone and colluvium are also found associated with this system. This system lies along rugged to gently rolling landscapes of hills and mountains at intermediate elevations. This systems typically occupies Igneous Hill and Mountain as well as Limestone Hill and Mountain ecoclasses, but may occur on various other ecoclasses, including Limestone Hill, Mountain Loam, Foothill Slope, Igneous Divide, Shallow, Sandstone Hill and Mountain, and others. This system occurs in the Chihuahuan Deserts ecoregion of Texas.

This system occurs in the hills and mountains of the Trans-Pecos as well as in Mexico, New Mexico, and Arizona. Soils, often derived from igneous or limestone parent material (but other substrates are encountered) in Texas, are generally dry and rocky on rugged to gently rolling mountain slopes, foothills, and hills. This system can present as shrublands, open woodlands, or closed woodlands. Pinyon pines and junipers typically dominate, but oaks may co-dominate some occurrences and are often present. Pine species typical of the canopy include *Pinus cembroides* (Mexican pinyon pine), *Pinus edulis* (pinyon, primarily in the Guadalupe and Sierra Diablo Mountains), or *Pinus remota* (paper-shell pinyon). Junipers codominating with the pines include *Juniperus deppeana* (alligator juniper), *Juniperus pinchotii* (redberry juniper), *Juniperus monosperma* (one-seeded juniper), or *Juniperus coahuilensis (rose-fruited juniper)*. Oaks, which may be present to codominant with pines and junipers, include *Quercus grisea* (gray oak), *Quercus mohriana* (Mohr's shin oak), *Quercus emoryi* (Emory oak), and/or *Quercus gravesii* (Chisos red oak). In woodlands, the understory may have a well-developed shrub layer, often of the species in the canopy but also sometimes including species such as *Cercocarpus montanus* (mountain mahogany), *Rhus trilobata* (skunkbush sumac), and *Mimosa aculeaticarpa* var. *biuncifera* (catclaw mimosa). The herbaceous layer of woodlands or shrublands are typically dominated by graminoids, and may include species such as *Bouteloua curtipendula* (sideoats grama), *Bouteloua gracilis* (blue grama), *Bouteloua hirsuta* (hairy grama), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Muhlenbergia pauciflora* (New Mexican muhly), *Muhlenbergia setifolia* (curlyleaf muhly), *Nassella tenuissima* (finestem needlegrass), *Piptochaetium fimbriatum* (pinyon ricegrass), and *Muhlenbergia emersleyi* (bull muhly). In Culberson County, the pine (*Pinus edulis*) and juniper (*Juniperus monosperma*) show the relationship of this system to other pinyon-juniper systems to the north, but other components of these occurrences recommend the relationship to the Madrean system.

Potential Threats:

Human activities have disrupted the Madrean pinyon-juniper woodland ecological system. Fire suppression and grazing have increased woody species and changed woody species composition. The fire regime has been impacted differently based on stand structure. Pinyon-juniper woodlands face threats from fuelwood cutting, fragmentation, and invasive non-native species, which alter age structure, tree density, and cover, and increase fire frequency and size.

Rocky Mountain Aspen Forest and Woodland

These woodlands are described within the “forest” section of this document. Due to the arid nature of these systems many examples of this habitat type have a more open canopy and would be considered a woodland.

Potential Threats:

Populus tremuloides forests in the western US are mainly used for grazing and wood products. Heavy grazing by livestock can deplete understory and convert it to grazing-tolerant grasses. Logging and human development have impacted many locations in the ecoregion. Stand structure is affected by silviculture treatment. Prescribed burning and introduced species can regenerate stands.

Rocky Mountain Bigtooth Maple Ravine Woodland

These woodlands are described within the “forest” section of this document. Due to the arid nature of these systems many examples of this habitat type have a more open canopy and would be considered a woodland

Potential Threats:

Range-limited: In Texas, this system occurs as small patches within the higher elevation conifer systems of the Guadalupe, Davis, and Chisos mountains. These patches are considered relictual remnants in this southwestern extension of this more commonly encountered type further north.

Southern Rocky Mountain Pinyon-Juniper Woodland

This vegetation system mainly occupies Tertiary igneous substrates, including rhyolitic and tuff formations, as well as Permian and Cretaceous limestones. Other substrates such as sandstone and colluvium are also found associated with this system. This system lies along rugged to gently rolling landscapes of hills and mountains at intermediate elevations. These system soils typically occupies Igneous Hill and Mountain as well as Limestone Hill and Mountain ecoclasses, but may occur on various other ecoclasses, including Limestone Hill, Mountain Loam, Foothill Slope, Igneous Divide, Shallow, Sandstone Hill and Mountain, and others. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregions of Texas.

This system occurs in the hills and mountains of the Trans-Pecos as well as in Mexico, New Mexico, and Arizona. Soils, often derived from igneous or limestone parent material (but other substrates are encountered) in Texas, are generally dry and rocky on rugged to gently rolling mountain slopes, foothills, and hills. This system can present as shrublands, open woodlands, or closed woodlands. Pinyon pines and junipers typically dominate, but oaks may co-dominate some occurrences and are often present. Pine species typical of the canopy include *Pinus cembroides* (Mexican pinyon pine), *Pinus edulis* (pinyon, primarily in the Guadalupe and Sierra Diablo Mountains), or *Pinus remota* (paper-shell pinyon). Junipers codominating with the pines include *Juniperus deppeana* (alligator juniper), *Juniperus pinchotii* (redberry juniper), *Juniperus monosperma* (one-seeded juniper), or *Juniperus coahuilensis (rose-fruited juniper)*. Oaks, which may be present to codominant with pines and junipers, include *Quercus grisea* (gray oak), *Quercus mohriana* (Mohr's shin oak), *Quercus emoryi* (Emory oak), and/or *Quercus gravesii* (Chisos red oak). In woodlands, the understory may have a well-developed shrub layer, often of the species in the canopy but also sometimes including species such as *Cercocarpus montanus* (mountain mahogany), *Rhus trilobata* (skunkbush sumac), and *Mimosa aculeaticarpa* var. *biuncifera* (catclaw mimosa). The herbaceous layer of woodlands or shrublands are typically dominated by graminoids, and may include species such as *Bouteloua curtipendula* (sideoats grama)*, Bouteloua gracilis* (blue grama)*, Bouteloua hirsuta* (hairy grama)*, Bothriochloa laguroides* ssp. *torreyana* (silver bluestem)*, Muhlenbergia pauciflora* (New Mexican muhly)*, Muhlenbergia setifolia* (curlyleaf muhly)*, Nassella tenuissima* (finestem needlegrass)*, Piptochaetium fimbriatum* (pinyon ricegrass), and *Muhlenbergia emersleyi* (bull muhly). In Culberson County, the pine (*Pinus edulis*) and juniper (*Juniperus monosperma*) show the relationship of this system to other pinyon-juniper systems to the north, but other components of these occurrences recommend the relationship to the Madrean system.

Potential Threats:

The system of open woodland on rocky ridges has been significantly altered since 1900 due to altered fire regimes, overgrazing, and tree cutting. Fire suppression and grazing by livestock have reduced fire frequency and increased tree density.

Stressors like invasive species, insect/disease outbreaks, fuel wood cutting, and soil erosion affect stand quality and fire behavior. Livestock disturb soil crusts and spread invasive species. Human development, mining, and road building fragment vegetation. Chaining pinyon-juniper stands creates epidemic outbreaks of beetles that attack and kill healthy pinyons. Drought stresses pinyon trees and makes them vulnerable to ips beetle attacks.

Southern Rocky Mountain Ponderosa Pine Woodland

This vegetation system occurs within the region occurs in the southern Rocky Mountains at the lower treeline/ecotone between grassland or shrubland and more mesic coniferous forests.

Stands are typically found in warm, dry, exposed sites at elevations ranging from 1980-2800 m (6500-9200 feet). This systems climate is temperate with cold winter and warm summers.

Precipitation generally contributes 25-60 cm annually to this system, mostly through winter snow and some monsoonal summer rains. Typically, a seasonal drought period occurs throughout this system as well. This system stands can occur on all slopes and aspects; however, it commonly occurs on moderately steep to very steep slopes or ridgetops in foothills and lower montane slopes. This system soils are variable. This ecological system generally occurs on soils derived from igneous, metamorphic, and sedimentary material, including basalt, basaltic, andesitic flows, intrusive granitoids and porphyrites, and tuffs (Youngblood and Mauk 1985).

Characteristic soil features include good aeration and drainage, coarse textures, circumneutral to slightly acidic pH, an abundance of mineral material, and periods of drought during the growing season. Some occurrences may occur as edaphic climax communities on very skeletal, infertile, and/or excessively drained soils, such as pumice, cinder or lava fields, and scree slopes. Surface textures are highly variable in this ecological system ranging from sand to loam and silt loam. Exposed rock and bare soil consistently occur to some degree in all the associations. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregions of Texas.

Pinus ponderosa (primarily *var. scopulorum* and *var. brachyptera*) is the predominant conifer; *Pseudotsuga menziesii, Pinus edulis, Pinus contorta, Populus tremuloides*, and *Juniperus* spp. may be present in the tree canopy. The understory is usually shrubby, with *Artemisia nova, Artemisia tridentata, Arctostaphylos patula, Arctostaphylos uva-ursi, Cercocarpus montanus, Purshia stansburiana, Purshia tridentata, Quercus gambelii, Symphoricarpos* spp., *Prunus virginiana, Amelanchier alnifolia* (less so in Montana), and *Rosa* spp. common species. *Pseudoroegneria spicata, Pascopyrum smithii*, and species of *Hesperostipa, Achnatherum, Festuca, Muhlenbergia*, and *Bouteloua* are some of the common grasses.

Potential Threats

With settlement and a century of anthropogenic disturbance and fire suppression, stands now have altered species composition resulting in altered fire regime and ecological functions. Many stands now contain understories of more shade-tolerant species, such as *Pseudotsuga menziesii* and/or *Abies* spp., as well as younger cohorts of *Pinus ponderosa*. Presettlement fire regimes were primarily frequent (5- to 15-year return intervals), low-intensity ground fires triggered by lightning strikes or deliberately set by Native Americans. With fire suppression and increased fuel loads, fire regimes are now less frequent and often become intense crown fires, which can kill mature pines (Reid et al. 1999).

Conversion of this type has commonly come from urban and exurban development, especially along the Front Range, water developments and reservoirs. With long-term fire suppression, stands have converted through succession to Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland (CES306.823). Restoration to open woodland is difficult or impossible when adjacent to housing development. Common stressors and threats include fragmentation from housing and water developments, altered fire regime from fire suppression and indirectly from livestock grazing and fragmentation, and introduction of invasive non-native species (CNHP 2010).

West Gulf Coastal Plain Chenier and Upper Texas Coastal Fringe Forest and Woodland

This system occupies Quaternary deposits associated with migrating shorelines, shell ridges, and coastal salt domes. The Ingleside Barrier strandplain, an ancient barrier ridge composed of deep sands and occurring well inland of the current Gulf shoreline, may have occurrences of this system associated with it. Most occurrences of this systems occupy ridges formed from sediments deposited along ancient shorelines. These ridges, which often parallel the coast and are composed of coarse material such as sand or shell, may be up to 3 meters above mean sea level. Some occurrences occupy coastal salt domes, which may rise 30 meters above the surrounding landscape. This system soils are typically entisols of coarse textured material, either sand or shell. The Ecological Site Description, which may be related to this system, is the Coastal Sand ecoclass. This system occurs West Gulf Coastal Plain ecoregion of Texas.

This woodland occupies sand and shell ridges which resulted from ancient abandoned beach ridges. It may also be found on salt domes near the coast. Typically these forests and woodlands are dominated by *Quercus virginiana* (coastal live oak), however other species such as *Celtis laevigata* (sugar hackberry) and *Quercus nigra* (water oak) may be present to co-dominant in the canopy. Other species such as *Liquidambar styraciflua* (sweetgum), *Carya illinoinensis* (pecan), *Diospyros virginiana* (common persimmon), *Fraxinus pennsylvanica* (green ash), and *Magnolia grandiflora* (southern magnolia) may also be present in the canopy. The understory is often patchy but may include species such as *Ilex vomitoria* (yaupon), *Callicarpa americana* (American beautyberry), *Zanthoxylum clava- herculis* (Hercules-club pricklyash), *Crataegus viridis* (green hawthorn), *Sabal minor* (dwarf palmetto), *Morella cerifera* (wax-myrtle), and/or *Sideroxylon lanuginosum* (gum bumelia).

Woody vines present in this system include *Vitis mustangensis* (Mustang grape), *Parthenocissus quinquefolia* (Virginia creeper), *Campsis radicans* (trumpet creeper), and *Toxicodendron radicans* (poison ivy). The two epiphytes, *Tillandsia usneoides* (Spanish moss) and *Pleopeltis polypodioides* (resurrection fern), may be commonly encountered in this system. The herbaceous layer is usually sparse, but may include species such as *Schizachyrium scoparium* (little bluestem), *Sanicula canadensis* (Canada snakeroot), *Malvaviscus arboreus* var. *drummondii* (Drummond turk's cap), *Elephantopus carolinianus* (leafy elephantfoot), and *Oplismenus hirtellus* (basketgrass). Areas that were mapped tended to represent wetter areas than are typical of this type, with species such as *Quercus phellos* (willow oak) and *Quercus laurifolia* (laurel oak) conspicuous in the canopy. *Triadica sebifera* (Chinese tallow) and *Ligustrum sinense* (Chinese privet) may be important non- native invaders into this system.

Potential Threats:

The primary threats to this ecological system are clearing and conversion to other land uses such as pasture, residential development, and infrastructure, sand mining, invasive species such as *Triadica sebifera*, and the reduced formation of new beach ridges (Neyland and Meyer 1997). Only 2 to 10% of the presettlement occurrences of this system remain in Louisiana (LDWF 2005) and these fragmented remnants are further impacted by overgrazing and invasive species. Very little of this system is under conservation ownership (LDWF 2005).

West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland

The vegetation is generally associated with Eocene sand formations such as Carrizo, Sparta, and Queen City sands. Also found on sands derived from the Pliocene Willis formation. This system is generally found on high, convex landscape positions, such as hilltops and ridgetops. This system's soils include deep sands of soils such as the Betis, Darco, Letney, Tehran, Tonkawa, and other grossarenic or psammentic soils. This system occurs in the West Gulf Coastal Plain and East Central Plain ecoregions of Texas.

This system occupies deep sands on generally high, convex landforms, and often displays a relatively open overstory canopy. It may occur as pine dominated woodlands, with *Pinus palustris* (longleaf pine) dominating some sites within the range of this species, and *Pinus echinata* (shortleaf pine) dominating areas where *Pinus palustris* (longleaf pine) is absent. In the current landscape, *Pinus taeda* (loblolly pine) is a common and sometimes dominant pine species. Pines may co-dominate along with deciduous species, or the canopy may be dominated by oak and other deciduous species such as *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), *Quercus incana* (bluejack oak), *Quercus falcata* (southern red oak), *Quercus margarettae* (sand post oak), and *Carya texana* (black hickory). Other deciduous trees present may include *Sassafras albidum* (sassafras), *Liquidambar styraciflua* (sweetgum), and *Quercus nigra* (water oak). The shrub stratum can be fairly well-developed, and includes shorter individuals of canopy species in addition to such species as *Callicarpa americana* (American beautyberry), *Ilex vomitoria* (yaupon), *Vaccinium arboreum* (farkleberry), *Rhus aromatica* (fragrant sumac), *Asimina parviflora* (dwarf pawpaw), *Cornus florida* (flowering dogwood), and *Smilax bona-nox* (saw greenbrier). The herbaceous layer may be quite well-developed or relatively patchy (with areas of bare sandy soil exposed). Commonly encountered species include *Schizachyrium scoparium* (little bluestem), *Pteridium aquilinum* (brackenfern), *Aristida desmantha* (curly threeawn), *Ambrosia psilostachya* (western ragweed), *Cnidoscolus texanus* (Texas bull-nettle), *Rudbeckia hirta* (blackeyed susan), *Dichanthelium dichotomum* (cypress panicgrass), *Pityopsis graminifolia* (narrowleaf silkgrass), *Croton argyranthemus* (silverleaf croton), *Tragia urticifolia* (nettleleaf noseburn), *Froelichia floridana* (Florida snake-cotton), *Matelea cynanchoides* (creeping milkvine), *Opuntia humifusa* (eastern pricklypear), *Sporobolus junceus* (pineywoods dropseed), *Triplasis purpurea* (purple sandgrass), *Bulbostylis ciliatifolia* (capillary hairsedge), *Chamaecrista fasciculata* (partridge pea), *Berlandiera pumila* (soft greeneyes), *Commelina erecta* var. *angustifolia* (narrowleaf dayflower), *Stylisma pickeringii* (bigpod bonamia), *Tradescantia reverchonii* (Reverchon spiderwort), *Rhynchosia* spp. (snoutbeans), *Tephrosia* spp. (tephrosia), and *Yucca louisianensis* (Gulf Coast yucca). Accurate mapping of this system proved problematic because this system does not occur on all areas where the typical deep sands are mapped. Mapping only areas of high landscape position (the method used in this effort) tended to under-represent the system as it occurs on the landscape.

Potential Threats:

The primary threat to this system is conversion to pine plantations or other agriculture (e.g., watermelon farms), increase in canopy closure due to alterations of the natural fire regime, and conversion developed land uses.

Forest

Forests as defined in this document are generally have a closed canopy, or upper layer tree crown leaf-cover. They can be deciduous, evergreen, or mixed forest types. Evergreen forests in Texas can be comprised of needle-leaf trees, broadleaf evergreen trees or a combination of both. This category only includes Texas' upland forests. These occur throughout the state but tend to cover less area in the western portion of Texas.

Riparian (related to the banks of a river), forested wetland, and bottomland hardwood habitat types are recognized as distinctly different from surrounding lands because of unique soil and vegetation characteristics strongly influenced by water and the influence those types have on the health of aquatic systems. They are separated from this category to emphasize that connectivity to water resources and contributions to aquatic system function.

Cross Timbers Oak Forest and Woodland

The eastern occurrences of this system are associated with sandy members of the Cretaceous Woodbine Geologic Formation, while western occurrences occupy soils derived from the sands of the Cretaceous

Trinity Group (such as Paluxy, Antler, and Twin Mountain- Travis Peak Sands). Further west, in the fringe of the Western Crosstimbers, the system occurs on more rugged, rocky and gravelly sites derived from Pennsylvanian formations. These forests and woodlands occur on gently rolling, moderately dissected uplands, and irregular plains becoming more rugged in the western fringe of the distribution of this system. Sands or sandy loam soils, some with a claypan, are characteristic of this system. This ecological system is widespread in Oklahoma and occurs at a smaller scale in Arkansas, with its northern extant in Kansas

This system is generally described as a savanna or woodland dominated by *Quercus stellata* (post oak) and/or *Quercus marilandica* (blackjack oak) and occurring in southwest-northeast trending bands separated by the Grand Prairie. Other species in the canopy may include *Ulmus crassifolia* (cedar elm), *Quercus fusiformis* (plateau live oak), *Celtis laevigata* (sugar hackberry), and *Juniperus virginiana* (eastern redcedar). The understory may have been historically dominated by *Schizachyrium scoparium* (little bluestem), but current understory composition may be determined by land use history and grazing pressure. In the east, where precipitation is greater, tallgrass species such as *Andropogon gerardii* (big bluestem) and *Sorghastrum nutans* (Indiangrass) may be important components of the understory or occupy prairie patches. In the drier west, shortgrass species such as *Buchloe dactyloides* (buffalograss) become more conspicuous. Other grass-like species that may be present include *Schizachyrium scoparium* (little bluestem), *Paspalum setaceum* (fringeleaf paspalum), *Sporobolus compositus* (tall dropseed), *Bouteloua curtipendula* (sideoats grama), *Bouteloua hirsuta* (hairy grama), *Bouteloua rigidiseta* (Texas grama), *Bothriochloa laguroides* ssp. torreyana (silver bluestem), *Nassella leucotricha* (Texas wintergrass), and *Aristida* spp. (threeawn). Non-native species such as *Bromus catharticus* (rescuegrass), *Cynodon dactylon* (Bermuda grass) and *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem) frequently dominate the herbaceous layer.

With the disruption of a natural fire cycle, branching of overstory species may be continuous to near ground level, reducing light penetration and leading to reduced herbaceous cover. The shrub layer may contain species such as *Smilax bonanox* (greenbrier), *Rhus glabra* (smooth sumac), *Rhus trilobata* (skunkbush sumac), *Crataegus* spp. (hawthorn), and *Symphoricarpos orbiculatus* (coral-berry). Sites dominated by *Prosopis glandulosa* (mesquite), sometimes with *Ziziphus obtusifolia* (lotebush) as a common shrub component, are particularly common to the west. Juniper (including Juniperus virginiana (eastern redcedar), *Juniperus ashei* (Ashe juniper), and *Juniperus pinchotii* (redberry juniper), depending on the site) dominated sites are also frequently encountered. Prairie openings and inclusions tend to occur on tighter soils.

The Eastern Crosstimbers occupy a relatively narrow band, approximately 20 miles wide running from McLennan County in the south to the Red River. The Western Crosstimbers is a broader belt, running from about Callahan County in the south, north and east to Montague County. The Western Crosstimbers can further be divided into the Main Belt which has developed on soils derived from the Cretaceous Trinity Group sands, and the more westerly Fringe which has developed on the more rugged and rocky/gravelly sites derived from Pennsylvanian formations.

Bastrop Lost Pines Forest and Woodland

Sandy Eocene formations, such as Carrizo, Sparta, and Queen City formations are most frequent geology associated with this system, though it may also occur on the Reklaw Formation and other adjacent formations. Landforms consist of dissected uplands and sandy soils characterize this system. However, it may also occupy gravelly sites, associated with more recent geologic strata.

This system is dominated by *Pinus taeda* (loblolly pine), often with *Quercus stellata* (post oak) and *Quercus marilandica* (blackjack oak) present to co-dominant. *Quercus incana* (bluejack oak), *Quercus margarettae* (sand post oak), *Carya texana* (black hickory), *Ulmus crassifolia* (cedar elm), *Celtis* spp. (hackberry), and *Juniperus virginiana* (eastern redcedar) may also be present.

Vaccinium arboreum (farkleberry) is a frequent shrub component of the system. Other shrub and woody vine species that may be present include *Sideroxylon lanuginosum* (gum bumelia), *Callicarpa americana* (American beautyberry), *Ilex vomitoria* (yaupon), *Toxicodendron radicans* (poison-ivy), *Rhus aromatica* (fragrant sumac), *Smilax bona-nox* (saw greenbrier), *Parthenocissus quinquefolia* (Virginia creeper), and *Vitis* spp. (grape). A grassy herbaceous layer may be present with *Schizachyrium scoparium* (little bluestem) commonly encountered, but other species including *Andropogon gerardii* (big bluestem), *Nassella leucotricha* (Texas wintergrass), *Sporobolus junceus* (pineywoods dropseed), *Paspalum plicatulum* (brownseed paspalum), *Paspalum setaceum* (thin paspalum), *Aristida* spp. (threeawn), *Sporobolus clandestinus* (rough dropseed), *Digitaria cognata* (fall witchgrass), *Dichanthelium oligosanthes* var. *scribnerianum* (Scribner panicgrass), and *Dichanthelium oligosanthes* (fewflower panicgrass). Flowering herbaceous plants are conspicuous and include *Heterotheca subaxillaris* (camphor weed), *Euphorbia corollata* (flowering spurge), *Monarda citriodora* (lemon beebalm), *Galactia volubilis* (downy milkpea), *Liatris aspera* (rough gayfeather), *Brazoria truncata* (bluntsepal brazoria), *Diodia teres* (rough buttonweed), and others. Local accumulations of pine needles result in a patchy distribution of herbaceous cover. This system bears some resemblance to pine woodlands and forests further to the east, and may represent a western, more xeric, outlier of these similar systems.

Potential Threats:

Altered fire regime, habitat loss because of human development and agriculture conversion.

Edwards Plateau Mesic Canyon

These canyons are associated with lower Cretaceous limestone of the Edwards Plateau geology and often on the Glen Rose or other related geologic formations. This system occurs on lower slopes (toe slopes) and onto the margins of adjacent valleys of small drainages. Occurrences are generally found in steep canyons where insolation is minimal, or on lower positions on north facing slopes. The soils may be rich loams, often very rocky, with little soil development.

Its presence at lower slope positions makes it transitional between slope and riparian/floodplain systems. This system is endemic to the Edwards Plateau ecoregion and occurs on canyon bottoms, mesic lower slopes and steep canyons, primarily in the Southern Balcones Escarpment, but also in the Eastern Balcones Escarpment (also on the Limestone Cutplain). This system also includes areas of cliff faces and lower slopes of boxed canyons occurring as narrow, sometimes long bands in areas often with seeps where moisture is consistently more available than on adjacent slopes. The tree canopy is closed. Common components include *Ulmus crassifolia* (cedar elm), *Juglans major* (Arizona walnut), *Quercus buckleyi* (Texas oak), *Quercus laceyi* (Lacey oak), *Prunus serotina* var. *eximia* (escarpment black cherry) (becoming less common to the north), *Fraxinus texensis* (Texas ash) (dominant in the northeastern plateau), *Quercus muehlenbergii* (chinkapin oak), *Tilia americana* (American basswood), and *Acer grandidentatum* (bigtooth maple). Canyon bottoms may have scattered *Quercus macrocarpa* (bur oak).

Substrate (limestone) and topographic position (north and east aspects and lower slopes) are the dominant characteristics of this system. Small seepage areas may be identified as the Edwards Plateau Cliff system and are often dominated by *Adiantum capillus-veneris* (maiden-hair fern), with *Thelypteris ovata* var. *lindheimeri* (Lindheimer's maidenfern) on nearby moist habitats. Fire probably plays little role in the system, while grazing and browsing (by native as well as exotic ungulates) may play an important role in recruitment and understory composition. Adjacent, drier slopes are usually dominated by various *Quercus* species and *Juniperus ashei* (Ashe juniper). Woodlands and forests downslope of occurrences of this system may be well- developed riparian woodlands, small stringers of *Platanus occidentalis* (American sycamore), or this system may occupy the lowest topographic positions along extremely small, rocky drainages.

Potential Threats:

The most prominent threats include overgrazing, excessive herbivory, altered fire regime, residential/urban development, and fragmentation (TNC 2004).

Madrean Lower Montane Pine-Oak Forest and Woodland

Tertiary igneous geologic substrates are commonly encountered with this system in the Davis Mountains region, but the system may also occur on sandstone and limestone substrates, such as in the Guadalupe Mountains region. These forests occupy the relatively rugged slopes of the mountainous areas of the Trans-Pecos, but may also occupy gently rolling landscapes at higher elevations. The soils are often rocky and derived from igneous and sedimentary substrates, but also mountain loams.

This system occurs at higher elevations of the Davis, Chisos, and Guadalupe Mountains than the Madrean Pinyon – Juniper Woodland. It is typically dominated by *Pinus ponderosa* (ponderosa pine) [or *Pinus arizonica* (Arizona pine) in the Chisos], but oak species such as *Quercus emoryi* (Emory oak), *Quercus grisea* (gray oak), *Quercus x pauciloba* (wavyleaf oak), and *Quercus gambelii* (Gambel oak) may be present to codominant. The subcanopy and shrub layer are typically not dense and may include species of the canopy as well as *Quercus hypoleucoides* (silverleaf oak), *Juniperus deppeana* (alligator juniper), *Cercocarpus montanus* (mountain mahogany), *Holodiscus dumosus* (rockspirea), *Symphoricarpos* spp. (snowberries), *Nolina* spp. (sacahuista), *Cylindropuntia imbricata* (tree cholla), and *Mimosa aculeaticarpa* var. *biuncifera* (catclaw mimosa). *Pinus cembroides* (Mexican pinyon pine), and in the Guadalupe Mountains, *Pinus edulis* (pinyon pine), becomes a common component, particularly at the lower elevational limits of this type and in more xeric situations. The herbaceous layer is typically dominated by graminoids including *Piptochaetium fimbriatum* (pinyon ricegrass), *Muhlenbergia emersleyi* (bull muhly), *Muhlenbergia pauciflora* (New Mexican muhly), *Bouteloua curtipendula* (sideoats grama), *Bouteloua gracilis* (blue grama), *Bouteloua hirsuta* (hairy grama), *Bothriochloa barbinodis* (cane bluestem), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Andropogon gerardii* (big bluestem), *Blepharoneuron tricholepis* (pine dropseed), *Koeleria macrantha* (junegrass), *Hesperostipa neomexicana* (New Mexico feathergrass), *Heteropogon contortus* (tanglehead), *Muhlenbergia montana* (mountain muhly), *Muhlenbergia dubia* (pine muhly), *Muhlenbergia rigida* (purple muhly), *Eragrostis intermedia* (plains lovegrass), *Panicum bulbosum* (bulb panicum), *Schizachyrium cirratum* (Texas bluestem), and *Schizachyrium scoparium* (little bluestem).

Potential Threats:

Madrean Montane Conifer-Oak Forest and Woodland ecosystem in a good condition is large, uninterrupted, and has a diversity of stand age and size classes in response to a functioning natural fire regime. A poor condition occurrence is highly fragmented, reduced in size, and has high density of trees and heavy fuel loading that would lead to large, high-severity, stand-replacing fires.

Principal threats to good condition occurences include a large percentage of the surrounding landscape converted to exurban development, heavy or improperly timed livestock grazing, and active fire suppression, resulting in a high density of trees and heavy fuel loading that would lead to large, high-severity, stand-replacing fires.

Rocky Mountain Aspen Forest and Woodland

This habitat occurs on high elevations on Permian limestone (Guadalupe Mountains) and igneous substrates (Davis and Chisos Mountains). Landforms may include high mountain slopes, valleys and ridges. They occur on a diverse array of soil types.

This system occurs at high elevations of the Guadalupe, Davis, and Chisos Mountains. It typically occurs as small patches within the higher elevation conifer systems present in each of the ranges. *Populus tremuloides* (quaking aspen) dominate the stands, which are maintained by disturbance, but may also occupy talus slopes for extended periods. These patches are considered relict remnants in this southwestern extension of this more commonly encountered type further north.

Potential Threats:

In the western U.S., Populus tremuloides forests have been utilized primarily for livestock grazing and to a lesser extent harvested for wood products. Stands typically have lush understory because tree canopy allows significant light to pass through, and sites tend to be relatively mesic (DeByle and Winokur 1985, Howard 1996). Heavy grazing by livestock can deplete or convert an understory dominated by shrubs and forbs to an understory dominated by grazing-tolerant grasses. Degraded stands were often seeded to grazing-tolerant introduced forage species such as Bromus inermis, Dactylis glomerata, Phleum pratense, and Poa pratensis (DeByle and Winokur 1985). Excessive browsing by livestock or wildlife can also significantly impact regeneration by suckers (DeByle and Winokur 1985, Howard 1996).

Harvesting Populus tremuloides trees greatly stimulates regeneration by suckering. Stand structure is obviously affected depending on silviculture treatment (clearcut versus partial cut) and management objectives (DeByle and Winokur 1985). Prescribed burning can also regenerate stands (DeByle and Winokur 1985, Howard 1996). Introduced species can be brought in during logging operations and other management actions that disturbed soil.

Human development has impacted many locations throughout the ecoregion. High- and low-density urban and industrial developments also have large impacts. For example, residential development has significantly impacted locations within commuting distance to urban areas. Impacts may be direct as vegetation is removed for building sites or more indirectly through natural fire regime alteration, and/or the introduction of invasive species. Mining operations can drastically impact natural vegetation. Road building and power transmission lines continue to fragment vegetation and provide vectors for invasive species.

West Gulf Coastal Plain Mesic Hardwood Forest

This habitat is distributed on Tertiary geologic formations, from the Willis formation in the south, northward through Eocene formations. It is fairly restricted to rugged landscapes and often occupies lower slope positions and adjacent steep slopes, where topographic position results in moisture accumulation and lower solar insolation. These sites may occur adjacent to bottomlands, but on more well drained soils and/or slightly higher topographic positions. Can occur on various soil textures, from sands to clays. These soils are often characterized by moderate to high fertility and moisture retention. Soil texture, fertility, and acidity may be controlling factors in determining the species composition of occurrences of this system.

Southern expressions of this system may have *Fagus grandifolia* (American beech) and *Magnolia grandiflora* (southern magnolia) as conspicuous to dominant components of the overstory where conditions are more mesic. Northern expressions fall outside of the range of these two species. The overstory canopy is generally dominated by deciduous hardwoods including *Quercus falcata* (southern red oak), *Quercus alba* (white oak), *Nyssa sylvatica* (blackgum), *Liquidambar styraciflua* (sweetgum), and *Quercus nigra* (water oak). *Acer rubrum* (red maple), *Quercus hemisphaerica* (upland laurel oak), *Quercus shumardii* (Shumard oak), *Quercus pagoda* (cherrybark oak), *Acer barbatum* (southern sugar maple), *Fraxinus americana* (white ash), and *Carya alba* (mockernut hickory) may also be conspicuous in the canopy. *Pinus taeda* (loblolly pine), and to a lesser extent, *Pinus echinata* (shortleaf pine) may be present to co-dominant in the overstory. An understory of species such as *Ilex opaca* (American holly), *Ulmus alata* (winged elm), *Cornus florida* (flowering dogwood), *Ostrya virginiana* (American hop-hornbeam), *Carpinus caroliniana* (American hornbeam), and/or *Acer leucoderme* (chalk maple) is often present. The shrub layer is typically limited, giving the forest an open aspect. Species in the shrub layer may include *Callicarpa americana* (American beautyberry), *Ilex vomitoria* (yaupon), *Arundinaria gigantea* (giant cane), and *Viburnum acerifolium* (maple-leaf viburnum). *Vitis rotundifolia* (muscadine grape), *Smilax* spp. (greenbriers), and *Parthenocissus quinquefolia* (Virginia creeper) are commonly encountered woody vines. Some occurrences on more calcareous substrates lack *Magnolia grandifolia* (southern magnolia) and may contain species such as *Tilia americana* (American basswood) and *Styrax* spp. (snowbells) and may have a rich, more calciphilic, vernal forb flora. Such species as *Podophyllum peltatum* (mayapple), *Arisaema dracontium* (green dragon), *Arisaema triphyllum* (jack-in-the-pulpit), *Sanguinaria canadensis* (bloodroot), *Erythronium* spp. (trout lilies), *Trillium* spp. (trilliums), and *Polygonatum biflorum* (great Solomon's seal) may dominate the aspect of the forest understory in the early spring. Later in the year, these species become inconspicuous and are replaced by species such as *Chasmanthium sessiliflorum* (narrowleaf woodoats), *Mitchella repens* (partridgeberry), *Sanicula canadensis* (Canada snakeroot), *Carex* spp. (caric sedges), and *Dichanthelium* spp. (rosette 51 grasses). Ferns, such as *Woodwardia* spp. (chain fern), *Osmunda cinnamomea* (cinnamon fern), *Athyrium filix-femina* ssp. *asplenioides* (Asplenium ladyfern), and *Polystichum acrostichoides* (Christmas fern), may be conspicuous. The mesic nature of sites occupied by this system, along with the topography of the sites, and the limited fine fuel production in the system, results in reduced fire frequency.

Potential Threats:

Not documented.

West Gulf Coastal Plain Pine-Hardwood Forest

This system is widespread and forms the matrix of the West Gulf Coastal Plain of Texas and therefore occurs on numerous Cenozoic sedimentary formations and some Cretaceous formations of the Mesozoic era. These formations range from sandstone, shale, alluvium, and conglomerate, to marl, with glauconitic formations (Weches) and tuffaceous formations (Catahoula) present. These forests over a wide variety of landforms, with drier expressions occurring on hilltops and ridges. It occupies slopes and lower landscape positions, where conditions are more mesic, and composition of the system varies across these gradients.

Numerous soil types are occupied by this system, but are generally alfisols or ultisols. Soils most commonly encountered are sands and loams.

This upland system forms the matrix over much of the West Gulf Coastal Plain. This is particularly the case outside of the range of *Pinus palustris* (longleaf pine). Within the range of *Pinus palustris* (longleaf pine), the historical matrix was often dominated by that species. The system occupies a range of topographic and edaphic conditions, replaced by other systems in areas where unique abiotic conditions result in occurrences of other, more restricted, systems. Typical pines that dominate these sites are *Pinus taeda* (loblolly pine) and *Pinus echinata* (shortleaf pine), though *Pinus palustris* (longleaf pine) may also be present to dominant, within its range. Historically, *Pinus echinata* (shortleaf pine) dominated drier sites, especially to the north. *Pinus taeda* (loblolly pine) was less dominant than in the current landscape, and occupied less dry sites and became more conspicuous to the south. Seventy-five percent or more of the canopy of some occurrences may be occupied by pines, often *Pinus taeda* (loblolly pine). Typical deciduous hardwoods conspicuous in this system include *Liquidambar styraciflua* (sweetgum), *Carya texana* (black hickory), *Quercus stellata* (post oak), *Quercus falcata* (southern red oak), *Quercus alba* (white oak), *Quercus nigra* (water oak), *Ulmus alata* (winged elm), *Ulmus crassifolia* (cedar elm), and *Nyssa sylvatica* (blackgum). Some sites may be primarily deciduous, with 75% or more of the canopy cover occupied by hardwoods. *Ilex vomitoria* (yaupon), saplings and seedlings of overstory species, *Callicarpa americana* (American beautyberry), *Morella cerifera* (wax-myrtle), *Vaccinium arboreum* (farkleberry), and *Cornus florida* (flowering dogwood) commonly occupy the shrub layer, which may be well-developed, with understory canopy cover to 40% or more. Woody vines in this system may be conspicuous and often include *Smilax bona-nox* (saw greenbrier), *Vitis* spp. (grape, often *Vitis rotundifolia* (muscadine grape)), *Parthenocissus quinquefolia* (Virginia creeper), and *Toxicodendron radicans* (poison ivy). The herbaceous layer is generally sparse (often < 20% cover), with *Schizachyrium scoparium* (little bluestem), *Chasmanthium laxum* (slender woodoats), *Chasmanthium sessiliflorum* (narrowleaf woodoats), and *Pteridium aquilinum* (brackenfern) often present to dominant. Forests with dense tree cover 53 (especially evergreen cover), have reduced shrub and herbaceous cover.

Herbaceous cover may be additionally limited by dense litter accumulation. Few occurrences of this system can be considered old growth, and much of the system, as it is mapped, constitutes pine plantations or sites recovering from previous logging. *Pinus elliottii* (slash pine) may be used in some plantations.

Potential Threats:

Not documented.

Riparian Vegetation

Riparian Vegetation as defined in this document generally includes river- or creek-dependent habitats which rely on periodic flooding/flushing, sub-irrigated substrates, and other influences of the ephemeral or perennial rivers/creeks to which they are adjacent: floodplains, wet woodlands, gallery riverine forests, oxbows; swamps, and vegetated islands. These occur throughout the state but tend to cover less area in the western portion of Texas.

Edwards Plateau Floodplain

This system usually occupies Quaternary alluvial deposits often within drainages largely underlain by Cretaceous limestones or drainages that receive outwash from landscapes dominated by these limestones. This system is confined to valley floors of large rivers and perennial streams. This system tends to occupy broad valley bottoms with alluvial deposits on the Edwards Plateau, and rivers and large creeks where outwash from the Edwards Plateau influences the substrate. Bottomland soils of various types (Loamy, Clayey, and Sandy). This system is primarily confined to the Edwards Plateau but also has outliers in the Cross Timbers, Southwestern Tablelands and Texas Blackland Prairies.

These are forests and woodlands with a canopy dominated or co-dominated by *Carya illinoinensis* (pecan), *Ulmus crassifolia* (cedar elm), *Ulmus americana* (American elm), *Celtis laevigata* (sugar hackberry), *Celtis laevigata* var. *reticulata* (netleaf hackberry), and/or *Quercus fusiformis* (plateau live oak). *Carya illinoinensis* (pecan) may be more likely to occur in deeper and better-developed alluvial soils. Apparent dominance of *Carya illinoinensis* (pecan) may also be an artifact of preferential harvesting of other species, leaving this species in greater abundance. *Melia azedarach* (chinaberry) is a common non-native tree encountered on floodplains. Other species present may include *Fraxinus texensis* (Texas ash), *Fraxinus pennsylvanica* (green ash), *Juglans major* (Arizona walnut), *Quercus macrocarpa* (bur oak), *Quercus buckleyi* (Texas oak), *Acer negundo* (boxelder), *Sapindus saponaria* var. *drummondii* (western soapberry), *Juniperus ashei* (Ashe juniper), *Prosopis glandulosa* (mesquite), and *Platanus occidentalis* (American sycamore). *Quercus stellata* (post oak) may be dominant on sandy soils within the floodplain at some sites. Woody species in the subcanopy may include *Sideroxylon lanuginosum* (gum bumelia), *Ptelea trifoliata* (wafer-ash), *Cornus drummondii* (roughleaf dogwood), *Morus rubra* (red mulberry), *Diospyros texana* (Texas persimmon), *Parthenocissus quinquefolia* (Virginia creeper), *Vitis* spp. (grape), *Smilax bona-nox* (greenbrier), *Baccharis neglecta* (roosevelt-weed), *Malvaviscus arboreus* var. *drummondii* (Turk's cap), *Juniperus ashei* (Ashe juniper), and *Ilex decidua* (possumhaw). The herbaceous layer may be continuous, though relatively sparse, or patchy with species such as *Elymus virginicus* (Virginia wildrye), *Chasmanthium latifolium* (creekoats), *Nassella leucotricha* (Texas wintergrass), *Verbesina virginica* (frostweed), and *Carex* spp. (caric sedge). Some sites lack, or have very sparse, overstory canopies and represent shrublands or grasslands. Shrublands may be dominated by species in the shrub layer of the surrounding woodlands. Other components or dominants may include species such as *Prosopis glandulosa* (mesquite), *Acacia farnesiana* (huisache), *Sapindus saponaria* var. *drummondii* (western soapberry), *Juglans microcarpa* (little walnut), *Mahonia trifoliolata* (agarito), and *Cephalanthus occidentalis* (common buttonbush). Grassland sites are frequently dominated by the non-native species *Cynodon dactylon* (bermudagrass) and/or *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem). Native species that may also be present in (and sometimes dominate) these sites include *Panicum virgatum* (switchgrass), *Andropogon glomeratus* (bushy bluestem), *Elymus virginicus* (Virginia wildrye), *Nassella leucotricha* (Texas wintergrass), *Hordeum pusillum* (little barley), *Tripsacum dactyloides* (eastern gamagrass), *Muhlenbergia lindheimeri* (Lindheimer's muhly), *Carex* spp. (carices), and *Eleocharis* spp. (spikerushes). Floodplain occurrences often include portions that resemble Edwards Plateau Riparian vegetation, especially along stream margins, where *Platanus occidentalis* (sycamore), *Taxodium distichum* (baldcypress), *Juglans microcarpa* (little walnut), *Brickellia* spp. (brickellbush), *Cladium mariscus* ssp. *jamaicense* (saw-grass), and *Panicum virgatum* (switchgrass) are frequently encountered.

Potential Threats:

Alluvial sedimentation processes dominate the formation and maintenance of this system. However, overgrazing and/or overbrowsing may influence recruitment of overstory species and composition of the understory and herbaceous layers.

Edwards Plateau Riparian

This system usually occupies Quaternary deposits along headwater streams. These may be alluvial or gravel deposits and are often within drainages dominated by limestone or other calcareous substrates on the Edwards Plateau or where substrate is influenced by outwash from the Edwards Plateau. Riparian systems occupy small streams, either intermittent or perennial.

These sites tend to be in erosional situations, as opposed to broad alluvial depositional sites. By definition, this system is mapped in areas upstream of significant development of bottomland soils on soil types of the surrounding uplands. This system is primarily confined to the Edwards Plateau but also has outliers in the Central Great Plains, Cross Timbers, Southwestern Tablelands and Texas Blackland Prairies.

Riparian vegetation may be characterized as woodlands, shrublands, or herbaceous vegetation. These erosional sites may be gravelly, cobbly, or rocky, and generally occupy the upper reaches of streams. Woodlands may have *Quercus fusiformis* (plateau live oak), *Platanus occidentalis* (American sycamore), *Taxodium distichum* (baldcypress), *Fraxinus texensis* (Texas ash), *Fraxinus pennsylvanica* (green ash), *Ulmus crassifolia* (cedar elm), *Celtis laevigata* (sugar hackberry) (including var. *reticulata*), *Acer negundo* (boxelder), *Prosopis glandulosa* (mesquite), *Quercus buckleyi* (Texas oak), *Juniperus ashei* (Ashe juniper), *Salix nigra* (black willow), and/or *Sapindus saponaria* (western soapberry). Shrub species that may be encountered in the understory of these woodlands (or, in some cases, may form shrublands lacking a significant overstory canopy) include *Juglans microcarpa* (little walnut), *Chilopsis linearis* (desert willow), *Baccharis* spp. (false- willow), *Salix nigra* (black willow), *Juniperus ashei* (Ashe juniper), *Sapindus saponaria* (western soapberry), *Cornus drummondii* (roughleaf dogwood), *Sophora secundiflora* (Texas mountain- laurel), *Sideroxylon lanuginosum* (gum bumelia), *Diospyros texana* (Texas persimmon), *Ungnadia speciosa* (Mexican buckeye), *Prosopis glandulosa* (mesquite), *Cephalanthus occidentalis* (common buttonbush), and/or *Aloysia gratissima* (whitebrush). Substantial patches of herbaceous cover may be present and often include species such as *Andropogon glomeratus* (bushy bluestem), *Panicum virgatum* (switchgrass), *Cladium mariscus* var. *jamaicense* (sawgrass), *Tripsacum dactyloides* (eastern gamagrass), *Setaria scheelei* (southwestern bristlegrass), *Nassella leucotricha* (Texas wintergrass), *Eleocharis* spp. (spikerush), *Brickellia* spp. (brickellbush), *Justicia americana* (American water-willow), *Hydrocotyle* spp. (water penny), and/or *Muhlenbergia lindheimeri* (Lindheimer muhly). Frequently, *Cynodon dactylon* (bermudagrass) and/or *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem) dominate these grassland sites. *Sorghum halepense* (Johnson grass) is also a commonly encountered non- native grass. This system includes vegetation along very small streams, reaching upstream to spring heads and runs.

Potential Threats:

Not documented.

North American Warm Desert Lower Montane Riparian Woodland and Shrubland

This system has developed on various geological formations associated with the mountains of the Trans-Pecos, including limestones, sandstones, igneous formations, and alluvial and colluvial deposits. This system is confined to drainages on lower mountain slopes. This system contains various soils and sometimes rocky sites lacking any soil development. This system occurs in the Arizona/New Mexico Mountains in Texas and Chihuahuan Deserts ecoregion of Mexico.

This system occupies valleys, drainages, and canyons of lower mountain slopes and foothills. These linear woodlands follow perennial and seasonally intermittent streams and may occur as woodlands or shrublands. Woody species that may be dominant include *Populus fremontii* (Arizona cottonwood), *Populus deltoides* ssp. *wislizeni* (Rio Grande cottonwood), *Juglans major* (Arizona walnut), *Fraxinus velutina* (velvet ash), *Salix gooddingii* (southwestern black willow), *Juglans microcarpa* (little walnut), *Sapindus saponaria* var. *drummondii* (western soapberry), *Ungnadia speciosa* (Mexican buckeye), and *Celtis laevigata* var. *reticulata* (netleaf hackberry). Shrubs may be present in the understory or may form shrublands lacking an overstory canopy or with a sparse emergent canopy. Shrubs commonly encountered include *Baccharis salicifolia* (seepwillow), *Salix gooddingii* (Southwestern black willow), *Fallugia paradoxa* (Apache plume), *Rhus microphylla* (littleleaf sumac), *Cephalanthus occidentalis* (common buttonbush), *Mimosa aculeaticarpa* var. *biuncifera* (catclaw mimosa), *Acacia constricta* (whitethorn acacia), *Brickellia californica* (California brickellbush), *Prosopis glandulosa* (honey mesquite), and *Acacia greggii* (catclaw). Some sites with sparse woody overstory may be dominated by grasses such as *Bouteloua curtipendula* (sideoats grama), *Muhlenbergia porteri* (bush muhly), *Distichlis spicata* (saltgrass), *Muhlenbergia rigens* (deergrass), *Sporobolus airoides* (alkali sacaton), *Pleuraphis mutica* (tobosa), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Bouteloua gracilis* (blue grama), and *Aristida* spp. (threeawns).

Potential Threats:

- Common types of conversion of communities include bridge crossings, agricultural conversion, drowning by reservoir creation, and dewatering of streams.
- Human activities such as concentrated grazing, cutting of woody vegetation, development, and river channelization pose threats.
- Reductions in flows can limit cottonwood and willow regeneration.
- Forecasts for 2060 show severe increases in monthly minimum temperature with no clear spatial pattern to the area that is not expected to experience these changes.
- Habitats of several species face conversion due to human activities like road installation, agricultural conversion, and reservoir creation.
- Grazing, vegetation cutting, development, pollution, and channelization are some common stressors and threats.
- Communities surrounding these habitats also face indirect effects of human activities altering watershed runoff and groundwater recharge.

- Reductions in flows can lead to reduced production of gravel and sand bars and limit cottonwood and willow regeneration.
- Forecasts for 2060 show significant increases in monthly maximum temperature and minimum temperature, likely to counteract any increase in precipitation.

North American Warm Desert Riparian Mesquite Bosque

This system is confined to Quaternary alluvium deposits in bottomland flood plains in western landscapes in Texas. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregion of Texas.

Though occurrences of this system have been reported in the Trans-Pecos, none were mapped. The system is reported to occur, or to have historically occurred along the Rio Grande and is/was dominated by *Prosopis glandulosa* (honey mesquite) forming a woodland canopy.

Modification of the flood cycle and introduction of *Tamarix* spp. (saltcedars) may have influenced the distribution of this system on the Rio Grande.

Potential Threats:

Not documented.

North American Warm Desert Riparian Woodland and Shrubland

This system occupies Quaternary Alluvium as well as nearby Cretaceous limestones through which drainages flow. This system occurs on relatively level floodplains and low landscape positions along drainages. Upper portions of these drainages are often flashy, and many are only infrequently and briefly inundated. This systems soils include loamy Bottomland, Salty Bottomland, and Draw are the most frequent Ecological Sites to be occupied by this system. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregions of Texas.

This system occurs along drainages and floodplains of the larger rivers and drainages of the Trans-Pecos. In addition to the woodland and shrubland expression of this system, sparsely vegetated areas also commonly occur. Sparsely vegetated sites may be mapped on gravel bars, mud flats, or exposed rock within drainages, but may also have sparse woody or herbaceous vegetation including species such as *Brickellia* sp. (brickellbush), *Chilopsis linearis* (desert willow), *Baccharis* sp., (baccharis), *Prosopis glandulosa* (honey mesquite), and *Salvia farinacea* (mealycup sage). The native streamside vegetation along the large drainages is frequently displaced by extensive areas of *Tamarix* sp. (saltcedar) and/or *Arundo donax* (giant reed).

Overstory canopy is often not well-developed but contain species such as *Celtis laevigata* var. *reticulata* (netleaf hackberry), *Salix amygdaloides* (peachleaf willow), *Salix gooddingii* (Southwestern black willow), *Prosopis glandulosa* (honey mesquite), *Populus fremontii* (Arizona cottonwood), *Populus deltoides* var. *wislizeni* (Rio Grande cottonwood), *Fraxinus velutina* (velvet ash), and *Sapindus saponaria* var. *drummondii* (western soapberry). Low woodlands and shrublands with species such as *Salix exigua* (Texas sandbar willow), *Baccharis salicifolia* (seepwillow), *Brickellia laciniata* (splitleaf brickellbush), *Chilopsis linearis* (desert willow), *Juglans microcarpa* (little walnut), *Fallugia paradoxa* (Apache plume), and *Celtis ehrenbergiana* (granjeno) are present and sometimes patchy. Flooding and scouring are the dynamic processes most influential in this system.

Potential Threats:

- Common conversion types include bridge crossings, road installation, agricultural conversion, and drowning by reservoir creation.
- Stressors and threats include concentrated grazing, cutting of woody vegetation, development, river channelization, diversion of flows, wildfire suppression, exotic species, unregulated recreation, road building, mining, pollution, channel dredging, bank armoring, and construction of dams.
- Human activities that alter watershed runoff and groundwater recharge and discharge indirectly affect communities surrounding watersheds.
- Road crossings and dams constrict flows and cause increased bank erosion.
- Forecasts for 2060 show monthly maximum and minimum temperatures to increase, with July experiencing the most significant increase.
- The increase in minimum temperature is pervasive, and the region is projected to exceed one standard deviation beyond the 20th century baseline for every month.
- There is no clear spatial pattern to the area that is not expected to experience these changes.
- Climate change could result in changes to temperature and precipitation patterns.
- These changes could have various effects on riparian resources, leading to higher evapotranspiration rates, increased water stress, reduced groundwater recharge, and more erosive runoff events.
- These effects could result in long-term impacts such as loss of riparian vegetation, declines in the spatial extent and biodiversity of perennial streams and open waters, and reduced discharge to springs and seeps.
- These impacts could continue over multiple decades and affect both high and low elevations.

North American Warm Desert Wash

This system occupies small drainages through various substrates. This system occurs in small on a variety of soil types transected by small drainages. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregions of Texas. This system occurs on flashy, intermittently flooded, often dry washes and arroyos on lower mountain slopes, plains, and basins. These drainages are often embedded within a matrix of desert shrublands and/or grasslands. Washes may be sparsely vegetated, rocky, gravelly, or sandy drainageways, to patchy shrublands to almost continuous shrublands along the drainages. Woody species found in and adjacent to these washes include *Acacia greggii* (catclaw), *Brickellia laciniata* (splitleaf brickellbush), *Baccharis salicifolia* (seepwillow), *Chilopsis linearis* (desert willow), *Fallugia paradoxa* (Apache plume), *Rhus microphylla* (littleleaf sumac), *Juglans microcarpa* (little walnut), *Fraxinus greggii* (little-leaf ash), *Leucaena retusa* (littleleaf leadtree), *Dasylirion leiophyllum* (smooth sotol), and *Prosopis glandulosa* (honey mesquite). Scattered individuals of *Celtis laevigata* var. *reticulata* (netleaf hackberry), *Chilopsis linearis* (desert willow), *Salix gooddingii* (southwestern black willow), *Juglans microcarpa* (little walnut), or other species may form a very sparse overstory. Shrubs from the surrounding upland shrubland, such as *Larrea tridentata* (creosotebush), *Viguiera stenoloba* (skeleton-leaf golden eye), *Flourensia cernua* (tarbush) and *Juniperus pinchotii* (redberry juniper) may be commonly encountered.

Potential Threats:

Not documented.

Red River Large Floodplain Forest

This system developed on Quaternary alluvial deposits in floodplains of the Red River and its major tributaries. This system contains some local topographic variation and includes terraces and oxbows. This system bottomland soils are quite variable. This system occurs in the West Gulf Coastal Plain Ecoregion in Texas, Arkansas, Louisiana, and Oklahoma.

This system is somewhat unique to Red River drainage but shares many of the species common to the West Gulf Coastal Plain Large River Floodplain. *Platanus occidentalis* (American sycamore), *Populus deltoids* (eastern cottonwood), *Salix nigra* (black willow), *Betula nigra* (river birch), *Acer negundo* (boxelder), and *Fraxinus pennsylvanica* (green ash) tend to occupy riverfront sites and newly exposed or disturbed sites. Seasonally flooded portions of the system do occur, and may contain species such as *Quercus lyrata* (overcup oak), *Carya aquatica* (water hickory), *Taxodium distichum* (baldcypress), *Nyssa aquatica* (water tupelo), *Nyssa biflora* (swamp tupelo), *Quercus phellos* (willow oak), *Gleditsia aquatica* (water honeylocust), and *Planera aquatica* (water elm). Less frequently flooded areas may be dominated by numerous hardwood species, such as *Liquidambar styraciflua* (sweetgum), *Quercus nigra* (water oak), *Quercus phellos* (willow oak), *Quercus shumardii* (Shumard oak), *Quercus macrocarpa* (bur oak), *Quercus michauxii* (swamp chestnut oak), *Quercus falcata* (southern red oak), *Carya illinoinensis* (pecan), *Celtis laevigata* (sugar hackberry), *Ulmus alata* (winged elm), *Ulmus americana* (American elm), *Ulmus crassifolia* (cedar elm), *Ulmus rubra* (slippery elm), *Gleditsia triacanthos* (common honeylocust), *Nyssa sylvatica* (blackgum), and *Fraxinus pennsylvanica* (green ash).

Juniperus virginiana (eastern redcedar), *Pinus taeda* (loblolly pine), and, to a lesser extent, *Pinus echinata* (shortleaf pine) may be found in the canopy. A mid-story component may include young individuals of the overstory, as well as species such as *Carpinus caroliniana* (American hornbeam), *Ostrya virginiana* (American hop-hornbeam), *Acer rubrum* (red maple), *Sassafras albidum* (sassafras), *Maclura pomifera* (bois d'arc), and *Morus rubra* (red mulberry).

Cephalanthus occidentalis (common buttonbush) may dominate some open sites within the floodplain. In addition to these species, shrubs such as *Crataegus viridis* (green hawthorn), *Crataegus marshallii* (parsley hawthorn), *Callicarpa americana* (American beautyberry), *Ligustrum sinense* (Chinese privet), and *Arundinaria gigantea* (giant cane) may be found in the understory of forests. Numerous woody vines may be encountered, including *Smilax rotundifolia* (common greenbriar), *Brunnichia ovata* (eardrop vine), *Berchemia scandens* (Alabama supplejack), *Lonicera japonica* (Japanese honeysuckle), *Ampelopsis arborea* (peppervine), and *Toxicodendron radicans* (poison ivy). Herbaceous species may be present in the understory of the forest, occur as marshy areas, or occupy herbaceous-dominated sites on areas less frequently flooded. *Saururus cernuus* (lizard's tail), *Nymphaea odorata* (American waterlily), *Rhynchospora* spp. (beaksedges), *Carex* spp. (caric sedges), *Dichanthelium* spp. (rosette grasses), *Chasmanthium* spp. (woodoats), *Juncus* spp. (rushes), *Leersia* sp. (cutgrass), *Geum canadense* (white avens), *Sanicula canadensis* (Canada snakeroot), *Woodwardia areolata* (chain fern), *Mikania scandens* (climbing hemp-weed), and *Polygonum* spp. (smartweeds) are among the herbaceous species that may be commonly encountered in this system.

Potential Threats:

The primary threats to this system are conversion to agriculture and developed land uses, repeated timber harvesting, alteration of natural hydrological processes (e.g., dams, levees, draining, ditching, dredging), intensive silvicultural practices, fragmentation, and water pollution. Viable forest patches must be large enough to allow for processes that maintain floral and faunal species composition and structure at the landscape scale (Harris 1989, Sharitz and Mitsch 1993). Fragmentation leads to disruption of natural processes such as plant succession, nutrient cycling, and litter accumulation. Increases in edges over interior of patches favor common and weedy species over specialists. In terms of generalists, this includes white-tailed deer, raccoons, opossums, and brown-headed cowbirds. These species affect others through activities such as increased browsing, nest predation, etc. (Harris 1989). Edge effects occur around forest patches, and are more intense and disruptive in small patches, and with more abrupt edges. Patches with natural edges are probably fairly functional, but sharp artificial edges lead to increased mortality of the trees and more severe deterioration of ecological processes. Intact natural forest patches buffered by areas of low-intensity forest management tend to be in better condition than those adjacent to agricultural land (Harris 1989). The most significant potential climate change effects over the next 50 years include alteration of waterflow, caused by periods of drought alternating with more intense storms.

Rocky Mountain Bigtooth Maple Ravine Woodland

(NatureServe Summary CES306.814) This ecological system occurs in cool ravines, on toeslopes and slump benches associated with riparian areas in the northern and central Wasatch Range and Tavaputs Plateau extending into southern Idaho, as well as in scattered localities in southwestern Utah, central Arizona and New Mexico. Substrates are typically rocky colluvial or alluvial soils with favorable soil moisture. These woodlands are dominated by *Acer grandidentatum* but may include mixed stands codominated by *Quercus gambelii* or with scattered conifers. Some stands may include *Acer negundo* or *Populus tremuloides* as minor components.

Potential Threats:

Not documented.

Southeastern Great Plains Floodplain Forest

This system generally occupies Quaternary alluvium of floodplain forests on relatively broad flats at low topographic positions, along large streams where alluvial deposition dominates. This system occurs along rivers such as the Sulphur, (and tributaries such as White Oak and Cuthand Creeks), Sabine (and Lake Fork), Trinity (and its major tributaries), Navasota, and portions of the Lower and Middle Brazos (and its major tributaries), Colorado, Guadalupe, Lavaca, Navidad, and San Antonio Rivers may support this system. The soils include several bottomland Ecological Sites (including Loamy, Sandy, and Clayey) that are characterize of this system. This systems occurs in the Central Great Plains, Cross Timbers, East Central Plains, Gulf Coast Prairies and Marshes, South Texas Plains, Southwestern Tablelands, and Texas Blackland Prairies ecoregions in Texas.

Dominant communities within this system range from floodplain forests to wet meadows to gravel/sand flats; however, they are linked by underlying soils and the flooding *Berchemia scandens* (Alabama supplejack), *Campsis radicans* (common trumpetcreeper), *Vitis* spp. (grape), *Parthenocissus quinquefolia* (Virginia creeper), *Toxicodendron radicans* (poison ivy), *Smilax bona-nox* (saw greenbrier), and *Ampelopsis arborea* (peppervine) may be conspicuous. Herbaceous cover includes *Elymus virginicus* (Virginia wildrye), *Verbesina virginica* (frostweed), *Chasmanthium latifolium* (creek oats), *Chasmanthium sessiliflorum* (narrowleaf woodoats), *Carex cherokeensis* (Cherokee sedge), *Tripsacum dactyloides* (eastern gamagrass), *Symphyotrichum drummondii* var. *texanum* (Drummond's aster), *Calyptocarpus vialis* (straggler daisy), *Geum canadense* (white avens), *Sanicula canadensis* (Canada snakeroot), *Ambrosia trifida* (giant ragweed), *Panicum virgatum* (switchgrass), *Galium* spp. (bedstraw), *Teucrium canadense* (American germander), and *Carex* spp. (caric sedges). Wetter sites may contain species such as *Zizaniopsis miliacea* (marshmillet), *Rhynchospora* spp. (beaksedges), *Eleocharis* spp. (spikerushes), *Nymphaea odorata* (American waterlily), and *Peltandra virginica* (Virginia peltandra). Non-native grasses that may dominate these sites include *Cynodon dactylon* (bermudagrass), *Bothriochola ischaemum* var. *songarica* (King Ranch bluestem), and *Sorghum halepense* (Johnsongrass). Herbaceous cover may be quite high, especially in situations where shrub cover is low. The non-native trees *Triadica sebifera* (Chinese tallow) and *Melia azedarach* (chinaberry) may be present.

Potential Threats:

Periodic and intermediate flooding is the most significant process controlling this system and is expected every 5 to 25 years. Grazing and conversion to agriculture can significantly impact this system and can lead to the degradation or extirpation of the majority of prairie and wet meadow communities from this system. Fire occurs infrequently relative to surrounding systems. Fuels tend to stay moister due to shady conditions and low topographic position. Other disturbances include ice storm/blowdowns, which are capable of setting back small to large patches; as well as beaver pond flooding, which even though a small-patch event, is expected to cycle throughout the forest over the long term, perhaps at a scale of hundreds or thousands of years.

Southeastern Great Plains Riparian Forest

As defined, this system occupies buffer zones of headwater streams, and soils develop in place over a variety of geologic surfaces. This system occurs in valleys and drainages along headwater streams of the Sulphur, Sabine, Navasota, Brazos, upper Trinity River, and middle portions of the Guadalupe and San Antonio River Basins. Typically in areas with erosional processes dominating over alluvial deposition. In the Trinity River basin, occurrences were mapped upstream of approximately the Leon/Madison County line, near the confluence with Cobb Creek. This system is mapped along drainages upstream of the Bottomland Ecoclasses, so they will be mapped on soils of the surrounding uplands. This system occurs in the Central Great Plains, Cross Timbers, East Central Plains, Gulf Coast Prairies and Marshes, South Texas Plains, Southwestern Tablelands, and Texas Blackland Prairies ecoregions in Texas.

Trees that may be present in stands of this system include *Celtis laevigata* (sugar hackberry), *Ulmus crassifolia* (cedar elm), *Platanus occidentalis* (American sycamore), *Populus deltoides* (eastern cottonwood), *Quercus fusiformis* (plateau live oak), *Quercus nigra* (water oak), *Quercus phellos* (willow oak), *Sapindus saponaria* var. *drummondii* (western soapberry), *Salix nigra* (black willow), *Fraxinus americana* (white ash), *Fraxinus pennsylvanica* (green ash), *Gleditsia triacanthos* (common honeylocust), *Prosopis glandulosa* (honey mesquite), and *Carya illinoinensis* (pecan). To the east, *Quercus falcata* (southern red oak) and *Liquidambar styraciflua* (sweetgum) may become important components of the overstory. To the east, evergreen dominated occurrences may contain *Pinus taeda* (loblolly pine) or *Pinus echinata* (shortleaf pine), as well as *Juniperus virginiana* (eastern redcedar). The shrub layer development is variable, sometimes with species such as *Amorpha fruticosa* (indigobush), *Forestiera acuminata* (swamp privet), *Ilex decidua* (possumhaw), *Ilex vomitoria* (yaupon), *Sideroxylon lanuginosum* (gum bumelia), *Juniperus virginiana* (eastern redcedar), *Diospyros virginiana* (common persimmon), *Cornus drummondii* (roughleaf dogwood), *Condalia hookeri* (brasil), *Acacia farnesiana* (huisache), and/or

Viburnum rufidulum (rusty blackhaw). A few sites may be shrub dominated without an overstory canopy, containing species such as *Forestiera acuminata* (swamp privet), *Cephalanthus occidentalis* (common buttonbush), *Acacia farnesiana* (huisache), or *Sesbania drummondii* (rattlebox sesbania). Herbaceous cover is also variable, depending on overstory and shrub canopies and recent flooding history. Herbaceous species may include *Elymus virginicus* (Virginia wildrye), *Verbesina virginica* (frostweed), *Chasmanthium latifolium* (creek oats), *Chasmanthium sessiliflorum* (narrowleaf woodoats), *Tripsacum dactyloides* (eastern gamagrass), *Symphyotrichum drummondii* var. *texanum* (Drummond's aster), *Amphiachyris dracunculoides* (common broomweed), *Ambrosia psilostachya* (western ragweed), *Geum canadense* (white avens), *Sanicula canadensis* (Canada snakeroot), *Panicum virgatum* (switchgrass), *Galium* spp. (bedstraw), and *Carex* spp. (caric sedges). Upland species such as *Schizachyrium scoparium* (little bluestem), *Nassella leucotricha* (Texas wintergrass), and *Sorghastrum nutans* (Indiangrass) may be common. Woody vines such as *Smilax bona-nox* (saw greenbrier), *Toxicodendron radicans* (poison ivy), *Ampelopsis arborea* (peppervine), and *Vitis* spp. (grapes) may be common. The environment and characteristics of the vegetation of this system become drier from east to west, with moister representatives (such as communities containing *Quercus nigra* (water oak)) occurring in the eastern parts of the range. Non-native grass species that may be common to dominant on these sites include *Arundo donax* (giant reed) and *Cynodon dactylon* (bermudagrass) and *Sorghum halepense* (Johnsongrass). The non- native species, such as *Ligustrum* spp. (privets) and *Triadica sebifera* (Chinese tallow), may be commonly encountered.

Potential Threats:

Not documented.

Tamaulipan Arroyo Shrubland

This system occurs over various geologic formations, from eolian sands, to the Lissie Formation, to the Goliad Formation. Occurrences are local and appear to be unrelated to underlying strata. This system occurs in local, internally draining basins or depressions. This systems soils may occur in a matrix of sandy substrate, the depressions that characterize it are typically lined by clays or clay loams. Lakebed Ecological Sites typify the occurrences. This system occurs in the Gulf Coast Prairies and Marshes and South Texas Plains ecoregions in Texas.

This system occupies small, internally drained basins occurring over various substrates, but concentrated over the Lissie and Goliad Formations and the South Texas Sandsheet south of the Nueces River. They may be locally referred to as potholes, lagunas, lagunitas, ponds, or copitas. These basins are typically lined by clay or clay loam soils which tend to hinder drainage, resulting in moist conditions over extended periods. Characteristic woody species surrounding these basins include *Acacia farnesiana* (huisache), *Parkinsonia aculeata* (retama), and *Prosopis glandulosa* (honey mesquite) which make up a relatively sparse woodland canopy at a height of about 6 m. *Celtis laevigata* (sugar hackberry), *Celtis ehrenbergiana* (granjeno), and *Ulmus crassifolia* (cedar elm) may sometimes be present. Shrubs of these species, and other species such as *Condalia hookeri* (brasil), *Lycium carolinianum* (Carolina wolfberry), *Heimia salicifolia* (hachinal), and *Sideroxylon celastrina* (la coma) may be present but typically do not occur as a dense shrub layer. *Sesbania drummondii* (rattlebox sesbania) is often encountered particularly in areas with reduced woodland canopy where water may stand for extended periods. The herbaceous layer winthin the woodland may commonly contain species such as *Urochloa maxima* (guineagrass), *Chloracantha spinosa* (spiny aster), *Clematis drummondii* (old man’s beard), and *Teucrium cubense*

(Cuban germander). Toward the center of the basin, woody cover is reduced or often absent and the herbaceous layer is often dominated by *Cynodon dactylon* (bermudagrass), but may also be characterized by a number of sedge species of the genera *Eleocharis* (including species such as *Eleocharis quadrangulata* (squarestem spikesedge) and *Eleocharis palustris* (bigstem spikesedge)) and *Cyperus* (including species such as *Cyperus articulatus* (jointed umbrellasedge), *Cyperus acuminatus* (taperleaf flatsedge), and *Cyperus squarrosus* (bearded umbrellasedge)), as well as *Schoenoplecuts saximontanus* (annual bulrush). Numerous other species may be present, including *Paspalum distichum* (knotgrass), *Setaria parviflora* (knotroot bristlegrass), *Eragrostis spicata* (spike lovegrass), *Calyptocarpus vialis* (straggler daisy), *Eryngium nasturtiifolium* (hierba del sapo), *Eclipta prostrata* (yerba de tajo), *Phyla nodiflora* (common frog-fruit), *Soliva mutisii* (Mutis' burrweed), *Rorippa teres* (tansyleaf yellowcress), *Lindernia dubia* (moistbank pimpernel), *Rotala ramosior* (tooth-cup), *Bacopa rotundifolia* (disc waterhyssop), *Heteranthera limosa* (blue mudplantain), *Echinodorus berteroi* (common burhead), *Echinodorus tenellus* (mudbabies), *Sagittaria longiloba* (longlobe arrowhead), *Nymphaea elegans* (tropical royalblue waterlily), *Marsilea macropoda* (bigfoot water-clover), *Lemna* sp. (duckweed) and *Wolffia* sp. (watermeal).

Potential Threats:

Not documented.

Tamaulipan Floodplain

This system occurs on Quaternary alluvium in floodplains of rivers and large creeks where sediment is deposited. This systems topography is relatively level with some relief associated with levees and depressions developed from meanders of the waterway, or historical meanders of the Rio Grande (Resaca). This systems soils comprise of Alluvial deposits of the Bottomland Ecological Sites, including loamy, clayey, and sandy. The Lowland Ecological Site type also supports this system. This system occurs in the Gulf Coast Prairies and Marshes and South Texas Plains ecoregions in Texas.

This ecological system occurs along rivers and major drainages in south Texas from the central portion of the Nueces River south to northeastern Mexico and west to the vicinity of Del Rio, Texas. Generally, the system is expressed as a deciduous woodland or forest with tree height reaching to 15 meters, and canopy cover variable but sometimes reaching near 100 percent. The canopy may have a conspicuous (sometimes dominant to co-dominant) evergreen component of species such as *Ebenopsis ebano* (Texas ebony) and *Ehretia anacua* (anacua). Dominant species of the overstory canopy often includes one or more of the following species: *Celtis laevigata* (sugar hackberry), *Ulmus crassifolia* (cedar elm), *Fraxinus berlandieriana* (Mexican ash), *Prosopis glandulosa* (honey mesquite), *Acacia farnesiana* (huisache), *Diospyros texana* (Texas persimmon), *Leucaena pulverulenta* (tepeguaje), *Celtis ehrenbergiana* (granjeno), *Sapindus saponaria* var. *drummondii* (western soapberry), *Ebenopsis ebano* (Texas ebony), *Ehretia anacua* (anacua), and *Parkinsonia aculeata* (retama). In northern portions of the range of this system, particularly within the Nueces River drainage, *Carya illinoinensis* (pecan) and *Quercus fusiformis* (plateau live oak) may be conspicuous components of the overstory. Forests and woodlands may have significant shrub cover including saplings of the overstory species in addition to species such as *Zanthoxylum fagara* (colima), *Condalia hookeri* (brasil), *Forestiera angustifolia* (desert olive), *Sideroxylon* spp. (bumelias), *Aloysia gratissima* (whitebrush), *Acacia greggii* var. *wrightii* (Wright's acacia), *Malpighia glabra* (Barbados cherry), *Guaiacum angustifolium* (guayacan), *Ziziphus obtusifolia* (lotebush) and *Amyris texana* (Texas torchwood). Other shrub species, such as *Buddleja sessiliflora* (Rio Grande butterflybush), *Phaulothamnus spinescens* (snake-eyes), *Lippia alba* (white lipia), and *Amyris madrensis* (Sierra Madre torchwood) may be encountered in southern expressions of the system. *Salix nigra* (black willow) may dominate sites, especially at river's edge and wet sites. Riverbanks and other sites with a reduced overstory canopy (either from disturbance or prolonged inundation) may also be shrub dominated, often with one or few species such as *Baccharis neglecta* (Rooseveltweed), *Baccharis salicifolia* (seepwillow), *Arundo donax* (giant reed), *Sesbania drummondii* (rattlebox sesbania), or *Cephalanthus occidentalis* (common buttonbush), and *Salix exigua* (Texas sandbar willow), *Mimosa asperata* (black mimosa), or *Cephalanthus salicifolius* (willowleaf buttonbush) in the lower Rio Grande Valley. The herbaceous layer is typically not well developed, but may include species such as *Trichloris pluriflora* (multiflower false Rhodes grass), *Setaria scheelei* (southwestern bristlegrass), *Panicum virgatum* (switchgrass), *Paspalum langei* (rustyseed paspalum), *Paspalum denticulatum* (longtom), *Carex crus-corvi* (crowfoot sedge), *Cyperus articulatus* (jointed umbrellasedge), *Rivina humilis* (pigeonberry), *Calyptocarpus vialis* (straggler daisy), *Chromolaena odorata* (cruciata), *Teucrium cubense* (Cuban germander), *Urtica chamaedryoides* (slim stinging nettle), *Parietaria pensylvanica* (cucumberweed), *Verbesina microptera* (southern frostweed), *Chloracantha spinosa* (spiny aster), *Parthenium confertum* (false ragweed), and *Malvaviscus arboreus* var. *drummondii* (Drummond Turk's cap). Vines such as *Serjania brachycarpa* (littlefruit sipple-jack), *Cocculus diversifolius* (orientvine), *Clematis drummondii* (old man's beard), and *Cissus trifoliata* (ivy treebine) are frequently encountered, and *Tillandsia usneoides* (Spanish moss) often drapes the branches of overstory species. Non- native grasses such as *Cynodon dactylon* (bermudagrass), *Urochloa maxima* (guineagrass), *Pennisetum ciliare* (buffelgrass), *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem), and *Bromus catharticus* (rescuegrass) are often present to dominant, and sometimes to the exclusion of most other herbaceous species.

Potential Threats:

Not documented.

Tamaulipan Palm Grove Riparian Forest

This system occurs on Quaternary alluvium of levees and resaca margins and adjacent lower sites near the current Rio Grande channel. Historically this system was more widespread within the Rio Grande delta. This system soils include Loamy or Clayey Bottomland Ecological Sites. This system is confined to the Gulf Coast Prairie and Marshes Ecoregion in Texas.

This system is currently limited to relatively small groves (typically less than 20 hectares) of *Sabal mexicana* (Mexican sabal palm, sometimes referred to as *Sabal texana*) located on loamy or clayey bottomland soils, such as those of the Rio Grande, Zalla, and Matamoros series, on the Rio Grande Delta and near the Rio Grande itself in Cameron County, Texas and similar sites in adjacent Mexico. These often occupy slight elevations along the margins of resacas or old river terraces, but may also occur on level sites. The system may have once occurred along the Rio Grande more than 120 km from its mouth, but is now limited to a few sites near the Gulf, with a few small stands identified in extreme southern Hidalgo County, Texas. These forests and woodlands often have a canopy dominated by *Sabal mexicana* (Mexican sabal palm), or may share dominance with other floodplain species such as *Ebenopsis ebano* (Texas ebony), *Celtis laevigata* (sugar hackberry), *Leucaena pulverulenta* (tepeguaje), *Ulmus crassifolia* (cedar elm), *Ehretia anacua* (anacua), and *Fraxinus berlandieriana* (Mexican ash). *Prosopis glandulosa* (honey mesquite), *Sapindus saponaria* var. *drummondii* (western soapberry), and *Diospyros texana* (Texas persimmon) are often present in the subcanopy. The canopy of these forests may reach a height of

15 m, and the subcanopy, to 10 m, may be composed of some of the species mentioned above. The shrub layer can be patchy with some areas extremely dense and containing species such as *Zanthoxylum fagara* (colima)*, Malpighia glabra* (Barbados cherry)*, Celtis ehrenbergiana* (granjeno)*, Erythrina herbacea* (coralbean)*, Ziziphus obtusifolia* (lotebush)*, Randia rhagocarpa* (crucillo)*, Parkinsonia aculeate* (retama)*, Havardia pallens* (tenaza)*, Chiococca alba* (David's milkberry)*, Iresine palmeri* (Palmer's bloodleaf)*,* and members of the canopy and subcanopy, and other areas relatively open. In some situations the ground may be covered with a layer of dead palm fronds, restricting the development of an herbaceous layer. In other areas, species including, but not limited to, *Leersia monandra* (bunch cutgrass)*, Salvia coccinea* (tropical sage), *Petiveria alliacea* (hierba de las gallinitas)*, Rivina humilis* (pigeonberry)*, Plumbago scandens* (climbing plumbago)*, Tamaulipa azurea* (blue boneset)*, Cocculus diversifolius* (orientvine)*,* and *Malvaviscus arboreus* (Turk's cap) may be present in the herbaceous layer. Fire may have been an important process in these forests as the sites may become extremely dry and a significant, if patchy, layer of palm thatch may be present. These forests appear to differ from other forests dominated by *Sabal mexicana* (Mexican sabal palm) further to the south. Ojeda and González Medrano (1977) describe a site of limited distribution in the northern part of the Sierra de San José de las Rusias in the Municipio of Soto La Marina in Tamaulipas, Mexico. It occurs at higher altitudes and on Oligocene geologic formations. Their brief description suggests that this is likely different in composition and process from the presently described system. Lopez and Dirzo (2007) describe a site further south in Vera Cruz, that also seems to differ relative to composition.

Potential Threats:

- Riparian forests along the Rio Grande are now reduced to scattered remnants due to development on both sides of the lower Rio Grande and Rio Corona in southern Texas and northeastern Mexico.
- Water development has significantly altered the hydrological regime and impacted the species.
- Pollution from development and agriculture degrades the water quality, affecting the floodplain and riparian ecosystems.
- Human activities such as construction, maintenance, recreation, industrial and residential development, agriculture, irrigation, livestock grazing, and gravel mining have greatly converted and altered this floodplain system.
- Non-native species dominate, and sometimes exclude most other herbaceous species.
- Climate change is predicted to cause a shift to species adapted to a hotter, generally drier environment, potentially leading to reduced plant growth and increased mortality from extreme events including exceptional drought.

Texas-Louisiana Coastal Prairie Slough

We are confident this system occurs in the upper coast of Texas (southeast Texas) and adjacent southwest Louisiana. However, a description of this community does not currently exist and will need to be quantified in the field, approved and published through NatureServe's Proceedings of the United States National Vegetation Classification.

West Gulf Coastal Plain Flatwoods Pond

This system occurs on Pleistocene terraces, including the upper Beaumont Formation, but also mapped on the high Pleistocene terraces in the northern part of Texas. These are mapped as Quaternary Fluviatile Terrace (Tile) Deposits along the Red, Sulphur, and Sabine Rivers. This system occupies local topographic lows within the flatwoods. This system occurs on relatively fine-textured soils with an impermeable subsoil horizon, giving rise to a perched water table and saturated conditions during extended periods of the year. This system

The system as currently described, focuses on those herbaceous dominated wetlands that are embedded within the West Gulf Coastal Plain Longleaf Pine Wet Savanna and Flatwoods. As we mapped this system, it occupies sites with a much broader distribution, including wet, herbaceous dominated sites within the West Gulf Coastal Plain Wet Hardwood Flatwoods or West Gulf Coastal Plain Pine – Hardwood Flatwoods. This mapped system is likely dominated by species such as *Panicum hemitomon* (maidencane), *Carex* spp. (caric sedges), *Rhynchospora* (beaksedges), *Eleocharis* spp. (spikerushes), *Andropogon glomeratus* (bushy bluestem), and *Ludwigia* spp. (water-primroses). On drier sites *Schizachyrium scoparium* (little bluestem) may be present. Some sites may be dominated by the non-native *Cynodon dactylon* (bermudagrass). A few woody species may occur, including *Nyssa biflora* (swamp tupelo), *Liquidambar styraciflua* (sweetgum), *Quercus nigra* (water oak), *Planera aquatica* (water elm), and *Cephalanthus occidentalis* (common buttonbush). Flatwood ponds, as described by Bridges and Orzell, represent a more restricted subset of herbaceous-dominated sites with saturated soils resulting from perched water table due to an impermeable subsurface.

Potential Threats:

West Gulf Coastal Plain Flatwoods Ponds have been greatly reduced from their presettlement extent. Only 10 to 25% of original extent in Louisiana remains today (LDWF 2005). Primary threats include alterations to hydrology and fire regime, damage to herbaceous ground cover, direct conversion to other land uses such as pine plantation, and residential and commercial development. Other impacts include contamination by chemical runoff, disturbance by off-road vehicles, rooting by feral hogs (*Sus scrofa*), road maintenance, and development and maintenance of utility corridors. Lack of fire has been a widespread threat, and generally only sites which are managed with prescribed fires conserve the biological diversity of this herbaceous wetland habitat. The lack of fire can lead to shrub and tree encroachment, increased shading and evapotranspiration, accumulation of leaf litter, and a drying out of the depression wetland during drier times of year.

West Gulf Coastal Plain Large River Floodplain Forest

This system typically occupies Quaternary Alluvium along major rivers including the Trinity (downstream of Cobb Creek), Neches, Angelina, Sabine, Sulphur, and San Jacinto, and a few of their major tributaries. This system occurs on broad floodplains with significant development of bottomland soils. These areas include an array of local geomorphic features such as natural levees, point bars, meander scrolls, oxbows, terraces, and sloughs. The soils of this system occupies various textures derived from alluvial processes of the associated rivers. The hydrology of these soils is variable, including temporary, seasonal, semi-permanent flooding regimes. This system is confined to the East Coastal Plain, Gulf Coast Prairie and Marshes, Texas Blackland Prairie, and the West Gulf Coastal Plain Ecoregions in Texas.

his system is typically represented by forests that vary relative to the flooding regime, which is often controlled by local topographic variation and proximity to the river. Swamps are typically represented by forests of *Taxodium distichum* (baldcypress), with other species such as *Nyssa aquatica* (water tupelo), *Gleditsia aquatica* (water honeylocust), and *Carya aquatica* (water hickory) also present. Some semi-permanently flooded sites may also be dominated by *Planera aquatica* (water elm). Floating aquatics, such as *Lemna minor* (common duckweed), *Potamogeton* spp. (pondweeds), *Ceratophyllum demersum* (coontail), and *Nymphaea odorata* (American waterlily) may also be present at those sites. *Quercus lyrata* (overcup oak) is characteristic of seasonally flooded bottomlands, but numerous other species are also important components of the canopy, including *Taxodium distichum* (baldcypress), *Quercus phellos* (willow oak), *Fraxinus pennsylvanica* (green ash), *Liquidambar styraciflua* (sweetgum), *Nyssa biflora* (swamp tupelo), *Fraxinus caroliniana* (Carolina ash), and *Quercus similis* (bottomland post oak). Commonly encountered, and sometimes dominant, species of temporarily flooded sites include *Liquidambar styraciflua* (sweetgum), *Quercus nigra* (water oak), and *Fraxinus pennsylvanica* (green ash). Numerous other species, such as *Quercus laurifolia* (laurel oak), *Quercus michauxii* (swamp chestnut oak), *Quercus pagoda* (cherrybark oak), *Celtis laevigata* (sugar hackberry), *Acer rubrum* (red maple), *Ulmus crassifolia* (cedar elm), *Ulmus americana* (American elm), and *Carya illinoinensis* (pecan) may also be important components of the canopy. *Platanus occidentalis* (American sycamore), *Populus deltoides* (eastern cottonwood), *Betula nigra* (river birch), and *Salix nigra* (black willow) are more conspicuous as early successional species along the riverfront. Understory and shrub cover is variable, but is typically relatively low, particularly in more frequently flooded sites and sites with significant overstory canopy. The understory may have small individuals of the overstory, as well as species such as *Alnus serrulata* (smooth alder), *Arundinaria gigantea* (giant cane), *Carpinus caroliniana* (American hornbeam), *Ilex decidua* (possumhaw), *Ilex opaca* (American holly), *Callicarpa americana* (American beautyberry), *Crataegus viridis* (green hawthorn), *Crataegus marshallii* (parsley hawthorn), *Crataegus opaca* (riverflat hawthorn), *Styrax americanus* (American snowbell), *Ditrysinia fruticosa* (sebastian-bush), *Sambucus nigra* ssp. *canadensis* (common elderberry), *Cephalanthus occidentalis* (common buttonbush), *Forestiera acuminata* (swamp privet), *Planera aquatica* (water elm), and/or *Sabal minor* (dwarf palmetto). Where the overstory canopy is open, *Planera aquatica* (water elm), *Cephalanthus occidentalis* (common buttonbush), or *Forestiera acuminata* (swamp privet) may form dense stands. Woody vines that may be encountered include *Berchemia scandens* (Alabama supplejack), *Smilax bona- nox* (saw greenbrier), *Vitis rotundifolia* (muscadine grape), *Toxicodendron radicans* (poison ivy), and *Campsis radicans* (trumpet creeper). Herbaceous species may include *Boehmeria cylindrica* (false nettle), *Saururus cernuus* (lizard's tail), *Saccharum baldwinii* (narrow plumegrass), *Elymus virginicus* (Virginia wildrye), *Onoclea sensibilis* (sensitive fern), *Carex cherokeensis* (Cherokee sedge), *Carex intumescens* (bladder sedge), *Carex joorii* (cypress swamp sedge), *Carex debilis* (spindlefruit sedge), other *Carex* (sedge) species, *Chasmanthium latifolium* (creek oats), *Chasmanthium sessiliflorum* (narrowleaf woodoats), *Justicia ovata* (looseflower waterwillow), *Bidens aristosa* (bearded beggarticks), *Panicum hemitomon* (maidencane), *Leersia virginica* (Virginia cutgrass), and numerous others. *Pinus taeda* (loblolly pine) may be found, particularly on some better drained sites, and where it has been planted. *Triadica sebifera* (Chinese tallow) sometimes invades this system.

Potential Threats:

Not documented.

West Gulf Coastal Plain Near-Coast Large River Swamp

This system occurs on Quaternary alluvium deposited within the Beaumont/Deweyville surfaces. This system occurs along large river floodplains of the Sabine, Neches, and Trinity Rivers near the coast, often with some tidal influence. The soils of this system includes bottomland soils of the near-coast region. This system occurs in the Gulf Coastal Prairies and Marshes and West Gulf Coastal Plain Ecoregion in Texas.

These swamps, usually dominated by *Taxodium distichum* (baldcypress) and/or *Nyssa aquatica* (water tupelo), occur along the Sabine, Neches, and Trinity Rivers as they enter the bays and estuaries and have some tidal influence. These are generally distributed downstream of Interstate Highway 10 (a coincidental landmark for the distribution of this system). On the Neches River, this is nearly coincident with the area downstream of the confluence with Pine Island Bayou. These swamps are typically interspersed with marshes of the coastal region. Other species are usually more minor components of the canopy, including *Fraxinus pennsylvanica* (green ash), *Acer negundo* (boxelder), and *Triadica sebifera* (Chinese tallow).

Potential Threats:

Not documented.

West Gulf Coastal Plain Nonriverine Wet Hardwood Flatwoods

Like the West Gulf Coastal Plain Pine – Hardwood Flatwoods, this system is associated with high Pleistocene terraces, of the Lissie and upper Beaumont Formations, as well as the Quaternary Fluviatile Terrace Deposits to the north. This system represents the lowest topographic position within the level to very gently undulating terraces occupied by flatwoods. Hydrology is controlled by local rainfall, not overbank flooding of nearby streams. The soils o this system are fine-textured, with an impermeable subsurface horizon, which leads to a perched water table. Because of the lower topographic position of these flatwoods, saturated soil conditions tend to occur over extended periods of the year. This system is confined to the West Gulf Coastal Plain Ecoregion in Texas.

This system represents the wetter end of the wooded toposequence of the flatwoods and occurs within low positions of swales and other wet circumstances. The canopy is often dominated by *Quercus phellos* (willow oak), *Quercus laurifolia* (laurel oak), *Quercus lyrata* (overcup oak), *Quercus nigra* (water oak), *Quercus michauxii* (swamp chestnut oak), *Ulmus alata* (winged elm), and *Liquidambar styraciflua* (sweetgum). *Pinus taeda* (loblolly pine) may be present in the canopy. *Triadica sebifera* (Chinese tallow) is a commonly encountered non-native species invading this system. The understory and herbaceous layers of this system are not well- developed, as the canopy tends to be closed.

Potential Threats:

Not documented.

West Gulf Coastal Plain Small Stream and River Forest

This system largely occurs on Quaternary Alluvium, but may also be found on other mapped geologic surfaces on drainages lacking significant alluvial development. This system occupies small rivers, streams, creeks, and upland drainages. These sites tend to be higher in the watershed where less depositional activity occurs. The local geomorphological variation tends to be less than in the West Gulf Coastal Plain Large River Floodplain Forest.

This system occupies bottomland soils on small streams. Fewer sites are seasonally or semi- permanently flooded. This system occurs in the East Coastal Plain Gulf Coastal Prairie and Marshes, Texas Blackland Prairie and West Gulf Coastal Plain Ecoregions in Texas.

This system, occupying the bottomlands of small rivers, streams, and creeks, is primarily dominated by hardwood species such as *Liquidambar styraciflua* (sweetgum), *Quercus nigra* (water oak), *Celtis* *laevigata* (sugar hackberry), *Fraxinus pennsylvanica* (green ash), *Betula nigra* (river birch), *Quercus phellos* (willow oak), *Quercus laurifolia* (laurel oak), *Ulmus americana* (American elm), *Ulmus crassifolia* (cedar elm), *Ulmus alata* (winged elm), *Quercus pagoda* (cherrybark oak), *Quercus falcata* (southern red oak), *Platanus occidentalis* (American sycamore) and *Acer rubrum* (red maple). *Pinus taeda* (loblolly pine), *Pinus elliottii* (slash pine), and/or *Juniperus virginiana* (eastern redcedar) may be present in the canopy or occur as a sub-canopy stratum. Wetter sites tend to be dominated by more flood-tolerant species such as *Taxodium distichum* (baldcypress), *Nyssa aquatica* (water tupelo), *Gleditsia aquatica* (water honeylocust), *Carya aquatica* (water hickory), *Quercus lyrata* (overcup oak), *Quercus similis* (bottomland post oak), *Planera aquatica* (water elm), and *Quercus phellos* (willow oak). Shrubs may form dense patches with species such as *Cephalanthus occidentalis* (common buttonbush) or *Planera aquatica* (water elm). The understory of forests may be made of species common to the canopy. Other understory and shrub species that may be common include *Carpinus caroliniana* (American hornbeam), *Ostrya virginiana* (American hop-hornbeam), *Morus rubra* (red mulberry), *Ilex decidua* (possumhaw), *Sabal minor* (dwarf palmetto), *Ilex opaca* (American holly), *Ilex vomitoria* (yaupon), *Morella cerifera* (wax-myrtle), *Callicarpa americana* (American beautyberry), *Itea virginica* (Virginia sweetspire), *Arundinaria gigantea* (giant cane), *Alnus serrulata* (smooth alder), and/or *Maclura pomifera* (bois d'arc). Early successional woodlands may be mapped as shrublands, due to reduced woody cover. These sites may be dominated by early successional species such as *Salix nigra* (black willow), *Gleditsia triacanthos* (common honeylocust), *Platanus occidentalis* (American sycamore), or *Ulmus alata* (winged elm). Non-native woody species that may be present include *Triadica sebifera* (Chinese tallow), *Lonicera japonica* (Japanese honeysuckle), and *Ligustrum* spp. (privets). Woody vines may be conspicuous and include *Berchemia scandens* (Alabama supplejack), *Toxicodendron radicans* (poison ivy), *Brunnichia ovata* (eardrop vine), *Smilax bona-nox* (saw greenbrier), and *Ampelopsis arborea* (peppervine). The herbaceous layer may be well developed in some cases. Non-natives such as *Cynodon dactylon* (bermudagrass), *Lolium perenne* (Italian ryegrass), *Paspalum notatum* (Bahia grass), and *Sorghum halepense* (Johnsongrass) may be dominant. Native herbaceous species of this system include *Chasmanthium laxum* (slender woodoats), *Chasmanthium latifolium* (creek oats), *Dichanthelium* spp. (rosette grasses), *Carex cherokeensis* (Cherokee sedge), *Boehmeria cylindrica* (false nettle), *Polygonum* spp. (smartweeds), *Ambrosia trifida* (giant ragweed), *Xanthium strumarium* (cocklebur), *Paspalum floridanum* (Florida paspalum), *Leersia* spp. (cutgrasses), *Tripsacum dactyloides* (eastern gamagrass), *Panicum virgatum* (switchgrass), *Elymus virginicus* (Virginia wildrye), and *Geum canadense* (white avens).

Potential Threats:

Not documented.

West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods

This system is associated with Lissie and upper Beaumont Formations (including the Montgomery, Irene, and Bentley terraces). This system occurs on mesic to seasonally saturated low areas and flats, on level to gently rolling uplands. Microtopographic variation is provided by the presence of swales and pimple mounds. The soils of this system include sandy loams to silty loams that are strongly acid, nutrient poor, and low in organic constituents. Typically, these soils are hydric, with seasonal fluctuations between saturation and droughtiness. This system occurs in the Gulf Coastal Prairie and Marshes and West Gulf Coastal Plain Ecoregions in Texas.

This system may be characterized as having a sparse canopy (under natural fire cycles) dominated by *Pinus palustris* (longleaf pine). Other species in the canopy include *Quercus stellata* (post oak), *Quercus marilandica* (blackjack oak), *Nyssa sylvatica* (blackgum), *Quercus laurifolia* (laurel oak), *Quercus falcata* (southern red oak), and *Liquidambar styraciflua* (sweetgum). Shrubs are typically limited in distribution within the system to local topographic highs and include species such as *Morella cerifera* (wax-myrtle), *Ilex vomitoria* (yaupon), *Symplocos tinctoria* (common sweetleaf), *Cyrilla racemiflora* (leatherwood), and others. The herbaceous layer may be highly diverse. Drier sites may be dominated by *Schizachyrium scoparium* (little bluestem), *Schizachyrium tenerum* (slender bluestem), *Eupatorium rotundifolium* (roundleaf eupatorium), and others. Wetter sites may not have species showing a clear dominance. Species such as *Liatris* spp. (gay-feathers), *Xyris* spp. (yellow-eyed grasses), *Rhexia* spp. (meadowbeauties), *Rhynchospora* spp. (beaksedges), *Fuirena* spp. (umbrellasedges), *Marshallia graminifolia* (grassleaf Barbara's buttons), *Aletris aurea* (golden colicroot), and many other species may share dominance in this system. Suppression of fire in this system has lead to increased woody dominance. *Pinus taeda* (loblolly pine), *Pinus elliottii* (slash pine), *Liquidambar styraciflua* (sweetgum), *Nyssa sylvatica* (blackgum), and *Acer rubrum* (red maple) may now dominate the canopy of these sites, with a thick understory dominated by *Ilex vomitoria* (yaupon) and *Morella cerifera* (wax-myrtle). Due in part to the difficulty in distinguishing *Pinus palustris* (longleaf pine) dominated sites from sites dominated by other pines, occurrences of this system may be mapped within the system West Gulf Coastal Plain Pine – Hardwood Flatwoods.

Potential Threats:

This ecological system is much reduced form its original extent. Today, only 1 to 5% of this system remains in Louisiana (Smith 1993). Current examples of this ecological system are primarily threatened by drainage, other forms of physical damage form logging, and conversion to residential and commercial development and pine plantations (LDWF 2005). Longleaf pine forests were among the most valuable economic resources in the region at the turn of the twentieth century (Bray 1906). Overall losses of longleaf pine in Texas have exceeded those of all other southern states (Outcalt 1997); less than 16,200 hectares of mostly second-growth stands remain (McWilliams and Lord 1988). Land use practices continue to degrade remaining examples of longleaf pine communities (Bridges and Orzell 1989).

Another primary threat is alteration of the natural fire regime. Longer fire-return intervals (10 years) will lead to significant woody encroachment of shrubs and fire-sensitive trees. This condition can also lead to increased fuel loading that will put the larger, more established trees at risk due to hotter, less frequent fires. An increase in cover of off-site woody species can suppress the regeneration and growth of species typical of this system in its natural state. Threats also include the limiting of prescribed burning due to urban interface, safety and smoke management concerns.

The proliferation of both invasive native and exotic vegetation is a negative impact on this ecosystem. Some native plants can be problematic in the absence of natural processes like fire. For example, *Ilex vomitoria* can crowd out other natives and become a dominant understory plant in some fire-suppressed areas. Most invasives are extremely difficult and costly to control once established. Other invasives already well-established include *Triadica sebifera, Sus scrofa* and non-native fire ants *Solenopsis invicta*.

If changes in regional climate bring about a decrease in precipitation, this could lead to drying and loss of this system.

Western Great Plains Floodplain

This system generally occurs on Quaternary Alluvium. This system lies on valley floors of large rivers and perennial streams. This system tends to occupy broad valley bottoms with deep alluvial deposits. In Phase 1, this system is found within the Clear Fork of the Middle Brazos watersheds. This system soils occur on Loamy Bottomland, Clayey Bottomland, and Draw ecoclasses. This system occurs in the Central Great Plains, High Plains, and the Southwestern Tablelands Ecoregions in Texas.

This system is characteristic of valley floors of large rivers and perennial streams where significant alluvial deposition occurs. Broad alluvial deposits commonly occur and are generally mapped as bottomland soils. This system can be expressed in numerous cover types including forests, woodlands, shrublands, and herbaceous vegetation (where marshes may develop in the floodplain soils, or mesic prairie dominated by *Andropogon gerardii* (big bluestem) and *Panicum virgatum* (switchgrass) may be conspicuous). *Populus deltoides* (eastern cottonwood), *Sapindus saponaria* var. *drummondii* (western soapberry), *Prosopis glandulosa* (mesquite), *Salix nigra* (black willow), *Ulmus americana* (American elm), and/or *Celtis laevigata* var. *reticulata* (netleaf hackberry) may be important components of forests or woodlands of this system. *Juniperus ashei* (Ashe juniper), *Juniperus pinchotii* (redberry juniper), and/or *Quercus fusiformis* (plateau live oak) may be present to dominant, but such evergreen dominated sites generally occur on the eastern edge of the range of this system. As this is the eastern extent of the overall distribution of the system, some species occur in the system at the western edge of their range, and may not be represented further west within the range of the system. Such species include *Quercus fusiformis* (plateau live oak) and *Ulmus americana* (American elm). Shrublands may also have *Prosopis glandulosa* (mesquite) and *Salix nigra* (black willow) as important components.

Some shrublands in this system, especially those on more saline sites, may be dominated by the non-native *Tamarix* spp. (saltcedar). Woodlands may sometimes be dominated by the non- natives *Tamarix* spp. (saltcedars), *Ulmus pumila* (Siberian elm), or *Elaeagnus angustifolia* (Russian olive). Herbaceous vegetation may include marshes occupying floodplain sites, with species such as *Schoenoplectus* spp. (bulrush) and/or *Typha* spp. (cattails). Some sites may be dominated by tallgrass species such as *Andropogon gerardii* (big bluestem) and *Panicum virgatum* (switchgrass). More typically, sites lacking significant woody cover may be dominated by *Pleuraphis mutica* (tobosa), *Nessella leucotricha* (Texas wintergrass), and *Panicum obtusum* (vine mesquite). Non-native graminoids are also commonly encountered and include *Cynodon dactylon* (bermudagrass), *Sorghum halepense* (Johnsongrass), *Bromus arvensis* (Japanese brome), and *Bothriochloa ischaemum* var. *songarica* (King Ranch bluestem). Shrublands are commonly dominated by *Prosopis glandulosa* (honey mesquite) and are mapped as Western Great Plains Mesquite Woodland and Shrubland.

Potential Threats:

This system has been heavily impacted by human activities. Agricultural development has affected many examples of this system. Direct conversion to cropland or pastures can destroy this system. Irrigation has had a major effect both by removing water from some parts of the system and, conversely, by providing more consistent flow in the summer through the return flow of water used for irrigation. Other indirect effects of agricultural within or near the floodplain include increased sediment loads from erosion and chemical pollution from pesticides, herbicides, and fertilizer. The flooding and channel migration that is important in maintaining this system has been affected by attempts to contain the channel in its current location through bank armoring (riprap or other bank stabilization techniques) and channelization (man-made levees, dredging, wing dams, closing dams). While these may not immediately affect large areas of this system, the changes to the flooding regime have longer term impacts. Dams, typically built for irrigation or recreation, have immediate impacts by flooding the reservoir area and increasing the amount of open water compared to floodplain. They have longer term effects by changing the flooding pattern, reducing the amplitude low water in the upstream pool and of high water both upstream and downstream. Dams also trap much of the sediment being transported by the river and reduce the erosion and deposition rates downstream (Johnson 1992).

Grazing by native species was not likely an important factor shaping this system, but grazing domestic livestock can impact this system and lead to decreased cover of many graminoids and some sensitive forbs. Weedy invasives can dominate parts of the floodplain. Several herbaceous species are particularly aggressive and can dominate floodplain marshes, sometimes forming near monocultures. These include *Phragmites australis, Phalaris arundinacea*, and *Typha x glauca*. Other weedy species can become abundant in the understory of floodplain forests.

A serious threat to stands of this system that contain *Fraxinus pennsylvanica* is emerald ash borer (*Agrilus planipennis*). This exotic beetle has seriously affected *Fraxinus* spp. trees in southern Michigan and is projected to continue to spread throughout the range of *Fraxinus* spp. in the Midwest and Northeast by 2045 (DeSantis et al. 2012). After prolonged infestation, mortality of *Fraxinus* spp. is nearly 100% (Herms et al. 2010).

Western Great Plains Riparian (mixed upland and wetland)

This system occurs along headwater streams and generally occurs over upland soils that have developed in place over a variety of bedrock types, often limestone. This system occurs along drainages that may be intermittent and tend to be dominated by erosional processes (as opposed to depositional processes) within the drainage of the Clear Fork of the Middle Brazos River. As this system is mapped, it by definition occurs outside of areas mapped as bottomland soils. Soils are therefore mapped with soils of the surrounding uplands. This system occurs in Chihuahuan Deserts, Central Great Plains, High Plains, and the Southwestern Tablelands Ecoregions in Texas.

Forests and woodlands may have species such *Populus deltoides* (eastern cottonwood), *Salix nigra* (black willow), *Celtis laevigata* var. *reticulata* (netleaf hackberry), and *Sapindus saponaria* var. *drummondii* (western soapberry). *Juniperus ashei* (Ashe juniper), *Juniperus pinchotii* (redberry juniper), or *Quercus fusiformis* (plateau live oak) may occur along the eastern edge of the range of this system where it grades into Edwards Plateau Riparian (CES303.652) or Southeastern Great Plains Riparian (CES206.709). Grasslands associated with riparian corridors may also be present and will generally be somewhat more mesic than grasslands of the surrounding landscape. Herbaceous species commonly encountered include *Pleuraphis mutica* (tobosa), *Nassella leucotricha* (Texas wintergrass), *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), and *Schizachyrium scoparium* (little bluestem). Marshes within these drainage corridors are mapped as Western Great Plains Open Freshwater Depression Wetland (CES303.675). Shrublands are typically strongly dominated by *Prosopis glandulosa* (honey mesquite) and are mapped as Western Great Plains Mesquite Woodland and Shrubland (CES303.668). The non-natives

Tamarix spp. (saltcedars), *Elaeagnus angustifolia* (Russian olive), and *Ulmus pumila* (Siberian elm) may also be commonly encountered in this system.

Potential Threats:

These areas are often subjected to heavy grazing and/or agriculture and can be heavily degraded. Non-native *Tamarix* spp., *Elaeagnus angustifolia*, forage grasses (*Agrostis gigantea, Bromus inermis, Dactylis glomerata, Elymus repens, Poa pratensis, Phleum pratense*), and less desirable grasses and forbs such as *Polypogon monspeliensis, Cirsium arvense, Euphorbia esula* can invade degraded examples up through central Colorado (Kittel et al. 1999, Muldavin et al. 2000, Carsey et al. 2003). Reduced annual flooding may cause channel down-cutting that can reduce the number of sandbars that provide seedbed for the characteristic tree species such as *Populus deltoides* (Scott et al. 1996). Groundwater depletion and stream diversion have frequently resulted in old gallery cottonwood riparian woodlands lacking cottonwood regeneration and encroachment of upland vegetation.

Other human impacts include highway, bridge, and pipeline construction; channel modifications for flood control; recreation; industrial and residential development; agriculture; irrigation; livestock grazing; and gravel mining. Offsite disturbances in the watershed that change watershed hydrology can also have adverse effects on the composition and productivity of riparian plants and corresponding animal associations (Manci 1989). Conversion of this type has commonly come from water developments/reservoirs and dryland wheat and irrigated agriculture especially hay meadows dominated by non-native forage grasses (CNHP 2010). Severe alteration of hydrological regime such as major diversions can convert riparian areas to intermittent streams dominated by upland vegetation as wetland species are eliminated.

Common stressors and threats include altered hydrologic regime from water development, channel modifications for flood control, urban and industrial effluent discharge, and gravel mining. Excessive livestock use leads to a shift in plant species composition to more grazing- and disturbance-tolerant species including invasive non-native forage species. Potential climate change effects could include alterations to the hydrologic regime causing reductions of flows available for natural processes and plant and animal communities, if climate change has predicted the effect of less effective moisture with increasing mean temperature (TNC 2013).

Western Great Plains Wooded Draw and Ravine (mixed upland and wetland)

This system is typically found associated with permanent or ephemeral streams though it may occur on steep northern slopes or within canyon bottoms that do not experience periodic flooding. Soil moisture and topography allow greater moisture conditions compared to the surrounding areas. Occurrences can be either tree-dominated or predominantly shrubland.

Juniperus scopulorum and Fraxinus pennsylvanica with Ulmus rubra or Ulmus americana typically dominate this system. Wetter areas within this system can have significant amounts of Populus deltoides. Component shrubs can include Prosopis glandulosa, Prunus virginiana, Rhus spp.,or Symphoricarpos occidentalis. Common grasses can include , Carex spp., Pascopyrum smithii, Piptatheropsis micrantha, Pseudoroegneria spicata, or Schizachyrium scoparium. This system was often subjected to heavy grazing and trampling by both domestic animals and wildlife and can be heavily degraded in some areas. In addition, exotic species such as Ulmus pumila and Elaeagnus angustifolia can invade these systems.

Potential Threats:

Not documented.

Riverine Vegetation

Riverine vegetation is defined as perennial or ephemeral river, stream, creek headwater and *in-stream* habitats (e.g. riffle, glide, pool, plunge; may include substrate descriptions such as mud, silt, gravel, cobble, bedrock, woody/vegetation inputs, etc.). These habitats are described and prioritized in Supplement 4.4 Texas Native Fish Conservation Areas Network.

Lacustrine

As defined in this document these priority habitats are freshwater and saline/salt lake environments – natural and manmade ponds, lakes, reservoirs. Which are managed primarily for natural resources conservation, but may also have contact recreation and/or aesthetic objectives; typically these sites have deep water and shallow-water habitats. A few of Texas' priority habitats may be described elsewhere in this document including freshwater or saline wetlands. Lacustrine habitats are diverse and may occur an any ecoregion across Texas.

It is important to note that these are different from "cultural aquatic habitats" which are managed primarily for human uses – commercial, stock, or industrial purposes – and do not have conservation management objectives in their primary purpose

Western Great Plains Closed Depression Wetland

These playas are described within the "freshwater wetland" section of this document. The deeper playas would be considered lacustrine systems in wet years.

South Texas Resacas

Resacas are occur in the Rio Grande valley of Texas and Mexico. They are described as oxbow lakes created by the historical seasonal flooding of the Rio Grande. This flooding created new river channels or oxbows, referred to as resacas. Several priority habitats types, described in the "Riparian" section of this document, also occur along the banks of these resacas. These include: Tamaulipan Palm Grove Riparian Forest, Tamaulipan Floodplain, and Rio Grande Delta Thorn Woodland and Shrubland.

Potential Threats:

Not documented.

West Gulf Coastal Plain Flatwoods Pond

This type is defined in the "freshwater wetland" section of this document. The deeper flatwoods ponds of East Texas would also be considered lacustrine.

Oxbow Lakes

The deeper oxbows lakes located in the wetter, eastern portions of the state of Texas may also considered lacustrine. Oxbow lakes are described in the "Freshwater Wetland" and section of this document. Several priority habitat types occur withing or on the banks of oxbow lakes.

These are described in the “Riparian” section of this document and include: Western Gulf Coastal Plain Large River Floodplain Forest, Red River Large Floodplain Forest, and Columbia Bottomlands Forest and Woodland.

Potential Threats:

Not documented.

West Gulf Coastal Plain Seepage Swamp and Baygall

This type is defined in the “freshwater wetland” section of this document. The deeper swamps and baygalls of East Texas would also be considered lacustrine.

Coastal Marine

As defined in this document these priority habitats may be subtidal (e.g. sea grass beds), shallow (e.g. submerged sand or mud substrates) and deep-water habitats. All priority marine habitats occur in the Gulf of Mexico or along the coast of the Gulf Coast Prairies and Marshes Ecoregion these habitats are non-estuarine, non-marsh and include substrates such as natural reefs, rocky bottoms, or muddy bottoms.

Potential Threats:

Not documented.

Texas Coastal Bend Seagrass Bed

This system includes seagrass beds occurring along the Texas Coast south of San Antonio Bay. Dominants may include, individually or in admixtures with other seagrasses, *Cymodocea filiformis*, which is restricted in Texas to this ecological system, *Halophila engelmannii* or

Halodule wrightii, which occupy thousands of acres of the Laguna Madre, and *Thalassia testudinum*. This system includes Texas' largest occurrences of *Thalassia testudinum* and *Halophila engelmannii*. Other dominants may include *Ruppia maritima*.

Potential Threats:

Not documented.

Upper Texas Coast Seagrass Bed

This system includes seagrass communities occurring in bays along the upper Texas coast north of and including San Antonio Bay. It includes vegetation dominated by *Thalassia testudinum*, *Halophila engelmannii, Ruppia maritima*, or *Halodule wrightii*. Many of these occurrences have declined in extent. Seagrass communities are declining in many bays along the Texas coast.

Potential Threats:

Not documented.

Texas-Louisiana Fresh-Oligohaline Subtidal Aquatic Vegetation

This system includes subtidal beds of aquatic vegetation in fresh to oligohaline tidal waters of the Gulf of Mexico in Louisiana and Texas. Species composition may include *Potamogeton perfoliatus*, *Zannichellia* *palustris*, *Vallisneria americana*, *Najas guadalupensis*, and *Ruppia maritima*. It is found in the Trinity Bay portion of the Galveston Bay complex along the upper coast of Texas. Although the substrate of most Texas bays is sand, this system occurs on mud- dominated substrates. This system is also distinguished by the prevalence of oligohaline waters, whereas other Texas bays are considerably more saline. As a consequence, the predominant species, *Najas guadalupensis* and *Vallisneria americana*, which are salt intolerant, are able to attain dominance here. Both species are largely restricted to the northeastern portions of the bay where they are protected by a sand bar system which restricts wave action and turbidity.

Potential Threats:

The extent and quality of this system have been heavily reduced by shoreline development and associated draining and filling, bulkheading, and channelization. Seagrass communities are declining in many bays along the Texas coast.

Freshwater Wetland

As defined in this document, these wetlands are freshwater-dependent non-riverine habitats, which rely on filling, flushing, and irrigated substrates caused by rain, runoff, groundwater, and/or perched water tables; includes their hydrophilic vegetation: swamps, bog, fen, freshwater marsh, non-desert playa, wet prairie, wet meadow, *surface expressions of groundwater* (seeps, springs, cienegas), vernal pools, tinajas, interdunal wetlands. These diverse wetlands occur in all ecoregions of the state and often provide a much-needed water source for faunal species in drier regions of the state.

Chihuahuan-Sonoran Desert Bottomland and Swale Grassland

This mixed grassland ad wetland habitat typically on Quaternary alluvium, but may be local in nature and mapped within various geological formations. Generally found on local topographic lows that may be associated with a drainage or may occur as basins or swales. Found on tight soils, typically Clay Flat Ecological Sites.

This system is named based on the regions (Chihuahuan and Sonoran Deserts) where it is best developed and occupies significant areas, however it does occur well outside these regions, at least as far north and east as the Rolling Plains of Texas. The system typically occurs in local topographic lows that may be associated with drainages, or may represent swales or basins, but typically receives run-off from the surrounding landscape. Soils are generally clayey, and in some cases the shrink-swell characteristics of the soil may limit the development of woody species.

Pleuraphis mutica (tobosa) is generally the clear dominant, though other species such as *Panicum obtusum* (vine-mesquite), *Sporobolus airoides* (alkali sacaton), and *Pascopyrum smithii* (western wheatgrass) may be present. *Prosopis glandulosa* (mesquite) may be present, and in some cases may develop into a significant canopy. The system often occupies the Clay Flat Ecological Site.

Potential Threats:

- Native mixed semi-desert grasslands are the dominant type
- They range from open grasslands to denser grasslands with higher shrub and succulent cover
- Without fire or other disturbance, they become dominated by woody vegetation and convert to shrublands or woodlands

- Drought and livestock grazing interact with grass cover and fire-return intervals can affect the rate of shrub increase
- After grassland conversion to shrubland there is a loss of perennial grasses and increases of bare ground
- Topsoil erosion can occur changing the site to be less suitable for grass recolonization
- Hydrological alterations occurred in semi-desert grasslands during early Anglo-American settlement time.
- Arroyo formation was initiated by building ditches, canals, roads and embankments along channels that altered valley floor hydrology.
- The invasive non-native, perennial grasses Eragrostis lehmanniana and Eragrostis curvula greatly impacted many semi-desert grasslands in this ecoregion.
- Eragrostis lehmanniana is a particularly aggressive invader and alters ecosystem processes, vegetation composition, and species diversity.
- Conversion of grassland to shrublands, desert scrub and woodlands due to fire suppression and oak, pinyon or juniper tree invasion
- Invasive non-native species such as Eragrostis lehmanniana and Eragrostis curvula have converted the grassland
- Threats include fragmentation from housing and water developments, altered fire regime from fire suppression and indirect fire suppression from livestock grazing and fragmentation
- Overgrazing by livestock can lead to severe soil compaction and reduce vegetation cover exposing soils to erosion of topsoil
- Potential climate change effects could include a reduction in the current extent of the ecosystem and conversion to desert scrub.

Eastern Great Plains Wet Meadow, Prairie, and Marsh

Not yet described

Edwards Plateau Upland Depression

These wetlands occur on massive Cretaceous limestone geologic formations, such as Edwards Limestone and are internally draining depressions of karstic origin on level plateau surfaces. The soils consist of loams and clay loams.

This system includes shallow wetlands formed over limestone on the Edwards Plateau of Texas. Variable in size and duration of inundation, these wetlands are typically found on level uplands. Dominant vegetation includes both graminoids and forbs tolerant of wet periods but not necessarily wetland-dependent. Dominant species may include *Pleuraphis mutica* (tobosa), *Bouteloua dactyloides* (buffalograss), *Tridens albescens* (white tridens), *Sedum pulchellum* (widowscross), *Sedum nuttallianum* (yellow stonecrop), *Sporobolus vaginiflorus* (poverty dropseed), *Chaetopappa bellidifolia* (hairy leastdaisy), *Ambrosia psilostachya* (western ragweed), *Paronychia* spp. (whitlow-wort), and the alga *Nostoc* commune (blue-green algae).

Panicum obtusum (vine-mesquite), *Bothriochloa barbinodis* (cane bluestem), *Pascopyrum smithii* (western wheatgrass), *Bouteloua gracilis* (blue grama), *Chenopodium album* (lambsquarters), *Helianthus ciliaris* (blue-weed), and *Solanum elaeagnifolium* (silverleaf nightshade) may also be present. Some larger occurrences of this wetland system are found in Crockett, Reagan, Schleicher, Irion, and Sterling counties in the northwest Edwards Plateau (the Eldorado Plateau). In Phase I, they are found primarily in

Runnels, Concho, and Sutton counties. Formation of these occurrences is apparently from solution of the underlying limestone.

Potential Threats:

Not documented.

North American Arid West Emergent Marsh

These wetlands may occur on various geologic substrates, but often Quaternary alluvium and include depressions, margins of freshwater lakes, and margins of streams and rivers. Substrates are comprised of various edaphic situations, with accumulation of organic material depending on the length of time the marsh has been established.

Vegetation occupying depressions, margins of lakes, or margins of streams that are frequently or continuously inundated by freshwater. This system includes marshes occupying stock tanks and other man-made depressions, and other moist to wet sites other than marshes. The vegetation is dominated by herbaceous species including *Schoenoplectus pungens* var. *longispicatus* (American bulrush), *Schoenoplectus acutus* (hardstem bulrush), *Cladium mariscus* ssp. *jamaicense* (saw-grass), *Eleocharis montevidensis* (sand spikerush), *Polypogon monspeliensis* (rabbitfoot grass), *Echinochloa crus-galli* (barnyardgrass), *Cynodon dactylon* (Bermudagrass), *Phragmites australis* (common reed), *Phalaris caroliniana* (Carolina canarygrass), *Typha domingensis* (southern cattail), *Juncus* spp. (rushes), *Potamogeton* spp. (pondweeds), *Polygonum* spp. (smartweeds), *Ceratophyllum demersum* (coontail), and *Chara* spp. (stoneworts).

Potential Threats:

- Marsh wetlands are often drained and filled for development, leading to conversion of the ecosystem type.
- Desiccation is caused by diversion of inflow from surface waters or by lowering the groundwater level from pumping or agriculture or industry.
- Common stressors and threats include dredging, prescribed fire, not allowing ponds to periodically drain, and alterations to the natural hydrology.
- Climate change models forecast substantial increases in maximum temperatures for all months of the year, with the greatest increases concentrated during the summer.
- November and December minimum temperatures only increase by one standard deviation beyond the baseline values.
- Standing water is a crucial habitat for many wildlife species.
- Introduced fish have already impacted many lakes.
- Climate change may exacerbate the stresses on the aquatic ecosystems.
- Increasing demand for water may impact wetland marshes and shrink marsh size.
- Salinity levels can increase beyond the tolerance of some or all plants in closed-basin marsh systems.
- As smaller water sources dry, wildlife, domestic livestock, and humans will increase use of larger or more stable water sources.

North American Warm Desert Cienega

While the cienegas themselves often occur within Quaternary alluvium, the springs that feed the marshes and moist-soil habitats emanate from contacts often of Cretaceous limestone with less permeable geologic formations. Desert cienegas include both spring runs and draws fed by freshwater springs.

This predominately herbaceous system occurs on drainages fed by freshwater springs. Evaporative processes may create saline conditions leading to the presence and/or dominance of species such as *Sporobolus airoides* (alkali sacaton*), Distichlis spicata* (saltgrass), *Sesuvium verrucosum* (winged sea purslane), and *Trianthema portulacastrum* (desert horse purslane), and *Limonium limbatum* (bordered sea-lavender). Other moist-soil species include *Schoenoplectus pungens* var. *longispicatus* (American bulrush), *Juncus* spp. (rushes), and *Eleocharis* spp. (spikerushes). Composition of the occurrence is dependent on the depth and availability of water associated with the originating spring. At some sites, rare species such as *Helianthus paradoxus* (Pecos sunflower), *Nesaea longipes* (longstalk heimia), and *Agalinis calycina* (Leoncita false foxglove) may be found. The non-native grass *Cynodon dactylon* (Bermudagrass) is often encountered.

Potential Threats:

- Activities like recreational use, cutting of woody vegetation, mining, land development, and roadways/railways development can lead to watershed pollution, withdrawal of groundwater, and wildfire suppression.
- Heavy livestock grazing can result in the removal of native vegetation, changes in vegetation composition, and increased water pollution.
- Recreational use can lead to habitat elimination, soil erosion, and increased pollution and fire risk.
- Cutting of woody vegetation alters native vegetation assemblage and overall ecological function, which can impact fish habitat.
- Development of roadways/railways alters spring habitat and increases non-point source pollution
- Mining activities eliminate spring habitat, alter groundwater flow paths, and are a source of pollution and sedimentation
- Altered watershed ground cover results in altered runoff and recharge, and increased non-point source pollution
- Land development reduces alluvial recharge, increases soil erosion, and non-point source pollution
- Development of springs alters natural structure and reduces soil moisture absorption.
- Spring flows are diverted into open troughs or covered tanks for watering and development of ponds, resulting in loss of surface flows and groundwater recharge/discharge dynamics.
- Agricultural and urban activities cause point-source pollution, which alters water quality of groundwater sources and strongly affects springs' ecosystem integrity.
- Non-point-source pollution from agricultural and urban areas within the watershed can also alter water quality in surface storm runoff into the ciénega itself, which is detrimental to fish habitats.
- Withdrawals of groundwater result in loss of baseflow and lowering of the alluvial water table.

- Wildfire suppression and changes in land use can lead to non-native vegetation invasion and alter plant water use in watersheds.
- Introduction of exotic plants and animals can lead to replacement of native vegetation, altering ciénega habitat suitability, and reducing native aquatic species.
- Alteration of shading of channel, fire risk, soil and ground-litter chemistry, and evapotranspiration rates and timing can also occur due to exotic plants and animals.
- The Southwest has experienced significantly higher warming than the global average.
- The region is predicted to continue warming at a faster rate than most of the U.S., particularly during summer months.
- Climate in the western U.S. has warmed an average of 1.4°F over the past 50 years.
- IPCC models predict further warming of 3.6° to 9.0°F by 2040 to 2069 in the summer months.
- Warmer climate is expected to increase water evaporation, leading to lower streamflows and affecting plant production and soil respiration., as described below.
- Climate change is expected to cause critical changes in precipitation in the Southwest, including the amount, pattern, and type of precipitation.
- High-intensity storms will likely become more common in the Southwest during summer months, resulting in more erosive events and an increase in the likelihood of flash flooding.
- Arizona's mountains are expected to experience less winter snowfall, more winter rain, and a faster, earlier snowmelt.
- Warmer temperatures may lead to earlier snowmelt, which will alter peak runoff in streams and rivers and may result in higher magnitude floods.
- Streams may become intermittent sooner in the season, with an increase in the spatial extent of intermittent stream reaches in summer months.
- Regional climate models indicate increased drying during dry seasons.
- Changes in oceanic circulation and regional wind patterns may decrease the amount of atmospheric moisture being delivered inland to the MAR.
- Summer-time decadal trends have been observed in the San Pedro and Santa Cruz Rivers.
- Peak annual flows are more often produced by winter cyclonic and tropical storms and with less frequency by summer convective storms.
- Increase in the frequency and strength of El Niño years tend to result in greater winter months precipitation over summer months be wetter-than-normal winter precipitation.
- Climate change could alter precipitation and evapotranspiration rates, leading to changes in soil moisture, surface flows, and groundwater quantity.
- These changes could impact both the watershed scale and ciénega and buffer areas.
- Human consumption of surface water and groundwater may also be affected by climate change.

North American Warm Desert Interdunal Swale Wetland

This interdunal wetland ecological system occurs in dune fields in the Chihuahuan Deserts and likely in the Sonoran and Mojave deserts. This isolated or partially isolated wetland system is an occasional component of the more extensive active and stabilized desert dune system. Stands are typically small (usually less than 0.1 ha) interdunal swales that occur in wind deflation areas, where sands are scoured down to the water table. Water table may be perched over an impermeable layer of caliche or clay layer. This system is restricted to the Chihuahuan Deserts Ecoregion in Texas.

These wetland areas are typically dominated by common emergent herbaceous vegetation, such as species of *Eleocharis, Juncus*, and *Schoenoplectus*, but may include endemic plants or animals.

Occasionally wetlands are dominated by trees and shrubs, such as *Populus fremontii* and *Baccharis salicifolia*, which survive both being buried as dunes advance and having their root system exposed when deflation of the dune occurs. The specific dune field ecological processes distinguish these wetlands from non-dune emergent wetlands with similar species composition. In west Texas, stands in the Monahan and Kermit sandsheets wet interdunal swales, ponds and fringing wetlands are vegetated by herbaceous graminoids (generally >10% plant cover) between active dunes in sandsheets derived from quartz sands. Common vegetation is characterized by herbaceous graminoids and *Salix* spp. These interdunal valleys over impermeable substrata (as with the Monahans Sandsheet) may contain seasonal swales or ephemeral ponds supporting *Achnatherum hymenoides* and other grasses, *Schoenoplectus tabernaemontani, Juncus* spp., *Cyperus* spp., *Baccharis* spp., *Prosopis glandulosa, Salix interior, Pluchea odorata (= Pluchea purpurascens), Xanthium strumarium*, and other weeds (TPWD 1989d). The fringing wetland plants of the more permanent ponds include *Salix* spp., *Scirpus* and/or *Schoenoplectus* spp., *Typha* spp., *Cyperus* spp., *Juncus* spp., *Ele ocharis* spp., and others. *Cyperus onerosus* is a rare plant, endemic to this region, also associated with these unusual wetlands (El-Hage and Moulton 1998).

Potential Threats:

- Invasive non-native species like Salsola tragus are stabilizing dunes at Petrified Forest National Park, which stops the formation of new interdunal deflation wetlands.
- Land use practices can affect hydrological regime, which threatens and stresses this ecosystem.
- Changes in hydrology affect wetland animals such as waterbirds, amphibians, or invertebrates.
- Maintenance of interdunal wetlands is critical for the survival of rare plant species like *Cyperus onerosus.*
- Changes in hydrology or non-native plant invasion can lead to conversion of wetlands.
- Common stressors include fragmentation from roads, altered hydrologic regime and invasive non-native plants.
- Climate change could reduce the extent of wetlands, converting them into an upland dune type.

Southeastern Coastal Plain Interdunal Wetland

The geology of these wetlands in Texas includes the coastal eolian sands and extend inland on the South Texas Sand Sheet. They also occur on Pleistocene barrier island and beach deposits of the Beaumont formation, such as on the Ingleside Barrier. These coastal wetlands occupy topographic lows of interdunal swales and potholes. The soils include deep sands and coastal sands.

The Southeastern Coastal Plain Interdunal Wetlands are alternately wet and dry (due to seasonal rainfall events) and generally lack tidal influence, but may contain halophytic species due to the influence of salt spray and repeated inundation and evaporation. They are graminoid dominated sites, with species such as *Spartina patens* (marshhay cordgrass), *Andropogon glomeratus* (bushy bluestem), *Panicum virgatum* (switchgrass), *Paspalum monostachyum* (gulfdune paspalum), *Distichlis spicata* (saltgrass), *Fimbristylis castanea* (chestnut fimbry), *Rhynchospora colorata* (whitetop sedge), *Eleocharis* spp. (spikerushes), *Rhynchospora* spp. (beaksedges), *Typha* spp. (cattails), and *Schoenoplectus pungens* (common threesquare). Forbs such as *Hydrocotyle bonariensis* (largeleaf pennywort), *Centella erecta* (spadeleaf), *Phyla nodiflora* (common frog-fruit), *Samolus ebracteatus* (coast brookweed), *Bacopa monnieri* (coastal water-hyssop), and *Pluchea foetida* (marsh fleabane) may be conspicuous. Woody species such as *Batis* *maritima* (saltwort), *Sesbania* spp. (rattleboxes), *Prosopis glandulosa* (honey mesquite), and *Baccharis* spp. (baccharis) may be present but do not typically constitute significant cover.

Potential Threats:

The native vegetation and geological stability of these ecosystems are coupled and vulnerable to erosion events, especially when there has been a lot of development (Feagin et al. 2010). Threats to these coastal wetlands include filling for development, excavation to make open-water ponds, dropping of water tables caused by pumping of shallow groundwater, water pollution from surrounding developed areas, and potentially saltwater intrusion into water tables. Development of surrounding uplands allows these wetlands to become eutrophic from urban stormwater runoff. Within coastal developed areas, these wetlands have lost much of the upland natural vegetation which used to surround them. Those natural upland vegetation buffers allowed the wetlands ecological resiliency after large disturbances from hurricanes and nor'easters. Invasive plant species such as *Triadica sebifera*, introduced exotic *Phragmites australis* and *Panicum repens* are threats, as are feral hogs (*Sus scrofa*) and nutria (*Myocastor coypus*).

Texas-Louisiana Coastal Prairie Pondshore

This system occurs on the coastal Pleistocene terraces, including the Beaumont and Lissie geologic formations. It occurs on local topographic lows such as ponds and swales within the generally level landscape. The soils tend to be fine-textured or are characterized by a relatively impermeable subsurface horizon.

This system occurs as ponds or swales within the coastal prairie matrix. Soils are poorly drained, and surface water from rainfall and local runoff is retained for much of the year (except for periods of high evapotranspiration). Occurrences are wetter than the *Tripsacum dactyloides* (eastern gamagrass) or *Panicum virgatum* (switchgrass) dominated prairie sites of the Texas- Louisiana Coastal Prairie. These wetlands are primarily herbaceous, sometimes with sparse woody cover, and are composed of various species, such as *Eleocharis quadrangulata* (squarestem spikesedge), *Fuirena squarrosa* (hairy umbrellasedge), *Cyperus haspan* (sheathed umbrellasedge), *Cyperus virens* (green flatsedge), *Rhynchospora* spp. (beaksedges), *Leersia hexandra* (clubhead cutgrass), *Steinchisma hians* (gaping panicum), *Panicum virgatum* (switchgrass), *Andropogon glomeratus* (bushy bluestem), *Xyris jupicai* (Richard's yellow-eyed grass), *Centella erecta* (erect centella), *Sagittaria papillosa* (nipplebract arrowhead), *Sagittaria longiloba* (longlobe arrowhead), *Ludwigia glandulosa* (Torrey water-primrose), *Ludwigia linearis* (narrowleaf water-primrose), *Bacopa* spp. (waterhyssops), Hydrocotyle spp. (pennyworts), *Symphyotrichum subulatum* (hierba del marrano), and *Sesbania* spp. (rattleboxes). Large areas of some of the occurrences may be relatively homogeneous, dominated by one or a few species. Areas of open water within the ponds may contain floating and submerged aquatic species, including *Stuckenia pectinata* (sago pondweed), *Ceratophyllum demersum* (coontail), *Brasenia schreberi* (Schreber watershield), *Nymphoides aquatica* (largeleaf floating heart), and *Nelumbo lutea* (yellow lotus).

Potential Threats:

A major threat to this system is conversion of the matrix ecological system within which this system occurs to other land uses (agriculture, pasture, and residential and commercial development). Historic loss of this matrix is estimated to be greater than 99% (USFWS and USGS 1999, LDWF 2005). A 29% loss of this wetland system occurred between 1955 and 1992 (Moulton et al. 1997). Other threats include alteration of the natural fire and hydrologic regimes, damage to the herbaceous ground cover, and invasion by the exotic tree *Triadica sebifera*. Other impacts include grading and filling, contamination by chemical runoff, disturbance by off-road vehicles, rooting by feral hogs (*Sus scrofa*), road maintenance, and development and maintenance of utility corridors. Lack of fire has been a widespread threat, and generally only sites which are managed with prescribed fires conserve the biological diversity of this herbaceous wetland habitat. The lack of fire can lead to shrub and tree encroachment, increased shading and evapotranspiration, accumulation of leaf litter, and a drying out of the depression wetland during drier times of year.

West Gulf Coastal Plain Flatwoods Pond

These ponds occur on Pleistocene terraces, including the upper Beaumont geologic formation, but also mapped on the high Pleistocene terraces in the northern part of Texas. The northern flatwood ponds are mapped as Quaternary Fluviatile Terrace (Tile) Deposits along the Red, Sulphur, and Sabine Rivers. All of these wetlands occupy local topographic lows within the flatwoods. The substrates are relatively fine-textured soils with an impermeable subsoil horizon, giving rise to a perched water table and saturated conditions during extended periods of the year.

The system as currently described, focuses on those herbaceous dominated wetlands that are embedded within the West Gulf Coastal Plain Longleaf Pine Wet Savanna and Flatwoods. As mapped in the Ecological Mapping Systems of Texas, it occupies sites with a much broader distribution, including wet, herbaceous dominated sites within the West Gulf Coastal Plain Wet Hardwood Flatwoods or West Gulf Coastal Plain Pine – Hardwood Flatwoods. This mapped system is likely dominated by species such as *Panicum hemitomon* (maidencane), *Carex* spp. (caric sedges), *Rhynchospora* (beaksedges), *Eleocharis* spp. (spikerushes), *Andropogon glomeratus* (bushy bluestem), and *Ludwigia* spp. (water-primroses). On drier sites *Schizachyrium scoparium* (little bluestem) may be present. Some sites may be dominated by the non-native *Cynodon dactylon* (bermudagrass). A few woody species may occur, including *Nyssa biflora* (swamp tupelo), *Liquidambar styraciflua* (sweetgum), *Quercus nigra* (water oak), *Planera aquatica* (water elm), and *Cephalanthus occidentalis* (common buttonbush). Flatwood ponds, as described by Bridges and Orzell, represent a more restricted subset of herbaceous-dominated sites with saturated soils resulting from perched water table due to an impermeable subsurface.

Potential Threats:

West Gulf Coastal Plain Flatwoods Ponds have been greatly reduced from their presettlement extent. Only 10 to 25% of original extent in Louisiana remains today (LDWF 2005). Primary threats include alterations to hydrology and fire regime, damage to herbaceous ground cover, direct conversion to other land uses such as pine plantation, and residential and commercial development. Other impacts include contamination by chemical runoff, disturbance by off-road vehicles, rooting by feral hogs (*Sus scrofa*), road maintenance, and development and maintenance of utility corridors. Lack of fire has been a widespread threat, and generally only sites which are managed with prescribed fires conserve the biological diversity of this herbaceous wetland habitat. The lack of fire can lead to shrub and tree encroachment, increased shading and evapotranspiration, accumulation of leaf litter, and a drying out of the depression wetland during drier times of year.

West Gulf Coastal Plain Herbaceous Seep and Bog

In Texas these wetlands are often associated with Eocene sand formations such as Queen City, Sparta, and particularly Carrizo Sands. They are generally found on slopes, as well as on valley floors and toe slopes where seepage from upslope occurs through the deep sands on site.

This small patch system typically presents as an herbaceous wetland, though sometimes significant shrub cover by *Morella cerifera* (wax-myrtle) and/or other species may be conspicuous. The herbaceous layer is dominated by a dense, species-rich, graminoid-forb layer less than 1 m tall with continuous to nearly continuous cover, typically 80-90%. Seepage results from the percolation of water through a porous sand layer until it encounters a more impermeable layer and flows to the surface. Grass species present may include species such as *Andropogon glomeratus* (bushy bluestem), *Dichanthelium scoparium* (velvet panicum), *Panicum anceps* (beaked panicum), *Panicum brachyanthum* (pimple panicgrass), *Panicum virgatum* (switchgrass), *Paspalum laeve* (smooth paspalum), *Saccharum giganteum* (sugarcane plumegrass), and *Steinchisma hians* (gaping panicum) [=*Panicum hians*]. Sedges and rushes are well-represented and may include *Cyperus strigosus* (false nutgrass), *Eleocharis acicularis* (needle spikesedge), *Fuirena squarrosa* (hairy umbrellasedge), *Juncus dichotomus* (forked rush), *Juncus diffusissimus* (slimpod rush), *Juncus effusus* (common rush), and *Rhynchospora* spp. (beakrushes, including *R. gracilenta, R. oligantha*, and/or *R. rariflora*). A diverse forb assemblage is typically present, and may include *Eryngium integrifolium* (simpleleaf eryngo), *Eupatorium perfoliatum* (common boneset), *Habenaria repens* (waterspider false reinorchid), *Hypericum mutilum* (dwarf St. John's wort), *Ludwigia alternifolia* (bushy seedbox), *Lycopodiella* spp. (clubmoss), *Osmunda cinnamomea* (cinnamon fern), *Osmunda regalis* (royal fern), *Pogonia ophioglossoides* (rose pogonia), *Polygala cruciata* (drumheads), *Rhexia mariana* (Maryland meadowbeauty), *Sarracenia alata* (pitcher-plant), *Symphyotrichum dumosum* var. *dumosum* (bushy aster), *Woodwardia* spp. (chainfern), and/or *Xyris* spp. (yellow-eyed grass, *X. ambigua, X. baldwiniana*, *X. difformis, X. jupicai, X. laxifolia*, and/or *X. torta*). Seeps may feed downslope depressional wetlands which may be overtaken by shrub species such as *Morella cerifera* (wax- myrtle), or may be dominated by *Eleocharis* spp. (spikerush), *Juncus* spp. (rush), *Panicum hemitomon* (maidencane), and/or *Rhynchospora* spp. (beakrush). The bogs of portions of the East-Central Texas Plains Post Oak Savanna, commonly referred to as "muck bogs," differ from similar bogs within the West Gulf Coastal Plain by a decrease in species richness towards the west. These bogs can become dominated by woody species such as *Morella cerifera* (wax- myrtle), *Ilex vomitoria* (yaupon), and *Smilax laurifolia* (bamboo-vine). East of the Post Oak Savanna, other woody species such as *Toxicodendron vernix* (poison sumac), *Magnolia virginiana* (sweetbay), *Persea borbonia* (redbay), and *Pinus palustris* (longleaf pine) may form a sparse emergent canopy. Sites east of the Post Oak Savanna may contain broadleaved evergreen woody species such as *Magnolia virginiana* (sweetbay), *Cyrilla racemiflora* (leatherwood), *Morella caroliniensis* (evergreen bayberry), *Persea palustris* (swamp redbay), and *Ilex coriacea* (bay-gall bush). Herbaceous species more 171 characteristic of eastern occurrences include *Gelsemium sempervirens* (Carolina jessamine), *Hypericum galioides* (bedstraw St. John's -wort), *Lachnocaulon anceps* (whitehead bogbutton), *Ludwigia hirtella* (spindleroot), *Marshallia graminifolia* (grassleaf Barbara's buttons), *Rhexia petiolata* (ciliate meadowbeauty), *Rhynchospora inexpansa* (nodding beaksedge), *Rhychospora plumosa* (plumed beaksedge), *Rudbeckia scabrifolia* (bog coneflower), and *Xyris drummondii* (Drummond's yellow-eyed grass).

Potential Threats:

Habitat loss and disruption of natural processes, including alterations to hydrology and fire regime, are the primary threats facing this ecological system. This wetland system is easily impacted by surrounding land uses. Its current extent is estimated to be only 25 to 50% of its original extent in Louisiana. Remaining occurrences are often surrounded by degraded or converted habitats and are impacted by forestry and other land management practices (LDWF 2005). Hydrologic alterations that degrade and destroy this ecological system include, but are not limited to, channelization of rivers or streams, drainage ditches, development of infrastructure, and groundwater removal. Other threats include physical damage from nearby and onsite land management activities, eutrophication within urban and agricultural landscapes (from nutrient-laden stormwater runoff), invasive exotic plants such as *Lonicera japonica, Ligustrum sinense*, and feral hog (*Sus scrofa*) rooting. If changes in regional climate bring about a decrease in precipitation, this could lead to drying and loss of this system.

Western Great Plains Closed Depression Wetland (Playa Wetland)

This system typically occurs on various formations of the tablelands of the High Plains. Playas are internally draining depressions, typically on the tablelands of the High Plains, including the Llano Estacado, and outliers of those level plateaus. These basins are typically lined by vertisols.

This system represents the playas of the southern Great Plains. They are shallow, small (averaging about 6 ha), generally circular, recharge basins receiving moisture from rainfall within internally draining watersheds and lacking significant overland drainage from the basins. They are usually characterized as occupying vertisols with a clay layer of reduced permeability and are variably wet and dry depending on local weather conditions. Moisture accumulation occurs through overland flow of rainfall falling on the surrounding, internally draining watershed, and drying results from evaporation, transpiration, and infiltration, with playas representing a significant recharge feature of the Ogallala Aquifer. This system is typically dominated by herbaceous vegetation including species such as *Pascopyrum smithii* (western wheatgrass),

Bouteloua dactyloides (buffalograss), *Eleocharis macrostachya* (pale spikerush), *Panicum obtusum* (vine mesquite), *Helianthus ciliaris* (blue-weed), *Phyla nodiflora* (common frog-fruit), *Oenothera canescens* (beakpod eveningprimrose), *Chenopodium leptophyllum* (narrowleaved goosefoot), *Ambrosia grayi* (woollyleaf burr ragweed), *Polygonum pensylvanicum* (Pennsylvania smartweed), and *Symphyotrichum subulatum* (hierba del marrano). Species such as *Bouteloua dactyloides* and *Pascopyrum smithii* may occupy drier portions of a playa or may occupy entire playas when those playas have lacked inundation for extended periods. Wetter portions of the playa may be occupied by marshes if the inundation has been maintained over extended periods. Species richness can vary considerably among individual examples of this system and is especially influenced by hydroperiod and adjacent land use, which is often agriculture. Dynamic processes that affect these depressions are hydrological changes, grazing, and conversion to agricultural use. This system differs from Western Great Plains Open Freshwater Depression Wetland (CES303.675) in that the hydrology of these open wetlands are influenced by associated drainages.

Potential Threats:

- Playas can be cultivated without filling during dry years, causing damage to existing vegetation and increasing wind erosion on bare soil.

- Playas can also be ditched or dug out to create stock ponds or sources for irrigation water, decreasing the amount of water over most or all of the playa.
- Deepening a portion of the playa creates a deeper, more permanent lake or pond habitat, but also drains water from the remainder of the site and causes sedimentation.
- Physical disruptions to playas include island construction, road building, and filling, which can split a playa in two and introduce sediment and chemicals associated with road construction and maintenance.
- Playas are often favored for grazing, both by wildlife and livestock, and have increased production in comparison to surrounding uplands.

Western Great Plains Open Freshwater Depression Wetland

These wetlands occur on various geologic substrates, but often on alluvium and include depressions along drainages and lakes. These may also occupy other landforms, but typically do not occur within closed basins as in the Western Great Plains Closed Depression Wetland. Various soils, often tight soils that restrict drainage, but also other soil types where water accumulates due to position along a drainage.

This ecological system is composed of lowland depressions; it also occurs along lake borders that have more open basins and a permanent water source through most of the year, except during exceptional drought years. These areas are distinct from Western Great Plains Mesquite Woodland and Shrubland (CES303.668) by having a large watershed and/or significant connection to the groundwater table. A variety of species are part of this system, including emergent species of *Typha* (cattails), *Carex* (carices), *Eleocharis* (spikerushes), *Juncus* (rushes), and *Schoenoplectus* (bulrushes), as well as floating genera such as *Potamogeton* (pondweed), *Sagittaria* (arrowhead), or *Ceratophyllum* (hornwort). The system includes submergent and emergent marshes and associated wet meadows and wet prairies. These types can also drift into stream margins that are more permanently wet and linked directly to the basin via groundwater flow from/into the pond or lake. Some of the specific communities will also be found in the floodplain system and are here considered a separate system. These types should also not be considered a separate system if they are occurring in lowland areas of the prairie matrix only because of an exceptional wet year. As mapped, this system may also occupy anthropogenic ponds and lakes.

Potential Threats:

- Invasive non-native species, such as *Salsola tragus*, are preventing the formation of new interdunal deflation wetlands.
- Land use practices can threaten and stress this ecosystem and its hydrological regime.
- Changes in hydrology can have adverse effects on wetland animals, including waterbirds, amphibians, or invertebrates.
- Maintenance of interdunal wetlands is critical for the survival of rare plant species, including *Cyperus onerosus*.
- Common stressors include fragmentation from roads, altered hydrologic regime and invasive non-native plants.
- Climate change could cause wetlands to convert into an upland dune type, leading to a reduction in their extent.

Oxbow Lakes

Oxbow lakes occur mainly in the eastern potion of the state of Texas. The lakes may be curved or U-shaped as a result of a meandering river. When a large meander is cut-off from a main river channel the oxbow lake is formed. These lakes vary widely is both size and depth. Oxbow lakes throughout Texas have unique vegetation communities and provide habitat for a significant number of SGCN species. It is important to note, however, the oxbow lakes along the Trinity River are ecologically significant and are of conservation importance. Many priority ecological systems may occur within or along the banks of these lakes and may be described elsewhere in the "Riparian" section of this document. These include: Western Gulf Coastal Plain Large River Floodplain Forest, Red River Large Floodplain Forest, and Columbia Bottomlands Forest and Woodland.

Potential Threats:

Not documented.

Saltwater Wetland Vegetation

Saltwater wetland vegetation includes areas with brackish, saline or saltwater-dependent habitats: Brackish marsh, salt marsh, saline springs, shallow saline groundwater swales, saline or salt shallow pools.

Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (mixed upland and wetland)

This system typically occurs on Quaternary alluvium but may be local in nature and mapped within various geological formations. This system is generally found on local topographic lows that may be associated with a drainage or may occur as basins or swales. This system is found on tight soils, typically Clay Flat Ecological Sites. This system occurs in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecoregions of Texas.

This system is named based on the regions (Chihuahuan and Sonoran Deserts) where it is best developed and occupies significant areas, however it does occur well outside these regions, at least as far north and east as the Rolling Plains of Texas. The system typically occurs in local topographic lows that may be associated with drainages, or may represent swales or basins, but typically receives run-off from the surrounding landscape. Soils are generally clayey, and in some cases the shrink-swell characteristics of the soil may limit the development of woody species.

Pleuraphis mutica (tobosa) is generally the clear dominant, though other species such as *Panicum obtusum* (vine-mesquite), *Sporobolus airoides* (alkali sacaton), and *Pascopyrum smithii* (western wheatgrass) may be present. *Prosopis glandulosa* (mesquite) may be present, and in some cases may develop into a significant canopy. The system often occupies the Clay Flat Ecological Site.

Potential Threats:

- Native mixed semi-desert grasslands are the dominant grassland type.
- Without fire or other disturbance, stands become dominated by woody vegetation and convert to shrublands or woodlands.
- Conversion to juniper woodlands or mesquite shrublands is common when trees or mesquite exceed 15% cover.
- Historically, grasslands were maintained as open grasslands with low shrub cover by fire-return intervals of 2.5 to 10 years.

- Drought and livestock grazing interact with grass cover and fire-return intervals can affect the rate of shrub increase.
- After grassland conversion to shrubland there is a loss of perennial grasses and increases of bare ground.
- Hydrological alterations also occurred in many semi-desert grasslands during early Anglo-American settlement time with a period of arroyo formation from 1865 to 1915.
- Arroyo formation was initiated by building ditches, canals, roads and embankments along the channels that altered valley floor hydrology.
- The introduction of non-native grasses has greatly impacted semi-desert grasslands.
- *Eragrostis lehmanniana* is a particularly aggressive invader and alters ecosystem processes, vegetation composition, and species diversity.
- Urban and exurban development, altered hydrological regimes, and irrigated agriculture are the common causes of conversion.
- Fire suppression has allowed succession and conversion to shrublands, desert scrub and woodlands.
- Threats to the ecosystem include fragmentation, altered fire regime, invasive species, and overgrazing by livestock.
- Overgrazing can lead to soil compaction, reduce vegetation cover, and expose soils to erosion.
- Climate change could further reduce the ecosystem's extent and result in desert scrub conversion.

Central and Upper Texas Coast Salt and Brackish Tidal Marsh

This system developed on recent alluvial and eolian deposits along the coast. This system occurs on nearly level very gentle slopes, and flats influenced by tides. The souls of this system include coastal sands and various Salt Marsh Ecological Sites. This system occurs in the Gulf Coastal Prairies and Marshes Ecoregion in Texas.

These marshes occupy relatively low-lying, coastal situations on level landforms influenced by tidal fluctuations. Some sites are only influenced by storm tides, or tides resulting from extreme wind events. The composition of these marshes is primarily influenced by the frequency and duration of tidal inundation. Salinity on some marshes, particularly in the south, is maintained by salt spray from prevailing southeasterly winds. Low marshes are regularly flooded, and representative examples are dominated by *Spartina alterniflora* (smooth cordgrass), *Juncus roemerianus* (blackrush), or *Avicennia germinans* (black mangrove). Significant areas of *Avicennia germinans* (black mangrove) become more frequent towards the south, while extensive areas of *Spartina alterniflora* (smooth cordgrass) become rare south of Corpus Christi Bay. Areas of decreased frequency and/or duration of tidal inundation are often referred to as high, or irregularly flooded, marsh. These marshes may be dominated by species such as *Spartina patens* (marshhay cordgrass), *Distichlis spicata* (saltgrass), *Schoenoplectus robustus* (sturdy bulrush), *Schoenoplectus americanus* (three-square bulrush), *Sporobolus virginicus* (seashore dropseed), *Monanthochloe littoralis* (shoregrass), and *Spartina spartinae* (Gulf cordgrass). Shrubs, subshrubs, and forbs, such as *Batis maritima* (saltwort), *Borrichia frutescens* (sea ox-eye daisy), *Sesuvium portulacastrum* (shoreline seapurslane), *Salicornia* spp. (glassworts), *Suaeda linearis* (annual seepweed), *Limonium* spp. (sea-lavenders), and *Lycium carolinianum* (Carolina wolfberry) are commonly encountered in these marshes. Some irregularly flooded sites may become shrub-dominated with species such as *Iva frutescens* (shrubby sumpweed) or *Baccharis halimifolia* (eastern baccharis). In the south, extensive areas are dominated by *Borrichia frutescens* (sea ox-eye daisy) and these often occur at very slightly lower elevations and higher salinities than nearby *Spartina spartinae* (Gulf cordgrass) salty prairie. These *Borrichia* flats may be very infrequently flooded, perhaps only under extreme storm tide conditions. Other species that may be encountered in these situations include *Maytenus phyllanthoides* (gutta-percha), *Prosopis reptans* (tornillo), *Monanthochloe littoralis* (shoregrass), *Distichlis spicata* (saltgrass), and *Batis maritima* (saltwort). The aspect dominant on these sites is clearly *Borrichia frutescens* (sea ox-eye daisy).

Potential Threats:

Not documented.

Eastern Great Plains Wet Meadow, Prairie and Marsh

This system is found along creeks and streams from Nebraska and Iowa to Illinois, and from Minnesota to Texas. It is also found in depressions and along lake borders, especially in the northern extension of its range into Minnesota. It is often adjacent to a floodplain system but is devoid of trees and riparian vegetation. It is also distinguished from upland prairie systems by having more hydrology, especially associated with silty, dense clay soils that are often hydric, classified as Vertic Haplaquolls. The landform is usually floodplain or poorly drained, relatively level land. This system occurs in the Southwest Tablelands Ecoregion in Texas.

The vegetation is dominated by *Spartina pectinata, Tripsacum dactyloides*, numerous large sedges, such as *Carex frankii* and *Carex hyalinolepis*, and in wetter areas, *Eleocharis* spp. Other emergent marsh species such as *Typha* spp. can be associated with this system. Forbs can include *Helianthus grosseserratus, Vernonia fasciculata*, and *Physostegia virginiana*. Some parts of this system may be saline and have species such as *Distichlis spicata* and *Bolboschoenus maritimus (= Schoenoplectus maritimus)*. Fire has been the primary influence in keeping these wet areas free of trees. Other dynamic processes include grazing and flooding (often in late spring). Many areas have been converted to agricultural, but this usually requires some sort of drainage.

Potential Threats:

The primary threat to this system is drainage followed by conversion to agriculture or urban/infrastructure development. In addition to the direct effects of conversion of this system, landscape fragmentation from conversion of this or other related natural systems affects remaining stands by further reducing the opportunities for landscape-level fires, increasing the opportunities for exotic species to invade from nearby populations, and reducing the amount of suitable habitat that can be converted to this system as part of the natural fluid response to fire and precipitation. A lack of fire quickly results in invasion by shrubs and trees and conversion to a shrub swamp or swamp.

Gulf Coast Chenier Plain Salt and Brackish Tidal Marsh

This system occupies recent alluvial deposits. This system occurs along bay margins and outlets of coastal rivers where freshwater inflow is sufficient to drive marsh composition. Sites may be interspersed with areas of open water. This systems soils include saturated, very deep, mineral soils, often with high organic content, at least at the surface. Ecoclasses (from Ecological Site Descriptions) include various Fresh and Intermediate Marsh types. This system is restricted to te Gulf Coastal Prairie and Marshes Ecoregion in Texas.

This herbaceous system occupies coastal sites with mucky soils and salinities less than 4 ppt. Dominants are graminoids, including *Panicum hemitomon* (maidencane), *Paspalum vaginatum* (seashore paspalum), *Zizaniopsis miliacea* (marshmillet), *Typha latifolia* (common cattail), *Spartina patens* (marshhay cordgrass), *Schoenoplectus* spp. (bulrushes), and *Phragmites australis* (common reed). Other wetland species such as *Sagittaria* spp. (arrowheads), *Ludwigia* spp. (water-primroses), and *Vigna luteola* (cow pea) may also be present. Some occurrences may have some woody cover with species such as *Iva frutescens* (bigleaf sumpweed) or *Baccharis halimifolia* (baccharis).

Potential Threats:

- The coastal wetlands of Texas and Louisiana are facing a grave threat due to a combination of climate change and human activities.
- Marsh loss is expected to increase with the rising sea levels when sedimentation and organic matter accumulation cannot keep up with the increased waters.
- Models predict significant marsh and swamp loss in by 2100 if eustatic sea-level rise exceeds 0.75 m.

North American Arid West Emergent Marsh

These wetlands are described within the “freshwater wetland” section of this document. Evaporative processes may create saline conditions in some instances).

North American Warm Desert Cienega

These wetlands are described withing the “freshwater wetland” section of this document. Evaporative processes may create saline conditions in some instances.

North American Warm Desert Interdunal Swale Wetland

These wetlands are described withing the “freshwater wetland” section of this document. Evaporative processes may create saline conditions in some instances

Texas Saline Coastal Prairie

This vegetation system occurs principally on the Pleistocene Beaumont Formation. This system lies on mostly level or very gently undulating landform, typically near the coast. These sites may be inundated by saltwater during storm surges. Pimple mounds may lend some local topographic variation to the otherwise level surface. This system soils are very deep, somewhat poorly to poorly drained with high salinity and/or sodicity, at least at some depth. These may be loams or clays. These soils may be saturated from local rainfall or, occasionally from storm surges. This system occurs in the Gulf Coastal Prairies and Marshes Ecoregions in Texas.

This system occupies saline soils, generally near-coast, on level topography of the Beaumont Formation. Sites may be nearly monotypic stands of *Spartina spartinae* (Gulf cordgrass). Other gramimoids that may be present to abundant include *Schizachyrium scoparium* (little bluestem), *Andropogon glomeratus* (bushy bluestem), *Panicum virgatum* (switchgrass), *Muhlenbergia capillaris* (Gulf muhly), or *Sporobolus indicus* (rat-tail smutgrass). *Spartina patens* (marshhay cordgrass), *Aristida oligantha* (oldfield threeawn), *Paspalum hartwegianum* (Hartweg paspalum), *Sporobolus virginicus* (seashore dropseed), *Paspalum vaginatum* (seashore paspalum), and *Distichlis spicata* (saltgrass) may be common, particularly on lower, somewhat wetter sites. Forbs are generally uncommon, but may include species such as *Borrichia frutescens* (sea ox-eye daisy), *Solidago sempervirens* (seaside goldenrod), *Iva angustifolia* (narrowleaf sumpweed), *Euthamia* spp. (goldentops), or other species more common to the non-saline soils nearby, or the salt marsh that may also be nearby. Microtopographic highs in the form of pimple mounds often have species more characteristic of less saline adjacent habitats. Shrubby species may invade the prairie, commonly including species such as *Iva frutescens* (shrubby sumpweed), *Prosopis glandulosa* (honey mesquite), *Acacia farnesiana* (huisache), *Lycium carolinianum* (Carolina wolfberry), *Tamarix* sp. (salt cedar), and *Baccharis halimifolia* (baccharis).

Potential Threats:

Primary historic and current threats to this system include conversion to agriculture and coastal development, and alterations to the natural fire regime. In the absence of regular fire, this system will be invaded by woody shrubs. If changes in regional climate bring about an increase in precipitation, this could lead to an increase in woody encroachment; a decrease in precipitation could lead to loss of the wet prairie components of this system. Due to its proximity to the coast and coastal marshes, sea-level rise could further impact this system by saltwater inundation. Sea-level rise is expected to have a greater impact in places with insufficient buffer to allow landward migration. Increased storm intensity predicted under future climate change also threatens this system.

Western Great Plains Closed Depression Wetland

These wetlands are described withing the "freshwater wetland" section of this document. Evaporative processes may create saline conditions in some instances

Western Great Plains Open Freshwater Depression Wetland

These wetlands are described withing the "freshwater wetland" section of this document. Evaporative processes may create saline conditions in some instances.

Western Great Plains Saline Depression Wetland

This vegetation system typically is often associated with the Tahoka Formation or the Ogallala Formation, but may occur over other substrates including Quaternary alluvium. Somewhat circular basins, or sometimes forming linear bands adjacent to drainages. The soils are often high in lime, salty bottomland, and wet saline ecological sites. This system occurs in the Chihuahuan Deserts and High Plains Ecoregions in Texas. Saline lakes and salty bottomlands often with salt encrusted surfaces and sometimes sparsely vegetated. Some of these lakes were thought to form from wind deflation and/or dissolution of subsurface strata and some have associated springs, with evaporation causing concentration of salts at the surface. Dominant species of the sites are often halophytic, or at least salt tolerant, including *Sporobolus airoides* (alkali sacaton), *Distichlis spicata* (saltgrass), *Hordeum jubatum* (foxtail barley), *Sporobolus pyramidatus* (whorled dropseed), *Schoenoplectus* spp. (bulrushes), *Suaeda suffrutescens* (desert seepweed), *Allenrolfea occidentalis* (pickle-weed), *Salsola tragus* (prickly Russian thistle), and *Bassia scoparia* (kochia). Woody species including *Atriplex canescens* (four-wing saltbush) and *Prosopis glandulosa* (honey mesquite) may also be present and sometimes develop significant cover. During periods of high rainfall and as one moves further from the salt encrusted surfaces into surrounding habitats, species composition becomes less dominated by halophytes with species such as *Bothriochloa laguroides* ssp. *torreyana* (silver bluestem), *Sporobolus cryptandrus* (sand dropseed), *Aristida purpurea* (purple threeawn), and *Ziziphus obtusifolia* (lotebush). *Tamarix* spp. (saltcedar) may be present to dominant.

Potential Threats:

Some stands have been irrigated and converted to crop fields (Rolfsmeier 1993a), but even with the flushing of the soil by irrigation, most sites in this system are not well-suited to growing crops. Drainage of this system, with or without subsequent irrigation, also damages stands and results in reduced water-holding capacity and often reduced salinity as water is able to flow off the site and remove some of the salts. Many stands have been used for pasture and haying. Low-intensity uses of this nature do not pose a serious threat, but livestock can quickly cause damage by churning up the wet soils, overgrazing the palatable species on the less saline parts of the site, and introducing seeds of exotic species. Many invasives common to the mixedgrass prairies cannot tolerate the saline conditions, but there are several aggressive species that can, including *Thinopyrum ponticum (= Agropyron elongatum), Tamarix ramosissima*, and *Trifolium fragiferum* (Ungar 1967, Rolfsmeier 1993a). Disruptions in the watershed can cause increased or, more typically, decreased water inflow.

Estuary/Estuarine

In Texas, estuaries and their surrounding wetlands are areas where fresh water from rivers and streams mixes with salt water from the Gulf of Mexico. They are highly sensitive ecosystems that provide habitat for a diverse array of species.

Estuaries in Texas occur solely within the Gulf Coast Prairies and Marshes ecoregion. However, the river systems throughout the rest of the state and beyond, eventually flow to these estuaries and bays of the Gulf of Mexico. Therefore, conservation actions in ecoregions crafted for riverine systems should continue to support instream flows and estuary/bay health.

Texas Coast Fresh and Oligohaline Tidal Marsh

These marshes occur on young quaternary alluvium just south of the Chenier Plain mainly in the mouths of rivers and bayous emptying into bays of the Galveston Bay system. They may also occur in other rivers and bays south to Corpus Christi Bay, where freshwater inflows are high enough to maintain a low salinity.

Tidal marshes where salinity is maintained sufficiently low through freshwater inflows to produce fresh to oligohaline water chemistry. These marshes typically occur as small patches along bay margin and river or bayou mouths. Herbaceous plants cover typically includes *Paspalum vaginatum* (seashore paspalum), *Spartina patens* (marshay cordgrass) *Phragmites australis* (common reed), *Typha spp.*(cattail) and *Schoenoplectus americanus* (three-square bulrush).

Potential Threats:

Threats to this system include altered hydrology, increases in salinity, sea-level rise, and point and nonpoint source pollutants. While fresh to oligohaline marsh species have been shown to adapt to rising water levels, increased salinity has been shown to reduce the growth and survival of these species (Howard and Mendelssohn 1999, Couvillon and Beck 2013, Neubauer 2013). As salinity increases, fresh marsh composition shifts to species more tolerant of higher salinity causing a reduction in species richness. If the increase in salinity is accompanied by increased water levels, this can ultimately result in conversion of marsh to open saline waters. These marshes are also threatened by reduced freshwater inflow caused by upstream dams and water diversion. Invasive plant species such as *Triadica sebifera* are threats. Some invasive exotic mammals are threats, such as nutria (*Myocastor coypus*) and feral hogs (*Sus scrofa*). An increase in storm intensities and barriers to landward marsh migration could further exacerbate the impacts of sea-level rise. Other threats include pollution entering the marsh from point and nonpoint sources.

Gulf Coast Chenier Plain Fresh and Oligohaline Tidal Marsh

This system occupies recent alluvial deposits and occurs along bay margins and outlets of coastal rivers where freshwater inflow is sufficient to drive marsh composition. Sites may be interspersed with areas of open water. Soils are saturated, very deep, mineral soils, often with high organic content, at least at the surface.

This herbaceous system occupies coastal sites with mucky soils and salinities less than 4 ppt. Dominant species are grass-like plants, including *Panicum hemitomon* (maidencane), *Paspalum vaginatum* (seashore paspalum), *Zizaniopsis miliacea* (marshmillet), *Typha latifolia* (common cattail), *Spartina patens* (marshhay cordgrass), *Schoenoplectus* spp. (bulrushes), and *Phragmites australis* (common reed). Other wetland species such as *Sagittaria* spp. (arrowheads), *Ludwigia* spp. (water-primroses), and *Vigna luteola* (cow pea) may also be present. Some occurrences may have some woody cover with species such as *Iva frutescens* (bigleaf sumpweed) or *Baccharis halimifolia* (baccharis).

Potential Threats:

Threats to this system include altered hydrology and increases in salinity. The coast of Louisiana, including the fresh to oligohaline marshes, is being impacted by saltwater intrusion and inundation because the lack of sediment supply by the Mississippi River, eustatic sea-level rise and enhanced relative sea-level rise caused by the natural compaction of coastal sediments and the increased subsidence resulting from groundwater and oil and gas removal. Dredging canals that increase the connection between the fresh and oligohaline marshes and the saline waters of the Gulf of Mexico also work to increase salinity of these marshes. While fresh to oligohaline marsh species have been shown to adapt to rising water levels, increased salinity has been shown to reduce the growth and survival of these species (Howard and Mendelssohn 1999, Willis and Hester 2004, Couvillon and Beck 2013, Neubauer 2013). As salinity increases fresh marsh composition shifts to species more tolerant of higher salinity causing a reduction in species richness. If the increase in salinity is accompanied by increased water levels (e.g., relative sea-level rise and dredged canals), this can ultimately result in conversion of marsh to open waters. These marshes are also threatened by reduced freshwater inflow caused by upstream dams and water diversion. Invasive plant species such as *Triadica sebifera* are threats. Some invasive exotic mammals are threats, such as nutria (*Myocastor coypus*) and feral hogs (*Sus scrofa*).

Coastal Vegetation

Coastal vegetation types in Texas may include but not limited to beach and shoreline, dunes (shoreline and barrier island, but not including dunes), intertidal “flats”, mud, sand, wind, and algal.

Outermost zone of coastal vegetation ranging from and including Bolivar peninsula south to include Padre Island in Texas. These habitats typically have variable Vegetation cover is, depending on the amount of exposure to wave and wind action, but on average is sparse. Succulent species are characteristic, and typically low-growing or mat-forming.

Priority habitats of this broadly defined type occur within the following Texas ecoregions: Gulf Coast Prairies and Marshes.

South Texas Salt and Brackish Tidal Flats

This system occurs in tidal and other hypersaline situations along upper marsh edges and in tidal flats ranging in scale from narrow bands to hundreds of hectares along the Gulf Coast of southern Texas and Mexico. It is regularly to irregularly flooded by shallow brackish waters as a result of lunar, wind, and storm tides. As these waters evaporate, high concentrations of salt accumulate, producing hypersaline conditions, forming "salt pannes." It is found on recent wind- distributed coastal sands along barrier island and mainland shores of hypersaline lagoons and bays where evaporation often exceeds freshwater input. Tidal fluctuations and wind continue to redistribute these sands. Landforms are extensive, very gentle (nearly flat) slopes.

This system occurs on flats influenced by tidal fluctuations in water level, primarily driven by winds rather than by diurnal or semidiurnal tidal fluctuations. Due to the nearly level condition of these flats, small fluctuations in tidal level may result in extensive changes in inundation patterns. These flats are typically associated with hypersaline bay waters of the Laguna Madre. Some sites may have sparse vegetation consisting *of Salicornia bigelovii* (dwarf glasswort), *Salicornia depressa* (Virginia glasswort), *Batis maritima* (saltwort), *Suaeda linearis* (annual seepweed), Sesuvium portulacastrum (shoreline seapurslane), Monanthochloe littoralis (shoregrass), and/or *Distichlis spicata* (saltgrass), but are typically unvegetated or covered by a layer of *Lyngbya* spp. (blue-green algae).

The development of vast areas dominated by *Lyngbya* spp. (blue-green algae) occurs with appropriate frequency and duration of inundation. Higher flats may be too dry to support the algae, and at lower elevation, flats may remain inundated for extended periods. Occasionally flats (usually not those supporting extensive blue-green algae) may develop a substantial herbaceous cover, especially during years of increased rainfall.

Development of significant areas of marsh grasses such as *Spartina patens* (marshhay cordgrass) or *Spartina alterniflora* (smooth cordgrass) is generally lacking. Scattered individuals of *Avicennia germinans* (black mangrove) occur within these flats.

Potential Threats:

Not documented.

Texas Coastal Beach

This ecological system includes the typically sparsely vegetated, back beach area of the mainland and barrier islands composed of sand and shell fragments in a microtidal environment (<0.5m) as it transitions into more stabilized coastal communities. These areas generally lie near mean sea level (~1 m) and are often found between foredunes and tidal waters. Examples are found on retreating, prograding and aggradating sandy barrier segments. In the case of beaches along bay margins, an active dune system is generally lacking and beaches lie between tidal waters and near-shore vegetation. Recently deposited sands are transported by gulf currents and distributed and redistributed by onshore winds. Landforms are very gently sloping and restricted to the margins of the Gulf of Mexico as well as interior bays. Soils are recently deposited sands.

This system represents unvegetated to sparsely vegetated sandy shorelines adjacent to the Gulf of Mexico and bays interior to the barrier islands. Species such as *Ipomoea pescaprae* (goat-foot morning-glory), *Ipomoea imperati* (beach morning-glory), *Cakile* spp. (searockets), and *Tidestromia lanuginosa* (espanta vaquero) provide sparse vegetative cover. These areas generally lie near mean sea level and are often found between foredunes and tidal waters. In the case of beaches along bay margins, an active dune system is generally lacking and beaches lie between tidal waters and near-shore vegetation. As they are mapped, this system would include sparsely vegetated coppice dunes and even low foredunes. This system is dependent on highly dynamic coastal geomorphology.

Potential Threats:

This system is threatened by alteration of sediment input through control of rivers entering the Gulf of Mexico, creating an imbalance between sediment input and natural erosion processes. Erosion in some areas can lead to significant loss of this system (Morton et al. 2004). Other threats include sea-level rise, coastal development, vehicle-use impacts, and coastal engineering such as beach armoring, seawalls, jetties and other structures which interfere with sand movement and shoreline migration (Defeo et al. 2009). Increasing sea-level rise associated with global climate change, will lead to more loss of beach, especially in developed areas where infrastructure such as seawalls, buildings and coastal roads restrict the potential for inland migration of the beach and dunes. The use of sand for renourishment which does not match the grain size and composition of the beach to be restored can be a threat, especially where sand is applied deeply. Invasive animals include imported red fire ants (*Solenopsis invicta*) and feral hogs (*Sus scrofa*) which prey on the eggs of sea turtles (Defeo et al. 2009). Feral house cats, dogs, and coyotes are a threat to nesting birds and other small animals which occur in coastal habitats. This system provides important nesting habitat for sea turtles and shorebirds; certain restrictions on the timing and location of recreational uses may help accommodate nesting wildlife and promote nesting success.

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Texas Native Fish Conservation Areas Network: Strategic Investments in Restoration and Preservation of Freshwater Fish Diversity

Timothy W. Birdsong*
Texas Parks and Wildlife Department, Inland Fisheries Division
4200 Smith School Road, Austin, Texas 78744, USA

Gary P. Garrett
Biodiversity Center, Department of Integrative Biology, University of Texas at Austin
10100 Burnet Road, PRC176 East/R4000, Austin, Texas 78758, USA

Ben J. Labay
Siglo Group
1619 West 6th Street, Austin, Texas 78703, USA

Megan G. Bean and Preston T. Bean
Texas Parks and Wildlife Department, Inland Fisheries Division
5103 Junction Highway, Mountain Home, Texas 78058, USA

John Botros
Texas Parks and Wildlife Department, Inland Fisheries Division
505 Staples Road, Building 1, San Marcos, Texas 78666, USA

Melissa J. Casarez and Adam E. Cohen
Biodiversity Center, Department of Integrative Biology, University of Texas at Austin
10100 Burnet Road, PRC176 East/R4000, Austin, Texas 78758, USA

Thomas G. Heger
Texas Parks and Wildlife Department, Inland Fisheries Division
4200 Smith School Road, Austin, Texas 78744, USA

Arlene Kalmbach
Texas Parks and Wildlife Department, Wildlife Division
1887 County Road 324, Lincoln, Texas 78948, USA

Dean A. Hendrickson
Biodiversity Center, Department of Integrative Biology, University of Texas at Austin
10100 Burnet Road, PRC176 East/R4000, Austin, Texas 78758, USA

Stephan J. Magnelia and Kevin B. Mayes
Texas Parks and Wildlife Department, Inland Fisheries Division
505 Staples Road, Building 1, San Marcos, Texas 78666, USA

* Corresponding author: timothy.birdsong@tpwd.texas.gov

Monica E. McGarrity
Texas Parks and Wildlife Department, Inland Fisheries Division
4200 Smith School Road, Austin, Texas 78744, USA

Ryan McGillicuddy, M. Melissa Parker, and Sarah Robertson
Texas Parks and Wildlife Department, Inland Fisheries Division
505 Staples Road, Building 1, San Marcos, Texas 78666, USA

Abstract.—Texas harbors 191 species of native freshwater fishes, 48% of which are considered imperiled. The primary cause of fish species imperilment in Texas is anthropogenic alteration of freshwater systems, which continues to occur at rates and scales that threaten the long-term resiliency of freshwater habitats, species, and ecosystems. Innovative conservation approaches are needed to restore and maintain functional watershed processes, restore freshwater habitats, and conserve native species while simultaneously supporting human needs, such as flood control, municipal and agricultural water supply, water quality protection, and water-based recreation. The need for an integrated and holistic approach to conservation of freshwater systems has been the impetus for development of the Texas Native Fish Conservation Areas Network (hereafter "Texas NFCAs Network"). The Texas NFCAs Network consists of springs, ciénegas, creeks, rivers, and associated watersheds uniquely valued in preservation of Texas freshwater fish diversity. Twenty native fish conservation areas have been designated throughout the state. These were selected based on a spatial prioritization focused on identification of freshwater systems critically important to the long-term persistence of 91 freshwater fishes considered species of greatest conservation need. Through a shared vision of collaborative stewardship, conservation partnerships have formed among nongovernmental organizations, universities, and state and federal agencies to plan and deliver actions within the Texas NFCAs Network to restore and preserve native fishes and their habitats. Furthermore, the Texas NFCAs Network has increased awareness of the ecological, recreational, and economic values of Texas freshwater systems and helped increase interest and capacity of local landowners, communities, and recreational users (e.g., paddlers, anglers) to act as advocates and local stewards of these systems. By facilitating partnership development, coordinating broad-based conservation planning, and leveraging technical and financial resources toward strategic conservation investments, the Texas NFCAs Network has served as a catalyst for collaborative, science-based stewardship of native freshwater fishes and their habitats in Texas. The Texas NFCAs Network offers a successful case study in multispecies and watershed approaches to freshwater fish conservation transferrable to other states in the United States, with particular relevance to those states that, similar to Texas, consist predominately of privately owned landscapes.

Conservation Needs of Texas Freshwater Fishes

Texas harbors 191 species of native freshwater fishes, 48% of which are considered imperiled (Table 1). An additional 67 species of native estuarine fishes have also been documented to occur in Texas freshwater systems, with 9 of those species considered imperiled (Table 1). The primary cause of fish species imperilment in Texas is anthropogenic alteration of freshwater systems, which continues to occur at rates and scales that threaten the long-term re-

Table 1. Fishes of the Texas Native Fish Conservation Areas Network. F = NFCA focal species and listed as a Texas species of greatest conservation need; FR = NFCA focal species and a recommended addition to the list of Texas species of greatest conservation need (Cohen et al. 2018); FL = NFCA focal species that is a Texas species of greatest conservation need and is listed as state or federally threatened or endangered; NN = species that occurs in and is non-native to the NFCA; C = species that is considered common that occurs in the NFCA; CR = species that is currently listed as a Texas species of greatest conservation need, but that is recommended for removal from that list by Cohen et al. (2018).

	Native fish conservation area																			
Taxa	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Chestnut Lamprey *Ichthyomyzon castaneus*																			C	C
Southern Brook Lamprey *I. gagei*																		C	C	
Atlantic Stingray *Dasyatis sabina*														C					C	
Shovelnose Sturgeon *Scaphirhynchus platorynchus*							FL	FL			FL									FL
Paddlefish *Polyodon spathula*																			FL	FL
Alligator Gar *Atractosteus spatula*					F	F	F	F			F	F	F	F	F	F		F	F	F
Spotted Gar *Lepisosteus oculatus*	C	C			C	C	C	C			C	C	C	C	C	C	C	C	C	C
Longnose Gar *L. osseus*	C	C		C	C	C	C	C			C	C	C	C	C	C	C	C	C	C
Shornose Gar *L. platostomus*		C																		C
Bowfin *Amia calva*													C	C			C	C	C	
Goldeye *Hiodon alosoides*		F																		F
Ladyfish *Elops saurus*														C					C	
Tarpon *Megalops atlanticus*														F					F	
American Eel *Anguilla rostrata*	F	F	F	F	F	F	F	F			F	F	F	F	F	F	F	F	F	F
Speckled Worm Eel *Myrophis punctatus*																			C	
Striped Anchovy *Anchoa hepsetus*														C					C	

Table 1. Continued.

Taxa	Native fish conservation area																			
	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Bay Anchovy *A. mitchilli*														C				C	C	
Skipjack Herring *Alosa chrysochloris*													C				C	C		
Finescale Menhadden *Brevoortia gunteri*														C					C	
Gulf Menhaden *B. patronus*														C				C	C	
Gizzard Shad *Dorosoma cepedianum*	C	C		C	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C
Threadfin Shad *D. petenense*	C			C	C	C	NN	NN		NN		NN	C	C	C		C	C	C	C
Scaled Sardine *Harengula jaguana*														C						
Central Stoneroller *Campostoma anomalum*	C	C	C	C	C	C					C	C	C	C	C	C	C	C	C	C
Mexican Stoneroller *C. ornatum*							FL	FL												
Highland Stoneroller *C. spadiceum*																				FR
Goldfish *Carassius auratus*	NN			NN			NN	NN		NN	NN	NN			NN	NN	NN	NN	NN	NN
Grass Carp *Ctenopharyngodon idella*													NN	NN	NN					NN
Plateau Shiner *Cyprinella lepida*						F														
Red Shiner *C. lutrensis*	C	C	C	C	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C
Maravillas Red Shiner *C. l. blairi*								F												
Conchos Shiner C. panarcys							FL													
Proserpine Shiner *C. proserpina*											FL	FL								
Nueces River Shiner *Cyprinella* sp.						F														
Blacktail Shiner *C. venusta*	C	C		C	C	C	NN	NN		NN	NN	C	C	C	C	C	C	C	C	C
Steelcolor Shiner *C. whipplei*																				C
Common Carp *Cyprinus carpio*	NN	NN	NN	NN	NN	NN	NN	NN		NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Manatial Roundhouse Minnow *Dionda argentosa*											F	F								

Table 1. Continued.

Taxa	Native fish conservation area																			
	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Devils River Minnopw *D. diaboli*												FL								
Roundnose Minnow *D. episcopa*										F	F									
Guadalupe Roundnose Minnow *D. flavipinnis*				FR	FR															
Medina Roundnose Minnow *D. nigrotaeniata*						F														
Frio Roundnose Minnow *D. serena*						F														
Conchos Roundnose Minnow *Dionda* sp. 1						FR														
Colorado Roundnose Minnow *Dionda* sp. 3				FR																
Nueces Roundnose Minnow *D. texensis*						FR														
Rio Grande Chub *Gila pandora*									FL	FL										
Rio Grande Silvery Minnow *Hybognathus amarus*							FL	FL			FL		FL							
Cypress Minnow *H. hayi*																				C
Mississippi Silvery Minnow *H. nuchalis*																FR		FR	FR	FR
Plains Minnow *H. placitus*	FR	FR	FR	FR	NN							NN				FR	FR	FR		
Pallid Shiner *Hybopsis amnis*					FR									FR	FR	FR	FR	FR	FR	FR
Striped Shiner *Luxilus chrysocephalus*																				C
Ribbon Shiner *Lythrurus fumeus*					C									C	C			C	C	C
Redfin Shiner *L. umbratilis*																			C	C
Speckled Chub *Macrhybopsis aestivalis*							F	F			F	F	F							
Prairie Chub *M. australis*		F																		
Shoal Chub *M. hyostoma*	FR	FR		FR										FR	FR	FR	FR	FR	FR	FR
Burrhead Chub *M. marconis*				FR	FR	FR									FR					

Table 1. Continued.

Taxa	Native fish conservation area																			
	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Silver Chub *M. storeriana*	F	F														F		F		F
Peppered Chub *M. tetranema*			FR																	
Golden Shiner *Notemigonus crysoleucas*	NN	NN	NN	NN	C	C	NN	NN		NN	NN		NN	C	C	NN	NN	C	C	C
Texas Shiner *Notropis amabilis*				CR	CR	CR					CR	CR	CR		CR					
Emerald Shiner *N. atherinoides*		C	C												NN			NN	C	C
Blackspot Shiner *N. atrocaudalis*																		F	F	F
Red River Shiner *N. bairdi*		F																		
River Shiner *N. blennius*		F																		F
Bigeye Shiner *N. boops*		C																		
Tamaulipas Shiner *N. braytoni*							F	F			F	F	F							
Smalleye Shiner *N. buccula*	FL			FL											FL	FL	FL	FL		
Ghost Shiner *N. buchanani*	C	C		C	C	C					C	C	C	C	C	C	C	C	C	C
Ironcolor Shiner *N. chalybaeus*					F														F	F
Chihuahua Shiner *N. chihuahua*							FL	FL												
Arkansas River Shiner *N. girardi*			FL																	
Rio Grande Shiner *N. jemezanus*							F	F			F	F	F							
Taillight Shiner *N. maculatus*																				F
West Texas Shiner *N. megalops*											FR	FR								
Phantom Shiner *N. orca*							F	F			F		F							
Sharpnose Shiner *N. oxyrhynchus*	FL			FL											FL	FL	FL	FL		
Chub Shiner *N. potteri*	F	F												F		F	F	F	F	F
Sabine Shiner *N. sabinae*														F					F	F

Table 1. Continued.

Taxa	Native fish conservation area																			
	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Silverband Shiner *N. shumardi*	F	F												F	F	F	F	F	F	F
Pecos Bluntnose Shiner *N. simus pecosensis*											FL									
Rio Grande Bluntnose Shiner *N. s. simus*							F	F												
Sand Shiner *N. stramineus*	C	C	C	C	C	C	C	C			C	C			C	NN	NN	NN	NN	
Weed Shiner *N. texanus*				C	C	C								C	C	NN				C
Mimic Shiner *N. volucellus*	C			C	C	C								C	C	C	C	C	C	C
Pugnose Minnow *Opsopoeodus emiliae*				C	C	C								C	C	C	C	C	C	C
Suckermouth Minnow *Phenacobius mirabilis*		FR	FR	FR											FR				FR	FR
Fathead Minnow *Pimephales promelas*	C	C	C	C	C	C	C	C			C			C	C	C	C	C	C	C
Bullhead Minnow *P. vigilax*	C	C	NN	C	C	C	NN	NN		NN	NN	C	C	C	C	C	C	C	C	C
Flathead Chub *Platygobio gracilis*			FR																	
Bluehead Shiner *Pteronotropis hubbsi*																				FL
Longnose Dace *Rhinichthys cataractae*							F	F			F		F							
Rudd *Scardinius erythrophthalmus*													NN							
Creek Chub *Semotilus atromaculatus*																			C	C
River Carpsucker *Carpiodes carpio*	C	C		C	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C
Quillback *C. cyprinus*																				C
Llano River Carpsucker *Carpiodes* sp.				FR																
Blue Sucker *Cycleptus elongatus*		FL		FL											FL	FL	FL	FL	FL	FL
Rio Grande Blue Sucker *Cycleptus* sp.							FL	FL			FL	FL	FL							
Western Creek Chubsucker *Erimyzon claviformis*														FL				FL	FL	FL
Lake Chubsucker *E. sucetta*					C									C				C	C	C

Table 1. Continued.

Taxa	Native fish conservation area																			
	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Smallmouth Buffalo *Ictiobus bubalus*	C	C		C			C	C		C	C		C	C	C	C	C	C	C	C
Bigmouth Buffalo *I. cyprinellus*																			C	C
Black Buffalo *I. niger*		NN					NN	NN			NN	NN							NN	
Spotted Sucker *Minytrema melanops*				F										C		C	C	C	C	C
Longlip Jumprock *Moxostoma albidum*											FR	FR								
Mexican Redhorse *M. austrinum*							F	F			F		F							
Gray Redhorse *M. congestum*	C			C	C	C	C	C		C	C	C	C		C	C	C	C		
Black Redhorse *M. duquesnii*																				C
Golden Redhorse *M. erythrurum*																				C
Blacktail Redhorse *M. poecilurum*														C					C	C
Mexican Tetra *Astyanax mexicanus*				NN	NN	C	C	C		C	C	C	C		NN		NN	NN	NN	
Black Bullhead *Ameiurus melas*	C	C	C	C	C	C			C	C	C	C	C	C	C	C	C	C	C	C
Yellow Bullhead *A. natalis*	C	C		C	C	C	NN	NN						C	C	C	C	C	C	C
Blue Catfish *Ictalurus furcatus*	C						C	C			C	C	C	C		C	C	C	C	C
Headwater Catfish *I. lupus*				F	F	F	F	F		F	F	F	F							
Channel Catfish *I. punctatus*	C	C	C	C	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C
Chihuahua Catfish *Ictalurus* sp.							F	F	F	F	F	F								
Rio Grande Blue Catfish *Ictalurus* sp.							FR	FR			FR	FR								
Tadpole Madtom *Noturus gyrinus*	C				C								NN	C	C	C	C	C	C	C
Freckled Madtom *N. nocturnus*	C													C		C	C	C	C	C
Mexican Blindcat *Prietella phreatophila*											FL	FL								
Flathead Catfish *Pylodictis olivaris*	C	C	C	C	C	C	C	C			C	C	C	C	C	C	C	C	C	C

Table 1. Continued.

Taxa	Native fish conservation area																			
	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Widemouth Blindcat *Satan eurystomus*					FL	FL														
Toothless Blindcat *Trogloglanis pattersoni*					FL	FL														
Hardhead Catfish *Ariopsis felis*														C					C	
Gafftopsail Catfish *Bagre marinus*														C					C	
Armadillo Del Rio *Hypostomus* sp.												NN	NN							
Southern Sailfin Catfish *Pterygoplichthys anisitsi*														NN						
Vermiculated Sailfin Catfish *P. disjunctivus*					NN															
Orinoco Sailfin Catfish *P. multiradiatus*														NN						
Redfin Pickerel *Esox americanus*														C				C	C	C
Chain Pickerel *E. niger*																				C
Rio Grande Cutthroat Trout *Oncorhynchus clarkii virginalis*									F	F										
Rainbow Trout *O. mykiss*						NN			NN										NN	
Pirate Perch *Aphredoderus sayanus*														C			C	C	C	C
Mountain Mullet *Agonostomus monticola*													FR	FR	FR	FR	FR	FR	FR	
Striped Mullet *Mugil cephalus*													C	C	C			C	C	
White Mullet *M. curema*														C					C	
Brook Silverside *Labidesthes sicculus*	NN	NN														NN	NN		C	C
Rough Silverside *Membras martinica*														C			NN	C	C	
Inland Silverside *Menidia beryllina*	NN	NN	NN	NN	C	NN	NN	NN		NN	NN	NN	NN	C	C	NN	NN	C	C	NN
Texas Silverside *M. clarkhubbsi*														F					F	
Tidewater Silverside *M. peninsulae*														C					C	

Table 1. Continued.

Taxa	Native fish conservation area																			
	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Atlantic Needlefish *Strongylura marina*														C		C	C	C	C	
Diamond Killifish *Adinia xenica*														C					C	
Western Starhead Topminnow *Fundulus blairae*														C				C	C	C
Golden Topminnow *F. chrysotus*														C				C	C	C
Gulf Killifish *F. grandis*	NN	NN		NN	NN	NN	NN	NN		NN	NN		NN	C	C	NN	NN	C	C	
Saltmarsh Topminnow *F. jenkinsi*														F					F	
Northern Plains Killifish *F. kansae*			C																	
Blackstripe Topminnow *F. notatus*	C	C		C	C	NN								C	C	C	C	C	C	C
Blackspotted Topminnow *F. olivaceous*														C		C	C	C	C	C
Bayou Killifish *F. pulvereus*														C					C	
Longnose Killifish *F. similis*														C						
Plains Killifish *F. zebrinus*	C	C		C			NN	NN		C	C	C			C	C	C	C	C	
Bluefin Killifish *Lucania goodei*														NN						
Rainwater Killifish *L. parva*					NN				C	C	C		C	C					C	
Pike Killifish *Belonesox belizanus*						NN														
Western Mosquitofish *Gambusia affinis*	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Amistad Gambusia *G. amistadensis*											F									
Big Bend Gambusia *G. gaigei*								FL												
Largespring Gambusia *G. geiseri*				NN	C	NN				NN	NN	NN								
San Marcos Gambusia *G. georgei*					FL															
Clear Creek Gambusia *G. heterochir*				FL																
Spotfin Gambusia *G. krumholzi*												FL								

Table 1. Continued.

Taxa	Native fish conservation area: Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Pecos Gambusia *G. nobilis*										FL	FL									
Blotched Gambusia *G. senilis*												FL								
Tex-Mex Gambusia *G. speciosa*											C	C								
Least Killifish *Heterandria formosa*																			C	
Amazon Molly *Poecilia formosa*					NN	NN							C					NN		
Sailfin Molly *P. latipinna*				NN	NN	NN						NN	C	C	C	NN		C	C	
Guppy *P. reticulata*						NN														
Green Swordtail *Xiphophorus hellerii*						NN														
Variable Platyfish *X. variatus*															NN					
Leon Springs Pupfish *Cyprinodon bovinus*											FL									
Comanche Springs Pupfish *C. elegans*										FL	FL									
Conchos Pupfish *C. eximius*							FL					FL								
Pecos Pupfish *C. pecosensis*											FL									
Red River Pupfish *C. rubrofluviatilis*	F	F	F	NN																
Sheepshead Minnow *C. variegatus*	NN			NN	NN					NN	NN	NN	C	C	C			C	C	
Opossum Pipefish *Microphis brachyurus*														FL					FL	
Dusky Pipefish *Syngnathus floridae*														C					C	
Chain Pipefish *S. louisianae*														C					C	
Gulf Pipefish *S. scovelli*														C					C	
White Bass *Morone chrysops*	NN	C	C	NN			NN	NN		NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	C
Yellow Bass *M. mississippiensis*														C					C	C
Striped Bass *M. saxatilis*	NN			NN										NN				NN	NN	NN

Table 1. Continued.

Taxa	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
	Native fish conservation area																			
Rock Bass *Ambloplites rupestris*					NN															
Flier *Centrarchus macropterus*														C					C	C
Redbreast Sunfish *Lepomis auritus*	NN	NN		NN	NN	NN	NN	NN		NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Green Sunfish *L. cyanellus*	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Warmouth *L. gulosus*	C	C		C	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C
Orangespotted Sunfish *L. humilis*	C	C	C	C	NN									C	C	C	C	C	C	C
Bluegill *L. macrochirus*	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Dollar Sunfish *L. marginatus*														C				C	C	C
Longear Sunfish *L. megalotis*	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Redear Sunfish *L. microlophus*	C	C	C	C	C	C	NN	NN		NN	NN	NN	NN	C	C	C	C	C	C	C
Redspotted Sunfish *L. miniatus*	C			C	C	C						C		C	C	C	C	C	C	C
Bantam Sunfish *L. symmetricus*														C	C			C	C	C
Smallmouth Bass *Micropterus dolomieu*				NN	NN	NN						NN			NN	NN	NN	NN	NN	
Spotted Bass *M. punctulatus*	C	C			C									C	C	C	C	C	C	C
Largemouth Bass *M. salmoides*	C	C	C	C	C									C	C	C	C	C	C	C
Florida Largemouth Bass *M. salmoides floridanus*	NN	NN	NN	NN	NN	NN	NN	NN		NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
Rio Grande Largemouth Bass *M. salmoides nuecensis*						FR	FR	FR		FR	FR	FR	FR							
Guadalupe Bass *M. treculii*				F	F	F									F	F	F			
White Crappie *Pomoxis annularis*	NN	C		C	NN	NN	NN	NN					NN	C	C	C	C	C	C	C
Black Crappie *P. nigromaculatus*	NN			NN	NN								NN	C	C	C	C	C	C	C
Western Sand Darter *Ammocrypta clara*																			F	F
Scaly Sand Darter *A. vivax*																			C	C

Table 1. Continued.

Taxa	Native fish conservation area: Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Redspot Darter *Etheostoma artesiae*																			C	C
Mud Darter *E. asprigene*																				C
Bluntnose Darter *E. chlorosoma*					C									C	C			C	C	C
Fountain Darter *E. fonticola*					FL															
Swamp Darter *E. fusiforme*																			C	
Slough Darter *E. gracile*					C									C	C	C	C	C	C	C
Rio Grande Darter *E. grahami*											FL	FL	FL							
Harlequin Darter *E. histrio*																			C	C
Greenthroat Darter *E. lepidum*				C	C	C														
Goldstripe Darter *E. parvipinne*														C	C			C	C	C
Cypress Darter *E. proeliare*														C	C				C	C
Plains Orangethroat Darter *E. pulchellum*	C	C		C	C	C									C	C	C	C		C
Orangebelly Darter *E. radiosum*																				F
Speckled Darter *E. stigmaeum*																			C	
Gumbo Darter *E. thompsoni*																			FR	FR
Yellow Perch *Perca flavescens*			NN																	
Guadalupe Darter *Percina apristis*					F															
Logperch *P. caprodes*		C																		C
Texas Logperch *P. carbonaria*	C			C	C	C									C	C	C	C	C	
Bigscale Logperch *P. macrolepida*	C	C		C								C	C	C	C	C	C	C	C	C
Blackside Darter *P. maculata*														FL						FL
Slenderhead Darter *P. phoxocephala*																				C

Table 1. Continued.

Taxa	Native fish conservation area																			
	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Dusky Darter *P. sciera*	C			C										C	C	C	C	C	C	C
River Darter *P. shumardi*		FR			FR														FR	FR
Sauger *Sander canadensis*		NN																		NN
Walleye *S. vitreus*	NN		NN		NN															
Crevalle Jack *Caranx hippos*																			C	
Leatherjacket *Oligoplites saurus*														C					C	
Spotfin Mojarra *Eucinostomus argenteus*																			C	
Silver Jenny *E. gula*																			C	
Tidewater Mojarra *E. harengulus*														C						
Flagfin Mojarra *E. melanopterus*														C					C	
Sheepshead *Archosargus probatocephalus*																			C	
Pinfish *Lagodon rhomboides*																			C	
Atlantic Threadfin *Polydactylus octonemus*																			C	
Freshwater Drum *Aplodinotus grunniens*	C	C		C	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C
Silver Perch *Bairdiella chrysoura*														C						
Sand Seatrout *Cynoscion arenarius*														C					C	
Spotted Seatrout *C. nebulosus*														C					C	
Silver Seatrout *C. nothus*																			C	
Spot *Leiostomus xanthurus*														C					C	
Atlantic Croaker *Micropogonias undulatus*														C					C	
Black Drum *Pogonias cromis*														C					C	
Red Drum *Sciaenops ocellatus*														C					C	

Table 1. Continued.

Taxa	Upper Brazos River	Upper Red River	Upper Canadian River	Central Edwards Plateau Rivers	Guadalupe and San Antonio Rivers	Southern Edwards Plateau Rivers	Upper Big Bend	Lower Big Bend	Guadalupe Mountains Streams	Davis Mountains Streams	Pecos River	Devils River	Lower Rio Grande	Central Coast Rivers and Streams	Lower Colorado River	Middle Brazos River	San Gabriel River	Lower Brazos River	Southeast Texas Rivers	Northeast Texas Rivers
Star Drum *Stellifer lanceolatus*																			C	
Banded Pygmy Sunfish *Elassoma zonatum*														C				C	C	C
Rio Grande Cichlid *Herichthys cyanoguttatus*	NN			NN	NN	NN	C	C		C	C	C	C	NN	NN	NN	NN	NN		
Blue Tilapia *Oreochromis aureus*	NN			NN	NN	NN	NN	NN		NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	
Mozambique Tilapia *O. mossambicus*					NN						NN	NN								
Redbelly Tilapia *Tilapia zillii*					NN															
Fat Sleeper *Dormitator maculatus*														C				C	C	
Largescaled Spinycheek Sleeper *Eleotris amblyopsis*														C					C	
Bigmouth Sleeper *Gobiomorus dormitor*														C						
Darter Goby *Ctenogobius boleosoma*														C					C	
Freshwater Goby *C. shufeldti*														C					C	
Lyre Goby *Evorthodus lyricus*																			C	
Violet Goby *Gobioides broussonetii*														C					C	
Highfin Goby *Gobionellus oceanicus*														C					C	
Naked Goby *Gobiosoma bosc*														C					C	
Code Goby *G. robustum*														C					C	
Clown Goby *Microgobius gulosus*														C					C	
Spotted Whiff *Citharichthys macrops*																			C	
Bay Whiff *C. spilopterus*														C					C	
Southern Flounder *Paralichthys lethostigma*														F					F	
Lined Sole *Achirus lineatus*														C					C	
Hogchoker *Trinectes maculatus*														C					C	
Least Puffer *Sphoeroides parvus*																			C	

siliency of freshwater habitats, species, and ecosystems (Dodds et al. 2013). Extraction of groundwater for agricultural irrigation, energy development, and municipal water supply has substantially altered groundwater levels and resulted in concomitant reductions in spring discharge and instream flows (Costigan and Daniels 2012; Steward et al. 2013; Garrett et al., in press). The construction of dams has fragmented rivers, altered natural flow patterns, and reduced the availability of suitable habitats for native fishes (Costigan et al. 2012; Wilde and Urbanczyk 2013; Perkin et al. 2014; Worthington et al. 2014; Perkin et al. 2015; Mayes et al. 2019, this volume; Smith et al. 2019, this volume). The cumulative impacts of urbanization and other land use changes have substantially altered natural watershed processes. These and a myriad of other interrelated challenges—degradation of water quality, instream habitat degradation, and the negative effects of nonindigenous species (e.g., predation, competition, and hybridization with native species)—threaten freshwater fish diversity (Gido et al. 2010; Hoagstrom et al. 2011). Left unchecked, these issues will likely continue to contribute to the imperilment and loss of native fishes and other freshwater species (Gido et al. 2010; Hoagstrom et al. 2011). Coordinated conservation intervention is urgently needed to ensure the preservation of native freshwater fish diversity (Hoagstrom et al. 2011; Perkin et al. 2015).

Declining freshwater fish diversity is a conservation issue not unique to Texas (Haslouer et al. 2005; Jelks et al. 2008). Freshwater fish diversity is threatened globally (Dodds et al. 2013; Dudgeon et al. 2006; Strayer and Dudgeon 2010). Innovative and systematic conservation approaches are needed that can be effective at restoration and maintenance of the functional watershed processes necessary to sustain freshwater systems, including native fishes and the habitats they need to thrive (Margules and Pressey 2000; Groves et al. 2002; Balmford and Whitten 2003; Abell et al. 2007; Martinuzzi et al. 2014; Donlan 2015). For those approaches to be supported sociopolitically, they must simultaneously address human needs (e.g., flood abatement, municipal and agricultural water supply, water quality protection, and recreation; Limburg et al. 2011). Collaborative, integrated, and holistic approaches will become increasingly necessary as conflicts and competition for dwindling freshwater resources become unavoidable (Vorosmarty et al. 2010; Dodds et al. 2013; Martinuzzi et al. 2014; Palomo et al. 2014). Lynch et al. (2016) summarized climate trends that have the potential to influence freshwater fishes and compiled findings of 31 peer-reviewed studies from throughout North America that documented climate change effects on freshwater fishes. Of particular concern for native freshwater fishes of Texas is the forecast for droughts to increase in frequency and severity, especially in arid rivers, affecting the timing and frequency of flows and water levels necessary to support spawning and other habitat requirements of freshwater fishes. Complex interactions are also expected to occur between climate change and existing anthropogenic stressors (e.g., invasive species, watershed alteration, river fragmentation, and pumping of groundwater and surface water), making separating and understanding the relative magnitude of climate effects challenging. Paukert et al. (2016) recommended that to support the ability of native freshwater fishes to adapt to climate change, resource managers will need to increasingly focus available resources on actions that enhance the resiliency of watersheds, habitats, and ecosystems.

Although conflicts and competition for available freshwater resources seem inevitable, case studies are available that demonstrate innovative and effective approaches involving cooperation among diverse and seemingly competing interests to deliver beneficial and shared solutions (Garrett 2003; Birdsong et al. 2015; Garrett et al. 2015; Magnelia et al. 2019a, this volume; Robertson et al. 2019, this volume; Smith et al. 2019). These case studies have utilized the native fish conservation areas (NFCAs) approach (Dauwalter et al. 2011; Williams et al. 2011; Garrett et al. 2019, this volume; Harris et al. 2019, this volume; Labay et al. 2019, this volume), which ensures consideration of the conservation needs of native fishes and their habitats in river and watershed management. Furthermore, the NFCAs approach emphasizes management of freshwater systems toward an explicit goal of sustaining native fish diversity while encouraging compatible human uses. This concept is especially relevant to the conservation of freshwater systems in Texas, where many fish species have experienced population declines associated with anthropogenic changes in watersheds where public lands are scarce and large-scale preservation opportunities are limited.

Spatial Prioritization of Native Fish Conservation Areas in Texas

The 2012 Texas Conservation Action Plan (i.e., the State Wildlife Action Plan for Texas; TPWD 2012) identified the need to prioritize areas of the state critically important to the restoration and preservation of freshwater, marine, and terrestrial species of greatest conservation need (SGCN), with the intent of informing future investments of project funding, staff, and other resources toward strategic conservation actions (Margules and Pressey 2000; Fausch et al. 2002; Knight et al. 2006; Knight et al. 2008; Fontaine 2011). To address this need for freshwater fishes, known and modeled fish species distributions, hydrologic and environmental variables, and spatial prioritization analysis were combined to identify high-priority freshwater systems throughout Texas that meet the four critical elements of an NFCA, as described by Williams et al. (2011): (1) natural physical processes remain intact (or have the potential to be restored) within the watershed that support the maintenance of freshwater habitat complexity, diversity and connectivity; (2) habitats are contained within the watershed that support all life history stages of the fish species being preserved; (3) the watershed or fragmented river segment is large enough to provide for long-term persistence of native fish populations (e.g., effective population size); and (4) management plans and other agreements can be developed that will allow the watershed or river segment to be managed in a manner that sustains aquatic and riparian habitat integrity over time and across management jurisdictions and land ownerships. This effort resulted in development of conservation planning products, including species distribution models for freshwater fish SGCN, a landscape ranking and prioritization that identifies focal areas for conservation of freshwater fish SGCN, and a spatial framework for conservation planning and delivery via identification of high-priority freshwater systems considered NFCAs. Detailed descriptions of the concepts and methods used in creation of these products are discussed by Labay et al. (2019), who used consistent methods to prioritize freshwater systems for conservation of fish diversity in the U.S. Great Plains. Thus, methods will be only briefly discussed here.

Fish species chosen for distribution modeling and subsequent analyses were selected on the basis of their inclusion in a recommended list of Texas freshwater fish SGCN assembled by Cohen et al. (2018). The list identifies 91 species of freshwater fishes, each with a conservation status that warrants listing as SGCN (Table 1). It is anticipated that those 91 species will be listed as SGCN in the forthcoming update of the Texas Conservation Action Plan in 2023. Species distribution models (SDMs) were assembled for 85 of the 90 species; SDMs were not assembled for four species and subspecies that are likely extinct (Maravillas Red Shiner, San Marcos Gambusia, Phantom Shiner, Rio Grande Bluntnose Shiner) or for one additional species considered a unique, disjunct population (Spotted Sucker).

The SDMs converted point occurrence data into rangewide probabilities of occurrence (Guisan et al. 2013). Fish occurrence data used in development of SDMs consisted of museum-vouchered specimens available from the University of Texas at Austin Fishes of Texas database and data available from the Global Biodiversity Information Facility that were compiled, reviewed, and partially normalized by Hendrickson et al. (2010) and Cohen et al. (2013). Specific hydrologic, climatic, and topographic variables included in SDM development are described by Labay et al. (2019). Individual SDMs in geographic information system-ready formats and detailed information on the model production methodology can be accessed through the University of Texas at Austin Fishes of Texas Project model download portal (www.fishesoftexas.org/models/).

The SDMs were used within Zonation (Moilanen et al. 2005), a conservation planning software, to spatially rank and prioritize freshwater systems statewide based on their value in conservation of the diversity of Texas freshwater fish SGCN. Conservation value was assessed based on spatially explicit levels of species, habitat, or ecosystem occurrence, as defined by SDM estimation of the relative probability of occurrence. The prioritization emphasized species rarity as opposed to species richness (Moilanen et al. 2005). This approach resulted in prioritization of freshwater systems important in preservation of the diversity of freshwater fish SGCN (Figure 1). Zonation was then used to identify species-based geographic management units, here referred to as NFCAs, based on distance and compositional similarity among the priority freshwater systems. This analysis resulted in identification of 20 NFCAs for inclusion in the Texas Native Fish Conservation Areas Network (hereafter, "Texas NFCAs Network"; Figure 2), which represents a selection of springs, ciénegas, creeks, rivers, and associated watersheds that serve as native fish strongholds and that are now considered priority landscapes for conservation investments by the Texas Parks and Wildlife Department (TPWD) and partners. The diversity of native and nonnative fishes known to occur within each of the 20 NFCAs are outlined in Table 1.

Initial efforts to prioritize freshwater systems for inclusion in the Texas NFCAs Network were conducted in 2013. That pilot phase focused on prioritization of freshwater systems for conservation of 71 fish SGCN that occur within six ecoregions located in the northwestern portion of the state (i.e., High Plains, Southwestern Tablelands, Central Great Plains, Arizona/New Mexico Mountains, Chihuahuan Desert, and Edwards Plateau ecoregions; Griffith et al. 2007). Prioritization of freshwater systems in that geography identified the following 11 conservation priority areas: Upper Canadian River NFCA, Upper Red River NFCA, Upper Brazos River NFCA, Central Edwards Plateau Rivers NFCA, Southern Edwards Plateau Rivers NFCA, Devils River NFCA, Pecos River NFCA, Guadalupe Mountains Streams NFCA, Davis Mountains Streams NFCA, Upper Big Bend NFCA, and Lower Big Bend NFCA (Figure 2). The statewide NFCA prioritization was subsequently completed in 2015, identifying nine additional conservation priority areas located in the eastern and southern portions of the state: Northeast Texas Rivers NFCA, Southeast Texas Rivers NFCA, San Gabriel River NFCA, Middle Brazos River NFCA, Lower Brazos River NFCA, Lower Colorado River NFCA, Guadalupe and San Antonio Rivers NFCA, Central Coast Rivers and Streams NFCA, and Lower Rio Grande NFCA (Figure 2).

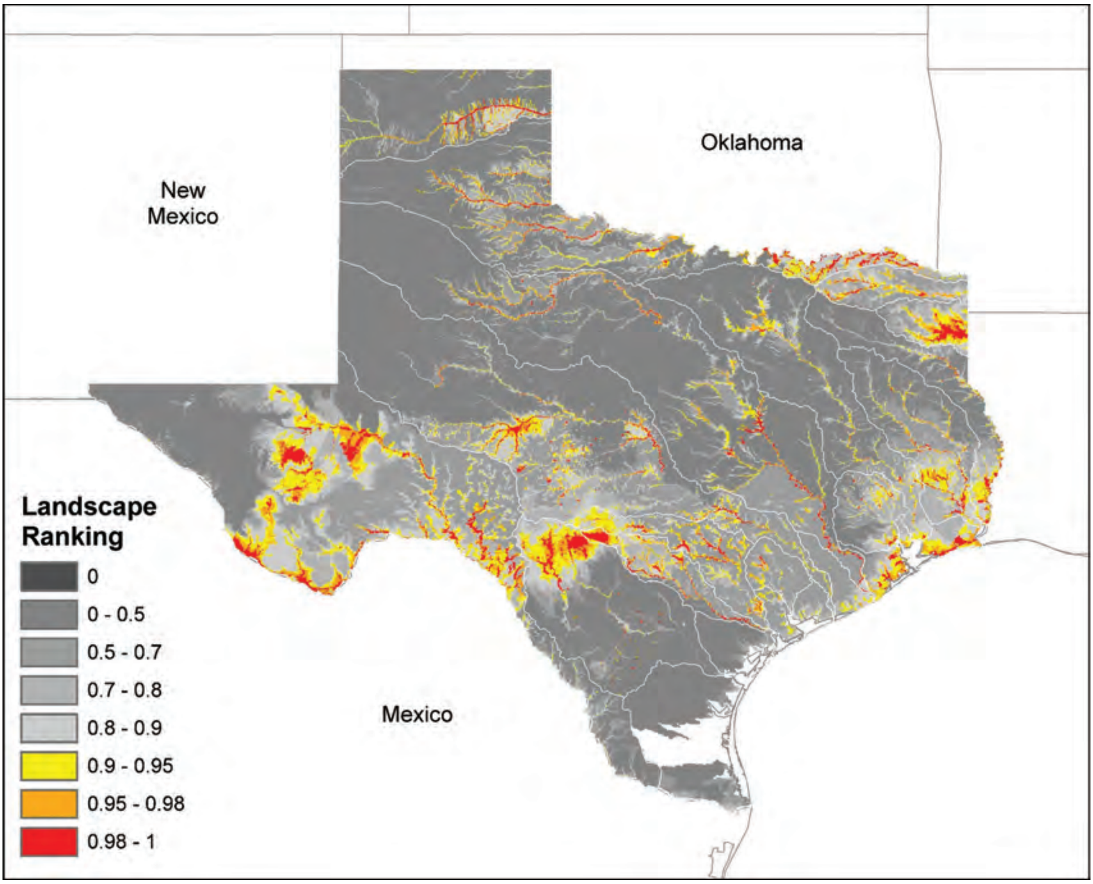

Figure 1. Raw spatial prioritization of freshwater systems for conservation of Texas freshwater fish species of greatest conservation need.

Conservation Planning and Delivery within the Texas Native Fish Conservation Areas Network

Since the initial NFCA prioritization in 2013, the TPWD and partners have focused available technical and financial resources toward conservation planning and delivery within the Texas NFCAs Network. This has included investments in habitat restoration, habitat preservation, research, and surveys. Those investments have contributed toward achieving the vision for the Texas NFCAs Network of restoring and preserving freshwater systems to the level that native fishes thrive as stable components of diverse ecological communities, simultaneously providing clean water, outstanding outdoor recreation, and a stable economic base for present and future citizens. This vision was adapted from the vision established for the Little Tennessee River NFCA (Harris et al. 2019), which is considered the first NFCA officially designated in the United States.

Conservation planning and delivery within the Texas NFCAs Network has involved a diverse group of conservation partners from nongovernmental organizations, state and federal agencies, and universities with a desire to participate in collaborative conservation and a shared mission to restore and preserve wild and native fishes and the habitats they need to thrive. Partners have focused on guiding strategic investments

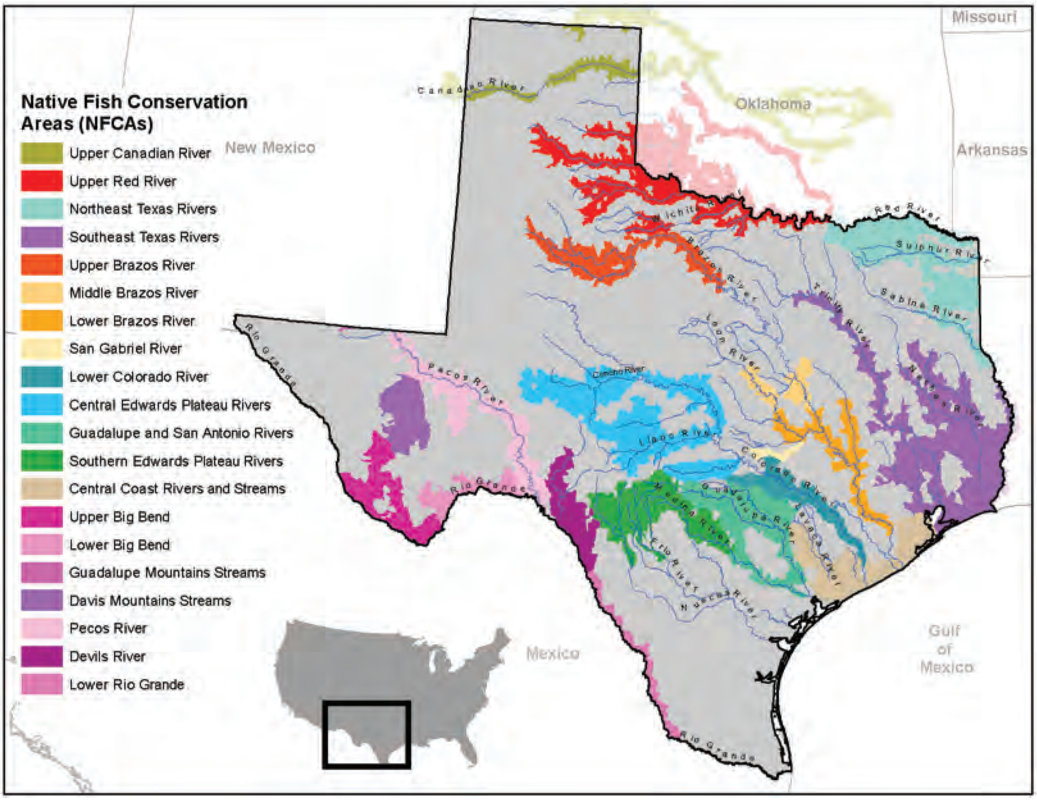

Figure 2. Freshwater systems adopted as native fish conservation areas by the Texas Parks and Wildlife Department.

and leveraging available technical and financial resources to achieve scale-appropriate and transformative actions for conservation of native fishes, their habitats, and other freshwater resources. The critical elements of NFCAs described by Williams et al. (2011), outlined previously in this chapter, have been adopted as the core principles of the Texas NFCAs Network. To facilitate conservation planning and align specific conservation actions undertaken within the Texas NFCAs Network with those core principles, the following eight goals were established for the Texas NFCAs Network:

1. Protect and maintain intact habitats
2. Restore altered habitats
3. Restore instream and floodplain connectivity
4. Mitigate effects of invasive species
5. Organize and facilitate conservation partnership networks
6. Establish conservation demonstration areas
7. Conduct research to fill critical science needs
8. Monitor conservation outcomes and perform adaptive management

Adoption of these eight goals was intended to promote the restoration of watershed functions, emphasizing actions that curtail or eliminate activities on the landscape that degrade water quality, reduce water quantity, degrade riparian systems, favor nonnative species, or fragment river systems while encouraging a wide array of sustainable land-use and water-based recreational activities that are compatible with freshwater fish conservation. Furthermore, these goals have served as thematic topics used to facilitate cooperative planning and identification of NFCA-specific conservation needs, related conservation strategies, project-level conservation actions, and research and monitoring needs. Summaries of conservation investments toward achieving each of these eight goals from 2013 to 2018 are provided below.

Goal 1: protect and maintain intact habitats

Effective January 2016, the Texas Legislature authorized and provided funding for the TPWD to administer the Texas Farm and Ranch Lands Conservation Program (TFRLCP), a grant program designed to provide cost-share funding to land trusts for the purchase of conservation easements on private lands in support of the following objectives: (1) conserve water or protect water quality, (2) conserve native wildlife species through protection of their habitat, (3) conserve rare or sensitive species, (4) demonstrably contribute to preservation of a landscape of conservation lands, or (5) protect productive open-space land threated by fragmentation or development. Specific project scoring, ranking, and selection criteria were assembled by the TPWD and approved by the governor-appointed Texas Farm and Ranch Lands Council, which provides leadership and oversight of the TFRLCP.

The 100 possible points awarded to grant applications submitted to the TFRLCP consider the following scoring criteria: (1) threat of development (20 points), (2) value and cost-effectiveness (20 points), (3) value in protection of watershed processes and aquatic habitats (20 points), (4) value in protection of habitats for SGCN (20 points), (5) contributions to protection of a conservation landscape such as a wildlife migration route or riparian corridor (10 points), and (6) terms of the conservation easement (10 points). Application scoring criteria 3–5 for the TFRLCP directly relate to variables considered in selection of freshwater systems included in the Texas NFCAs Network. Grant applications to the TFRLCP that proposed conservation easements on private lands located within the Texas NFCAs Network scored considerably higher than those located elsewhere in the state. As such, the Texas NFCAs Network prioritization substantially influenced scoring of individual applications, and 13 of the 14 grants awarded by the TFRLCP in 2016–2018 supported preservation of private lands within the Texas NFCAs Network (Table 2).

Those 13 conservation easements funded by the TFRLCP protected 10,563 ha of springs and instream, riparian, and upland habitats within the Central Coast Rivers and Streams, Central Edwards Plateau Rivers, Guadalupe Mountains Streams, Guadalupe and San Antonio Rivers (Figure 3), Lower Colorado River (Figure 4), San Gabriel River, Southeast Texas Rivers, Southern Edwards Plateau Rivers, and Upper Red River NFCAs. Conservation biologists from the TPWD Inland Fisheries Division conducted site visits to the private properties selected for funding and consulted with landowners and partnering land trusts on terms and conditions of the conservation easements to maximize their benefit and value in long-term protection of native fishes, their habitats, and other freshwater resources within those nine NFCAs.

The Western Association of Fish and Wildlife Agencies Crucial Habitat Assessment Tool (CHAT; www.wafwachat.org) identifies important fish and wildlife habitats and corridors across the 17 western states of the United States, including Texas. The purpose of the tool is to incorporate and inform consideration of fish and wildlife habitats in land-use planning, zoning, and development decisions, such as planning of new energy or transportation corridors. Habitats identified as priorities within CHAT were selected by cooperating state fish and wildlife

Table 2. Conservation easements secured within the Texas Native Fish Conservation Areas Network through the Texas Farm and Ranch Lands Conservation Program (2016–2018).

Native fish conservation area	Number of conservatgion easements	Area protected (ha)	Habitat types protected
Central Coast Rivers and Streams	2	2,276	Freshwater wetlands in the Colorado River and Tres Palacios River
Central Edwards Plateau Rivers	1	554	Riparian buffer of the Colorado River
Guadalupe Mountains Streams	1	2,925	Tributaries and riparian buffer of McKittrick Creek
Guadalupe and San Antonio Rivers	1	85	Tributaries and riparian buffer of the Blanco River
Lower Colorado River	3	635	Tributaries and riparian buffer of Barton and Onion creeks
San Gabriel River	1	248	Tributaries and riparian buffer of the San Gabriel River
Southeast Texas Rivers	1	2,230	Tributary Streams and riparian buffer of the Neches River
Southern Edwards Plateau Rivers	2	953	Tributaries and riparian buffer of the Nueces River
Upper Red River	1	656	Riparian buffer of the Red River

Figure 3. Riparian corridor of Wanslow Creek, a stream located within the Guadalupe and San Antonio Rivers Native Fish Conservation Area that was protected through a conservation easement supported through the Texas Farm and Ranch Lands Conservation Program.

Figure 4. Riparian corridor of Onion Creek, a stream located within the Lower Colorado River Native Fish Conservation Area that was protected through multiple conservation easements supported through the Texas Farm and Ranch Lands Conservation Program.

agencies. Each state agency utilized a standard set of definitions, guidelines, and criteria to achieve a consistent regional approach. In 2018, the TPWD finalized CHAT input layers for Texas, including the Aquatic CHAT layer (Figure 5), which incorporated priority freshwater systems of the Texas NFCAs Network as a top-tier priority for conservation of native fishes and other freshwater SGCN. As is the intent of CHAT, this is expected to encourage land developers toward increased consideration, avoidance, and protection of freshwater systems contained within the Texas NFCAs Network.

Goal 2: restore altered habitats

Actions to restore altered habitats within the Texas NFCAs Network have primarily centered on restoration of habitats for Guadalupe Bass, a SGCN and the official state fish of Texas (Figure 6; Birdsong et al. 2015; Garrett et al. 2015; Magnelia et al. 2019a, 2019b). Supported through funding provided by the Southeast Aquatic Resources Partnership, National Fish and Wildlife Foundation, and U.S. Fish and Wildlife Service (USFWS) Texas Partners for Fish and Wildlife Program, the TPWD and partners restored 3,199 ha of springs, creeks, and riparian buffers within the Central Edwards Plateau Rivers NFCA (Table 3), improving habitat conditions for native fishes in approximately 89 km of the James, Llano, and Pedernales rivers and their tributaries (Figures 7 and 8). Additionally, the TPWD provided technical guidance to approximately 850 landowners and other local stakeholders on recommended stewardship practices for management of instream and riparian habitats. Stewardship practices to maintain or restore physical watershed processes have been implemented on approximately 42,389 ha of ranchlands. Habitat restoration was conducted in con-

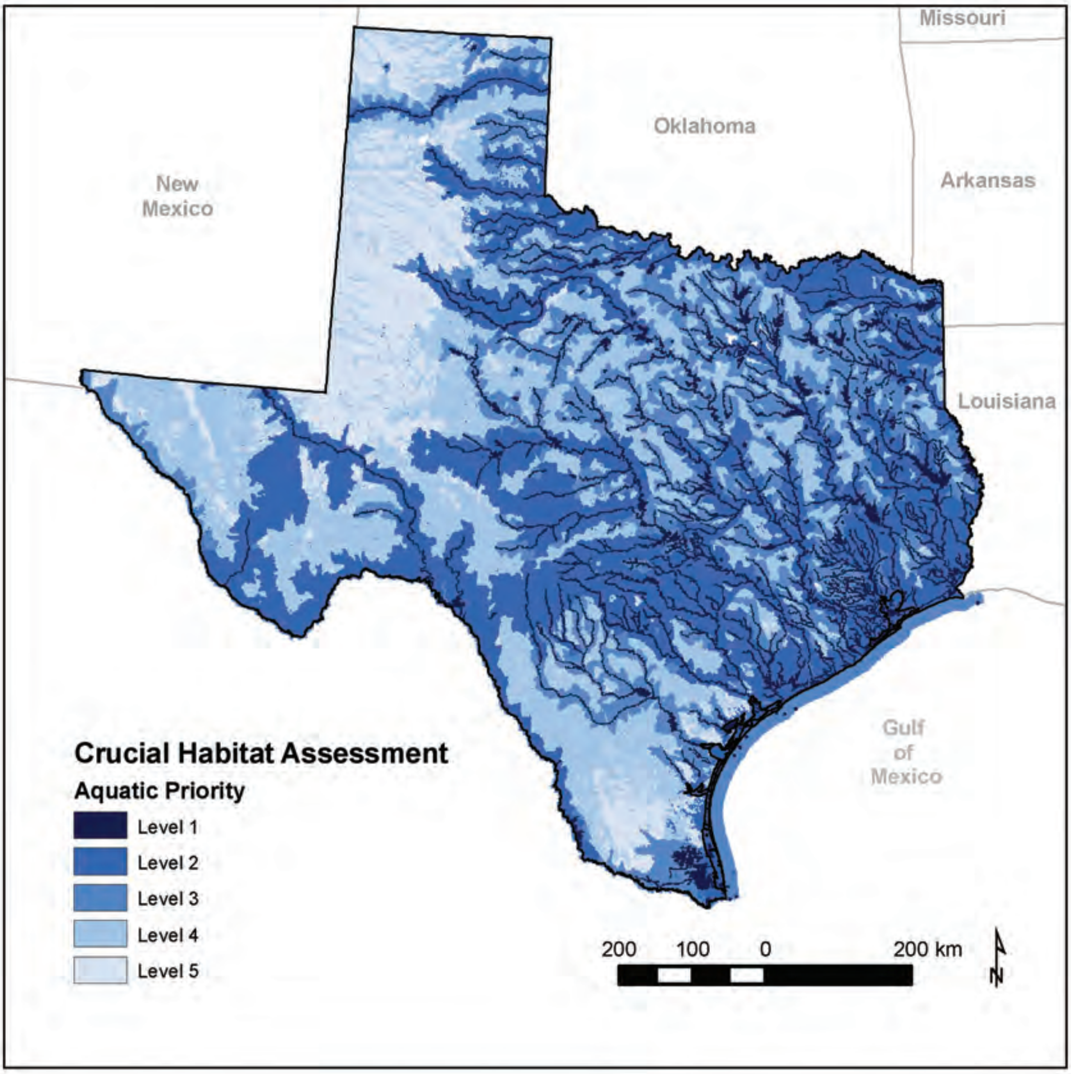

Figure 5. Spatial priorities for conservation of freshwater fish species of greatest conservation need identified within the Western Association of Fish and Wildlife Agencies Crucial Habitat Assessment Tool (Tier 1 = perennial streams within the native range of fish species of greatest conservation need; Tier 2 = Texas Native Fish Conservation Areas Network; Tier 3 = Hydrologic Unit Code 12s that contain perennial streams within the native ranges of fish species of greatest conservation need; Tier 5 = all other areas of the state).

junction with Guadalupe Bass genetic restoration efforts, which involved the production and stocking of more than 793,629 genetically pure Guadalupe Bass fingerlings to ameliorate hybridization between Guadalupe Bass and nonnative, introduced Smallmouth Bass (Lutz-Carrillo et al. 2015).

Within the Southern Edwards Plateau Rivers NFCA, the TPWD collaborated with private landowners and nongovernmental organizations to restore 209 ha of grasslands, riparian buffers, and instream habitats (Table 3). Biologists from the TPWD cooperated with landowners to implement

Figure 6. Guadalupe Bass, the official state fish of Texas and a species of greatest conservation need.

Table 3. Landowner technical guidance and habitat restoration completed within the Texas Native Fish Conservation Areas Network (2013–2018).

Native fish conservation area	Area of ranchlands that received prescriptive guidance on best practices for watershed management (ha)	Quantity of habitats restored (ha)	Habitat types restored
Central Edwards Plateau Rivers	42,389	3,199	Grasslands, springs, riparian, and instream habitats
Guadalupe and San Antonio Rivers	472	142	Riparian and instream habitats
Pecos River	5,036	0.4	Springs and instream habitats
Southern Edwards Plateau Rivers	9,930	209	Grasslands, riparian, and instream habitats
Upper Big Bend	120,343	16,596	Grasslands, springs, riparian, and instream habitats
Upper Brazos River	2,711	2,711	Riparian and instream habitats

Figure 7. Llano River, located within the Central Edwards Plateau Rivers Native Fish Conservation Area.

Figure 8. Pedernales River, located within the Central Edwards Plateau Rivers Native Fish Conservation Area.

conservation best management practices on 9,930 ha within the watersheds of the Frio, Medina, Nueces, and upper Guadalupe rivers. Additionally, a partnership was formed among the TPWD, The Nature Conservancy, the USFWS Partners for Fish and Wildlife Program, and the Texas Master Naturalists Program to provide landowners and citizen scientists with technical guidance on watershed stewardship practices, aquatic species identification, and aquatic resources monitoring strategies.

In the Guadalupe and San Antonio Rivers NFCA, the TPWD and partners organized 13 riparian habitat restoration workshops attended by 544 riparian landowners and other local stakeholders. A landowner restoration manual was assembled that identifies strategies for accommodating recreational access to rivers while maintaining riparian functions (Asher et al. 2017). Similar to conservation efforts in the Central Edwards Plateau Rivers NFCA, the Southeast Aquatic Resources Partnership provided funding to the TPWD and partners to deliver restoration of 142 ha of riparian buffer along the Blanco River (Table 3). Restoration included planting of 3,300 native riparian saplings and 15,000 riparian sedges to support revegetation of erosional riverbanks denuded of vegetation following catastrophic flooding. Habitat restoration was completed in conjunction with a nonnative Smallmouth Bass removal and Guadalupe Bass stocking program, which successfully repatriated Guadalupe Bass to a fragmented reach of the Blanco River (Magnelia et al. 2019b).

Freshwater systems of the Texas NFCAs Network have also been adopted as geographic priorities for investments by multiple conservation funding programs administered by federal agencies and foundations. The most recent 5-year strategic plan of the USFWS Texas Partners for Fish and Wildlife Program (2017–2021) adopted the Davis Mountains Streams, Pecos River, Upper Big Bend, Lower Big Bend, Devils River, Central Edwards Plateau Rivers, Southern Edwards Plateau Rivers, Guadalupe and San Antonio Rivers, and Lower Colorado River NFCAs as geographic focus areas for investments in habitat restoration and species conservation. The USFWS Texas Partners for Fish and Wildlife Program has an active partnership with the TPWD Landowner Incentive Program focused on restoration of grasslands, riparian buffers, and instream habitats. From 2013 to 2018, the two organizations cooperated on restoration of 1,793 ha of grasslands and 11 km of instream habitats and riparian buffers within the Upper Big Bend NFCA (Figures 2 and 9). Comparable investments are expected to continue across the Texas NFCAs Network.

The Texas Parks and Wildlife Foundation (TPWF) is the official nonprofit partner of the TPWD, and in 2013, the TPWD and TPWF partnered to establish the Conserving Texas Rivers Initiative (CTRI), a fundraising program that has supported habitat restoration, native fish conservation, river access, and conservation demonstration within the Texas NFCAs Network. The CTRI represents a public–private partnership, in which private donations have been leveraged with public funding available to the TPWD (e.g., state fishing license revenues, federal grants through the Wildlife and Sport Fish Restoration Program, and federal grants through the National Fish Habitat Partnership). During 2013–2018, private donors contributed US$190,000, which was leveraged against approximately $1.2 million in state and federal funding to implement conservation projects in the Central Edwards Plateau Rivers, Guadalupe and San Antonio Rivers, and Devils River NFCAs. In 2017, the TPWD designed a new vehicle license plate with artwork that features a Texas river (Figure 10). An annual fee of $30 is paid by Texas drivers to display the plate, with $22 allocated to the CTRI. Nearly 1,000 plates were sold in the initial 12 months that the plate was available for purchase, and efforts to market and raise pub-

Figure 9. Rio Grande at the Terlingua Creek confluence within the Upper Big Bend Native Fish Conservation Area.

Figure 10. Texas rivers-themed vehicle license plate, which is sold to raise funding for habitat restoration, native fish conservation, river access, and conservation demonstration implemented within the Texas Native Fish Conservation Areas Network.

lic awareness of the plate are ongoing. The CTRI continues to address a critical need of providing nonfederal funds to meet the cost-share requirements of grants that support conservation projects within the Texas NFCAs Network.

The National Fish and Wildlife Foundation Southwest Rivers Program was established in 2017 to “fund effective conservation projects that achieve measurable outcomes and fill knowledge gaps where they exist, reinvigorating habitats throughout this unique American landscape” (www.nfwf.org/swrivers). The NFCAs located in the Chihuahuan Desert ecoregion of Texas (i.e., Davis Mountains Streams, Guadalupe Mountains Streams, Pecos River, Devils River, Upper Big Bend, and Lower Big Bend NFCAs) were adopted as focal watersheds in the initial request for proposals of the Southwest Rivers Program. Grants totaling $1,535,755 were subsequently awarded by the National Fish and Wildlife Foundation in 2018 to the TPWD, the TPWF, and Sul Ross State University for restoration of streams, riparian buffers, and grasslands in those six NFCAs. A 10-year business plan is currently being assembled for the Southwest Rivers Program. The NFCAs of the Chihuahuan Desert ecoregion of Texas and the associated freshwater fish SGCN are being considered by the National Fish and Wildlife Foundation as strategic priorities are formalized within the plan.

State Technical Advisory Committees (STACs) serve in an advisory capacity to the Natural Resources Conservation Service (NRCS) and other agencies within the U.S. Department of Agriculture on the implementation of the natural resources conservation provisions of the U.S. Farm Bill legislation. The Texas STAC includes an active Wildlife Sub-Committee that informs consideration of fish and wildlife conservation needs and that recommends geographic (e.g., focal watersheds, species ranges) and thematic priorities (e.g., riparian restoration, instream habitat improvements) for conservation initiatives supported through the U.S. Farm Bill in Texas. Since the statewide Texas NFCAs Network prioritization was completed in 2015, the TPWD has recommended that the Texas STAC adopt the Texas NFCAs Network as geographic priorities for a variety of programs, including the Conservation Stewardship Program, Environmental Quality Incentives Program, and Agricultural Conservation Easement Program. Additionally, the Texas STAC Wildlife Sub-Committee initiated establishment of an ad-hoc working group in 2018 to identify riparian habitat conservation priorities in Texas, and the TPWD has encouraged the working group to consider inclusion of the Texas NFCAs Network within that prioritization.

Also occurring in 2018, the NRCS awarded $5,150,000 through the Regional Conservation Partnership Program for habitat restoration and conservation easements in portions of the Central Edwards Plateau Rivers, Lower Colorado River (Figure 11), and Guadalupe and San Antonio Rivers NFCAs. The NRCS also selected the Lower Colorado River NFCA as a 2018 strategic priority for aquatic species conservation through the Working Lands for Wildlife Program. This is expected to increase funding available for restoration and preservation of instream and riparian habitats, potentially benefiting the 12 freshwater fish SGCN that occur in the Lower Colorado River NFCA (Table 1).

Goal 3: restore instream and floodplain connectivity

Efforts to restore instream connectivity (i.e., longitudinal connectivity) within rivers and streams of the Texas NFCAs Network has primarily centered on the removal of low-head dams and the redesign or removal of culverted stream crossings. In 2014, the TPWD and the Texas Commission on Environmental Quality cooperated on removal of a 1.2-m-tall low-head dam spanning a 55-m-wide reach of the North Fork Guadalupe River (Figures 12 and 13), which is located within the Southern

Figure 11. Lower Colorado River Native Fish Conservation Area.

Edwards Plateau Rivers NFCA. In 2016, the USFWS, the TPWD, and local partners cooperated on the removal of Ottine Dam, a 4-m-tall and 30-m-wide low-head dam on the San Marcos River, located within the Guadalupe and San Antonio Rivers NFCA. Removal of Ottine Dam restored instream connectivity in 63 km of the San Marcos River. Also occurring in 2016, the TPWD cooperated with the USFWS on removal of a 2.4-m-tall and 30-m-wide culverted stream crossing in the Upper Brazos River NFCA on the Double Mountain Fork Brazos River. Removal of the crossing restored instream connectivity for the last remaining populations of Sharpnose Shiner and Smalleye Shiner, two highly migratory, pelagic spawning prairie minnows currently listed as federally endangered. Additionally, the TPWD has consulted on the redesign of several culverted stream crossings planned for renovation in the Central Edwards Plateau Rivers and Southern Edwards Plateau Rivers NFCAs.

To undertake a more proactive, strategic approach to restoration of instream connectivity, the TPWD is currently partnering with the Southeast Aquatic Resources Partnership to complete a barrier inventory and prioritization for a portion of the Southern Edwards Plateau Rivers NFCA. Initiated in 2017, this project is expected to serve as a pilot program for possible expansion of the Southeast Aquatic Connectivity Program into Texas (Graham et al. 2019, this volume). The mission of the program is to restore connectivity, habitat, and ecological functions to streams by identifying and removing dams as well as other barriers to aquatic species passage.

Restoration of floodplain connectivity (i.e., lateral connectivity) in rivers and streams of the Texas NFCAs Network has been primarily limited to the Northeast Texas Rivers NFCA (Smith et al. 2019), where The Nature Conservancy, the U.S. Army Corps of Engineers, the Northeast Texas Municipal

Figure 12. Dam removed from the North Fork Guadalupe River to restore instream connectivity and fish passage.

Figure 13. Active removal of a dam on the North Fork Guadalupe River to restore instream connectivity and fish passage.

Water District, the TPWD, the Caddo Lake Institute, and numerous other local conservation partners cooperated on a flow agreement to restore a more natural flow regime in Big Cypress Bayou downstream of Lake O' the Pines. The flow regime included prescriptions for high-flow pulses and overbank flows intended to reconnect the river to its natural floodplain and benefit floodplain spawning fish SGCN, including Ironcolor Shiner and Taillight Shiner. Instream flow recommendations for high-flow pulses and overbank flows to support longitudinal and lateral connectivity within the Texas NFCAs Network are also expected to result from research described within the summary for Goal 7.

Goal 4: mitigate effects of invasive species

Efforts to address the negative effects of invasive species within the Texas NFCAs Network have focused on identification and implementation of regulatory and permitting measures to mitigate impacts of invasive tilapia *Oreochromis* spp. (McGarrity 2019, this volume) and control of invasive riparian plants that form dense, monotypic stands and degrade riparian habitat quality (Bell 1997; Di Tomaso 1998). Efforts to control invasive riparian plants have primarily focused on management of saltcedar *Tamarix* spp. and river cane *Arundo donax*. These species have been shown to accumulate sediment, narrow stream channels, isolate floodplains, reduce instream flow, degrade water quality, increase erosion, and alter instream habitats (Blackburn et al. 1982; Shafroth et al. 2002; Birken and Cooper 2006; Stromberg et al. 2007; Merritt and Poff 2010; Dean and Schmidt 2011; Dean et al. 2011).

In the Guadalupe and San Antonio Rivers, Central Edwards Plateau Rivers, and Southern Edwards Plateau Rivers NFCAs, the TPWD has partnered with The Nature Conservancy, the Hill Country Alliance, the Texas Department of Transportation, river authorities, local municipalities, and approximately 400 cooperating riparian landowners to implement large-scale management of river cane along 200 km of the Blanco, Guadalupe, Medina, Nueces, and Pedernales rivers and their tributaries. In the Blanco and Pedernales rivers, the scope of these efforts was expanded to include mapping of other invasive plants and restoration plantings to augment passive recolonization by native species. Biological monitoring sites were also established along Barons Creek, a tributary of the Pedernales River, to evaluate effects of control efforts on riparian plant communities, fish and invertebrate communities, water quality and quantity, and channel morphology. Similar efforts to implement large-scale control of river cane and to re-establish native riparian vegetation are being implemented by the National Park Service, World Wildlife Fund, Rio Grande Joint Venture, and TPWD in the Upper Big Bend and Lower Big Bend NFCAs (Garrett et al. 2019).

In the Upper Brazos River NFCA, the TPWD has partnered with the USFWS Partners for Fish and Wildlife Program, Texas A&M AgriLife, Texas Tech University, University of Texas at Austin, and more than 60 riparian landowners to manage 4,209 ha of saltcedar, focusing initial efforts along 286 km of the Double Mountain Fork Brazos River. Aerial surveys of saltcedar were completed throughout the entire Upper Brazos River NFCA, and control efforts were expanded to the Salt Fork Brazos River in 2018, with restoration planting of cottonwood *Salix populus* currently in the planning stages. Research is being conducted in partnership with the University of Texas at Austin Bureau of Economic Geology to evaluate the effects of saltcedar control on water budget, water quality, river channel morphology, and riparian plant communities (Mayes et al. 2019).

In the Central Edwards Plateau Rivers NFCA, the TPWD has partnered with the Texas Tech University Llano River Field Station, the Llano River Watershed Alliance, cooperating landowners, and volunteers to implement management of invasive elephant ear *Colocasia esculenta* along more than 80 km of the Llano River and Gorman Creek. Partners have also implemented management of river cane at the South Llano River State Park. Restoration plantings and changes to stewardship practices implemented at the South Llano River and Colorado Bend state parks will be used to provide demonstration sites for outreach to increase awareness of the negative impacts of invasive riparian plants.

Goal 5: organize and facilitate conservation partnership networks

To plan and coordinate conservation delivery within the Texas NFCAs Network, the TPWD, University of Texas at Austin, and Siglo Group facilitated development of regional conservation partnerships. To initiate the partnerships, local, state, and federal natural resources management agencies, universities, nongovernmental organizations, and other local conservation partners were invited to participate in conservation planning webinars, workshops, and field days. Webinars were used to present an overview of the Texas NFCAs Network prioritization and to invite technical review and input into conservation plans assembled for each of the NFCAs (accessible for download at www.nativefishconservation.org). The conservation plans identify desired outcomes for populations of freshwater fish SGCN and their habitats, with an emphasis on maintenance of watershed processes, restoration of degraded habitats, preservation of intact habitats, and long-term strategies for ensuring that conservation actions are sustainable. Each plan contains a brief description of the NFCA, a checklist of fish species, descriptions of the biology and life history of each fish SGCN, a description of the current and desired biological status of each fish SGCN, and a summary of conservation goals for the NFCA.

Facilitated workshops were subsequently organized with partners to refine the conservation plans. During 2015–2018, workshops were conducted for the Upper Canadian River, Upper Red River, Upper Brazos River, Lower Colorado River, Central Edwards Plateau Rivers, Upper Big Bend, Lower Big Bend, Guadalupe Mountains Streams, Davis Mountains Streams, Pecos River, and Devils River NFCAs (Birdsong et al. 2018). Those workshops were attended by 132 fish and wildlife conservation professionals tasked with identification and prioritization of specific conservation projects that could be conducted to conserve native fishes within the NFCAs (e.g., improved land management practices within associated watersheds, barrier removal, water rights acquisition, flow agreements, and research). Workshop participants identified and prioritized 172 individual conservation projects, which are identified in Figure 14 by location and by the corresponding goal of the Texas NFCAs Network addressed by the project.

Additional webinars and conservation planning workshops are scheduled to occur during 2019–2020 in the Northeast Texas Rivers, Southeast Texas Rivers, Guadalupe and San Antonio Rivers, Central Coast Rivers and Streams, San Gabriel River, Middle Brazos River, Lower Brazos River, Southern Edwards Plateau Rivers, and Lower Rio Grande NFCAs. Detailed outcomes of the conservation planning workshops, including descriptions of the planning process and priority projects, will continue to be made accessible at www.nativefishconservation.org.

Goal 6: establish conservation demonstration areas

Through a partnership among the TPWD, the Texas Council of Fly Fishers International, Keep Texas Beautiful, the Devils River Conservancy, the Llano River Watershed Alliance, the Hill Country Alliance, All Water Guides, the Colorado River Alliance, and other local partners, an extensive list of service-oriented river stewardship projects has been

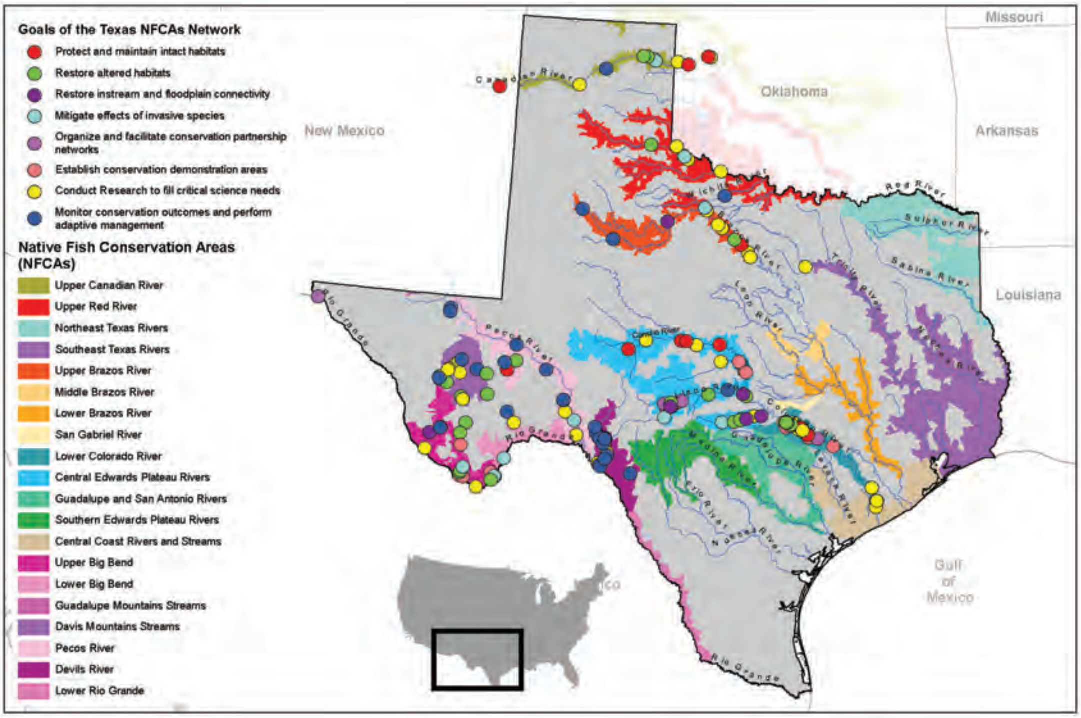

Figure 14. Proposed conservation projects prioritized at conservation planning workshops, with projects identified by location and by the corresponding goal of the Texas Native Fish Conservation Areas Network that would be addressed by each proposed project.

organized and conducted within the Texas NFCAs Network. River stewardship projects have consisted of river-wide trash cleanups, invasive fish and plant removal, planting of native trees and reseeding of erosional banks, establishment of nature trails, installation of educational kiosks, and creation of paddler manuals and other educational resources for river users. Partners have hosted river stewardship workshops for landowners and local communities in order to demonstrate and promote best management practices for conservation of riparian and instream habitats.

River stewardship projects have primarily been conducted in reaches of river where public river access is supported through partnerships with local communities or through lease agreements with willing riparian landowners (Figure 15). The intent of the TPWD-supported river access areas is to facilitate nature-oriented recreation on Texas rivers (e.g., paddling, fishing, and wildlife viewing) and to demonstrate and encourage best practices in the management and conservation of instream and riparian habitats. During 2016–2018, lease payments and habitat improvements were funded through a grant provided by the U.S. Department of Agriculture's Voluntary Public Access and Habitat Incentive Program. Lease agreements between the TPWD and cooperating landowners supported public river access and conservation demonstration at 15 riparian properties within the Texas NFCAs Network. Public river access at these properties provided enhanced paddling and river fishing within approximately 274 km of the NFCAs and served as a catalyst for grassroots involvement in river stewardship activities (Birdsong et al. 2019).

Partnering landowners cooperated with the TPWD and local conservation organizations to assemble resource conservation

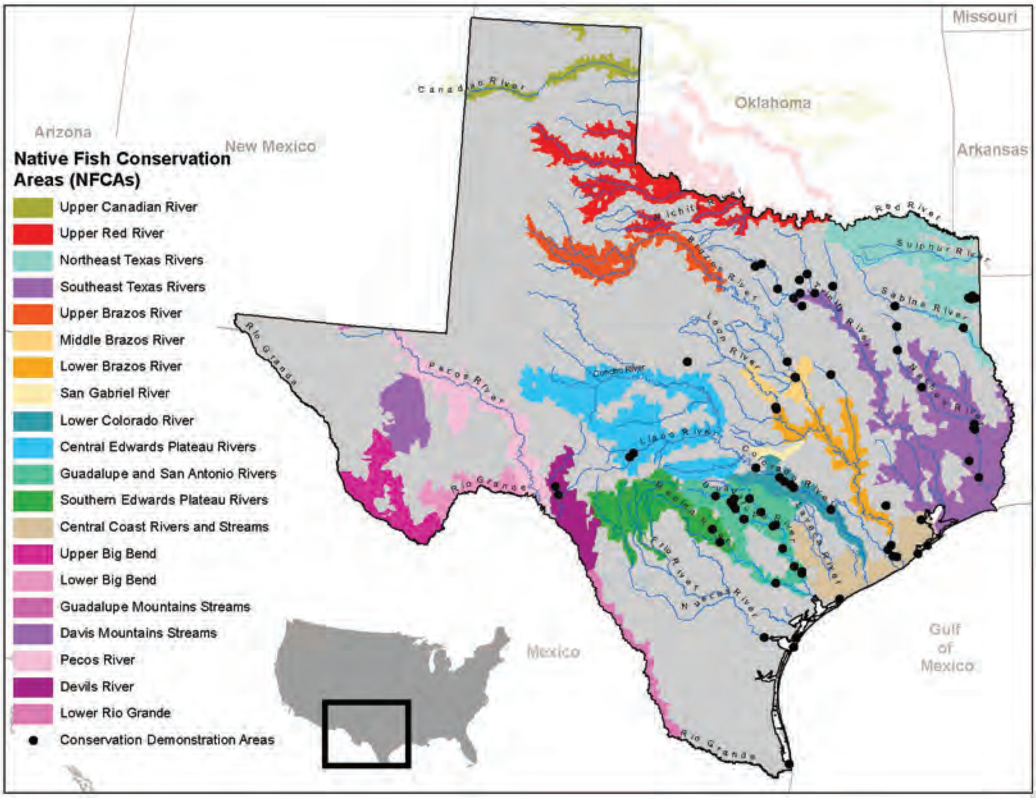

Figure 15. Location of public river access areas utilized by Texas Parks and Wildlife Department as conservation demonstration areas.

plans and deliver habitat improvements and recreational enhancements (e.g., trail maintenance, development of primitive campsites for river users) at the riparian properties. In partnership with Keep Texas Beautiful, a state-based nonprofit organization with numerous local chapters, 19 community outreach and service projects were conducted at the river access areas located within the Lower Colorado River, Guadalupe and San Antonio Rivers, and Southeast Texas Rivers NFCAs. Outreach events promoted river stewardship to 611 attendees. Service projects were supported by 329 volunteers and resulted in removal of 1,411 kg of litter, 280 kg of recyclables, and 675 tires.

In the Central Edwards Plateau Rivers NFCA, the TPWD partnered with the Hill Country Alliance, Llano River Watershed Alliance, and Texas Council of Fly Fishers International to conduct river-wide trash cleanups, install protective exclosures to support recruitment of native riparian seedlings and saplings (decimated by herbivory by nonnative ungulates), and broadcast native riparian seed mix on bare, erosional riverbanks. A series of public "town hall" conversations were also organized in the Central Edwards Plateau Rivers NFCA. These aired on Texas Public Radio and involved a dialogue among the general public, landowners, elected officials, and subject matter experts on river conservation topics such as groundwater management, invasive species management, riparian restoration, conservation easements, and ecosystem services. Partners also produced a 14-min video on the importance of effective riparian management in promoting river resilience; hosted workshops on riparian management, rotational grazing of livestock, and preservation of natural landscapes (through conservation easements); and organized a series of Wild and Scenic Film Festivals that further promoted river conservation through inspirational videos on topics such as protection and restoration of wild lands and waters and biodiversity conservation.

In the Guadalupe and San Antonio Rivers NFCA, a riparian conservation demonstration area was established on the Blanco River in partnership with the Lady Bird Johnson Wildflower Center and cooperating landowners. Stewardship practices implemented at the site included native plant seeding and installation, extensive tree plantings, invasive species control, assimilation of large woody debris into site design, soil compaction remediation for seep restoration, and installation of native turf grasses for access areas. Guided tours of the site began in spring 2018 and are expected to continue, with 50 land managers, to date, having received hands-on instruction in riparian stewardship practices.

In the Devils River NFCA (Figure 16), the TPWD partnered with the Devils River Conservancy to conduct four river-wide trash cleanups, invasive fish removal, and outreach to paddlers and landowners. Outreach included production of a Devils River paddler manual and accompanying video that promotes recreational etiquette and river stewardship practices. Partners also organized two river stewardship workshops that engaged Devils River landowners in demonstration of riparian and land management practices that support healthy rivers.

The Texas Council of Fly Fishers International played an active role in supporting identification of specific reaches of rivers where anglers desired improved access and in establishing and maintaining positive relationships with cooperating landowners of

Figure 16. Devils River Native Fish Conservation Area.

the leasing program. The organization has also distributed 5,000 citrus fruit bags (Figure 17; used for river trash cleanups) to their network of 20 local fly-fishing clubs located throughout the state. The clubs conducted river trash cleanups in conjunction with routine club fishing trips to the access areas.

In 2018, the TPWD was awarded a grant from the USFWS Sport Fish Restoration Recreational Boating Access Grant Program in the amount of $240,000 dollars that will allow for establishment of additional river access and conservation demonstration areas on rivers throughout the state. The grant is expected to support 20 lease agreements with private riparian landowners, opening approximately 322 km of rivers for paddling and kayak fishing. The grant will also add 20 new and maintain 133 existing river access areas supported through partnerships with local communities, providing opportunities for paddling and fishing on 1,081 km of Texas rivers. More than half of those river access areas occur within the Texas NFCAs Network, and through cooperation with local communities, the TPWD intends to utilize these access areas (riparian properties) and the recreationally accessible reaches of river as conservation demonstration areas. In addition to the variety of service-oriented

Figure 17. A youth volunteer holds a mesh bag used to collect trash during a river cleanup on Onion Creek, located within the Lower Colorado River Native Fish Conservation Area.

stewardship projects referenced above, these reaches of river were recently prioritized by the TPWD for management of invasive riparian plants, with an emphasis on management of the problematic species referenced within the summary for Goal 4.

Goal 7: conduct research to fill critical science needs

Since completion of the initial Texas NFCAs Network prioritization in 2013, the TPWD has invested approximately $3 million in State Wildlife Grant funding to fill critical science needs for conservation of freshwater fish SGCN in the Texas NFCAs Network. A primary emphasis of this research has been to quantify flow-ecology relationships for flow-dependent fishes, freshwater mussels, and riparian productivity within highly managed and regulated river reaches (i.e., downstream of reservoirs). This research is ongoing in the Guadalupe and San Antonio Rivers, Middle Brazos River, Lower Brazos River, Lower Colorado River, and Southeast Texas Rivers NFCAs. Results (see TIFP and SARA 2017) are expected to inform strategies for environmental flow restoration and protection (Valente et al. 2019, this volume), adaptive management of environmental flow standards, and related management of river flows and reservoir water levels.

In the Devils River NFCA, similar investments of State Wildlife Grant funding have been made to improve understanding of the relationships among groundwater levels, spring discharge, river flows, and habitat conditions for fish and freshwater mussel SGCN (Robertson et al. 2019, this volume). Potential establishment of a groundwater management district for the portion of the Edwards-Trinity Aquifer that is the source of spring discharge and base flows in the Devils River NFCA has been contemplated by the Texas State Legislature. Meanwhile, the comprehensive science needed to inform such actions has historically been lacking. Over the past 5 years, the TPWD and partners have prioritized investments of State Wildlife Grant funding within the Devils River NFCA to provide the science needed to ensure consideration of the instream flow needs of native fishes and mussels, their habitats, and river recreation in water management decisions for this spring-dominated system.

In the Guadalupe Mountains Streams NFCA, the TPWD partnered with Trout Unlimited, the National Park Service, and the U.S. Geological Survey New Mexico Cooperative Fish and Wildlife Research Unit in 2013–2014 to assess the potential for repatriation of Rio Grande Cutthroat Trout and Rio Grande Chub into McKittrick Creek (Zeigler and Caldwell 2017), a stream that currently hosts a nonnative, introduced population of Rainbow Trout (Garrett and Matlock 1991).

Additional research supported by State Wildlife Grants within the Texas NFCAs Network has centered on filling critical science needs in the life history, distribution, and status of freshwater fish SGCN. This included ongoing research to address the status and distribution of American Eel in the Central Coast Rivers and Streams NFCA and the status of the undescribed Chihuahua Catfish and other regionally endemic fish SGCN in the Central Edwards Plateau Rivers, Southern Edwards Plateau Rivers, Devils River, Pecos River, Davis Mountains Streams, Upper Big Bend, and Lower Big Bend NFCAs.

Priority research needs identified at NFCA conservation planning workshops have also been communicated to other science funding programs. For example, priority research needs identified during the conservation planning workshops held for the Central Edwards Plateau Rivers, Upper Brazos River, Upper Canadian River, and Upper Red River NFCAs during 2015–2016 were presented to the Steering Committee of the Great Plains Landscape Conservation Cooperative in spring 2016. The Great Plains Landscape Conservation Cooperative adopted a subset of those priority research needs for their spring 2016 request for proposals, emphasizing the desire to receive proposals for projects that would examine opportunities for water leases, water rights acquisition, and voluntary incentive-based programs to achieve flow restoration targets within those four NFCAs. One of the projects selected for funding through that request for proposals is described by Valente et al. (2019).

Goal 8: monitor conservation outcomes and perform adaptive management

To fill data gaps and monitor status and trends of fish SGCN within the Texas NFCAs Network, the TPWD and the University of Texas at Austin collaborated on development and implementation of an aquatic gap sampling program. Initiated in 2013 in conjunction with the pilot phase of the Texas NFCAs Network prioritization, the partnership has surveyed 187 locations within the Texas NFCAs Network (Figures 18 and 19). This has resulted in 46,617 museum-vouchered fish specimens and 316 corresponding tissue samples deposited and permanently housed at the University of Texas at Austin Biodiversity Collections. Surveys resulted in the addition of one new species to the state's faunal list (i.e., Bigeye Shiner), additional records of rarely collected fishes (e.g., Pallid Shiner, Cypress Minnow, Emerald Shiner, and Arkansas River Shiner), and records representing range expansions for native (i.e., Least Killifish) and invasive species (i.e., Sheepshead Minnow and Gulf Killifish in the Red River). Surveys have also

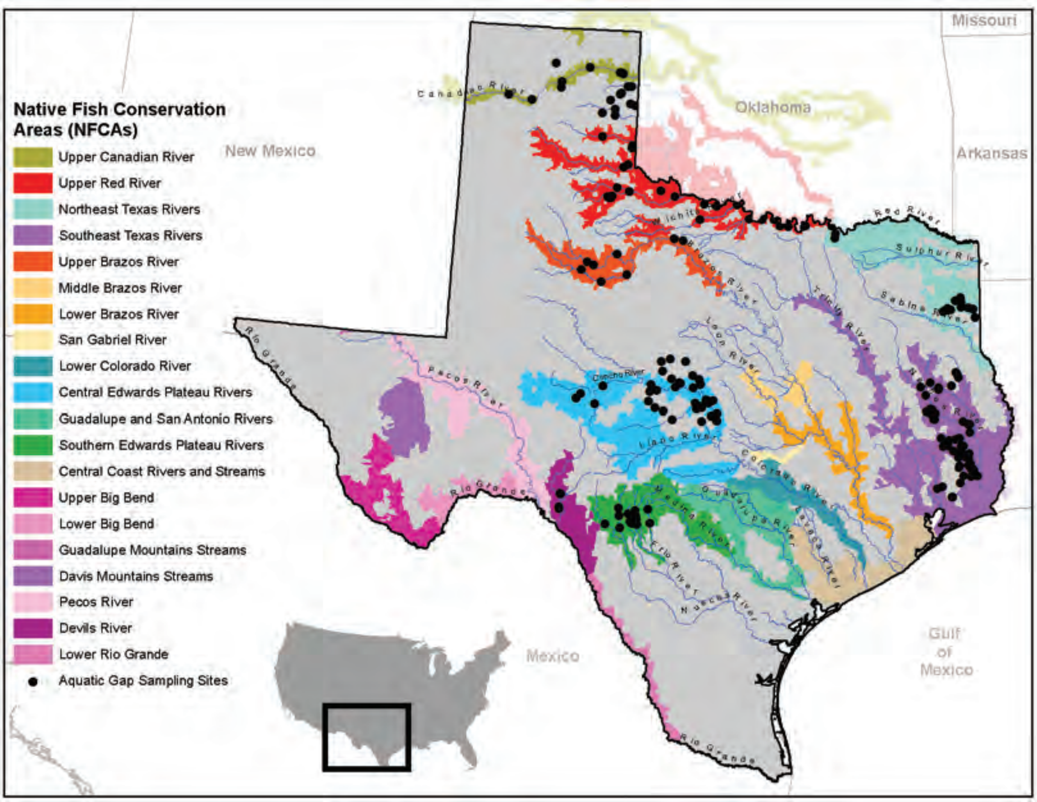

Figure 18. Location of surveys conducted through the joint Texas Parks and Wildlife Department and University of Texas at Austin Aquatic Gap Sampling Program (2013–2018).

Figure 19. Biologists from Texas Parks and Wildlife Department and the University of Texas at Austin conduct surveys within the Upper Canadian River Native Fish Conservation Area.

provided evidence of range reductions (e.g., Suckermouth Minnow, Red River Pupfish, Pallid Shiner, and Emerald Shiner) and possible extirpations (e.g., Flathead Chub) from the state.

Aquatic gap sampling has supported data-driven recommendations to multiple TPWD-managed state parks (i.e., Colorado Bend, Garner, and Village Creek) and wildlife management areas (i.e., Alabama Creek, Alazan Bayou, Gene Howe, and Matador), increasing consideration of native fishes and their habitats in site management plans (Robertson 2015; Robertson et al. 2016, 2017; Cohen et al. 2018). Surveys conducted in the Northeast Texas Rivers NFCA served as the baseline biological assessment for the Cypress Basin Flows Agreement (Robertson et al. 2016; Smith et al. 2019), which was previously referenced under Goal 3. Restoration of the natural flow regime in the Cypress basin is expected to improve instream and riparian habitats, support repatriation of Paddlefish, and benefit conservation of other fish SGCN.

Discussion

The Texas NFCAs Network represents a strategic, science-based approach to planning and delivery of multispecies, watershed approaches to freshwater fish conservation. It has served as the impetus for increased, focused, and sustained investments (e.g., research, monitoring, and habitat restoration and protection) in native fish conservation within priority freshwater systems of the state. Furthermore, it has enhanced communication and fostered collaboration among Texas-based nongovernmental organizations, universities, and state and federal agencies and has facilitated the leveraging of staff, expertise, project funding, and other resources toward delivery of proactive, voluntary conservation projects. These voluntary investments have complemented traditional state-based native fish conservation efforts in Texas, which historically involved reactive, regulatory activities (e.g., state listing as threatened or endangered, permitting of nongame fish collection, permitting of fish stocking in public waters, and permitting of dredging and other instream habitat disturbances) and consultation with other agencies on water management and watershed development projects seeking state or federal permits through requirements of the U.S. Clean Water Act, the U.S. National Environmental Policy Act, or other state and federal laws (e.g., water rights permitting, hydropower relicensing, dam construction, and urban development).

The majority of the technical and financial resources that have supported the conservation activities referenced in this chapter are accessible to fish and wildlife agencies throughout the United States. As such, this chapter offers a case study transferrable to other state fish and wildlife agencies, and that is particularly relevant to those states that, similar to Texas, consist predominately of privately owned lands. This holistic, landscape-scale approach has been adopted in response to the multitude of interrelated natural and anthropogenic stressors affecting native freshwater fishes in Texas, including climate change. As fish and wildlife agencies plan and prepare for current and anticipated effects of climate change, the Texas NFCAs Network offers a case study in engagement of the broader community of conservation practitioners to scale up investments in conservation planning and delivery to enhance the resiliency of freshwater systems. Directly aligned with the goals of the National Fish, Wildlife and Plants Climate Adaptation Strategy (NFWPCAP 2012), efforts to implement the Texas NFCAs Network have emphasized conservation and management of natural landscapes, watershed processes, habitats, species, and ecosystems in a manner that enhances their resiliency and adaptive capacity,

The greatest challenge and opportunity for successful implementation of a statewide network of NFCAs has been the ability to build and sustain grassroots interest, capacity and leadership for river conservation. An important step taken by the TPWD to facilitate grassroots engagement was investment of modest financial support in the operations of local nonprofit organizations, including the Devils River Conservancy, Llano River Watershed Alliance, Hill Country Alliance, and numerous local chapters of the Texas Council of Fly Fishers International and Keep Texas Beautiful. Small capacity grants provided project-based funding to organize and host local outreach events and community service projects, such as riparian stewardship workshops, preparation of seed mix for revegetation projects, tagging of invasive riparian plants at parks and greenspace (for follow up treatment by the TPWD), installation of educational kiosks at river access areas, river trash cleanups, and work days at conservation demonstration areas. In many cases, those projects effectively served as gateway activities that increased stakeholder interest and awareness of broader conservation challenges facing their hometown rivers. River trash cleanups have since given way to grassroots engagement on arguably more significant river conservation issues, such as advocating the need for establishment of more holistic and integrated frameworks for management of aquifer levels, spring discharge, and instream flows, especially for the karst, spring-fed streams that occur in central and west Texas.

An additional lesson learned from implementation of the Texas NFCAs Network was recognition of the importance of building relationships with local thought leaders, early adopters, and trendsetters willing to cooperate on a pilot project. Furthermore, by selecting an initial set of conservation projects that could be completed in a relatively short amount of time, local cooperators were able to quickly demonstrate the feasibility, value, and benefits of the NFCAs approach. The resulting proof of concept was then showcased and promoted to neighboring communities and landowners, supporting expansion throughout the watershed and offering a case study transferable to other NFCAs. Initial successes in delivery of the NFCAs approach in the Central Edwards Plateau Rivers NFCA, notably within the watersheds of the Llano and Pedernales rivers, generated considerable momentum and facilitated rapid expansion into other NFCAs of the state. Although significant conservation challenges remain for Texas freshwater systems, the Texas NFCAs Network offers a holistic and innovative approach that has undeniably increased the scope and scale of efforts to restore and preserve Texas freshwater fish diversity.

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Chapter 5

Priority Threats to SGCN Populations (Element 3)

Threat Types and Definitions

The third required element of state wildlife action plans is: *Element 3: Descriptions of problems which may adversely affect species identified* [as SGCN] *or their habitats, and priority research and survey efforts needed to identify factors which may assist in restoration and improved conservation of these species and habitats.* This element is commonly referred to as "Threats."

Chapter 5 describes conservation threats in fulfillment of that element. The chapter is organized according to the World Conservation Union-Conservation Measures Partnership (IUCN-CMP) classification of threats to biodiversity (Salafsky et al., 2008). According to that format, the Priority Conservation Threats are organized according to the following structure:

1. Residential and Commercial Development
2. Agriculture and Aquaculture
3. Energy Production and Mining
4. Transportation and Service Corridors
5. Biological Resource Use
6. Human Intrusions and Disturbance
7. Natural System Modification
8. Invasive and Other Problematic Species and Genes
9. Pollution
10. Geological Events
11. Climate Change and Severe Weather

The use of a unified language to classify and describe conservation threats can help conservation practitioners communicate more effectively and advance knowledge more efficiently. To see more detail and Texas-relevant examples of the unified language, also referred to as the "common lexicon," refer to **Supplement 5.1.** Although this revision maintains the previous edition's descriptions of threats, the 2013 TCAP had not yet adopted the standard lexicon. Therefore, the *SWAP: Texas* editors compiled the previous edition's conservation threats into the common lexicon and deleted any duplication, when possible, in the 2023 *SWAP: Texas*. Conservation threats within the chapter are numbered based on the structure of the common lexicon (e.g. "Excess energy (9.6)").

SWAP: Texas editors sought to understand stakeholder priorities to ensure this edition highlighted threats perceived as especially impactful and relevant. In 2022, the *SWAP: Texas* review team issued a survey to assess the relative importance of conservation threats, re-classified into the standard lexicon, to stakeholders. Texas residents, established conservation partners, and Texas Parks and Wildlife conservation staff and leadership were the intended respondents of the survey. In that survey, respondents ranked conservation threats, as classified in the common lexicon, in order of perceived impact by our survey respondents (Figure 5.1). Review more of the survey results in **Chapter 8**, **Use of Public Survey to guide 2023 *SWAP: Texas*** Section."

During the development of the *2013 TCAP,* stakeholders identified threats in ecoregion conservation workshops, follow-up surveys, and other conservation planning instruments (Texas Parks and Wildlife Department, 2013). In the 2023 comprehensive revision, threats from each ecoregion were combined with statewide threats, duplicates were eliminated, and language was refined to reflect the specific areas threats were tied to or broadened to include all of Texas.

This list represents the best available knowledge of the time and is intended to be expanded, refined, and prioritized with time.

Conservation Threats

1.0 Residential and Commercial Development

People may think that Texas is full of wide-open spaces — and it is. But it also has some of the country's largest and fastest-growing metropolitan areas. Its growth rate, nearly four percent per year, is ten times that of California. In fact, since 2010, Texas's population has grown by almost 15 percent (U.S. Census Bureau, 2020). The most populous city in Texas is Houston, with 2,304,580 residents. That's the fourth largest city in the nation. Number two is San Antonio, with 1,434,625 people. Dallas is number three, with 1,304,379 residents, though the Dallas-Fort Worth metroplex, one of the fastest growing regions in the country, has an incredible 7,637,387 in its metropolitan statistical area. (U.S. Census Bureau, 2020).

Housing & Urban Areas (1.1)

Threats in this category relate to human settlement or other nonagricultural land uses with a substantial footprint (human cities, towns, and settlements, including non-housing development typically integrated with housing). From 1997 to 2017, Texas lost approximately 2.2M acres of working lands (i.e., converted to non-agricultural uses), with a decline of nearly 1.2M acres converted in the last 5-year period (Lopez et al., 2019). Before urban development, these lands had enhanced wildlife habitat management and restoration potential. Growing human populations with additional infrastructure needs result in development that directly takes habitat and species during construction (loss), degrades adjacent habitat (fragmentation), and may hinder movement (daily or seasonal). Growing human populations' water use and needs, effluent releases, impervious cover and stormwater controls, zoning and planning related to controlling expanded urban land use (aka "sprawl"), and setting aside open space (type, quality, location) all affect natural resources in and around these areas.

Human population growth, urbanization, and shifting demographics affect where conservationists must prioritize actions, how they might deliver conservation messaging, and what partners might be best to help tackle a problem.

Human population growth is a complex issue in the conservation framework. When done without consideration of ecological systems, these changes can negatively impact the health and well-being of fish and wildlife. However, human population growth can have a positive impact. Some population growth or movement into an area might be neutral or even beneficial if that introduction is accompanied by ecologically-aware development and land management.

The Texas State Demographer predicts an increase in the overall Texas population of 38.8% from 2020 to 2030 and maps our population to approaching 47 million people by 2050. (Texas Demographic Center, 2019). Population growth continues in and near urban areas, while more rural areas are experiencing human population losses (U.S. Census Bureau, 2018) (Figure 5.2).

This growth presents both issues and opportunities for conservation in Texas.

The shift of the Texas population from primarily rural to primarily urban is well-known. What is less documented are the actual effects that this shift may have on fish and wildlife conservation. While living in an urban center or a rural countryside will certainly affect perspective and values, conservationists sometimes make assumptions about values and priorities that prove untrue.

For example, conservation professionals have long warned that the urbanization of Texans is reflected in lost connections with nature and wildlife and that urban people are less likely to support conservation initiatives. This is more of a stereotype than science. A 2021 study found that the ability to identify common species was poor among all people, regardless of how urban or rural their existence (Bashan, Colleony, & Schwartz, 2021). A study by the Nicholas Institute for Environmental Policy Solutions (Duke University) in 2020 found that rural Americans value environmental protection about the same as urban/suburban Americans, though there are differences in which specific environmental issues are most important. Rural people voiced strong support for conservation and environmental protection in the abstract, but then raised concerns for the impacts and efficacy of environmental policies. Urban respondents both appreciated and supported environmental issues such as climate change mitigation (Bonnie, Diamond, & Rowe, 2020).

Finally, urban and rural supporters of environmental justice might be strong advocates and partners for conservation, but not if their respective concerns on equitable access and resident health related to environmental health are dismissed or ignored.

Population growth and demographic shifts are opportunities to examine ways that planning, education, and action implementation might better address local communities' needs. The changes that generally happen along with population growth -- housing and commercial development, energy production and power delivery, communication and transportation infrastructure, increased lighting, flood control, floodplain development, landscaping, and uncontrolled development – all contribute to direct habitat loss. Additionally, poor air quality and unregulated air pollution caused by increased transportation and power use in growth areas may exacerbate climate change for the state and the region.

Regional planning doesn't always favor habitat and wildlife needs. Metropolitan Planning Organizations (MPOs); Councils of Governments (COGs); other regional planning authorities for transportation, surface water planning groups, and groundwater districts; city and county governments; legislative bodies; regulators, and others are all plan- and decision-makers who are working in these urban and growing areas. Their planning processes are not synced, nor do they have similar requirements for natural resources considerations in their decision-making processes. Action Plans provide valuable information on species, habitat needs, and vulnerability, which project planners (e.g., transportation authorities, surface and groundwater planning groups, wind, and solar energy developers) can consider early in development stages to identify sensitive habitats and vegetation communities to avoid, ways to minimize the unavoidable impacts, and areas where compensatory mitigation could be most ecologically beneficial.

While information to planners is key to implementation, their constituencies must also consider the connection between what they do daily and the resources their actions affect. These two concepts – community outreach and planning support – are most effective when they work together. It is insufficient to inform the homeowner about alternatives to planting certain exotic species available at their local home improvement nursery if not coupled with outreach, incentives, or regulatory pressure to the landscaping services, nurseries, professional societies, and permitting entities that continue to promote these plants as beneficial options in urban environments. Conservation efforts must reach all relevant and targeted sectors of our population with a clear message about what they can do to help and why they should care.

Zoning current agricultural or ranching lands for future commercial or municipal use removes the opportunity to restore these lands to functional habitats and contributes to their disconnection/fragmentation. However, lack of zoning and planning can contribute to urban "sprawl," which affects how much habitat is directly lost to housing, transportation corridors, and other infrastructure development, as well as indirectly lost, as more miles are traveled in vehicles that negatively impact air quality.

In ecoregions such as the Central Great Plains and Arizona/New Mexico Mountains and Chihuahuan Deserts, local planning efforts are minimal and rarely regional except for federally funded highway and bridge crossing projects; even then, consideration is limited to federally listed species in the constraints analysis. Urban sprawl and little regulation on development type in drier ecoregions like the Arizona/New Mexico Mountains and Chihuahuan Deserts and High Plains contributes to arid land habitat loss of many types (grasslands, shrublands, montane grasslands, lowland grasslands, desert shrublands) with potential to further adversely affect prairie dogs, mountain plover, and other SGCN.

In coastal areas in the Gulf Coast Prairies and Marshes ecoregion, lack of zoning and planning has contributed to residential and commercial development without setbacks from important natural areas, shorelines (contributes to erosion), and dunes. Also, development in marshlands and shallow open water environments encourage bulk-heading and channelization for marinas and loss of natural system function (tidal influence, bottom habitat loss, vegetation loss).

Urbanization also affects water availability and recharge. In ecoregions with greater rainfall, rivers, creeks, and streams in urban areas are typically manipulated or “armored” to convey floodwaters faster, removing important riparian and instream habitats and depleting natural water quality controls. Growing populations’ water needs contribute to the loss and degradation of aquatic, riparian, and upland habitats in areas where new reservoirs are proposed for water supply and water quality issues where wastewater effluent treatment systems are insufficient before release to native waters. Growing metropolitan areas and their outlying emerging communities continue seeking water resources outside their basins: reservoir development, inter-basin transfers, groundwater development, and pipelines. Water costs are related to what customers will pay and not related to the water development impacts. Mitigation for resource loss under reservoirs, groundwater, and estuaries is insufficient, and rates do not replace ecological values.

In arid ecoregions like the Arizona/New Mexico Mountains and Chihuahuan Deserts, outlying and rural areas with water are targeted to supply municipal needs in other basins, depleting water for local wildlife and recreational opportunities.

In the Edwards Plateau, burgeoning development along the IH-35 corridor from Fort Hood to San Antonio has created widespread suburban and suburban/rural communities in former ranchlands within driving distance, mostly east of an arc from San Saba to Uvalde. Many of these communities are on aquifer-sourced water supplies; few have centralized wastewater collection or treatment other than septic systems,

In the Southern Texas Plains, the June 2009 Borderlands/International Affairs Report noted the Lower Rio Grande Valley region is experiencing rapid housing and commercial development (trade and homeland security related, primarily) which is contributing to development in floodplains (loss of riparian woodlands, water quality impacts), drainage district clearing practices for flood water conveyance (loss of all woody vegetation in temporary and permanent waterways), and senescence of resacas (waterway drainage, lack of flooding). In this ecoregion, many sites are being cleared in advance of development.

When large-scale vegetation clearing to bare ground occurs in preparation for lot sales, flooding, inadequate rainwater filtration and recharge, and increased water pollution are generally the result.

The lack of local jurisdiction or authority to protect sensitive environmental features in urban areas presents additional challenges. Throughout Eastern Central Plains, Edwards Plateau, and adjacent ecoregions, urban expansion, sprawl, and suburban development into the outlying counties to escape financially restrictive city jurisdictions and capitalize on more affordable acreage is an ever-growing issue. Development is concentrated in outlying areas where its most scenic often coincides with sensitive features – canyons, cliffs, near lakes, waterways and floodplains, and springs. Karst-filling, stream-armoring, and the lack of stormwater pollution prevention are also issues. Existing urban areas (Kingsville, Corpus Christi, Lubbock, Amarillo, Rio Grande Valley) and small but still considerable communities (Brownwood, Abilene, Fort Davis) are provisioning and launching points for many industrial operations. Many of these areas have large expanses of flat, open space attractive for building, road construction, and “room to breathe,” so high-density development and in-fill are not favored unless economically necessary.

Regional planning authorities like MPOs, COGs, Regional Transportation authorities, and other planning entities that serve emerging and outlying communities are not bound to consider fish and wildlife resources, communities, or habitats as part of their process in development, zoning, and permitting. Counties in Texas have little authority to regulate growth or guide environmental protection during planning processes, and counties rarely have authority to require stormwater pollution prevention, flood control projects, appropriate road development, conservation of non-jurisdictional wetlands, open space planning, or water or other conservation measures from developers. Urban sprawl, bedroom communities, and suburban commuter communities continue contributing to prairie loss, woodland clearing, filling non-jurisdictional wetlands, and degradation of instream and stream-adjacent habitats from water quality and quantity impacts. This is an issue for fish and wildlife resources and prime farmland and ranchland in affected ecoregions.

Permitting thresholds that are in place typically are insufficient to trigger adequate mitigation for most developments, especially those that impact non-jurisdictional wetlands and unregulated habitats like prairies, riparian zones, bottomlands, native shrublands, and mature forests. Authorities who exercise their ability to protect sensitive features, water quality, and open space (including floodplains and riparian areas, mature woodlands and tall grass prairies, jurisdictional and non-jurisdictional wetlands of all kinds, natural floodways) can benefit their local water planning processes, recreation opportunities, future food production and quality of life.

Commercial & Industrial Areas (1.2)
Threats in this category are related to factories and other commercial centers. This category can include manufacturing plants, shopping centers, office parks, military bases, power plants, train and shipyards, and airports, though for purposes of this Plan are generally limited to power plants (Figure 5.3)

Coal-fired power plants (Figure 5.4): Currently (2022), Texas has coal-fired power plant units yielding 18,141.6 megawatts of capacity (U.S. Energy Information Administration, 2023). Participants in 2012 listening sessions identified their primary concern with coal-fired plants is surface and groundwater consumption, though emissions that may contribute to climate change are also a concern. The footprint of power plants and adjacent reservoirs is a direct loss of terrestrial habitats. If the water-cooling pond is a dammed natural waterway, then it contributes to the loss of instream flows for aquatic SGCN and riparian communities; if a cooling pond is a stand-alone feature, water must still be drawn from existing water budgets which currently do not adequately account for fish and wildlife needs. Coal-fired plants are also a source of evaporative loss from the water system via towers and open ponds. The current review of this plan yielded an additional concern about mercury deposition in water and contamination of fish, invertebrates, wading birds, bats, and more species (Becker et al. 2018, Chumchal et al. 2018, Gerstle, Drenner, & Chumchal 2019).

Nuclear power plants (Figure 5.3): In 2022, Texas' two nuclear power plants yielded 5120 megawatts daily capacity (U.S. Energy Information Administration, 2023). Expanding the existing South Texas Nuclear Project has been proposed in the Gulf Coast Prairies and Marshes ecoregion. This expansion would have resulted in changes within the local estuary system, affecting hydrography and freshwater inflows (chemistry, temperature) and threatening pollution through potential releases. In addition to other direct effects, this impact can encourage invasive species with wider water quality tolerances.

Tourism & Recreation Areas (1.3)
Threats in this category are related to tourism and recreation sites with a substantial impact on specific resources. This category can include developments such as ski areas, golf courses, beach resorts, sports fields, county parks, and campgrounds. During the development of previous SWAPs, it was noted in the workshops and surveys that there are few public or private lands managed primarily for fish and wildlife conservation, grassland conservation, and water quality protection. While many public lands are managed for recreation compatible with wildlife and fisheries resources, some improvements could be made to consider wildlife habitat needs and conservation better. For example, trails and recreation facilities can be managed to prevent soil erosion and vegetation loss.

Streamside and arroyo trails, camping areas, and recreation zones need to be routed and designed to prevent erosion-based damage to rare plant communities, instream, and stream-adjacent resources that provide important habitats for SGCN fishes and riparian wildlife and reduce human disturbance in roosting or breeding areas. Erosion and vegetation losses do not recover in some instances, even in a generation, given the arid conditions in some ecoregions.

Off Road Vehicle (ORV) recreation sites exist or have been proposed in several ecoregions. ORV use in streams and on breaks degrades water quality through bank erosion and instability, stream bottom degradation, and direct impact on freshwater mussels, invertebrates, and SGCN fishes. It causes human disturbance in nesting or roosting areas. Increased turbidity and chemical releases (oil, gasoline, mechanical fluids) into systems where fishes dependent on consistent temperature gradients and extremely clear spring-fed waters can be adversely affected.

Listed below are habitat types that are particularly sensitive to ORV disturbance in their respective ecoregions:

- Central Great Plains: stream beds, "breaks"
- Arizona/New Mexico Mountains and Chihuahuan Deserts: dunes on private sites
- Eastern Central Plains: sand hills, wet soils of all types, bottomlands
- Edwards Plateau: stream beds/instream habitats (substrates disrupted or lost), riparian corridors, steep hillsides

Cave and karst recreation can physically damage cave and karst features and contribute to groundwater degradation. These activities can introduce contaminants, and a lack of decontamination protocols could introduce the fungus known as *Pseudogymnoascus destructans* (or Pd) to the karst system with overwintering bats. Once established, the fungus thrives in cold, damp places where spores can attach and begin to grow on bats while in their inactive state of hibernation. Once in contact with the fungus, infected bats develop the disease known as white-nose syndrome (WNS). WNS is responsible for devastating declines of bat populations in North America; additional disturbance of hibernacula or maternity colonies can increase impacts on bat populations.

Unlike farming or ranching lands, *many recreation lands lack active management that prioritizes fish and wildlife populations and habitats.* Recreation lands not primarily managed for conservation are limited in ability/capacity to restore sites or apply management since recreation land managers typically must prioritize urban-wildland interface issues (trespass, feral cats, vandalism) and overspending resources on habitat restoration or management. Additionally, some tools may be limited in their utility. Discomfort or public concern about applying prescribed fire near urban areas and cutting down trees, even if those are nonnative and will be replaced with natives, will reduce habitat quality.

2.0 Agriculture and Aquaculture

Working lands in agricultural production are primarily used for food production, such as row crops, orchards, vineyards, or concentrated animal feeding operations (CAFO). Biofuel, timber, and range livestock production are each categorized separately.

Annual & Perennial Non-Timber Crops (2.1)

One of the main issues in farming and ranching is the fragmentation of land ownership. Smaller, more diversified farms appear to be better for wildlife and fish resources than larger commercial operations. What we do on the land is more important for conservation than the size of the site.

Incentive programs for farming landowners can be incompatible with wildlife conservation goals and may not be sufficiently funded to compete with agricultural incomes.

Inappropriate use of fertilizers, herbicides, fungicides or pesticides, feeding, manure containment/disposal, and lack of stormwater controls adversely affect terrestrial and aquatic natural systems. Runoff from these areas can contribute to impaired water quality, aquatic life impacts, and riparian zone loss.

Unsustainable irrigation practices exacerbate poor surface and groundwater management, depletion, and loss. Loss of natural sites to cultivation and agricultural sites to urban development are both issues.

Small roads and other "rough" access development installed across ephemeral or perennial water sources (e.g., low water crossings, bridges, culverts, driveways) can degrade stream habitats, fish passage and genetic exchange, water quality, and quantity.

Large industrial farm and feedlot operations typically take more land out of habitat potential. However, they can benefit species that rely on ag lands during migration, such as hawks and mountain plovers. Family sites with diverse uses, such as woodlots, recreation, hunting, and heritage, can contribute to habitat values.

Landowner/land management soil and water conservation programs may incentivize inappropriate fencerow/windrow planting, brush removal, and water development. Invasive and non-native grasses are promoted, brush removal may not be appropriately implemented, and water development may include damming natural creeks and springs, drilling groundwater wells, and more.

Incentives for farmland operators to retain wildlife and fisheries habitats frequently do not encourage long-term, permanent, or reliable beneficial actions in "regional conservation accounting" because management and conversion incentives are insufficient overall and not responsive enough to compete with cyclic ag market fluctuations.

CAFOs and croplands without adequate stormwater runoff controls on certain topographies allow excess nutrients and chemicals to run into area waterways.

Herbicide or pesticide overspray from farm management may adversely impact adjacent native habitats and species, particularly amphibians and invertebrates.

Wood and pulp plantations (2.2)
Wood and pulp plantations require careful management to protect hardwoods in the Eastern Central Plains. Small operations should implement best management practices for hardwood harvest, conversion, streamside buffers, and fire management. Mature bottomland hardwoods are rare; even dead snags in this community are important to many regional SGCN. In addition, hardwoods in pine-oak savanna communities diversify forage and roosting habitats. The post-oak savanna/prairie matrix is the primary habitat type in the region and supports many types of rare bogs, seeps, springs, and other wetlands. Bogs are particularly threatened by unsuitable logging practices that can alter these sites' vegetation, temperature, and water quality, leading to the loss of rare plant communities and fauna that rely on them. Commercial timber harvest also threatens Baygalls and forested seeps without adequate protections for streamside buffers and wetlands. Thus, it is crucial to retain sufficient streamside buffers even using current best management practices.

Livestock Farming & Ranching (2.3)
This issue refers to working lands in range-based livestock production – partially or wholly managed for sheep, goats, cattle, and exotic hoofstock forage. Biofuel, timber, row crops, orchards, vineyards, and CAFO production are covered under other categories.

Land ownership fragmentation is an issue in both farming and ranching. Larger contiguous ranches with diverse, well-managed native grazing and browsing forage provide better benefits to wildlife and fish resources. Smaller fragmented sites typically imply more development, diverse goals/intentions, and various levels of management capacity, not all favorable to wild resources. Loss of natural sites to clearing for ranching operations is an issue. Still, conversely, the loss of larger range sites, which can provide wildlife habitat for some SGCN to urban/suburban development, is also a big conservation issue.

Some incentive programs (e.g., reseeding, replanting) and alternative incomes (e.g., mineral development, hunting operations) for ranch/range landowners are, in some areas, incompatible with wildlife conservation goals.

Some incentive programs (e.g., riparian buffers, wildlife habitat development, long-term set-asides, conservation easements) may be insufficiently funded to compete with livestock incomes, may not be advertised enough or structured in a way to be compatible with landowner needs, or conservation practitioners need more training to implement them well.

Poor historic or currently unsustainable grazing or wildlife management practices exacerbate non-native and native invasive species, slow natural vegetation recovery, ability to apply current beneficial land practices, and poor surface and groundwater management.

Small roads and other “rough” access developments installed across ephemeral or perennial water sources (e.g., low water crossings, bridges, culverts, driveways) can degrade stream habitats, fish passage and genetic exchange, water quality, and quantity.

Many large ranches are being subdivided into smaller parcels. Unfortunately, many smaller parcels are not large enough to contribute meaningfully to regional conservation needs or qualify for available incentives for wildlife or fisheries conservation actions. Additionally, there are incompatible stocking practices that involve too many animal units for the native forage to support, which is often dictated by tax structure rather than by agricultural professionals. This results in insufficient or inappropriate recovery or vegetation management on historically overgrazed sites. Another issue is insufficiently managed or unmanaged exotic hoofstock, whether intentionally introduced or not, for hunting and other recreational purposes. There are also unmanaged private and public wildlife resources behind high game fences. The promotion of exotic grasses for livestock forage is another concern. Brush clearing and other vegetation removal on inappropriate or sensitive sites, such as headwaters, canyons, and riparian areas, without regard to slope, aspect, vegetation community potential, and recovery objectives, is another issue that needs to be addressed. Some water resource development is also a problem, such as damming natural waterways, springs, and seeps, pond construction, and stocking in inappropriate sites where altered hydrology and invasive species can be a problem for native species. Finally, fire suppression and lack of site-appropriate, well-planned/managed prescribed fire is a concern.

Marine & Freshwater Aquaculture (2.4)
Oyster shell harvesting: Reef extraction during harvest is not replenished; typically, the “waste” shells are dumped for terrestrial uses rather than repatriated to oyster reef areas to provide habitat.

3.0 Energy Production and Mining

Texas has always been at the forefront of the nation for energy:

- Texas is the leading crude oil-producing State in the Nation (excluding Federal offshore areas, which produce more than any single State).
- The State’s signature type of crude oil, West Texas Intermediate (WTI), remains the major crude oil benchmark in the Americas.
- Texas’s 27 petroleum refineries can process more than 4.7 million barrels of crude oil daily, accounting for over one-fourth of total U.S. refining capacity.
- Approximately three-tenths of total U.S. natural gas production occurs in Texas, making it the Nation’s leading natural gas producer.
- Texas also leads the Nation in wind-powered generation capacity; there are over 2,000 wind turbines in West Texas alone.
- Texas produces and consumes more electricity than any other State, and per capita residential use is significantly higher than the national average.

Oil & Gas Drilling (3.1)
Because these industries are evident in many ecoregions, there are different impacts on different habitats, from desert grasslands to marine and coastal environments. Many habitats do not recover quickly or without intensive, appropriate reclamation.

In addition to direct species and habitat loss and habitat fragmentation, activities may have secondary adverse effects such as invasive species introductions, disruption of daily and seasonal activities for fossorial animals (small mammals, reptiles, ground-foraging and ground-nesting birds), light and noise during night operations which impact daily bat foraging and seasonal bird migrations, mortality from road network traffic, potential and realized impacts to water resources from spills, extraction chemicals, saltwater injection and a lack of knowledge about the drilling material or equipment behaviors in certain substrates, acid deposition from flaring, and resource contamination or mortality from lack of appropriate spill response.

Oil and natural gas industries occur in nearly every ecoregion of Texas – from pad sites and pump jacks to deep drilling rigs and collection sites on land and offshore. Grasslands, shrublands, woodlands, forests, estuaries, and soft and hard bottoms in the bays and Gulf are all potentially affected by direct habitat loss where pad sites, drilling rigs, roads, collection lines, and delivery systems are sited. Seismic exploration can significantly affect wetland, riverine, and karst habitats, and the associated shockwaves can be fatal or cause permanent injury to aquatic species occurring nearby. Linear features associated with this industry, such as those needed for transportation through drilling fields, cut straight-line swaths and are typically unremediated/unrestored with native seed sources after disruption. Natural salt domes are used for natural gas storage, and salt is “washed” out of the deposit to form an open cavern where materials are stored. This uses large quantities of water, resulting in brine leachate, for which disposal is an issue. Activities have secondary effects, too: invasive species introductions in disturbed, unrestored or inappropriately restored areas and roadsides; disruption of daily and seasonal activities for fossorial SGCN; road mortality; and ground and surface water contamination from unreported and unregulated amounts of spills, extraction chemicals (e.g. those used in hydraulic fracturing, or stored improperly on any site), saltwater injection, saltwater or brine releases/discharges, and lack of resource-appropriate and adequate spill response or remediation (e.g. Deepwater Horizon oil spill).

Alternatives to traditional extraction have been developed to increase production. Some alternatives are hydraulic fracturing (fracking), tar sands, and shale extraction. These methods have some of the same impacts as traditional extraction, with additional concerns related to groundwater extraction and a greater likelihood of contamination from new types of chemicals spilled or purposefully released. Groundwater and groundwater expression (springs, seeps, isolated wetlands) dependent species, karst, plant populations and communities, small mammals, and reptiles are particularly vulnerable.

Seismic exploration can incur surface and subsurface impacts such as linear networked vegetation clearing and soil disturbance, vibration and "explosive" disturbance, and habitat loss and fragmentation in arid lands that do not recover quickly. In areas with subsurface irrigation, these areas become prime opportunities for invasive species introductions/colonization, brought in on equipment and through time without adequate or appropriate reclamation. Other impacts include disruption of daily and seasonal activities for fossorial animals (small mammals, reptiles, ground-foraging, and ground-nesting birds) and potential collapse of karst features, many of which harbor SGCN.

Fish kills associated with seismic operations, which utilize high-velocity source charges, have been well documented. Other aquatic and water-dependent species, such as diving ducks and wading birds, may also be affected. Detonated charges that do not kill fish will cause stress, causing stressed fish to seek refuge and not feed, further reducing their viability. Seismic activities also impact foraging, nesting, spawning, rearing, and resting sites for aquatic and terrestrial species and increase the risk of secondary bacterial or viral infections.

Mining & Quarrying (3.2)

Mining is the extractive use of naturally occurring materials for building, road bases, commercial and industrial uses, power production, and other uses. Mining in this context does not include oil and gas. The most commonly listed primary commodities in Texas mines are copper, uranium, and silver. When these mines were surveyed, 321 mines in Texas were observed to have ore mineralization in an outcrop, shallow pit, or isolated drill hole—known as an occurrence mine. Two hundred ninety-two mines were produced when the data was entered into USGS records (United States Geological Survey, 2023).

Aside from the direct removal of some substrates important to species and habitat health (riparian cover, gravel in and adjacent to streams, coastal sands, and oyster beds), mining may include impacts to surface and groundwater resources' quality (lack of stormwater controls, substrate disturbance increases turbidity, wastewater, and other chemical discharge or spills) and amounts/flow (unregulated uses, diversions and dewatering for direct use in mining operations). Equipment may also create spill hazards.

Reclamation is insufficient to recover area to pre-mining habitat quality and usefulness for species; impacts include invasive species, soil horizon disturbance causing change in soil chemistry, and water loss.

Mining in Texas known to impact habitat directly includes the following products:

Sand and Gravel - sand and gravel mining along and within streams and rivers causes loss of riparian habitats for instream and adjacent mining. Sedimentation in streams contributes to the loss and degradation of high-quality instream habitats. Reclamation is not required, and mining off watercourses does not go through a TPWD review for potential natural resource impacts. Not all are required to have stormwater pollution prevention facilities or plans.

Although new TCEQ rules now require water quality permitting for stream and river adjacent mining, none of the sand and gravel permitting review processes require a site assessment to avoid or mitigate impacts to habitats, of which this plan prioritizes riparian, sand hills, wetlands, and uplands.

Caliche mining can be large or small scale. Because reclamation is often not required, surface communities are lost completely and permanently. Several SGCN plants and plant communities are affected by caliche mining.

Renewable Energy (3.3)

Renewable energy in the *SWAP: Texas* includes exploring, developing, and producing renewable energy, such as solar and wind farms. Specific project-types relevant to Texas include:

- Land-based and Offshore Wind: turbine siting in migratory bird corridors can cause direct mortality; operations near bird and bat flight and feeding can cause barotrauma; vibrations and increased activity levels impact fisheries or displace rare species in ocean settings.

- Wind: turbine "farms"; Competitive Renewable Energy Zones (CREZ) targeting certain areas with high wind potential in the High Plains, west and central Texas; wind development has expanded from traditional sites to other areas of the state (e.g., East Texas) as well as those areas considered particularly sensitive to this development type and developers once avoided that; offshore wind energy leases in the Gulf of Mexico.
- Solar or PV array: large areas of vegetation removal and ongoing "bare ground" maintenance, some with high water use.
- Hydropower: altered water quality and hydrology affecting instream and riparian habitats; barriers to aquatic species passage and dispersal.
- Biofuels/Biomass Crops: conversion of diverse native habitats to expansive monotypic stands, some with copious water usage.
- Biofuels: certain row crops, switchgrass, other herbaceous monocultures, "whole tree" utilization, algae.
- Power Generation in Texas does not include tidal or wave generation, as this power type has not been an issue in the Gulf of Mexico.

Wind generation in Texas was jumpstarted in 2005, with the state goal to meet power demands with 10,000 MW (megawatts) by 2025 from this source (we've already exceeded that goal) and the determination of the Competitive Renewable Energy Zones (CREZ) in north, central and west Texas (Figure 5.7, polygons are CREZ; red lines represent new transmission). High wind potential in these areas makes Texas a prime location for this alternative to coal-fired traditional power generation. The Public Utilities Commission has not designated CREZ in other parts of the state; however, additional developments outside these "hotspots" occur in north, central, west, and coastal Texas.

The wind resource map (Figure 5.8) shows the predicted mean annual wind speeds at an 80-m height, presented at a spatial resolution of about 2 kilometers that is interpolated to a finer scale for display. Areas with an annual average wind speed of around 6.5 meters per second and greater at 80 m height are generally considered to have a resource suitable for wind development. Utility-scale, land-based wind turbines are typically installed between 80- and 100 m high, although tower heights for new installations are increasing—up to 140 m—to gain access to better wind resources higher aloft.

Wind generation facility (towers, roads, auxiliary structures) siting is not regulated in Texas unless there is a nexus with a federally regulated resource, such as the impact on a jurisdictional wetland that can't be addressed through the US Army Corps of Engineers Nationwide permit process, or an endangered species impact which requires consultation with the USFWS under the Endangered Species Act. More than 7,000 towers have been constructed in Texas. Current science shows that operating wind turbines can cause direct wildlife mortality through impact and barotrauma, affecting bats, crepuscular and night-feeding birds, migratory birds, and birds congregating in updraft areas (hawks, vultures). The location of the wind farms also has proven to be an issue for species such as prairie chickens since they do not tolerate tall structures in or within miles of their habitats. Tall structures potentially represent perches for predatory hawks. Rare species whose habitats are fragmented by tower and road siting are also impacted (Black-capped Vireo, Golden-cheeked Warbler, Tobush fishhook cactus, and others). Along the Gulf coast, wind farms are a particular concern in and near migratory bird corridors – neotropical migrants, migratory and overwintering water and shorebirds, and whooping cranes – and setting the towers offshore and in coastal marsh areas can cause loss of soft and hard bottom benthic and seagrass habitats.

Solar is an abundant energy source in Texas, and it is an alternative to coal-fired and other petroleum-based fuels in many applications. Some advocates have said that local solar may be the best option to reduce our power generation and transmission footprint; however, large solar arrays away from load centers still require much land, water, and transmission lines to produce and deliver that power source. This type of power installation is also unregulated in Texas. It will impact large tracts of land through direct habitat loss, large swaths of fragmented habitats, and another significant water use source for which current stakeholder planning groups need to account. Small isolated desert and prairie plant populations, rare plant communities, reptiles, and small mammals may be disproportionately affected. There is a research need to understand the potential effects on wildlife and habitat from solar energy production. Most of the environmental impact analyses to date focus on the recyclability/toxicity of the components. Beyond the initial disturbance, the operational effects increase the heat on the ground surface and immediately above the panels. The additional heat at the ground surface and shading effects of the panels hinder most vegetation regrowth; maintenance activities remove the rest. The additional heat immediately above the panels may adversely affect low-flying species.

Biofuels, primarily ethanol and biodiesel, are an emerging issue to study regarding their potential impact on Texas habitats. Examples of biofuel production fields include row crops and other herbaceous monocultures like switchgrass, whole tree utilization in timber production areas, and algae farms. One primary concern is that lands that are productive for conservation, such as large acreages of grasslands and conservation reserve program grasslands, rangeland, and pasturelands, also have the potential to be converted to row crops for ethanol production. In 2023, the U.S. Energy Information Administration reported that four biofuel processing plants produced 174 million gallons/year of biodiesel and approximately 2% of the nation's overall ethanol production (Table 5.1). Plants are in Houston, El Pason, Liverpool, and Cleburn. Although biofuel production is an industrial operation, it is typically implemented and regulated as an agricultural one: monoculture, unregulated water use, herbicide and pesticide application, fertilizer, complete clearing after harvest, and few if any stormwater controls – impacting natural resources like other intensive commercial traditional farm operations. Because these are agricultural operations, no consultation is required for locating, clearing, filling, or planting. There are currently few conservation delivery programs or other agricultural operations incentives that can compete with the economic benefit of biofuel production.

Renewable Energy category	Production	Share of U.S.	Period
Utility-Scale Hydroelectric Net Electricity Generation	23 thousand MWh	0.1%	Jun-23
Utility-Scale Solar, Wind, and Geothermal Net Electricity Generation	11,876 thousand MWh	25.7%	Jun-23
Utility-Scale Biomass Net Electricity Generation	115 thousand MWh	2.9%	Jun-23

Small-Scale Solar Photovoltaic Generation	427 thousand MWh	5.7%	Jun-23
Fuel Ethanol Production	6,974 thousand barrels	2.0%	2021

Table 5.1 BioFuel production in Texas. Source: U.S. Energy Information Administration (2023).

4.0 Transportation and Service Corridors

Transportation and Service Corridors include threats from long, narrow transport corridors and the vehicles that use them, including associated wildlife mortality. Transportation infrastructure serves an ever-growing demand to convey goods and services to urban centers, commercial points of trade, and all sites in between. Transportation planning, design, and mitigation are necessary to avoid the habitat degradation that new and expanded infrastructure can inflict. Without it, transportation routes can increase invasive species, stormwater runoff, and water quality degradation, leading to habitat loss, fragmentation, and disruption of daily and seasonal wildlife movements.

Roads & Railroads (4.1)

Road and bridge construction (new and facility repairs)- Primarily related to riparian corridor effects - Bridge/culvert construction without consideration for stream gradient, downstream scour, and passage for seasonal and daily movements. Soils in this region are highly erodible, riverbanks are steep and deeply incised in many areas, and riparian habitats are immensely important for erosion control to protect water quality for freshwater mussels and as breeding habitat for resident birds and cover/stopovers for Central Flyway migrants through this area. Road and bridge construction does little to protect intact, native riparian zones, and frequently, no remediation is done following construction to match previous conditions or prevent the colonization of invasive plant species.

Texas Department of Transportation coordinates with TPWD regarding potential natural resource impacts to listed species; however, there is little accommodation for sensitive habitats unless those features are federally protected (federally listed species habitat, critical habitat, jurisdictional wetlands). State-listed species habitats, SGCN, rare communities, and the habitats they rely on would benefit protection during the planning process to the same level as federally listed species (avoidance, minimization, mitigation/compensation). The transportation improvements proposed under regional (e.g., I-69) upgrades of existing facilities and new construction may create barriers to fish and wildlife resources' daily and seasonal movements, vectors, and opportunities for nonnative species invasions, water quality impacts through stormwater runoff, loss of non-jurisdictional wetlands, and important riparian, grassland and savanna habitats that are not protected under regulation. In addition to any planned larger facilities, local connection transportation projects may contribute to the same kinds of losses and require even less coordination regarding environmental impacts from planning to implementation if no federal money is used.

Mitigating mature hardwoods and wetlands is typically insufficient to address ecological functional losses. Remediation efforts following construction can use non-native grasses, which contribute to prairie loss and degradation.

Right-of-way maintenance- maintaining clear right-of-way for vehicle clearance/access, minimizing fire danger, and maintaining driver visibility - mowing, trimming (permanent fragmentation, erosion). Most roadsides are reseeded after construction with nonnative species or plant materials, and regular maintenance activities also provide additional ground disturbance favorable to invasives. Herbicide application runoff can adversely affect sensitive aquatic features and aquifer conduits that harbor SGCN.

Some rare plants are known only from sites in ROW; these are not always adequately protected as staff changes occur, management plans are filed away, and information is not passed through the entire chain of command - needs better communication in some places. Adjacent landowners are allowed to clear within TXDOT right of way, which can adversely impact any conservation measures the agency has put in place in ROW.

The season and frequency of mowing can affect the natural regeneration of grassland plant species. Key habitat elements such as grassland structure and seedheads can be eliminated at the times of year most critical to animal and insect needs. Performing these activities during bird breeding seasons or migratory events adversely impacts species' success. Oak trimming can contribute to oak wilt and oak decline. “Brushhogging” borders leaves splintered, jagged cuts and adjacent vegetation communities vulnerable to disease and infestations such as oak wilt, oak decline, and Red Bay disease.

Utility & Service Lines (4.2)
Substations can present large-acreage footprints of impervious cover that can collect water and attract small birds, mammals, reptiles, and amphibians to potential electrocution hazards.

Even when the power generation facility is sited with careful consideration of impacts to listed species, the transmission and distribution line corridors are necessary to get the power from the generation site to the load center – places where people put power to use at home, and work. New lines and upgrades to existing transmission and distribution towers, lines, and road networks from many generation sources and substations are required to serve Texas’ growing population. Long, linear clearings cross-country, primarily through undeveloped areas. This fragments large blocks of habitat and creates edge opportunities for parasites and predators, habitat loss, and invasive species opportunities related to ongoing maintenance. Transmission and distribution line development through areas of karst, aquatic, or undeveloped habitat blocks causes habitat loss and fragmentation. Natural resources are not considered a primary constraint to routing or development.

Communication Infrastructure: Most communications infrastructure impacts are minimal and go through some environmental review for impacts to species; however, line installation typically follows road right-of-way, and these areas may not receive full coordination since they are assumed to be impacted already. The industry is not required to reclaim construction sites with native vegetation or back to pre-construction conditions, contributing to invasive species and direct habitat loss. Towers can cause bird mortality and confusion during migration.

Examples: Radio masts, antennas/aerials, telecommunications towers (cell, television, other), Distribution lines, fiber optic, cable – above and below ground.

Shipping Lanes (4.3)
Navigation channels (e.g., Sabine-Neches or the Gulf Intracoastal Water Way) to transport large and more frequent shipping vessels exacerbate habitat fragmentation, degrade coastal water quality, and contribute to coastal erosion and subsidence.

5.0 Biological Resource Use

Hunting & Collecting Terrestrial Animals (5.1)

Predator control without biological standards or supporting management - Several carnivore species (e.g., coyote, bobcat, mountain lion) are routinely trapped, hunted, and killed in these regions. It is unknown whether predator control activities affect the stability of SGCN populations or their contribution to natural system function. Predator control efforts cannot be declared "insufficiently regulated" or "underreported" as limited information is available to assess the stability of these populations. Community-based solutions must be devised based on full and accurate accounting of these populations and their effects on the natural systems and ranching communities in which they range. They are important contributors to these ecosystems.

Predator trapping and baiting hurts non-target species, including state-threatened black bears and smaller SCGN mammals such as ocelot, eastern spotted skunk, and swift fox.

Gathering Terrestrial Plants (5.2)

Cacti are among the most threatened taxonomic groups, with 31% of 1,478 evaluated species listed as threatened. Over-collection is one of the primary drivers of population loss (Goettsch, Hilton-Taylor, & Cruz-Piñón, 2015).

Logging & Wood Harvesting (5.3)

Many timber operations replace native species and age-diverse stands with monotypic single-aged stands, which provide lower quality or unsuitable habitats for some wildlife species. Short-term fast-growth timber is often used in replanting to produce pulp and other processed wood products at the expense of the potential in slower-growth natural timber-producing systems (e.g., shortleaf and longleaf pine savanna). In addition, bottomland hardwood habitats are sometimes completely removed and replaced with commercial timber and other agriculture operations.

Inconsistent application of existing or incompatible/inadequate voluntary Forestry Best Management Practices (BMPs) contributes to the degradation of terrestrial and aquatic natural resources in and adjacent to such timber production areas. Recent changes in timber company ownership have sometimes shifted stewardship goals and opportunities, natural resources investment potential, and fragmented remaining stands. Timber managed on public lands and private lands can be managed to accommodate many terrestrial and aquatic wildlife needs while still being profitable.

Examples: Voluntary BMP application on approximately 92% of Texas' estimated 12 million acres of timberland (Texas Forest Service 2008), primarily on individual/family forest lands, TIMOs (timber investment management organizations), and REITs (real estate investment trusts)

Instream salvage of cypress, oak, and elm trees in the Edwards Plateau region can negatively impact the ecological health of streams. Removing naturally occurring large woody debris can disrupt the habitat of several species, including turtles, frogs, fishes, and invertebrates. Large mature woody debris is a natural feature of many of these areas. It plays a significant role in stream rehabilitation by reducing scouring from flash flood events, providing cover for smaller species to escape predation, and contributing to the overall health of the riparian ecosystem. Woody debris removal disturbs important substrates, leading to detrimental turbidity, bank loss, and riparian damage.

Fishing & Harvesting Aquatic Resources (5.4)
Using non-targeted means of take or harvest can affect an entire system's worth of species and may adversely affect future habitat suitability in that area.

6.0 Human Intrusions and Disturbance

Threat category 6.0, **Human Intrusions and Disturbance**, relates to threats from human activities that alter, destroy, and disturb habitats and species associated with nonconsumptive uses of biological resources.

Recreational Activities (6.1)
The management of recreational areas is not always done with explicit conservation objectives or with the necessary planning to contribute to conservation goals. A lack of long-term conservation planning or collaboration among land managers may prevent these sites from reaching their full conservation potential. Additionally, natural areas near housing developments may have unique challenges, such as feral animals, fear of prescribed fires, and differing perceptions between "protection" and "management" approaches. Managers in one ecoregion or area may not know all the conservation or recreation lands available (including privately held sites). They could benefit from pooling their expertise, interests, and resources. Information about appropriate management practices specific to each site and its resources may not be readily available or affordable to all public and private open-space managers.

Recreational activities can harm the environment, especially when done in sensitive areas. Driving in spring-fed substrates, horseback riding, mountain biking near aquatic resources or erodible slopes, fishing close to nesting areas, and disturbing rookeries and bat maternity colonies can all cause harm. Direct disturbance or harassment of wildlife or fish resources can also affect their breeding, feeding, or sheltering abilities. Approaching wildlife too closely in breeding or resting areas can leave eggs or young vulnerable to predators. Exploration of caves and karst features, unintentional wildlife feeding, or feeding with improper feeds can cause illness and malnutrition and increase human-wildlife conflict.

6.2 War, Civil Unrest & Military Exercises
No war, civil unrest, or military exercise threats were noted.

6.3 Work & Other Activities
Border infrastructure such as the fence, roadways, levees, grading, and night operations cause habitat loss, create barriers to animal movement, and accelerate soil loss and water degradation. These structures fragment plant populations and habitats and increase the risk of depredation and direct roadway mortality. These activities threaten several endemic and rare species.

7.0 Natural System Modification

Fire and Fire Suppression (7.1)
Wildfire has historically been a natural community modifier that typically occurs in the summer months. However, due to fear of the potential risk to human life, livestock, and structures, wildfire is usually suppressed, especially in populated areas. However, carefully controlled prescribed fire can be used as a highly effective conservation tool that mimics the effects of wildfire and restores natural communities without causing catastrophic damage to humans or livestock.

However, managing with prescribed fire can be challenging. Public lands managed for natural resource conservation may not have enough land available for management, or proximity to concerned landowners may pose a problem, especially in the urban-wildland interface. Additionally, limited resources for outreach and suspension of recreation services during peak burning periods can create a public perception problem.

Some areas cannot apply prescribed fire adequately due to insufficient staff or training. Landowners may also be unfamiliar with the potential to use prescribed fire for brush control or grassland improvement. Regional conservation service providers do not have enough prescribed fire-certified leaders and teams to provide this as a landowner incentive service, even if the demand could be increased.

In the Edwards Plateau, managing wildfires is crucial, and more prescribed burning is needed to reduce the risk of wildfires. While prescribed fire can mimic the effects of wildfire, the timing, seasonality, and periodicity must be considered carefully to mimic natural occurrences. For example, prescribed fire in the fall or winter, when it can be more easily controlled, may be more beneficial than in the summer. Otherwise, vegetation communities and habitats may shift to favor other assemblages, such as more shrub mosaics or different grasses.

Dams & Water Management/Use (7.2)
The category of **Dams and Water Management and Use** describes the impact of activities that alter the natural flow patterns of water bodies. These changes can occur intentionally or as a result of various activities such as dam construction, sediment control, wetland filling for mosquito control, and surface water diversion. Texas faces several water management challenges, including interbasin transfers, desalination and chloride removal operations, treatment wetlands, water conservation measures and outreach, subsidized use, and cost structures for water customers.

Reservoirs are constructed throughout the state, serving our populations with drinking water supplies, recreational opportunities, and flood control. However, the construction of dams has led to the decline of forested river and creek floodplain vegetation from an estimated 16 million acres to 6 million acres. The 2007 State Water Plan has proposed building sixteen major dams (Figure 5.9) and hundreds of miles of water conveyance pipelines to meet the growing needs of urban areas.

While reservoirs are often beneficial for recreational activities and property values, they can harm many aquatic and riparian species of concern (SGCN), communities, and their habitats. Both surface and groundwater resources support SGCN and important habitats in Texas, from springs to riparian zones to bays and estuaries. However, there are few clear conservation frameworks for these water resources apart from sole-source drinking water aquifers and jurisdictional wetlands. Even the regulation and compliance of these two categories have limitations that potentially affect them and the SGCN that rely on them. From planning and policy to construction and operations of water management, there are many challenges in ensuring comprehensive and inclusive consideration of natural resource needs while meeting the needs of a growing human population.

Planning and Policy
Water availability for human, fish, and wildlife interests has been a top priority for Texas for decades. In 1997, Senate Bill 1 provided a regional framework for planning and developing the state's water resources. However, Senate Bill 2 (SB2) in 2001 propelled Texas to take decisive action on the issue of water availability. SB2 directed state agencies to establish an Instream Flow program, creating the Texas Instream Flow Program (TIFP). In 2007, Senate Bill 3 authorized the development of environmental flow standards for the entire state.

Instream flows are critical in protecting water quality under low flow conditions, maintaining physical habitat features, and preserving channel dimension and floodplain features during overbanking events. The Texas Parks and Wildlife Department works with two other state agencies, namely the Texas Water Development Board and the Texas Commission on Environmental Quality, to ensure water quality control at different levels. This collaboration also involves permitting water extraction and regional stakeholder-based planning that determines the minimum amount of water needed in streams to support the needs of fish and wildlife.

Texas water law is intricate and frequently in the news, and it's essential to consider it when developing fish and wildlife conservation approaches. Surface water use planning in Texas is accomplished through 16 Regional Water Planning Groups authorized under Senate Bill 1.

The conservation of Texas's water resources is of utmost importance, and the state has taken significant steps to ensure that water is available for all interests. Through its instream flow program and environmental flow standards, Texas is working towards improving water quality, preserving habitats, and ensuring that our water resources are protected for future generations.

Construction of dams and other water management structures

Dams are often built on ecologically important waterways, such as the Neches River, with inadequate consideration of natural resource priorities. The construction and operation of dams, reservoirs, and human development around these sites can contribute to other natural resource management issues, such as effluent releases, feral animals, and direct habitat loss through building or inundation. Mitigation efforts are often insufficient, and the impact on water quality and quantity in the reservoir can be significant, especially when bottomland hardwoods cannot easily or economically be replaced.

In the Eastern Central Plains and Edwards Plateau regions, there are plans to create new reservoirs or expand existing ones (Figure 5.9). However, the site selection process does not usually consider ecologically significant areas, such as high-quality streams and riparian zones (some of which are ancient forests), which are important to instream aquatic and stream-adjacent habitats for Species of Greatest Conservation Need (SGCN). These areas contribute high-quality water to the reservoirs and downstream segments and support rare communities. Reservoir construction and operation can create a barrier to SGCN movement and completely inundate important and irreplaceable riparian zones, spring systems, and downstream habitats.

Groundwater withdrawals and surface water diversions for agriculture and municipalities are another issue, as they deplete the water available for wildlife. Planning efforts do not always consider the connection between surface water and groundwater sources. As a result, surface water and groundwater use have reduced the amount of water in rivers, creeks, and springs in the Arizona/New Mexico Mountains and Chihuahuan Deserts regions, including the Rio Conchos in the US and Mexico.

Operations

The timing, periodicity, and intensity of water releases in the Central Great Plains, Arizona/New Mexico Mountains and Chihuahuan Deserts, Eastern Central Plains, and Edwards Plateau are unnaturally intense and short-lived, occurring in the "wrong" season to mimic natural flooding processes. This leads to changes in water chemistry and sediment load in all downstream areas, including the estuaries. Unnatural hydrograph scours instream and stream-adjacent habitats shifts vegetation communities out of sync with other riparian communities, and causes vegetation communities and instream animals such as invertebrates and fish to be unable to rely on the seasonal changes under which they evolved.

Reservoir construction, often followed by development, poses potential hazards for upland, riparian, and instream fish and wildlife. Housing developments remove habitat, and lake edges are typically cleared of native vegetation for recreational access and views, leading to increased erosion and sedimentation. Unregulated on-site wastewater facilities can cause elevated bacteria levels and toxic leaching events. Invasive plant and animal species typically follow reservoir construction through equipment transfers and colonization of disturbed areas. Increased recreational boat use can bring in exotic aquatic plants or animals from other “infected” water bodies. In contrast, landscaping with non-native plants can attract feral cats and dogs, which become introduced predators.

Reservoir development has the most significant impact in East Texas, where it impacts bottomland hardwood forest species, associated upland hardwoods, large contiguous forest corridors for wide-ranging species such as black bears, carbon sequestration, the forestry industry, and terrestrial recreational activities. The proposed Laredo Weir will impact the recently discovered population of Texas hornshells in the Rio Grande. The TPWD Borderlands program has worked with partners and identified a lack of natural flooding cycles to resaca senescence and loss of high-priority riparian woodlands such as Texas ebony, anacua/brasil forest, Texas sabal palm forest, and Texas ebony/snake-eyes shrubland. A few exceptions to the negative effects of reservoirs on fish and wildlife resources may be those aquatic SGCN or diving birds that rely on deeper water habitats created throughout the lake-influenced system.

Damming a free-flowing or periodically flooded river or creek, from low water crossings to major hydroelectric projects, causes instream habitat and riparian loss through inundation. The structure and the impoundment behind it fragment the connectivity of riparian areas and flowing habitats. Structures are barriers to natural amounts and periods of water flow, sediment, and nutrient movement important for downstream systems to estuaries. Also, seasonal or daily movements of instream species for breeding, spawning congregations or individuals, or young dispersal to colonize other stream stretches. The pooled water behind these structures changes the waterway's temperature, chemistry, and turbidity, to which many species cannot adjust.

Dam releases are frequently for human needs such as electrical generation, irrigation periods, and contractual drinking water allocations downstream for surface water extraction. Releases are rarely in sync with the natural flood, flow period, or intensity, which can scour downstream habitats. The altered chemistry and turbidity of the released water can create unsuitable conditions for fishes and aquatic invertebrates. Some riparian plant communities are flood-dependent in appropriate seasons to trigger seed release and deposition. Floodwaters cue some fishes in appropriate seasons to migrate to congregation and breeding areas.

Texas has 1051 documented impaired waters due to pollution, according to the Texas Commission on Environmental Quality (TCEQ) in their 2022 Report of Surface Water Quality for Clean Water Act. To regulate the maximum amount of pollutant that a waterbody can receive and still meet water quality standards for its use, Total Maximum Daily Load (TMDL) calculations are performed on some of these waters. An allocation of that load among the various sources of that pollutant is also identified. Although TMDL calculations can be helpful, current practices do not consider all potential downstream estuarine effects.

Fish and wildlife resources and their habitats are impacted by water quality, which is typically associated with water quantity (amount of instream flow) and the discharges to the stream. Such discharges may introduce pollutants that decrease oxygen availability, add toxins, or overload the system with unhealthy levels of sediments. Even a "minor" episodic spill or toxin release can cause major adverse effects if the stream has too little flow. This issue is an international concern, and the TPWD Borderland Affairs liaison has identified water quality as an opportunity to work together on water quality issues with biologists and policy representatives in Mexico for the stretch of the Rio Conchos to upstream of Falcon Reservoir and the Rio Grande above its confluence with the Rio Conchos.

Most surface water resources in the Edwards Plateau region come from groundwater, with spring-fed headwaters and river margins feeding high-quality streams and rivers that support significant ecological communities. Protecting the ground and surface water resources is essential for the survival of most of the significant ecological communities and SGCN on this ecoregion's list. It includes land management over recharge zones, impoundment placement decisions, and all users' direct withdrawals from ground and surface water. Consideration of environmental flow needs is necessary during all Regional Planning processes, especially regarding downstream uses and SGCN.

Pollution: This plan discussed five water quality impacts that adversely affect SGCN, rare communities, and their habitats. These include wastewater discharges, stormwater runoff, mining and energy production, navigation channel and port operations and maintenance, and desalination. Excessive nutrients from agricultural and municipal fertilizers, fecal material leaked or discharged from Concentrated animal feeding operations (CAFOs), and pollutants like herbicides, pesticides, drilling fluid additives such as chloride, sulfates, petrochemicals, and petrochemical runoff from roadways can contribute to these water quality impacts. Additionally, these impacts can introduce incompatible salinity into fresher systems due to physical channel manipulation and wave action in navigation projects and deposition and release of salt waste from desalination operations. Some progress has been made related to sand and gravel mine permitting through the 2011 Texas Legislative Session (HB 571), requiring sand and gravel operators to file a TCEQ permit before beginning their creek and riverside mining activities. Altered flooding regime (timing, periodicity, amounts) that adversely affects flood-dependent riparian and aquatic systems. The Rio Grande/Rio Bravo and its tributaries in the Arizona/New Mexico Mountains and Chihuahuan Deserts regions have been impacted by upstream withdrawals and impoundments, even on small second and third-order tributaries. These activities have hurt flood-dependent riparian and aquatic systems in the area. Lack of consideration of and coordination with groundwater planning in this ecoregion during surface water planning processes can significantly negatively impact water resources since most of the permanent water in this ecoregion is spring-fed.

Shoreline development can have numerous negative impacts on the environment. For instance, developers may clear vegetation up to the water's edge to enhance the view and provide recreational access, directly impacting habitat availability and quality. Additionally, developers may harden and armor banks (bulkheading), leading to further habitat degradation. Shoreline development may also lead to pollution through on-site septic leakage and non-compliance, and it may encourage development on vulnerable sites and steep banks, creating opportunities for erosion and vectors for invasive species.

Moreover, the loss of instream and riparian habitat due to inundation also affects the riparian" and upland habitats surrounding the lake edge. In the Edwards Plateau, these habitats typically include cliff edges, recharge features, upland shrubland, and canyonlands, which support several species of greatest conservation need (SGCN) and rare communities. Unfortunately, regional reservoir managers do not reserve much in the way of "setback" from the inundation pool level in their easements. This allows residential development (water withdrawals and septic installation), bulkheading shorelines, and clearing and "landscaping" up to the water's edge. These lakeside activities can contribute fertilizers and other chemicals (such as boat gas/oil), untreated or poorly treated human waste (although some lake authorities have permitting programs to manage/reduce this factor, but not all), and sedimentation to the lake, which eventually impacts in-lake and downstream habitats. Typically, residential development in these areas is also a vector for invasive aquatic and terrestrial plants and feral pets.

The habitats in Eastern Central Plains that rely on groundwater, such as bogs, baygalls, and forest seeps, are adversely affected by dry conditions. Subirrigated, instream, and stream-adjacent habitats, as well as isolated habitats, are particularly vulnerable, and some of them may be permanently impacted after drought periods. Overpumping of groundwater lowers the water table, which can change the instream and wetland conditions, such as temperature, oxygen availability, and other nutrient and chemical factors that aquatic life relies on. A significantly low water level can sometimes decrease and degrade aquifer recharge capacity. This can affect the flow quantity and quality into the aquifer from future recharge events, and "drying out the sponge" at certain levels within the aquifer can contribute to this.

Many rivers and their tributaries in the Central Great Plains region support instream species and streamside vegetation that have adapted to a certain salinity level. However, alterations in groundwater and surface water extraction methods have led to changes in salinity levels in some areas, which can negatively impact the tolerance of these species.

The Edwards Plateau region faces a severe problem of unsustainable groundwater withdrawals due to unaccounted withdrawals for personal use and municipal and agricultural uses outside the ecoregion. Most municipal and irrigation water sources from San Marcos south in the Texas Blackland Prairies and in the South Texas Plains (around Uvalde) rely on the aquifer-sourced freshwater stream resources originating on the Edwards Plateau. San Antonio's water supply also comes entirely from the Edwards Aquifer. However, these areas tap on the aquifers that recharge over the Plateau, and surface artesian expressions in the Plateau support rare species with waters also from that same source, leading to conflicts between these uses. To learn more about this issue, refer to the Edwards Aquifer Recovery Implementation Plan at http://earip.org/.

The physical changes to karst, springs, and cienegas (water amount and quality) adversely impact some species' thresholds for survival or sustainable life history, including reproduction, foraging, and resting. Moreover, decreased and degraded aquifer recharge capacity or "drying out the sponge or sieve" at certain levels within the aquifer can affect the flow quantity and quality into the aquifer from recharge events. This can cause sub-irrigated plant communities (even in dry creek beds) and instream aquatic habitats throughout the region to suffer from a lack of spring flow and spring-fed rivers. Lower groundwater levels and loss of groundwater can decrease the amount of water near the surface or coming into the stream, leading to changes in instream and stream-adjacent conditions such as temperature, oxygen availability, and other nutrient and chemical factors (including factors related to the age of water source that comes from the aquifer).

The Central Great Plains face several issues, such as potential reservoir development, water diversion, and chloride removal projects within the Upper Brazos region. These projects might increase salinity levels and cause other changes in water chemistry in the waterbodies that receive the discharge from these operations, potentially impacting the sharpnose and smalleye shiner species. To prevent or minimize these effects, it's essential to appropriately site these projects, discharge waste responsibly, and monitor the water quality.

The ecoregion comprising Arizona/New Mexico Mountains and Chihuahuan Deserts, Eastern Central Plains, and Edwards Plateau areas faces a significant issue of interbasin transfers of surface and groundwater, which are necessary to meet the increasing demand for municipal water supply. The potential development of well-fields for commercial export out of the region or to the largest municipalities is a concern in this region.

In the Edwards Plateau, water chemistry differences can negatively impact the aquatic species with narrow thresholds for change, especially those that have evolved in or near spring-fed rivers. Therefore, environmental flows must be considered in the receiving and withdrawal basins. Water transfer may also lead to the transfer of exotic aquatic species like hydrilla, water hyacinth, zebra mussels, and gill parasites.

The rise in interbasin transfers has increased the risk of opportunistic water well field development, which could harm groundwater resources and the SGCN that rely on them across various regions.

Although useful, water treatment wetlands may threaten sensitive species like gypsum scalebroom and mountain plover, especially in areas such as the Arizona/New Mexico Mountains and Chihuahuan Deserts. Proper siting, waste discharge, and monitoring will be crucial to avoid, minimize, or mitigate any negative impact. Water treatment wetlands can benefit some wildlife and fish resources in the Eastern Central Plains. However, they are usually not managed as natural systems as the vegetation is often homogenous and not a suitable habitat for local wetland-dependent SGCN.

The Gulf Coast Prairies and Marshes ecoregion is critical for conserving many endangered species and rare communities. However, natural processes in this region are disrupted by factors such as lack of instream flows, saltwater intrusion, tidal influence changes, erosion, and human disturbances. These problems are compounded by transportation and navigation projects, oil and gas development, stormwater runoff from upland activities, and non-jurisdictional wetlands vulnerability. All these issues affect not only the estuary vegetation, bottoms, and shorelines but also the freshwater inputs from the river systems that drain the lands of Texas to the Gulf of Mexico.

To preserve the estuary's health and function, it is essential to address these factors relatedly. For instance, upstream reservoir and dam operations contribute to many of the issues discussed in the table below, which also outlines their impacts. To ensure the sustainability of our natural resources in this region, it's crucial to take appropriate conservation actions.

The conservation of native fishes and their habitats is critical to the health and sustainability of aquatic ecosystems. The Texas Native Fish Conservation Areas Network (TNFCAN) is a statewide partnership effort to conserve native fish populations and their habitats in Texas by identifying, prioritizing, and implementing conservation actions within designated priority areas. The following excerpt was used with permission from Texas Native Fish Conservation Areas Network: Strategic Investments in Restoration and Preservation of Freshwater Fish Diversity (Birdsong et al., 2019).

Goal 3: Restore instream and floodplain connectivity

Efforts to restore instream connectivity (i.e., longitudinal connectivity) within rivers and streams of the Texas Native Fish Conservation Areas (NFCAs) Network have primarily centered on removing low-head dams and redesigning or removing culverted stream crossings. In 2014, the TPWD and the Texas Commission on Environmental Quality cooperated on the removal of a 1.2-m-tall low-head dam spanning a 55-m-wide reach of the North Fork Guadalupe River, which is located within the Southern Edwards Plateau Rivers NFCA. In 2016, the USFWS, the TPWD, and local partners cooperated on the removal of Ottine Dam, a 4- m-tall and 30-m-wide low-head dam on the San Marcos River, located within the Guadalupe and San Antonio Rivers NFCA. Removal of Ottine Dam restored instream connectivity in 63 km of the San Marcos River. Also occurring in 2016, the TPWD cooperated with the USFWS to remove a 2.4-m-tall and 30-m-wide culverted stream crossing in the Upper Brazos River NFCA on the Double Mountain Fork Brazos River. Removal of the crossing restored in-stream connectivity for the last remaining populations of Sharpnose Shiner and Smalleye Shiner, two highly migratory, pelagic spawning prairie minnows currently listed as federally endangered. Additionally, the TPWD has consulted on redesigning several culverted stream crossings planned for renovation in the Central Edwards Plateau Rivers and Southern Edwards Plateau Rivers NFCAs.

To undertake a more proactive, strategic approach to restoration of instream connectivity, the TPWD is currently partnering with the Southeast Aquatic Resources Partnership to complete a barrier inventory and prioritization for a portion of the Southern Edwards Plateau Rivers NFCA. Initiated in 2017, this project is expected to serve as a pilot program for possibly expanding the Southeast Aquatic Connectivity Program into Texas (Graham et al. 2019, this volume). The program's mission is to restore connectivity, habitat, and ecological functions to streams by identifying and removing dams and other barriers to aquatic species passage.

Restoration of floodplain connectivity (i.e., lateral connectivity) in rivers and streams of the Texas NFCAs Network has been primarily limited to the Northeast Texas Rivers NFCA (Smith et al. 2019), where The Nature Conservancy, the U.S. Army Corps of Engineers, the Northeast Texas Municipal Water District, the TPWD, the Caddo Lake Institute, and numerous other local conservation partners cooperated on a flow agreement to restore a more natural flow regime in Big Cypress Bayou downstream of Lake O' the Pines. The flow regime included prescriptions for high-flow pulses and overbank flows intended to reconnect the river to its natural floodplain and benefit floodplain spawning fish SGCN, including Ironcolor Shiner and Taillight Shiner. Instream flow recommendations for high-flow pulses and overbank flows to support longitudinal and lateral connectivity within the Texas NFCAs Network are also expected to result from the research described within the summary for Goal 7.

Goal 4: Mitigate the effects of invasive species

Efforts to address the adverse effects of invasive species within the Texas NFCAs Network have focused on identifying and implementing regulatory and permitting measures to mitigate the impacts of invasive tilapia Oreochromis spp. (McGarrity

2019, this volume) and control of invasive riparian plants that form dense, monotypic stands and degrade riparian habitat quality (Bell 1997; Di Tomaso 1998). Efforts to control invasive riparian plants have primarily focused on managing saltcedar Tamarix spp. and river cane Arundo donax. These species have been shown to accumulate sediment, narrow stream channels, isolate floodplains, reduce instream flow, degrade water quality, increase erosion, and alter instream habitats (Blackburn et al. 1982; Shafroth et al. 2002; Birken and Cooper 2006; Stromberg et al. 2007; Merritt and Poff 2010; Dean and Schmidt 2011; Dean et al. 2011).

In the Guadalupe and San Antonio Rivers, Central Edwards Plateau Rivers, and Southern Edwards Plateau Rivers NFCAs, the TPWD has partnered with The Nature Conservancy, the Hill Country Alliance, the Texas Department of Transportation, river authorities, local municipalities, and approximately 400 cooperating riparian landowners to implement large-scale management of river cane along 200 km of the Blanco, Guadalupe, Medina, Nueces, and Pedernales rivers and their tributaries. In the Blanco and Pedernales rivers, the scope of these efforts was expanded to include mapping of other invasive plants and restoration plantings to augment passive recolonization by native species. Biological monitoring sites were also established along Barons Creek, a tributary of the Pedernales River, to evaluate the effects of control efforts on riparian plant communities, fish and invertebrate communities, water quality and quantity, and channel morphology. Similar efforts to implement large-scale control of river cane and to re-establish native riparian vegetation are being implemented by the National Park Service, World Wildlife Fund, Rio Grande Joint Venture, and TPWD in the Upper Big Bend and Lower Big Bend NFCAs (Garrett et al. 2019).

In the Upper Brazos River NFCA, the TPWD has partnered with the USFWS Partners for Fish and Wildlife Program, Texas A&M AgriLife, Texas Tech University, University of Texas at Austin, and more than 60 riparian landowners to manage 4,209 ha of saltcedar, focusing initial efforts along 286 km of the Double Mountain Fork Brazos River. Aerial surveys of saltcedar were completed throughout the entire Upper Brazos River NFCA, and control efforts were expanded to the Salt Fork Brazos River in 2018, with restoration planting of cottonwood Salix populus currently in the planning stages. Research is being conducted in partnership with the University of Texas at Austin Bureau of Economic Geology to evaluate the effects of saltcedar control on the water budget, water quality, river channel morphology, and riparian plant communities (Mayes et al. 2019).

In the Central Edwards Plateau Rivers NFCA, the TPWD has partnered with the Texas Tech University Llano River Field Station, the Llano River Watershed Alliance, cooperating landowners, and volunteers to implement management of invasive elephant ear Colocasia esculenta along more than 80 km of the Llano River and Gorman Creek. Partners have also implemented the management of river cane at the South Llano River State Park. Restoration plantings and changes to stewardship practices implemented at the South Llano River and Colorado Bend state parks will be *used to provide demonstration sites for outreach to increase awareness of the negative impacts of invasive riparian plants.*

8.0 Invasive & other Problematic Species & Genes

As per Executive Order 13112 (Section 1. Definitions), an "invasive species" is a species that is:

1. non-native (or alien) to the ecosystem under consideration and,
2. whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

Invasive species that are non-native and native species that can become problematic can invade natural sites, especially sites that have been disturbed by forces like fire, overgrazing, or human infrastructure, and compete for resources to the exclusion of species found naturally in the community and ecosystem.

Disease vectors, voracious destructive feeders, or species that take nutrients to the detriment of the host species; in many instances, the issues presented for this plan are pests, parasites, or pathogens out of their native element and invasive OR are out of balance with their natural host due to exacerbating factors (some not well understood) and only recently problematic. Examples include:

- Pests: Cactoblastus moth on prickly pear. Example:
- Parasites: Haemonchus in pronghorn
- Pathogens: *Pseudogymnoascus destructans* (Pd) fungus and resulting White-nose Syndrome (WNS) in bats

Invasive Non-Native (8.1)

Most invasive vertebrate and plant species were intentionally introduced, whereas most invasive microbes and invertebrates in the US were unintentionally introduced. The total damage and control costs from all invasive species in the US are estimated to be $26 billion annually since 2010 (Crystal-Ornelas et al., 2021). Globally, it is estimated that the economic cost of invasive species has been $1.288 trillion over the past 50 years (Zenni, Essl, Garcia-Berthou, & McDermott, 2021). Many partners and stakeholders in this plan named invasive species as one of the top two negative impacts on native species and habitats.

TexasInvasives.org is a Texas partnership that includes state and federal agencies, conservation organizations, green industry, academia, and other private and public stakeholders who share the common goal of protecting Texas from the threat of invasive species. The organization tracks 178 plants, 24 animals (including mollusks and crustaceans), 48 insects and arachnids (including spiders, ticks, and mites), and six pathogens it considers invasive or potentially invasive. Incidents of non-native species becoming invasive are growing with greater globalization in travel and commerce, lack of awareness of the seriousness of the threat to our lands and waters, and deliberate introduction.

The U.S. Fish and Wildlife Service estimates that the costs to track, prevent, and control invasive species are higher than $219 billion annually: invasive species are an economic and ecological threat. Our understanding of the long-term environmental damages runs a gradient from well-understood to unknown. Invasive plants can degrade the structure of the native plant community and affect the soil chemistry and microclimate, which will adversely affect all plants with narrower habitat tolerances, including some SGCN such as Correll’s false dragon-head, bracted twistflower, Glass Mountains coral-root, Warnock's coral-root, Texas prairie dawn, Texas meadow rue.

With our temperate climate, diverse habitats, recreation destinations for wide-ranging travelers, and national and international ports, we are prime colonization territory for just about any non-native invasive that can get a foothold.

Terrestrial invasives enter natural and recovering habitats in many ways:

- adjacent developed areas' - tropical or xeric-adapted landscaping from other countries, feral cats and dogs, starlings
- direct/purposeful introduction - exotic ungulates released for recreation and hunting, planting for erosion control, pasture grass improvement such as buffelgrass, which outcompetes star cactus
- seed dispersal by birds and other animals
- accidental introductions - most pathogens, like the fungus that causes White-Nose Syndrome in bats, oak wilt, oak decline
- opportunistic colonization into disturbed open areas – unremediated construction zones, mining areas
- Invasive plants and animals enter our waterways through aquarium dumping, transfer on boats and other recreational equipment, bait-dumping, and runoff/downstream transfer from other "infected" areas.

The list of invasive species we are already battling is long (e.g., oak wilt, zebra mussels, emerald ash borer, Formosan termite, gypsy moth, nandina, ligustrum, China berry, Chinese tallow, armored catfish, feral hog) and every ecoregion has their own "plague."

Some plant pests with direct agricultural impacts are regulated through the Texas Department of Agriculture; however, there are many unregulated invasive plants and animals – the prevention and control of these rely on the awareness and voluntary actions of all Texas citizens.

Every conservation organization in Texas has some level of invasive species program – outreach, field control, mapping, prevention – in their stewardship toolbox. It is a widely recognized threat. Sponsored and supported by a Texas-wide network, TexasInvasives.org has involved state and federal agencies, conservation organizations, green industry, academia, and other private and public stakeholders who share in the common goal of protecting Texas from the threat of invasive species. This group is making significant headway in involving communities and scientists to collect data, identify best practices, and notify the public in each ecoregion about invasive species (plants, animals, pests, and pathogens). An additional resource for invasive plant lists, including "invasiveness" ranking, is TexasNonNatives.org. This organization also provides a list of species to watch, which may be an issue in Texas in the future.

- Example: Invasive: salt cedar, zebra mussels, Chinese tallow, Old World grasses, exotic ungulates, feral pigs. Lionfish

Resources: The following are portals for information on current invasive species detection and response.

- Texas Invasive Species Institute http://www.tsusinvasives.org/
- Texas Invasives (Texas Invasive Plant and Pest Council) https://www.texasinvasives.org/
- Texas Non-Natives (Texas Non-Native Plants Group, 2010) https://texasnonnatives.org/

Invasive Plant Threats:
Salt cedar/tamarisk (Tamarix spp.): Salt cedar affects water use, monotypic stands, and outcompetes native riparian vegetation(e.g. (cottonwood, sycamore) at all seral stages and canopy levels; armors banks and contributes significantly to channel incision and narrowing, which reduces the diversity and quality of habitat for aquatic SGCN and can adversely affect stream-adjacent spring habitats.

Giant reed/river cane (*Arundo donax*): salt cedar and Arundo line the banks of the Rio Grande in the Big Bend reach and streams in more arid parts of Edwards Plateau, armoring the banks and contributing significantly to channel incision and narrowing, which reduces the diversity and quality of habitat for aquatic species.

Cultivated and Old World grasses (e.g., Lehmann's lovegrass, King Ranch (KR) bluestem, Bermuda grass): Invasive grasses in “improved pastures” are a substantial threat to grassland-dependent species (e.g. grassland-obligate birds and pronghorn.) Invasive plants may also contribute to the loss of native pollinators (e.g., honey bees, moths, hummingbirds, and others) because of the reduced plant diversity and lack of herbaceous flowering plants other than grasses. Sodforming introduced grasses like Bermuda grass and other grasses such as buffelgrass, old world bluestems, KR bluestem, tanglehead, guinea grass, Lehmann’s lovegrass, and Johnsongrass are also very invasive and detrimental.

From pollinators to birds of prey, all prairie-dependent species experience population declines. Invertebrate abundance, important for breeding bird fecundity, is lower on introduced grass sites than in native grass areas. Breeding birds have been shown to select native prairie sites more than introduced grass sites for nesting. Prairie birds that nest and forage on the ground do not have suitable nesting, travel lanes, thermal cover, foraging, brooding, loafing, screening, or escape cover within introduced grass areas.

Species particularly threatened include bobwhite quail, dickcissel, loggerhead shrike, scissor-tailed flycatcher, many pollinating insects, and the plants that depend on these. Four grassland species have 5% or less of their distribution on public lands: breeding Dickcissels, Scissor-tailed Flycatchers, and Eastern Meadowlarks, and wintering Harris’s Sparrows; across the nation, 48% of grassland-breeding bird species are of conservation concern, including four with endangered populations. See North American Bird Conservation Initiative, U.S. Committee, 2022 for more details.

Kudzu introduced as a soil stabilizer, is an aggressive colonizer of disturbed areas, especially along waterways.

Invasive plants sold in nursery trade (e.g., ligustrum, chinaberry, nandina); Chinese tallow and the tree of heaven, and Aquatic invasives – giant salvinia, water hyacinth [Eastern Central Plains], hydrilla [Edwards Plateau]) Aquatic invasive plant species are highly successful in area lakes and riverine systems, crowding out native aquatic vegetation, inhibiting access by nesting freshwater fishes to bottom substrates, depleting nutrients, and degrading flow/natural hydrograph.

Invasive woody nursery plants that “escape” out of managed urban areas via waterways are distributed by bird and animal droppings or are deliberately placed in suburban and rural- suburban developments quickly can invade riparian areas, any wet swale or depression, and native grassland. These species displace native plant communities with which native wildlife have evolved; can smother or choke out small isolated bog, seep, or spring communities; and contribute to the loss of native pollinators (e.g., honey bee, moths, hummingbirds, others) and the animals which rely on insect fauna now changed by these invasions. Urban areas harbor numerous invasive plant species installed in residential and municipal landscapes, which escape and spread into nearby wildlands and all points downstream (once in waterways, these infestations can spread as far as the floodwater will carry them within the water system and into adjacent areas) spread naturally during rain events, bird and mammal droppings, and through vegetative spread. Degradation in the mesic canyons, riparian areas, and headwaters that are particularly vulnerable.

Urban areas harbor numerous invasive species – sod-forming grasses, ornamental shrubbery -- that are installed in residential and municipal landscapes, allowed to escape and spread into nearby wildlands and all points downstream (once in waterways, these infestations can spread as far as the floodwater will carry them within the water system and into adjacent areas). Urban/suburban “escaped” landscaping impacts natural resources within and outside of urban boundaries: invasive plants sold in the nursery trade are highly aggressive colonizers and escape cultivation easily. Chinese tallow is exceptionally aggressive and damaging to more habitat types – wet and dry alike. Other ornamental invasive woody species here are Ligustrum, Macartney rose, Japanese honeysuckle, and chinaberry.

Invasive Animal Threats:
Feral hogs can cause significant damage to delicate habitats such as springs, seeps, riparian areas, and wetlands in the Central Great Plains, Arizona/New Mexico Mountains and Chihuahuan Deserts, Eastern Central Plains, Edwards Plateau, and Gulf Coast Prairies and Marshes ecological regions. They also degrade instream water quality, alter the topography, and change runoff/collection patterns. Additionally, feral hogs reduce the viability of hardwood seedlings by rooting them up and eating them, which negatively impacts the composition of vegetation communities. They can be particularly harmful to some prairie plants that are intolerant to soil disturbance. Furthermore, hogs destroy new restoration sites, proving expensive or impossible to recover without hog control.

Free-ranging pets such as cats and dogs, both individually and in packs, are considered to be introduced predators that hunt small mammals, small reptiles, and birds. In packs, they can even cause harm to larger mammals and ground-nesting birds while also contributing to the spread of pathogens and diseases.

It is estimated that there are between 60 and 100 million feral cats in the United States, with an additional 60 million pet cats allowed to roam outside. While programs aimed at neutering and releasing these cats may limit their breeding, they do not address their negative impact on natural resources.

Feral cats are responsible for preying on over 1 billion birds annually in the United States alone, with many species of concern affected. The International Union for Conservation of Nature (IUCN) considers feral cats among the world's most harmful invasive species. For more information, refer to The Wildlife Society's Wildlife Professional publication, Spring (March) 2011, Vol. 5 No. 1.

Nutria have been known to cause damage to rare aquatic plants such as wild rice, which provide important cover for fishes designated as SGCN, in the Edwards Plateau and Gulf Coast Prairies and Marshes regions. These animals can also destabilize banks and streamside communities, adversely affecting some aquatic SGCN, such as fishes and insects. The loss of bank stabilization and vegetation can contribute to siltation and instream habitat degradation, leading to habitat loss for other aquatic SGCN.

Red Imported Fire Ants and Tawny Crazy Ants, formerly Rasberry Ants, are especially problematic in the Eastern Central Plains, Edwards Plateau, Gulf Coast Prairies, and Marshes regions. The Red Imported Fire Ant is an indiscriminate predator that swarms over ground-nesting birds, shrub-nesting birds, other insects, small mammals, reptiles, amphibians, and young mid-sized mammals. They also attack and eat the eggs and young of other species. In the Edwards Plateau region, these ants are highly invasive. They are a significant threat to various species, including karst invertebrates, karst-dependent amphibians, black-capped vireos, low-shrub nesting SGCN, and grassland birds in all periods. In the Gulf Coast Prairies and Marshes region, they are also a threat to the local ecology.

The Tawny Crazy Ants' exact impact on the local ecology is unknown. Still, a related species of this genus has been a serious pest in rural and urban areas of Colombia and South America. They reportedly displaced all other ant species and caused small livestock, such as chickens, to die of asphyxia. Larger animals, like cattle, have been attacked around the eyes, nasal fossae, and hooves. These ants cause grasslands to dry out because they aggravate sucking insect pests (hemipterans), as they feed on the sugary "honeydew" produced by these plant-feeding insects. These ants also irritate nesting songbirds, and mosses covering the ground and trees will affect ground and tree-nesting birds and other small animals, forcing wildlife to leave the area. Ironically, after experiencing the Tawny Crazy Ants, most residents prefer the Red Imported Fire Ants.

Domestic waterfowl in the Edwards Plateau, Gulf Coast Prairies, and Marshes regions hybridize with some SGCN waterfowl, and feral domestic mallards threaten the mottled duck.

Invasive ungulates such as Aoudad and Axis have been intentionally introduced into various ecological regions for hunting purposes. However, they have become a major problem in the Arizona/New Mexico Mountains, Chihuahuan Deserts, and the Edwards Plateau, causing significant damage to habitats, competing with native small mammals and ungulates for food, and spreading diseases that can affect native ungulates and domestic livestock. Axis and Aoudad reproduce rapidly and cause more extensive damage than even hogs in some areas.

Additionally, introduced exotic antelope and goats, which are also hunted, can outcompete native herbivorous ungulates and small mammals for grazing and browse forage and directly compete with livestock production. These animals can also decimate hardwood regeneration, springs, upland grasslands (by scraping), and other areas that are crucial for the survival of SGCN and rare communities.

Freshwater springs, streams, and marshes are a crucial part of the ecosystem in the Central Great Plains, Arizona/New Mexico Mountains and Chihuahuan Deserts, Edwards Plateau, and Gulf Coast Prairies and Marshes ecosystems. However, within streams, invasive baitfish pose a threat to native species. These baitfish can compete with natives for resources and be a predation risk. Some invasive species, such as tilapia and carp, are detrimental to native aquatic vegetation, negatively affecting the cover for small native species. In addition, released baitfish, such as "minnows," may hybridize with certain Gambusia species, which can compete or hybridize with natives. Invasive species can also be densely successful and crowd out natives and can affect water flow and quality. One example of this is the zebra mussel (Figure 5.5).

Aquarium dumping by hobbyists in the Eastern Central Plains and Gulf Coast Prairies and Marshes has introduced many invasive fish and mussels, including the ecologically devastating zebra mussel and quagga mussel. Within streams, zebra mussels compete with native freshwater mussels, many of which are listed as state-threatened. They may also be gill parasites on certain fishes, but whether they adversely affect any SGCN freshwater fishes is unknown. Smallmouth bass are voracious invasive predators that take a toll on smaller fishes in these systems. Invasive baitfish and aquarium species releases compete with native fishes in many habitats and can be detrimental if they are predacious.

The cactus moth (*Cactoblastis cactorum*) is a major pest of prickly pear cactus (Opuntia spp.) in Arizona/New Mexico Mountains and Chihuahuan Deserts, Edwards Plateau, and Gulf Coast Prairies and Marshes. Cactus moth larvae live and feed inside the pads of prickly pear cacti. Voracious feeding by cactus moth larvae destroys entire stands of prickly pear cactus. The cactus moth has been found in the upper coastal Texas counties of Brazoria, Chambers, Colorado, and Matagorda. The loss of biodiversity, habitat, forage, agricultural products, and the nursery industry could be substantial.

Lionfish in Gulf Coast Prairies and Marshes have been shown to consume 70% or more of the annual recruitment of reef species, including grouper. These and other invasive species directly compete with or alter the native habitat, leading to threatened or endangered species. Invasive marine species in ballast water from increased traffic in expanded ports may also be an issue. For more information on coordinated Lionfish response, see Johnston, Gittings, & Morris Jr. (2015).

Invasive Pathogen Threats:
White-nose Syndrome (WNS) is a disease that affects hibernating bats (Figure 5.6). It is caused by an introduced fungus pathogen called Pseudogymnoascus destructans. The disease is distributed through human and bat vectors, such as caving equipment, clothing, skin, hair, and hibernacula visitation. Unfortunately, there is no cure for WNS, and the mortality rate is high. The effects of this disease can be ecologically devastating. Texas Parks and Wildlife has developed a White-nose Syndrome Action Plan to address this issue in the Central Great Plains, Arizona/New Mexico Mountains and Chihuahuan Deserts, and Edwards Plateau regions.

Chytrid fungus is another concern, which can cause amphibian decline and population decimation. This fungus is found in Texas, but research is ongoing regarding its extent. Many of our amphibian species in the region are extremely rare and vulnerable, even if not threatened by other factors. An infection of this type in one of the highly isolated Eurycea populations may have extremely serious consequences. Humans can carry the fungus among populations, so field researchers and herptile enthusiasts are encouraged to follow the Declining Amphibian Task Force Fieldwork Code of Practice to prevent its spread.

Problematic Native Species (8.2)
In Texas, an individual or group of individuals of a native species can cause management issues, property damage, present a threat to public safety, or create an annoyance. These nuisance natives may be out of place (range change) or are overly abundant because of habitat disturbance or changes in populations of ecologically important species.

Brush: Historic land management practices, such as intense overgrazing after the advent of barbed wire fencing and water development, have led to open lands that are susceptible to expansion by native and invasive brush species. Meanwhile, fire suppression has further contributed to brush encroachment in grasslands as the land is privatized into parcels, native forests are converted to timber production, and urban areas begin to intrude into natural and working landscapes, particularly the urban-wildland interface.

The encroachment of native brush species, including juniper, mesquite, yaupon, oak, and other brush species, in habitats where they are not desired ecological conditions of grassland habitats can adversely affect all grassland, savanna, woodland, and forest habitats. This, in turn, negatively impacts various species, such as grassland birds (e.g., Lesser and Attwater's prairie chickens), pronghorn, small mammals, and reptiles. In diverse forests and monotypic stands managed for timber, yaupon, and juniper can form thickets that can choke out natural forest regeneration and make maturing forest sites unsuitable for some forest birds. If the savanna is the natural community, brush encroachment can remove habitat suitability entirely (e.g., Bachman's sparrow). Brush encroachment can also shift fire behavior and vegetation response in rare communities that are fire-dependent for regeneration (e.g., longleaf pine savanna, most native grasslands, pitcher plant bogs).

It is important to note that not all brush is "bad," just as white-tailed deer are not "bad." There are natural shrublands and woodlands, such as oak shinnery, mesquite savanna with open grasslands understory, dense mature oak-juniper woodlands, diverse native thickets along riparian corridors, certain geologic features like karst with shrubs and brush adjacent to them, Tamaulipan thorn scrub, which are beneficial and necessary to many of our SGCN and rare plant communities.

Finally, it is worth noting that topography, rainfall, slope, aspect, soils, and geology all contribute to whether shrubs and brush are a "natural" part of a particular landscape.

White-tailed deer: The success in nearly eradicating screwworm, combined with insufficient harvest of native game species in some areas, has led to over-browsing by white-tailed deer. This means they are eating shoots, twigs, leaves, acorns, nuts, fruits, and stems of woody vegetation, which has caused a loss of upland and bottomland hardwood regeneration. It is particularly concerning in systems where species of greatest conservation need to rely on hardwood diversity in various stages of maturity.

Brown-headed cowbirds have expanded their distribution and impact due to land use practices such as continuous cattle grazing and feedlot management. This has led to parasitism of nests and a reduction in the population health of grassland and shrubland species (Shaffer et al., 2003).

Sheepshead Minnow and Gulf Killifish: These native cyprinodontid coastal fishes are popular for use as bait. Baitbucket releases, combined with these hardy and highly reproductive species' ability to live in fresh or salt water, have resulted in ecological threats (Montana-Schalk & Perkin, 2021). As opposed to competition for food or habitat, the species primarily threatens other native fish populations through hybridization (crossing of two species). The minnows can breed with native species of the *Cyprinodon* genus, including the endemic Pecos pupfish *(Cyprinodon pecosensis*, state-threatened species), Leon Springs pupfish (*Cyprinodon bovinus*, state and federally endangered), Comanche Springs pupfish (*Cyprinodon elegans*, state and federally endangered) and potentially the Red River pupfish (*Cyprinodon rubrofluviatilis*) resulting in the hybridization of each of the pairs of species. Hybridization events can lower the biodiversity in a habitat and affect food web structure.

Harmful algal blooms: red and brown tides, Golden alga (Golden alga may belong in Non-native Invasive Species; it is not conclusively known whether golden alga is native or non-native) Research is fairly new to relate golden algal blooms to SGCN declines; however, these are anticipated especially in areas where SGCN are dependent on temporary water sources or water resources with wide oxygen or nutrient ranges throughout the year. Toxic algal blooms in Lake Balmorhea may adversely impact Comanche

Springs pupfish, also known in Pecos River. Harmful algal blooms adversely impact seagrasses and, in freshwaters, can adversely impact fish populations and vegetation.

Haemonchus parasite- Deadly and devastating parasite to pronghorn, additional stressor on already stressed populations. Pronghorn populations devastated by this parasite are thought to be a major contributing factor to the pronghorn decline across the Trans-Pecos.

The SGCN fountain darter (Etheostoma fonticola) is particularly vulnerable to catastrophe because the entire population is found in one water system, and is a known host to a native heterophyid trematode gill parasite. This parasite can decrease darter health by reducing fecundity and causing direct mortality of the fish through gill degradation. (Mitchell et al. 2000)

Oak wilt, oak decline, thousand canker, chinquapin wilt, and red bay infection are plant diseases that affect key woody plant communities in the Eastern Central Plains ecoregion. These communities include oak pine savanna, oak woodlands, and bottomland hardwoods, all of which can be affected by the pathogens that cause wilt and decline. The red bay is also part of the region's rare and declining plant community.

In the Edwards Plateau region, these plant pathogens can adversely affect hardwoods, an important component of many important SGCN habitats and rare communities in closed canopy mesic canyon woodlands and open savanna.

In the northern part of the Gulf Coast Prairies and Marshes ecoregion, the plant pathogens listed can adversely affect hardwoods, such as oak mottes, which provide migratory stopovers. These hardwoods are a component of many important SGCN habitats and rare communities in ravine woodlands, riparian borders with uplands, and open savanna.

Exotic invasive forest pest species, such as the Pine bark beetle, Soapberry Borer, and Emerald Ash Borer adversely affect tree populations that are essential components to a desired ecological condition, as well as negatively impact economic and ornamental values of timber stands.

West Nile virus, Avian botulism, cholera, duck plague, and salmonella - West Nile has been suggested as a factor in the global decline of the Tamaulipas Crow; it may adversely impact SGCN bird species in this region, which are shared international priorities. Many of these diseases/pathogens are detrimental to the region's bird populations, especially waterfowl.

Increase incidence of vibrio and waterborne viruses (oysters). Vibrio and other waterborne viruses can adversely impact oyster reefs.

Introduced Genetic Material (8.3)
Introduced genetic material can compete with native genetic material, dilute population genetics, and long-term population health, and may threaten a species with permanent hybridization or extinction.

- Congeneric introduced fishes such as some Cyprinodon sp.
- Non-local varieties (cultivar) vegetation and seed sources used in restoration
- Genetically modified insects for integrated pest management

Baitfish releases (“minnows”) can cause problematic congeneric hybridization (e.g., Gambusia sp.). Within streams, nonnative species compete with natives and are a predation risk (e.g., smallmouth bass are voracious non-native predators); some are detrimental to native aquatic vegetation (tilapia, carp), which adversely affects cover for small natives, compete or hybridize with natives (smallmouth bass with Guadalupe Bass, baitfish released "minnows" may hybridize with certain Gambusia sp.).

Domestic waterfowl hybridize with some SGCN waterfowl (e.g. Mottled Duck).

9.0 Pollution

Household Sewage & Urban Wastewater (9.1)
Lack of stormwater pollution prevention facilities and out-of-compliance water and wastewater discharges contribute significantly to water quality issues, particularly in the Rio Grande Valley area of the Gulf Goast Prairies and Marshes ecolocial region, and adversely affect all aquatic SGCN.

Industrial & Military Effluents (9.2)
Herbicide use by power grid developers: Power infrastructure corridors to meet urban user needs result in higher use of chemicals (herbicides, pesticides).

Oil spills: Areas heavily developed for oil and gas production and delivery have a concentration of facilities. The thresholds for reporting spills in any particular incident are insufficient to address the cumulative effect of many small spills in one region over time. Marine offshore operations may have inadequate response plans and mitigation requirements (e.g., Deepwater Horizon Spill, 2010); local authorities may be ill-equipped to address the outcome if the responsible companies are unprepared.

Agricultural & Forestry Effluents (9.3)
Gassing, poisoning, and flushing rattlesnake dens or prairie dog towns frequently adversely affect non-target species. Invertebrates, amphibians and reptiles, small mammals, and some birds (e.g., burrowing owls) are adversely affected directly by the actions. Additionally, there are potential long term adverse impacts to groundwater resources.

Irrigation and other water run-off:

- Contaminated runoff adversely impacts sensitive aquatic insects and other invertebrates, fishes, and amphibians in surface water. Because of the connection between surface water and aquifers, groundwater can also be contaminated. Insufficient stormwater controls between agricultural production and waterways (or dry drainages that lead to waterways during rain events) lead to chemical impacts to sensitive aquatic insects, freshwater mussels, riparian invertebrates, freshwater fishes, amphibians, and eventually bay and estuary systems – invertebrates, fishes, and birds.
- Waterways near croplands encounter severe sedimentation because of soil erosion in adjacent croplands. Surface water affected by sedimentation tends to be shallower, warmer, and lose its capacity to hold water.
- Orchards, vineyards, and some concentrated animal feeding operations without stormwater pollution prevention protection have adverse impacts on sensitive aquatic insects and other invertebrates, fishes, and amphibians.
- For streams already at "carrying capacity" for sediment and salinity. While some of the SGCN freshwater fishes have high tolerances for salinity, many of the species are headwater and spring-fed river-dependent; excessive chemicals from agricultural practices are known to

have adverse impacts on sensitive aquatic insects and other invertebrates, fishes, and amphibians.

- Concentrated Animal Feeding Operations (CAFOs): Nutrient loading and pollution in bays can shift the entire vegetation community, aquatic life community, and water chemistry; can have long-term effects on benthic communities as many chemicals are latent in sediments; TMDL recommendations need to account for wildlife and fisheries needs.

Herbicide use: reduces herbaceous resources necessary for breeding birds. Pesticides reduce high-protein insect forage for grassland birds and affect all insects in the community, including pollinators. Not much is understood about the collapse of certain pollinators. Overspray can decrease or completely wipe out native insect fauna, important pollinators in native grassland and prairie systems.

Excess Energy (9.6)
Algae "farms" (biofuel): Because these are not food crops, the application of fertilizer and pesticides is potentially a greater concern, especially adjacent to or within playas (direct conduit to the Ogallala Aquifer) and along the Gulf Coast. Impact on wildland native fauna/pollinators; site may favor invasive species.

10.0 Geological Events

Volcanoes (10.1)
No volcano threats were noted.

Earthquakes/Tsunamis (10.2)
No earthquake/tsunami threats were noted.

Avalanches/Landslides (10.3)
No avalanche/landslide threats were noted.

11.0 Climate Change and Severe Weather

In late 2006, Texas natural resources planners, ecologists, NGOs, and agencies began a more serious conversation about climate change’s potential impacts on our natural resources. The evidence and effects of phonological shifts, sea level rise, and the perception of more extreme climate changes in certain ecoregions precipitated a series of conversations and workshops.

Facilitated by the National Wildlife Federation, an invitational workshop was held in College Station in 2008 to help ecologists and policy leaders understand the state of the science and practice relevant to Texas resources. On the national front, other states and the Association of Fish and Wildlife Agencies were also seriously researching and addressing this issue, amassing information, and testing species vulnerability models. The science, documentation, and approach to climate change and assessing its effects on our natural resources have increased dramatically in the last few years. The Association for Fish and Wildlife Agencies (AFWA) and a panel of state and federal fish and wildlife agencies and NGO partners produced the Voluntary Guidance for Climate Change, a compendium of resources and approaches. Because of our vast resources and species abundance, Texas has decided to take a habitat-based approach to this issue.

Editor’s Note: Much of the information for this chapter was excerpted with permission from one of the contributors and reviewers of the source, *The Impact of Global Warming on Texas* (2nd Ed.).

Global climate trends indicate warming temperatures, sea level rise, and increased frequency of extreme precipitation in North America over the past century. Although the popular press may still refer to these phenomena collectively as "global warming," the scientific and conservation community has trended away from that to "climate change." In Texas, the observed and predicted changes in climate are varied and do not just include warmer temperatures.

The Earth's mean surface temperature has increased by approximately 0.9°F in the 20th century, with a large portion of this increase occurring since 1970. These trends are expected to continue into the foreseeable future as greenhouse gas emissions increase in the atmosphere. Over the past century, average temperatures in Texas and other southern states have risen much less than elsewhere in North America, from a 0°F rise in east Texas to up to 2°F in far west Texas. Researchers believe this anomaly is temporary, and in coming decades, Texas temperatures could rise by 3 to 7°F in summer, with increases in the July heat index of 10 to 25°F. Precipitation projections through 2100 for Texas are highly uncertain. Despite annual drought conditions, some long-term trend data demonstrates increased precipitation over parts of the state, but other models project more arid conditions. Likely, future precipitation patterns will differ seasonally or geographically from historical patterns.

As regions become more or less arid or wet, changes in temperature or seasonal durations, these consequences of climate trends will exacerbate other recognized impacts to fish and wildlife resources such as habitat fragmentation, degradation, and loss from changing land uses, exotic invasive species, pollution, and other stressors. Some native populations and communities may be unable to exist, compete, or adapt to conditions beyond their thresholds. More adaptable and aggressive exotics may thrive within certain changes.

Agricultural and ranching areas may shift. Water resource demands may change with increased aridity. With our current levels of information, it is difficult to predict exact system changes; therefore, to the extent we can reduce current adverse pressures and improve the resiliency of ecosystems, climate change's adverse impacts may be alleviated.

Climate is determined by a complex interaction among the atmosphere, ocean, and land surface. General circulation models (global climate models) study these complex interactions. When given information about the possible makeup of the atmosphere in the future (i.e., greenhouse gas scenarios), they generate projections of future climate, including temperature and precipitation. Climate projections vary among models, and, in general, there is greater consensus across models on the level of future warming than changes in precipitation or extreme rainfall events. Hence, in Texas, we can expect increased air and water temperatures, changes in precipitation patterns (including changes in seasonality, frequency, and intensity of storms), and rising sea levels. These changes are already underway and expected to accelerate this century. The exact magnitude of these changes will depend on global emission increases or decreases over the next several decades. Our understanding of the climate system is constantly improving; nonetheless, uncertainties are a part of this climate projection process, and we cannot predict the climate of any particular locality in Texas 20, 40, or 60 years from now. We can, however, examine a range of likely scenarios (e.g., hotter and drier, hotter and wetter) and use those as the basis of vulnerability assessments we may conduct.

Climate is one of the most important factors influencing species' distribution, abundance, and behavior, as well as one of the strongest forces on the distribution and characteristics of habitats and ecosystems. Climate is the key determining variable of species distributions. As the Earth warms, species shift to northern latitudes and higher altitudes. Phenology studies changes in the timing of biological behaviors such as flowering and migration. Phenological changes are being documented across taxonomic groups distributed around the globe. Some of the most pronounced changes include a general trend towards events earlier in the year (such as those triggered by the onset of spring) and lasting longer (such as a lengthened growing season).

Numerous studies have focused on determining the possible effects of climate change on fish, wildlife, and plants. Although most of these investigations were not conducted in Texas or on species native to the state, their overall conclusions and insights can still be applied. Those findings include:

- Changes in the timing of seasonal events, possibly leading to a potential loss of synchrony between species. There has been a general trend towards spring and summer events occurring earlier in the year. This includes earlier leafing out in trees, bird nesting behavior, flowering, and fruiting.
- Shifts in suitable climate conditions for individual species leading to changes in abundance and range. In 2007, Audubon published a study showing the center of bird populations in the U.S. had shifted, on average, 35 miles to the north over 40 years. South Texas bird species, including the least grebe, great kiskadee, green jay, and buff-bellied hummingbird, are expanding northward. Gray snapper have been reaching farther north in the Gulf of Mexico since the 1990s; once found only in the lower Laguna Madre and off the extreme southern shore of Texas, they are now migrating up to and routinely caught by anglers in Sabine Lake near Port Arthur.
- Changes in the habitats that species occupy. Texas bay waters have warmed by an average of nearly 3°F over the past 25 years. Cold-sensitive plant species, such as the red mangrove, are moving north up the Texas coast. Early maps showed no red mangrove north of the Rio Grande estuary; today, they appear as far north as the edge of Matagorda Bay.
- Changes to the composition of plant and animal communities. Increases in concentrations of CO2 favor woody shrubs invading prairie grasslands.
- Changes to ecosystem processes such as decomposition, nutrient cycles, and growth rates.

In addition, Texas coastal habitats are considered to be at a high risk of adverse impacts of sea-level rise because of the relatively high mean wave height of the waters of the Gulf of Mexico and issues such as subsidence. The highest vulnerability areas are typically low-lying beach and marsh areas. Over the next century, sea level will likely rise 55-60 cm along most of the Gulf Coast. This will mean more frequent and longer marshes flooding that could convert to open water. Seagrass beds will appear and disappear with changing water depths, tidal flats will spread inland, and bays and estuaries will expand. Coastal plains ecosystems may be threatened by saltwater intrusion.

Climate change will undoubtedly generate indirect impacts on plant and animal communities, effects that may be just as significant as direct impacts. For example, land use change is already a large factor in habitat destruction. Land fragmentation may be exacerbated as agriculture expands into new areas or human migration patterns shift.

Future biodiversity will directly extend the biological richness we conserve today. The most important tool in our climate change adaptation toolbox is protecting areas that already host diverse and healthy ecological communities. Moreover, now is the time to ensure that we are protecting the full range of habitats and species unique to Texas that typify the state's biodiversity and providing an insurance policy against the unknowns of climate change by conserving multiple examples of ecosystem type.

Climate change is only one of many sources of stress to ecosystems and their inhabitants. Unless these other threats are reduced or removed, actions to combat the impacts of climate change are less likely to be successful. In addition, wildlife will be more successful in adapting to climate change if these other stressors are absent than if they continue unabated. While managing these other factors is beyond the scope of this TCAP, practitioners should be aware of these threats and take action where possible. This list of outside stress factors includes pollution, competing demands for water, overgrazing, nutrient enrichment, introduction and spread of non-native species, and land development.

While a lot of research has examined the effects increasing temperature or altered water availability may have on organisms, many scientists are starting to suggest that the greater frequency of extreme weather events is likely to have as much, or even a greater, impact on shaping future ecosystems. For example, climate scientists now think that spells of extreme winter conditions, such as much of the United States experienced during the 2009-10 and 2010- 11 winters, maybe as much the signature of climate change as increased average daily temperatures. Extreme conditions will make anticipating how climate change will affect species and habitats much more challenging.

Landscapes will continue to change both as a direct effect of climate change and indirectly due to how Texans may interact with and alter their environment due to the adaptation of other sectors, such as agriculture, to climate change. This shifting and changing landscape may result in some habitats increasing, decreasing, or changing in structure and others appearing for the first time or disappearing. Maintaining a diversity of habitats is a goal of adaptation and may be achieved through habitat creation and restoration. An essential consideration is providing the range of habitat-patch characteristics species need to successfully establish, survive, and reproduce. Climate and habitat conditions can vary over very short distances, and many species are highly sensitive to these very small or microclimatic differences.

The best hedge against the uncertainty about exactly how climate change will manifest itself in Texas and its effects on species and habitats is improving connectivity between habitat patches and giving species room to disperse over large areas. With much of Texas' landscape under private land ownership, implementing this strategy will require large-scale cooperation among many partners.

As the climate continues to change and our understanding of the extent and impacts of that change expands, adaptation strategies will need review and possibly revision. Some species and habitats may become more abundant and others less. Accordingly, some conservation measures may become inappropriate over time, while others will be necessary. Monitoring of both species and strategy effectiveness will be essential.

Ecoregion-specific responses from stakeholders:
Within the Central Great Plains and Eastern Central Plains ecological regions, highly localized and intrinsically rare species will have few options to adapt as habitats shift, change, or disappear with climate change; options for transplanting or translocation are restricted as many of these habitats are edaphically specialized in the region (e.g. playas).

By the nature of their isolation and rarity, some habitats in the Arizona/New Mexico Mountains and Chihuahuan Deserts ecological regions, such as sky islands, montane grasslands and forests, and cienegas, are more vulnerable than others to changes in climate.

Isolated, rare, and water-dependent habitats found in the Eastern Central Plains and Edwards Plateau ecological regions may be more vulnerable to climatic changes. The habitats include wetlands, pockets of prairie grasslands, instream aquatic, bottomland hardwoods, wetland and water-dependent features such as riparian and instream habitats. Highly localized and intrinsically rare species associated with specific geologic features such as outcrops, ridges, mountain ranges, seeps, or springs will have few options to adapt as habitats shift, change, or disappear with climate change in this region. Options for transplanting or translocation are limited as many of these habitats are edaphically specialized in the region.

Shifts in habitats from grassland to shrubland vegetation shifts are anticipated and will affect this arid grassland ecoregion perhaps more than more temperate ecoregions in Texas.

Riparian and instream aquatic species' habitats may shift significantly with water availability and aquifers recharge from precipitation changes.

Additional Threats outside the standard lexicon

Some conservation threats or issues cited by staff, partners, and stakeholders are difficult to categorize with the standardized lexicon (Salafsky et al., 2008). These remaining issues are gathered here.

Inadequate Conservation Funding:
Conservation funding for non-game, rare, and declining species and habitats has always been challenging. Game species, which have defined hunting seasons and other regulations, receive dedicated legacy funding yearly through programs such as the Pittman-Robertson Wildlife Restoration Act and the Dingell-Johnson Sport Fish Restoration Act. On the other hand, non-game species and habitats, which are equally important, do not receive the same level of support.

If non-game species were funded per species level, similar to successful game species restoration, Texas would need about $50 million to implement the SWAP: Texas, as per the Texas Parks and Wildlife Department's 2019 report. However, this amount is still insufficient to complete many multi-year or multi-generational conservation projects. Unfortunately, no state currently has a reliable funding source to implement the necessary conservation actions to stabilize or reverse the decline of their SGCN.

In 2016, a group of former state politicians, environmental group representatives, academic researchers, business executives from outdoor equipment companies and the oil industry, and others recommended that the federal government allocate $1.3 billion annually to fund state conservation plans like SWAP: Texas (Blue Ribbon Panel on Sustaining America's Diverse Fish and Wildlife Resources).

In 2000, Congress created the State and Tribal Wildlife Grants program (SWG), which provides funding to states to implement their State Wildlife Action Plans for fish and wildlife species conservation. Unfortunately, though listed in Texas' state wildlife action plan, priority plant species are ineligible for funding under this program unless their conservation benefits SGCN fish, birds, or wildlife. Each year, Congress determines whether SWG will be apportioned, and a state's share of SWG may change. Until FY11, Texas annually received approximately $3.5 million in SWG funding to implement the State Wildlife Action Plan. In Fiscal Year 2011, SWG was reduced to near 2001 levels (Figure 5.10). The Alliance for

America's Fish and Wildlife, now a coalition of more than 175 member organizations, continues to strive for stable conservation funding.

Non-game species and habitats provide essential functions in every ecoregion, generating significant returns on recreational and economic drivers. They are dependent on conservation actions supported by annually fluctuating and diminishing funds, dedicated but few federal and state policymakers' support, and conservation grants through non-governmental organizations (which rely on charitable contributions, ever-fluctuating with economic swings). In the longer-term framework, conservation incentive programs struggle to remain competitive with other economic drivers, such as subsidies, crop insurance, and production markets. Habitat improvement, species restoration, recovery, and resiliency are long-term investments. In Texas, non-game conservation activities are primarily supported by non-governmental organizations, universities, and a few state programs.

Although Texas has an active and dedicated non-game program, the state budget for such activities is insufficient to implement the SWAP: Texas and prevent species from being added to the threatened and endangered species list. Dedicated, consistent, and directed funding sources are needed to hold and gain ground in conservation practice and to make progress toward preventing species' listings and downlisting currently listed species.

Lack of Information and Resources:
Limited information about SGCN and their habitats, distribution, needs, and causes for decline in Texas is available. This is mainly because Texas land is predominantly privately held, and very little statewide, coordinated research is conducted on private lands. Moreover, the data available to conservation planners may be scattered across many sources, with varying data standards and compatibility.

Challenges include insufficient or ineffective data sharing among natural resource professionals, public disconnection from natural resources, inadequate understanding of available or widely accepted conservation best management practices, and lack of focused outreach.

Additional challenges include a lack of data in terms of amount and type. Data is needed to make informed conservation decisions, listing and delisting decisions, and recovery recommendations. Examples include: information on distribution, population stability, and threats to small mammals, plants, and birds monitoring data for various ecosystems; data on freshwater aquatic SGCN and their tolerance to water quality and quantity changes; and recovery thresholds are needed for successful shortgrass prairie assemblages to craft specific management plans and recommendations.

Bottlenecks exist in entering data into the Texas Natural Diversity Database for conservation practitioners to view or use for monitoring or assessment. Species and habitats of conservation need on private lands may be more abundant than current data depicts. However, the lack of access to these sites prevents a complete understanding of how rare or common a species may be and limits cooperative stewardship and best management practices. Distribution, abundance, and trend information is needed specifically on SGCN breeding birds of riparian, shrubland, and grassland ecosystems, mountain lion range and effects on natural systems and ranching resources, distribution and health of spring systems, population distribution and stability of SGCN karst invertebrates, bats, other small mammals, amphibians, reptiles, and plants.

Species-specific monitoring needs: all breeding birds of riparian and montane ecosystems, including:

- Colima warbler
- common black hawk
- gray hawk
- mountain plover
- Montezuma quail
- northern aplomado falcon
- spotted owl
- Sprague's pipit
- summer tanager
- yellow-billed cuckoo
- mountain lion movements, effects on natural and ranching resources, population distribution, and stability
- Black Bear: see Black Bear Management Plan 2005-2015 http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_pl_w7000_1046.pdf
- Rafinesque's big-eared bat and Southeastern myotis– determine the potential for new roost locations
- Eastern spotted skunk – survey to determine status
- Houston Toad – more information needed in historical range, research needed re pond proliferation and breeding success dilution
- Texas Horned Lizards – identify areas of suitable habitat and survey to determine status in these areas; coordinate with red imported fire ant evaluation/survey to determine impact
- Amphibians and Reptiles: need a status update on all SGCN, primarily Timber Rattlesnake, Alligator Snapping Turtle, and Softshell turtles.
- eastern gamagrass-switchgrass-yellow Indiangrass-Maximilian sunflower (/)(G1/G2) and little bluestem-Indiangrass-big bluestem (G1/G2) prairie types – survey and revisit database accounts to ensure data is relevant and up to date.
- Painted Bunting, Scissor-tailed Flycatcher – large % of global breeding population, need to identify and publish Best Management Practices; evaluate STF use of urban areas (sink populations? Reasons for expansion into these areas? Management needs?)
- Bachman's Sparrow –Increase survey efforts along the western edge of the range to identify boundaries and suitable occupied habitats, such as within Red River County
- Freshwater Mussels – Continue documentation of distribution and status for all SGCN mussels, identify areas where most impacted and by what, craft management plans

Data Management:
Data from censuses, surveys, records, and collections are often stored in scattered or personal archives, making it difficult to detect trends and causes for upward or downward shifts in populations. Without this information, it is challenging to prioritize management objectives or share information with private landowners about the importance of certain sites, populations, or communities. This is especially important in Texas, where most of the land is privately owned, and conservation must occur with the help of landowners. Having access to this information would be beneficial in activities related to delisting and preventing listings.

Several websites and databases maintained by conservation practitioners all over the state provide information on fish distribution, rare species, poisonous plants, conservation lands, privately protected parcels, managed areas, planning zones, and more. However, to date, there is no single space where a field biologist or land trust coordinator can see on a map what resources occur and are relevant in their area to help hone their practice.

Few databases track species or habitats completely and continuously, and all of them are limited in their access to information on the land and in the water, human and financial resources to collect that information, and the time and effort it takes to manage data once collected. Of the 8,600+ rare species and plant community occurrence records in the Texas Natural Diversity Database (TXNDD; maintained by TPWD), nearly 85% of the records covering hundreds of species have not been monitored or updated since January 1st, 2000. Records are few compared to the number of rare species and the need for their distribution information to inform decision-making better. Few records since 2000 exist for fishes, invertebrates, amphibians, reptiles, or mammals. This database does not track all SGCN, rare communities, or actions are taken on their behalf.

The Natural History database maintained by the Nature Conservancy only covers species, communities, and geographic areas where they work. The Native Prairies Association is documenting the few intact native Blackland Prairies. Still, it does not have access to many private lands on which some of these examples may occur. This is just a small element of needed grassland information. The Texas Ecological Mapping Systems project is a valuable tool to see where certain important vegetation communities occur. However, we still have little information about species and rare communities in these larger types. The National Fish Habitat Action Plan is making strides in mapping watersheds where restoration and protection incentives may be most valuable, and their work improves as more information about species and habitat distribution is available to put in the models.

Species' and rare communities' distribution data must be current for a well-informed starting point for conservation delivery programs. In addition to the amount of currently available data, the data collection efforts need to be related to the most important issues of the conservation community – spatial and attribute data that are practically applicable to conservation in the field that can be shared to improve conservation practice. While single-species information is often important, the practice needs information about population and ecosystem health, relationships among species and systems, and threats (issues) that directly impact those systems. Practitioners need some way to share some level of standardized information in a useful way to develop best management practices, sound and meaningful data sets, and trend information so that future ecologists and landowners can understand more about the resources they care about and how to conserve them best.

Several web-based data collection and conservation practice sharing sites are available now (see Appendix IV in AFWA TWW 2011); however, Texas natural resources agencies and organizations do not use any of them in a coordinated way, given the fiscal constraints of many organizations and agencies, conferences and meetings are not the most feasible ways to deliver the amount and type of information to all who need it. Web-based tools accessible to all with a connection may best answer Texas's needs.

Relevancy:
Much of Texas and other border ecoregions have a very diverse bilingual or Spanish-speaking population. Conservation outreach messaging and incentives generally have not been crafted to influence and understand Hispanic and Latino/a audiences. With such a large percentage of the population that also uses and influences the resources not targeted for conservation messaging, effectiveness is highly variable and lower than it could be, especially in border urban areas where Rio Grande/Rio Bravo water

quality and quantity, riparian habitats, other water features (resacas, canals, wetlands) and certain brush and grassland communities are very important to SGCN.

An overarching concept in all of the issues presented so far in this document is a lack of effective information – how is it relevant to the problems we face, how is it presented and available to others, how do the project managers or developers get the information into the practical, appropriate application?

Inadequate Policies, Rules, Enforcement:
Conservation efforts can benefit from voluntary guidelines and compliance, but there are times when regulation becomes necessary. This is because voluntary measures may be insufficient to address the problem. However, even regulations may be ineffective due to limited funding, enforcement resources, or lack of political will. Certain regulations may also not be able to address emerging conservation issues or regulatory loopholes, such as poaching or the sale of prohibited species. Other concerns include inadequately regulated wetlands, outdated best management practices, and the lack of community-based natural resource management partnerships. State-listed threatened species and habitats for these species are also not adequately protected, and more enforcement ability is needed for nongame violations. Invertebrates, plants, and unregulated wild food animals are particularly vulnerable. Some project types may not be required to consult with natural resources agencies for environmental protection advice, and agencies may lack sufficient staff and information to handle the workload effectively.

In the Arizona/New Mexico Mountains and Chihuahuan Deserts, poaching, permitting avoidance, and violations are prevalent issues, with insufficient law enforcement for non-game concerns. Counties are large, and game wardens are few, which makes it difficult to protect plants, wildlife, and fisheries. Resources are stretched thin, as large landscapes, inaccessible areas, and border issues, such as human traffic, legal and illegal, complicate efforts.

Several carnivore species, including coyote, bobcat, and mountain lion, are routinely trapped, hunted, and killed in the region, with unregulated or inadequately regulated harvesting practices. However, it is unknown whether predator control activities are affecting the stability of these populations or their contribution to natural system function. Community-based solutions must be devised based on a full and accurately accounting of these populations and their effects on the natural systems and ranching communities in which they range. They are important contributors to these ecosystems.

Finally, the Edwards Plateau faces issues related to karst and cave features, with inadequate protections over the aquifer recharge zone to prevent impervious cover or fill in karst and cave habitats. These habitats contribute to groundwater and related surface water quality, quantity, or harbor unregulated SGCN. Special geologies are rarely protected unless the development approaches or exceeds water quality permitting thresholds.

Connectivity:
Land and habitat connectivity is an issue repeatedly in workshops, conversations, conferences, and other discussions. Connectivity is important for gene dispersal, seasonal and daily movements, water quality and quantity, and habitat for those species with more "interior" habitat needs (do not function well in edge habitats). Additionally, as species shift northward because of changing climate conditions, connections between habitat patches will be critical as animals seek new territories, search for food and

mates, and avoid predators. Connectivity is limited by reservoir development, high fencing, the “Border Wall,” transportation projects without adequate wildlife crossing or habitat island considerations, transmission line corridors maintained in a vegetation community incompatible with the surrounding native vegetation, and urban sprawl. Our development and planning activities can either enhance or completely sever habitats, which need to be connected to provide SGCN with their life history needs. One of the limitations to connectivity in Texas is the lack of spatial data available that could map all public and private conservation lands, intact best examples of certain habitats, and locations of functional SGCN populations, giving practitioners a better picture of where landowner incentives could be most effective to connect conservation delivery areas. Without connectivity, many of our riparian, prairie, and other grasslands, certain aquatic habitats, and migratory corridors lose their ability to function as a system; species and the benefits they provide drop out. In many cases, complete adjacency is not needed; rather, a series of habitat stepping stones can be beneficial.

Conservation Delivery:
Conservation success in Texas relies heavily on privately held lands, which comprise over 80% of the state's lands. To achieve this, landowner incentives and technical guidance are among the most effective delivery mechanisms. These incentives are usually provided by federal agencies such as NRCS Farm Bill programs and USFWS Partners Program, as well as state agencies such as Horned Lizard License Plate, state Landowner Incentive Program, and State Wildlife Grants. National conservation organizations such as Environmental Defense and Wildlife Conservation Society also provide grants to leverage federal programs and private funds on private lands for watershed scales.

These programs are designed to provide management practices like prescribed fire, herbicide and reseeding treatments, fencing, timber harvest, water development, and education opportunities such as workshops, technical guidance, and training. Private landowners must provide a financial match, typically 25 to 35% of the total project cost. Technical guidance includes a site assessment, a wildlife management plan that meets the landowner's objectives, and follow-up with the incentives mentioned above opportunities.

However, the need to be more proactive than reactive in conservation delivery is becoming increasingly important in Texas. With a growing urban population, more subdivided ranches, absentee landowners, and fewer large acreages, it is essential to identify areas of the highest conservation need and coordinate conservation-based objectives that deliver the most significant benefit to the environment on larger landscapes. Best management practices for all fish and wildlife resources, both game and non-game, must be implemented in their habitats.

Cross-purposes arise in conservation delivery when recommendations in some programs for brush removal, reseeding, fencing, and water development are incompatible with other area and regional conservation measures. This can encourage brush development, improve pasture or CRP lands with non-native seed sources, cause erosion control with non-native species, introduce exotic species for revenue generation, or recommend stocking or harvests incompatible with the site's capacity to generate native habitats. These practices conflict not because of conservation practitioners' deliberate intention to compete but because of the landowner's specific objectives and the service provider's obligation to customer service. To address these issues, realistic expectations for conservation versus non-conservation delivery programs must be set, and technical guidance that includes SGCN and priority habitats in site assessment, management planning, and a menu of options in front of landowners should be expanded.

Chapter 5 List of Figures

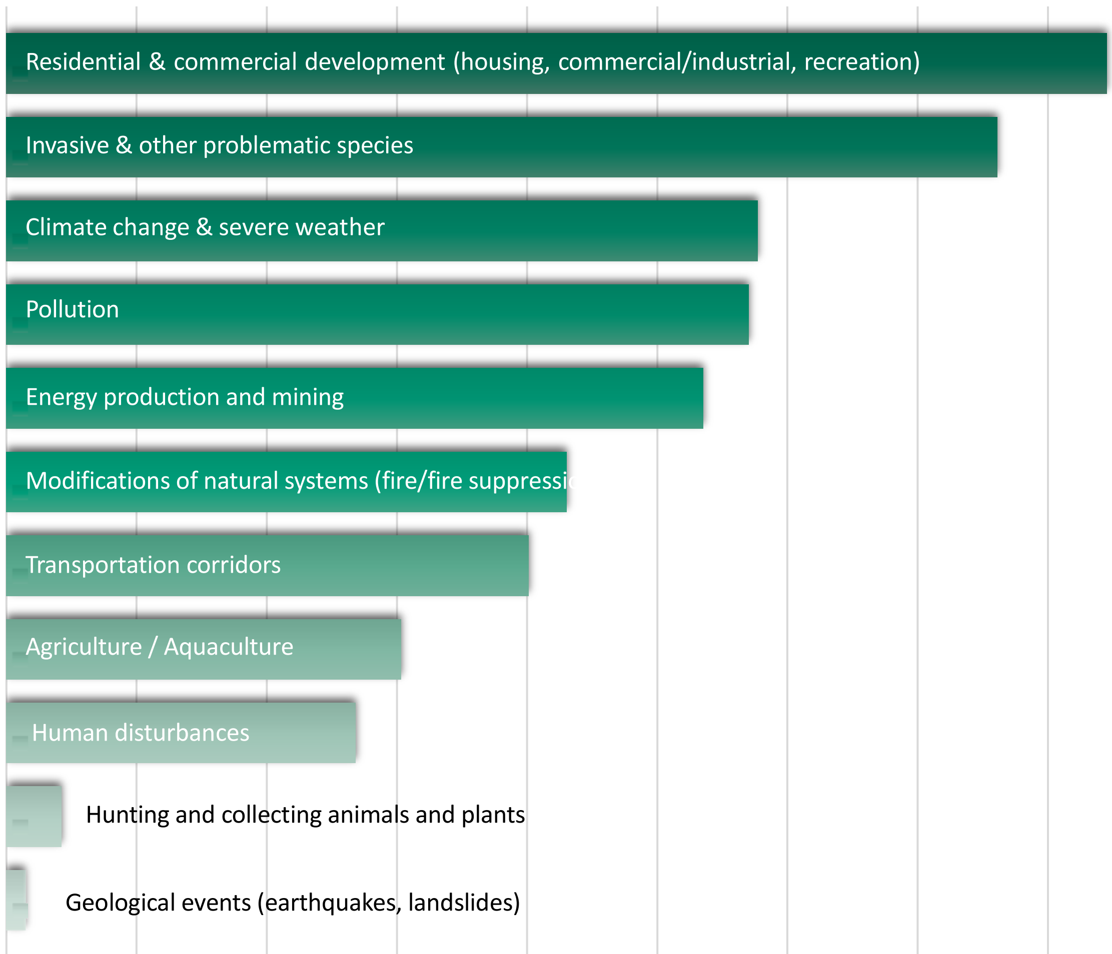

Figure 5.1: Conservation threats ranked in relative order of perceived impact by survey respondents

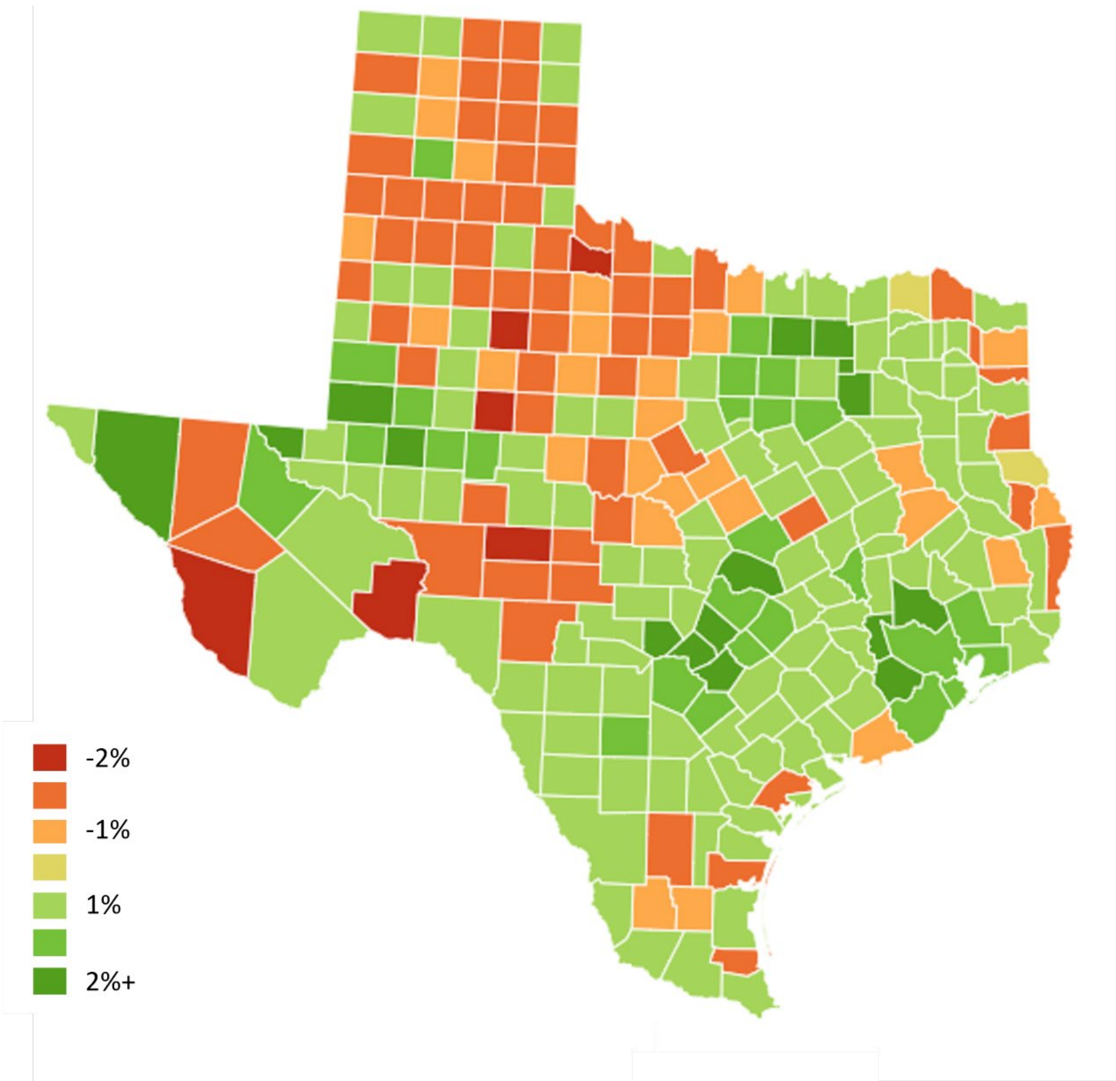

Figure 5.2. Change in human population by county in Texas, 2010 – 2018. The largest population increases happened in counties outside major cities, like the suburbs of Austin, Dallas, and Houston. Many rural counties experienced population declines between 2010 and 2018—source: U.S. Census Bureau, 2018 Population Projections by Stephanie Lamm, Dallas Morning News.

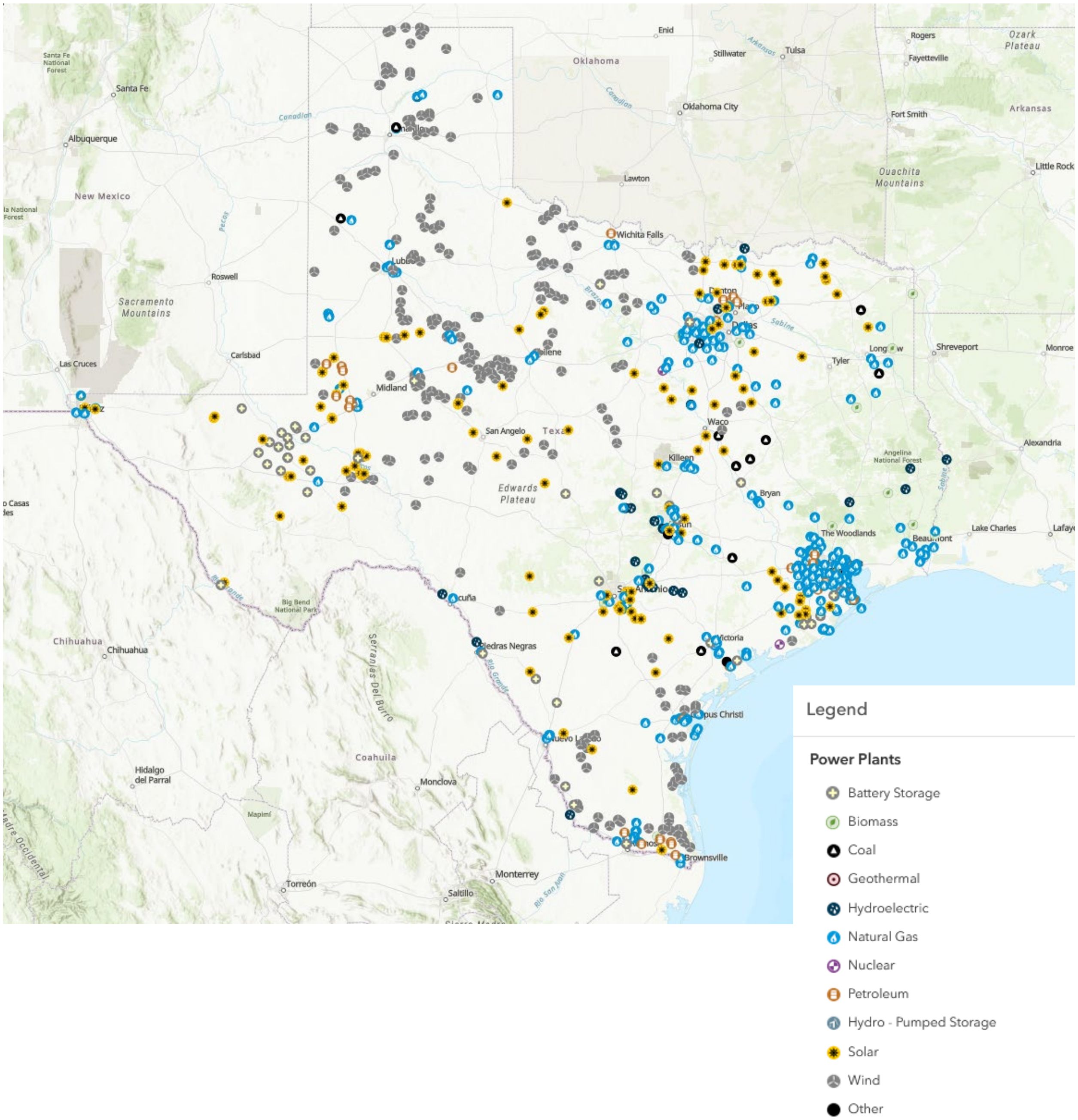

Figure 5.3. Power Plants in Texas (2023). Source U.S. Energy Atlas (https://eia.maps.arcgis.com/apps/mapviewer/index.html?layers=bf5c5110b1b944d299bb683cdbd02d2a). Retrieved November 2023.

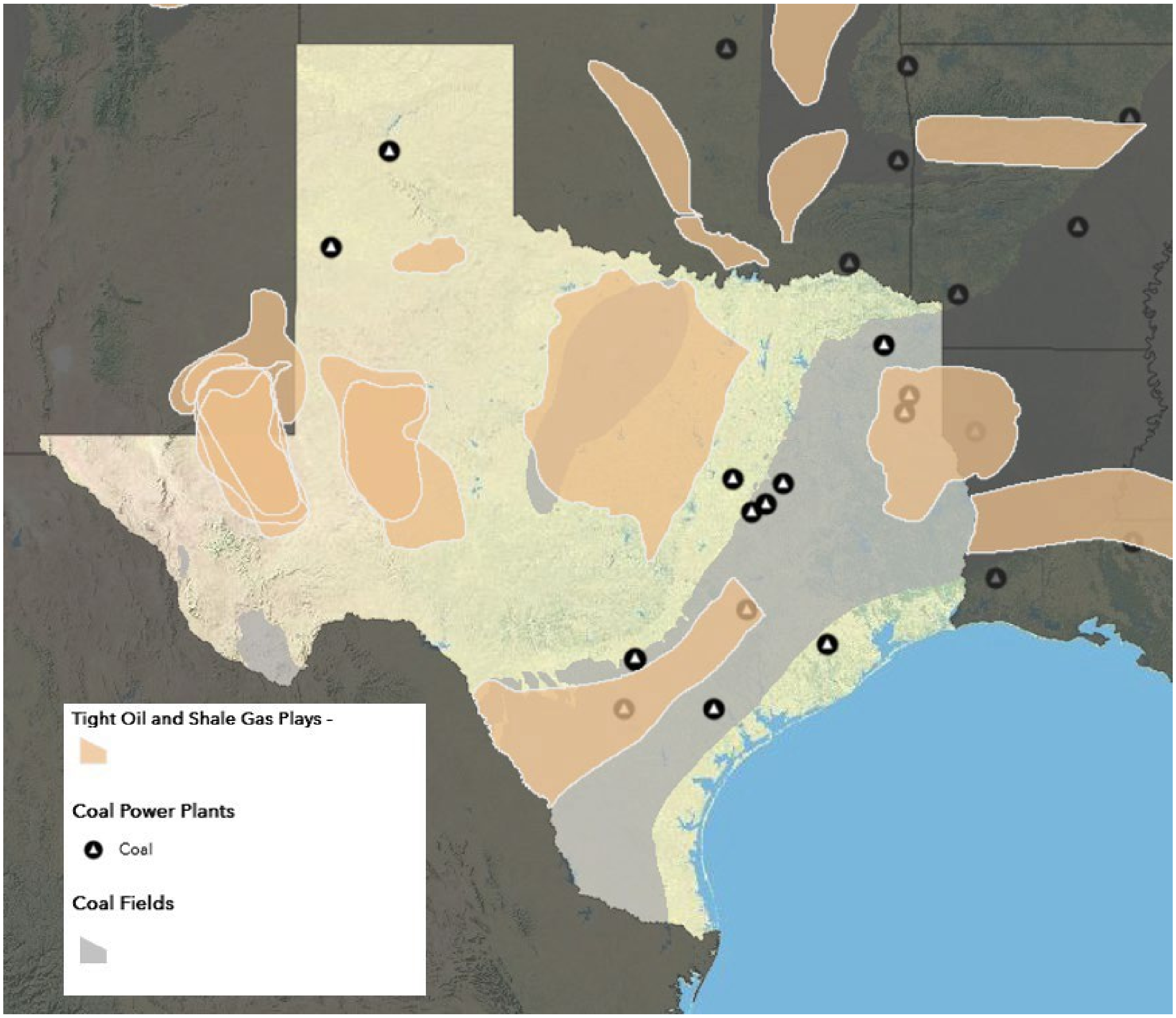

Figure 5.4. Texas Coal Power Plants, 2020, and energy-production zones. (U.S. Energy Information Administration, 2023)

Tight oil: light crude oil contained in unconventional petroleum-bearing formations.
Shale gas: unconventional natural gas trapped in shale formations. Both require hydraulic fracturing ("fracking") for economic extraction.
Plays are locations that exhibit similar geological characteristics and suggest potential for natural gas, oil, or similar resource extraction.

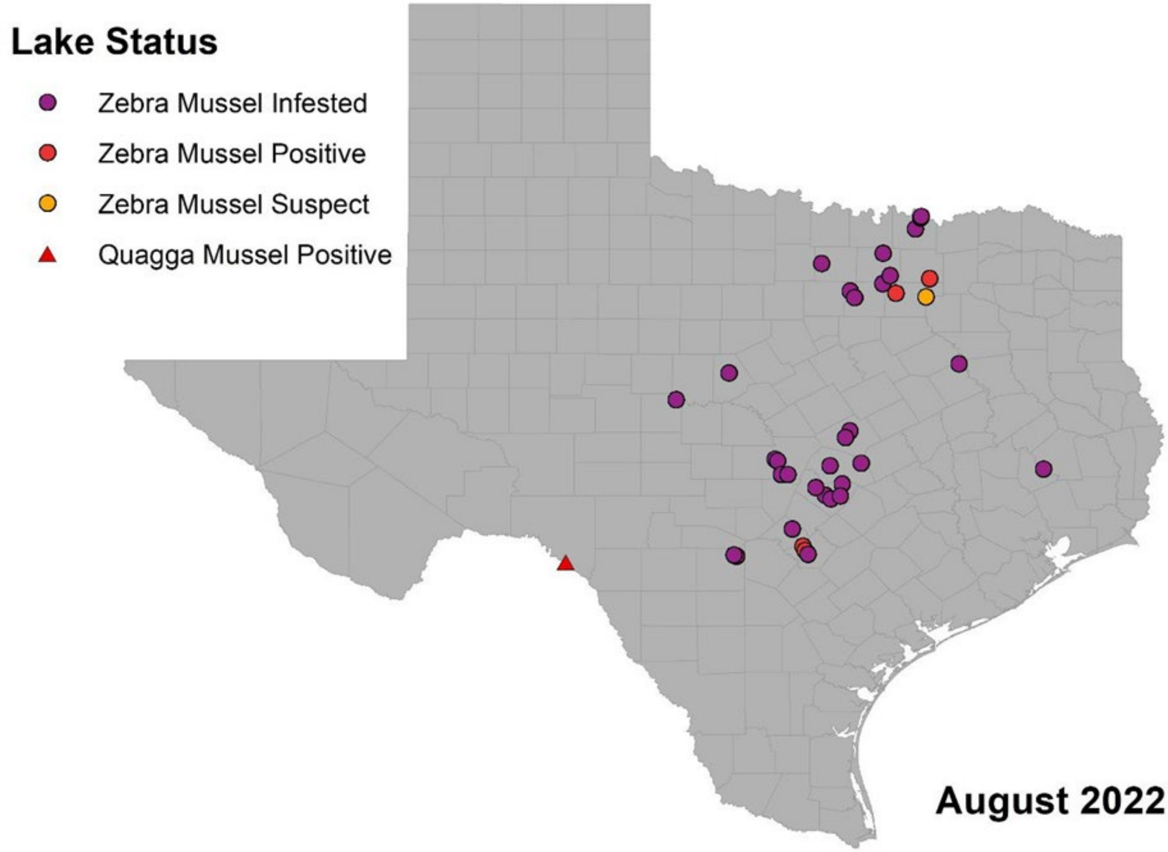

Figure 5.5. The location and status of Texas Lakes affected by Zebra and Quagga mussels, August 2022 (Texas Parks and Wildlife Department, 2022)

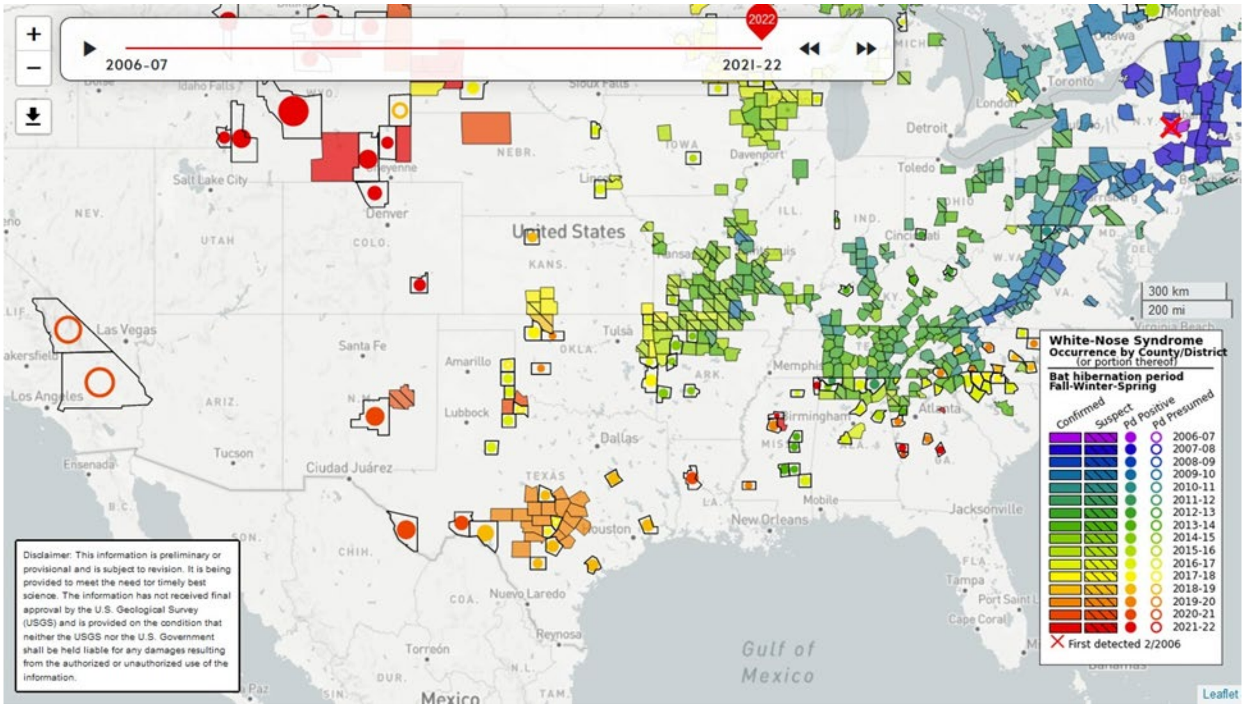

Figure 5.6. Distribution of known White-Nose Syndrome cases in the United States (White-Nose Syndrom Response Team, USFWS, 2022).

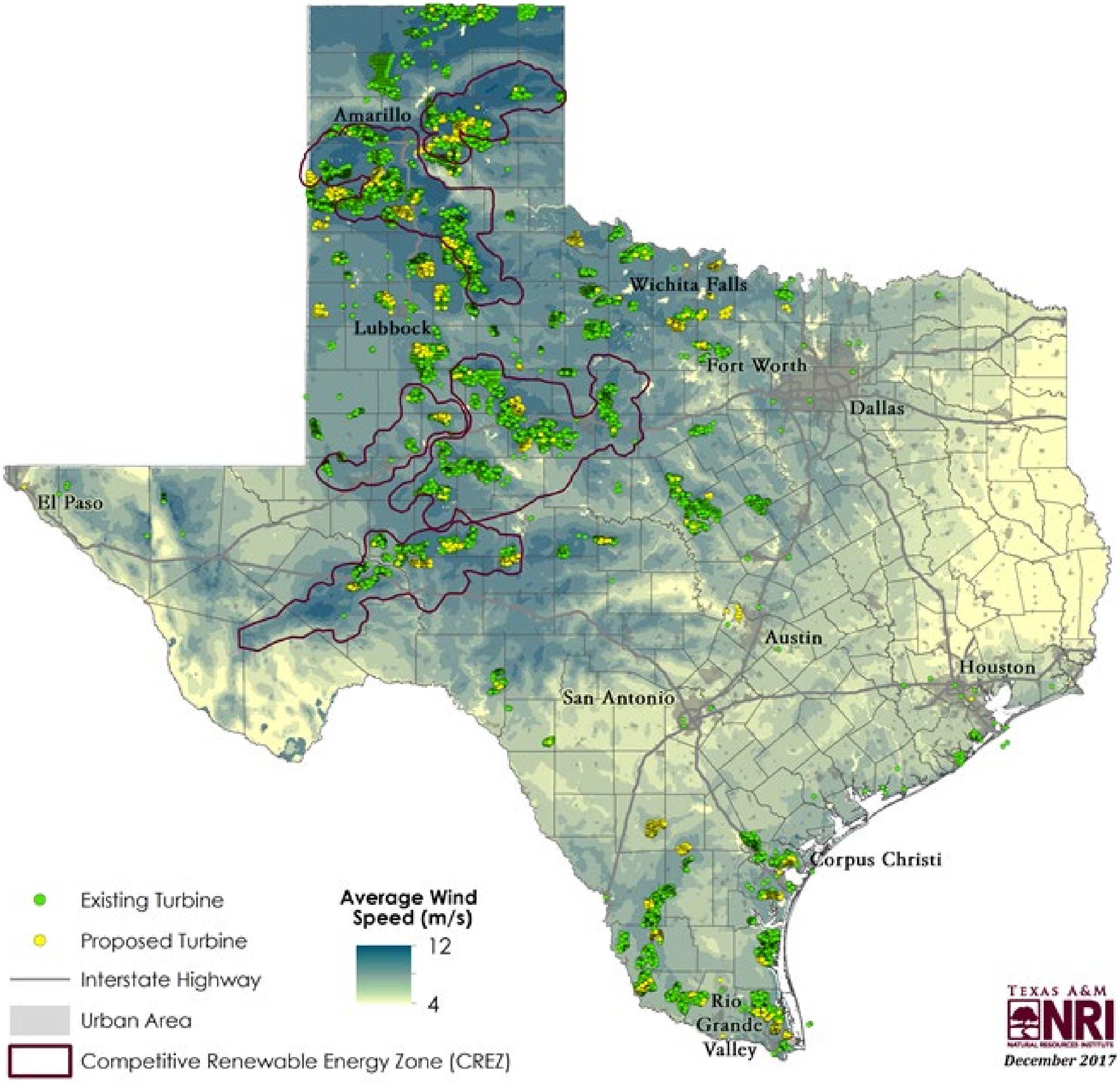

Figure 5.7. Wind Energy Potential Zones, Texas. Source: Map by Matt Crawford, Texas A&M Natural Resources Institute. https://nri.tamu.edu/blog/2017/december/map-of-the-month-wind-energy-in-texas/

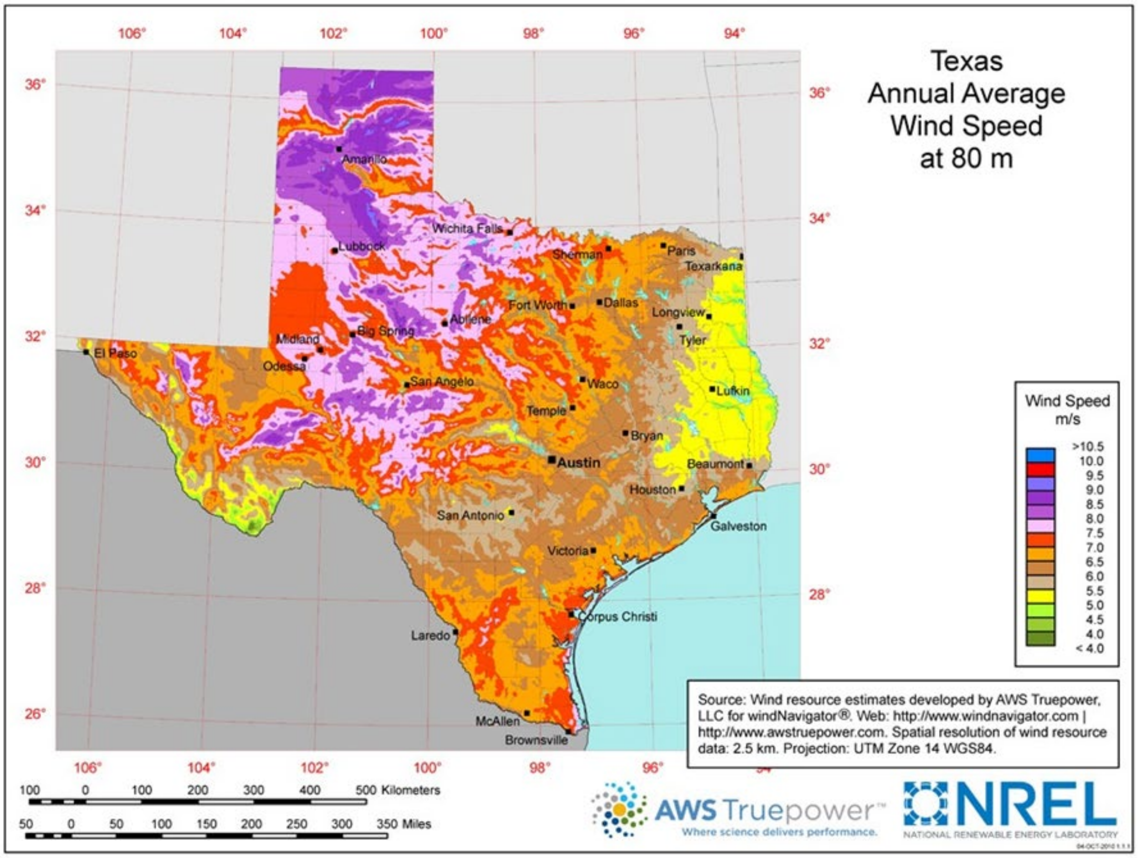

Figure 5.8. Texas 80-Meter Wind Resource Map. The wind resource map shows the predicted mean annual wind speeds at an 80-m height, presented at a spatial resolution of about 2 kilometers, that is interpolated to a finer scale for display. Areas with annual average wind speeds around 6.5 meters per second, and greater at 80 m height are generally considered to have a resource suitable for wind development. Utility-scale, land-based wind turbines are typically installed between 80- and 100 m high, although tower heights for new installations are increasing—up to 140 m—to gain access to better wind resources higher aloft.

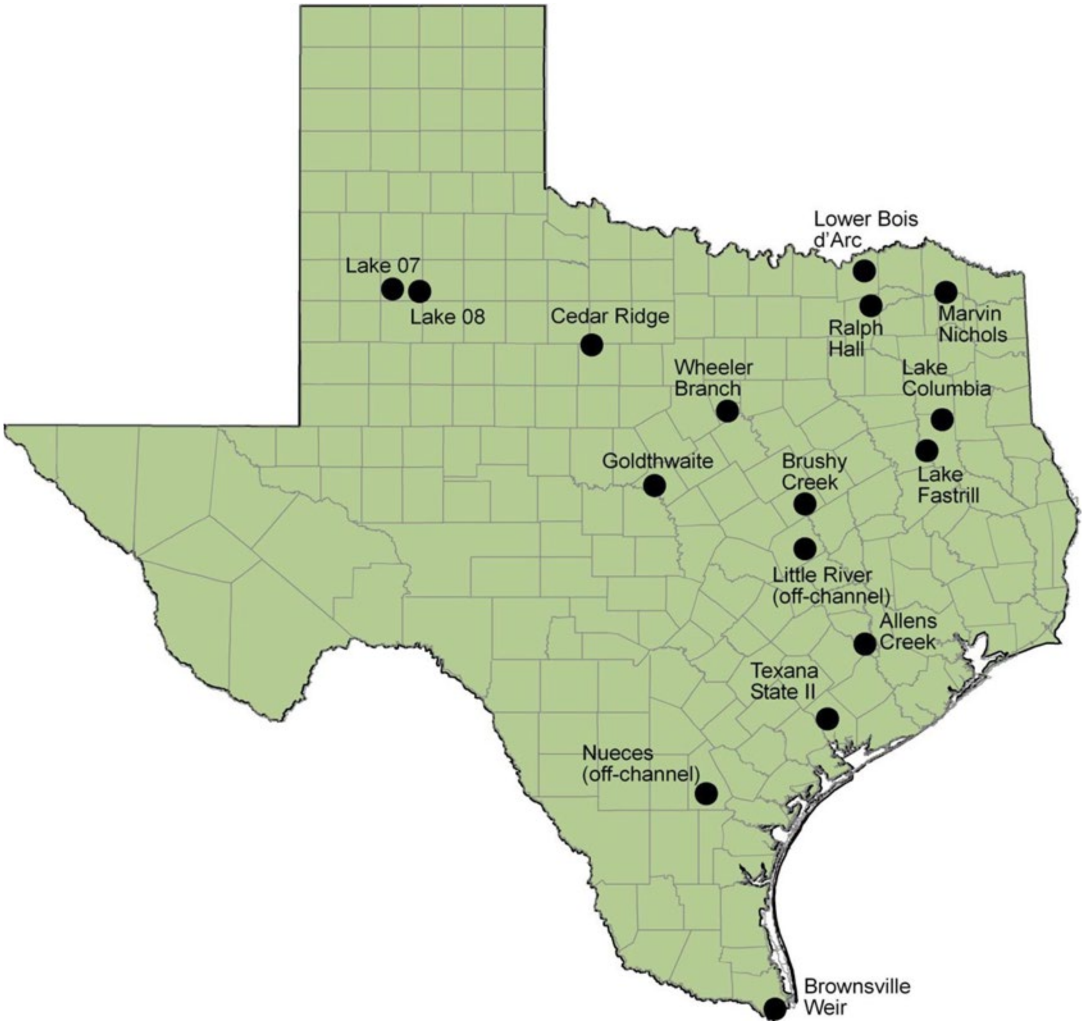

Figure 5.9. Proposed Dams/Reservoirs in the 2007 State Water Plan. Source: Texas Water Matters.
http://www.texaswatermatters.org/conservation_reservoirs.html

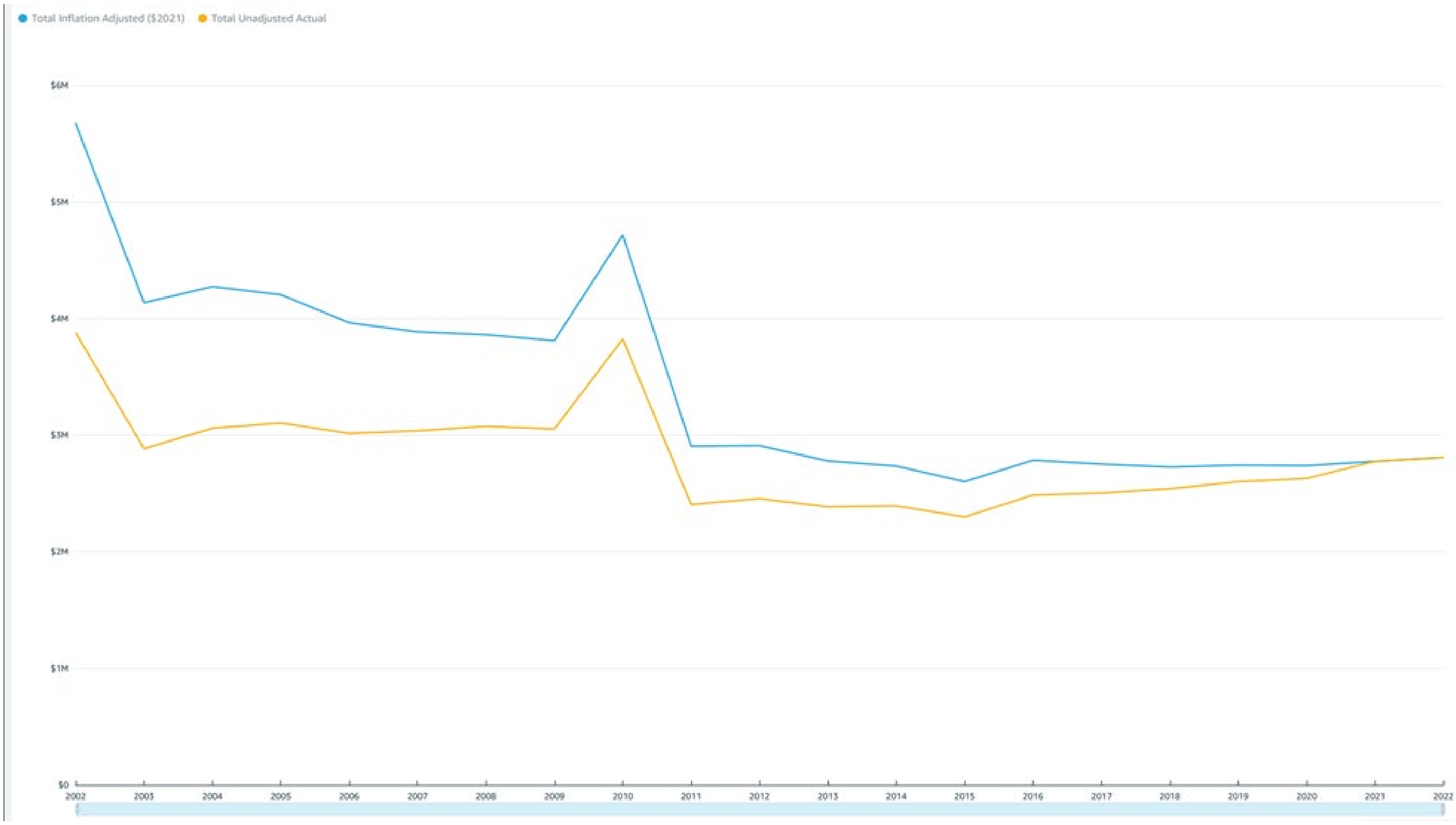

Figure 5.10. Texas Apportionment of State Wildlife Grant funding 2002 – 2022.

Supplement 5.1

Unified language describing threats to fish and wildlife conservation.

Descriptions of priority threats to SGCN populations (Element 3, Chapter 5) is organized according to the World Conservation Union-Conservation Measures Partnership (IUCN-CMP) classification of threats to biodiversity (Salafsky, et al., 2008). Unified language classifying and describing conservation threats assists conservation practitioners in communication and therefore advances knowledge more efficiently.

1.0 Residential and Commercial Development: human settlements or other nonagricultural land uses with a substantial footprint.

1.1 Housing and Urban Areas: human cities, towns, and settlements including non-housing development typically integrated with housing. Examples: urban areas, suburbs, villages, vacation homes, shopping areas, offices, schools, hospitals.

1.2 Commercial and Industrial Areas: factories and other commercial centers. Examples: manufacturing plants, shopping centers, office, parks, military bases, power plants, train and ship yards, airports.

1.3 Tourism and Recreation Areas: tourism and recreation areas tourism and recreation sites with a substantial footprint. Examples: ski areas, golf courses, beach resorts, cricket fields, county parks, campgrounds.

2.0 Agriculture and Aquaculture: Agriculture and aquaculture threats from farming and ranching as a result of agricultural expansion and intensification, including silviculture, mariculture, and aquaculture.

2.1 Annual and Perennial Non-Timber Crops: Crops planted for food, fodder, fiber, fuel, or other uses. Examples: farms, household swidden plots, plantations, orchards, vineyards, mixed agroforestry systems.

2.2 Wood and Pulp Plantations: Stands of trees planted for timber or fiber outside of natural forests, often with non-native species. Examples: Teak or eucalyptus plantations, silviculture, Christmas tree farms.

2.3 Livestock Farming and Ranching : Domestic terrestrial animals raised in one location on farmed or nonlocal resources (farming); also domestic or semidomesticated, animals allowed to roam in the wild and supported by natural habitats (ranching). Examples: cattle feed lots, dairy farms, cattle ranching, chicken farms, goat, camel, or yak herding.

2.4 Marine and Freshwater Aquaculture: Aquatic animals raised in one location on farmed or nonlocal. Also, hatchery fish allowed to roam in the wild. Examples: Shrimp or fin fish aquaculture, fishponds on farms, hatchery salmon, seeded shellfish beds, artificial algal beds.

3.0 Energy Production and Mining: Threats from production of nonbiological resources.

3.1 Oil & Gas Drilling: Exploring for, developing, and producing petroleum and other liquid hydrocarbons. Examples: Oil wells, deep sea natural gas drilling.

3.2 Mining and Quarrying: Exploring for, developing, and producing minerals and rocks. Examples: Coal mines, alluvial gold panning, gold mines, rock quarries, coral mining, deep sea nodules, guano harvesting.

3.3 Renewable Energy: Exploring, developing, and producing renewable energy. Examples: Geothermal power production, solar farms, wind, farms (including birds flying into windmills), tidal farms.

4.0 Transportation and Service Corridors: Threats from long, narrow transport corridors and the vehicles that use them including associated wildlife mortality.

4.1 Roads and Railroads: surface transport on roadways and dedicated tracks. Examples: Highways, secondary roads, logging roads, bridges, and causeways, road kill, fencing associated with roads, railroads.

4.2 Utility and Service Lines: Transport of energy and resources. Examples: Electrical and phone wires, aqueducts, oil and gas pipelines, electrocution of wildlife.

4.3 Shipping Lanes: Transport on and in freshwater and ocean waterways. Examples: Dredging, canals, shipping lanes, ships running into whales, wakes from cargo ships.

4.4 Flight Paths: Air and space transport. Examples: Flight paths, jets impacting birds.

5.0 Biological Resource Use: Threats from consumptive use of “wild” biological resources including deliberate and unintentional harvesting effects; also persecution or control of specific species.

5.1 Hunting and Collecting Terrestrial Animals: killing or trapping terrestrial wild animals or animal products commercial, recreation, subsistence, research or cultural purposes, or for control/persecution reasons; includes accidental mortality/bycatch. Examples: bushmeat hunting, trophy hunting, fur trapping, insect collecting, honey or bird nest hunting, predator control, pest control, persecution.

5.2 Gathering Terrestrial Plants: Harvesting plants, fungi, and other nontimber/nonanimal products for commercial, recreation, subsistence, research or cultural purposes, or for control reasons. Examples: Wild mushrooms, forage for stall fed animals, orchids, rattan, control of host plants to combat timber diseases.

5.3 Logging and Wood Harvesting: Harvesting trees and other woody vegetation for timber, fiber, or fuel. Examples: Clear cutting of hardwoods, selective commercial logging of ironwood, pulp operations, fuel wood collection, charcoal production.

5.4 Fishing and Harvesting Aquatic Resources: Harvesting aquatic wild animals or plants for commercial, subsistence, research, or cultural purposes, or for control/persecution reasons; includes accidental mortality/bycatch. Examples: Trawling, blast fishing, spear fishing, shellfish harvesting, whaling, seal hunting, turtle egg collection, live coral collection, seaweed collection.

6.0 Human Intrusions and Disturbance: Threats from human activities that alter, destroy and disturb habitats and species associated with nonconsumptive uses of biological resources.

6.1 Recreational Activities: People spending time in nature or traveling in vehicles outside of established transport corridors, usually for recreational reasons. Examples: Off-road vehicles, motorboats, jet-skis, snowmobiles, ultralight planes, dive boats, whale watching, mountain bikes, hikers, birdwatchers, skiers, pets in rec areas, temporary campsites, caving, rock-climbing.

6.2 War, Civil Unrest, and Military Exercises: Actions by formal or paramilitary forces without a permanent footprint. Examples: Armed conflict, mine fields, tanks and other military vehicles, training exercises and ranges, defoliation, munitions testing.

6.3 Work and Other Activities: People spending time in or traveling in natural environments for reasons other than recreation or military activities. Examples: Law enforcement, drug smugglers, illegal immigrants, species research, vandalism.

7.0 Natural System Modification: Threats from actions that convert or degrade habitat in service of "managing" natural or seminatural systems, often to improve human welfare.

7.1 Fire and Fire Suppression: Suppression or increase in fire frequency and/or intensity outside of its natural range of variation. Examples: Fire suppression to protect homes, inappropriate fire management, escaped agricultural fires, arson, campfires, fires for hunting.

7.2 Dams and Water Management Use: Changing water flow patterns from their natural range of variation deliberately or as a result of other activities. Examples: Dam construction, dam operations, sediment control, change in salt regime, wetland filling for mosquito control, levees and dikes, surface water diversion, groundwater pumping, channelization, artificial lakes.

7.3 Other Ecosystem Modification: Other actions that convert or degrade habitat in service of "managing" natural systems to improve human welfare. Examples: Land reclamation projects, abandonment of managed lands, rip-rap along shoreline, mowing grass, tree thinning in parks, beach construction, removal of snags from streams.

8.0 Invasive and Other Problematic Species and Genes: Threats from non-native and native plants, animals, pathogens/microbes, or genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread and/or increase in abundance.

8.1 Invasive Non-Native / Alien Species: Harmful plants, animals, pathogens and other microbes not originally found within the ecosystem(s) in question and directly or indirectly introduced and spread into it by human activities. Examples: Feral cattle, household pets, zebra mussels, Dutch elm disease or chestnut blight, Miconia tree, introduction of species for biocontrol, Chytrid fungus affecting amphibians outside of Africa.

8.2 Problematic Native Species: Harmful plants, animals, or pathogens and other microbes that are originally found within the ecosystem(s) in question, but have become "out of balance" or "released" directly or indirectly due to human activities. Examples: Overabundant native deer, overabundant algae due to loss of native grazing fish, native plants that hybridize with other plants, plague affecting rodents.

Introduced fishes and mollusks: Within streams, nonnative species compete with natives, and are a predation risk. Examples: Bait fish releases ("minnows") can cause problematic congeneric hybridization (e.g. Gambusia sp).

8.3 Introduced Genetic Material: Human-altered or transported organisms or genes. Examples: Pesticide resistant crops, hatchery salmon, restoration projects using nonlocal seed stock, genetically modified insects for biocontrol, genetically modified trees, genetically modified salmon.

9.0 Pollution: Threats from introduction of exotic and/or excess materials or energy from point and nonpoint sources

9.1 Household Sewage and Urban Wastewater: Water-borne sewage and nonpoint runoff from housing and that include nutrients, toxic chemicals and/or sediments. Examples: Discharge from municipal waste treatment plants, leaking septic systems, untreated sewage, outhouses, oil or sediment from roads, fertilizers and pesticides from lawns and golf-courses, road salt.

9.2 Industrial and Military Effluents: Water-borne pollutants from industrial and military sources including mining, energy production, and other resource extraction industries that include nutrients, toxic chemicals and/or sediments. Examples: Toxic chemicals from factories, illegal dumping of chemicals, mine tailings, arsenic from gold mining, leakage from fuel tanks, PCBs in river sediments.

9.3 Agricultural and Forestry Effluents: Water-borne pollutants from agricultural, silivicultural, and systems that include nutrients, toxic chemicals and/or sediments including the effects of these pollutants on the site where they are applied. Examples: Nutrient loading from fertilizer runoff, herbicide runoff, manure from feedlots, nutrients from aquaculture, soil erosion.

9.4 Garbage and Solid Waste: Rubbish and other solid materials including those that entangle wildlife. Examples: Municipal waste, litter from cars, flotsam and jetsam from recreational boats, waste that entangles wildlife, construction debris.

9.5 Air-Borne Pollutants: Atmospheric pollutants from point and nonpoint sources. Examples: Acid rain, smog from vehicle emissions, excess nitrogen deposition, radioactive fallout, wind dispersion of pollutants or sediments, smoke from forest fires or wood stoves.

9.6 Excess Energy: Inputs of heat, sound, or light that disturb wildlife or ecosystems. Examples: Noise from highways or airplanes, sonar from submarines that disturbs whales, heated water from power plants, lamps attracting insects, beach lights disorienting turtles, atmospheric radiation from ozone holes.

10.0 Geological Events: Threats from catastrophic geological events.

10.1 Volcanoes: Volcanic events. Examples: Eruptions, emissions of volcanic gasses.

10.2 Earthquakes / Tsunamis: Earthquakes and associated events. Examples: Earthquakes, tsunamis.

10.3 Avalanches / Landslides: Avalanches or landslides. Examples: Avalanches, landslides, mudslides.

11.0 Climate Change and Severe Weather: Long-term climatic changes that may be linked to global warming and other severe climatic or weather events outside the natural range of variation that could wipe out a vulnerable species or habitat.

11.1 Habitat Shifting and Alteration: Major changes in habitat composition and location. Examples: Sea-level rise, desertification, tundra thawing, coral bleaching.

11.2 Droughts: Periods in which rainfall falls below the normal range of variation. Examples: Severe lack of rain, loss of surface water sources.

11.3 Temperature Extremes: Periods in which temperatures exceed or go below the normal range. Examples: Heat waves, cold spells, oceanic temperature changes, disappearance of glaciers/sea ice.

11.4 Storms and Flooding: Extreme precipitation and/or wind events or major shifts in seasonality of storms. Examples: Thunderstorms, tropical storms, hurricanes, cyclones, tornados, hailstorms, ice storms or blizzards, dust storms, erosion of beaches during storms.

Chapter 6

Priority Conservation Actions (Element 4)

Action Types and Definitions

The fourth required element in State Wildlife Action Plans is *Element 4: Descriptions of conservation actions proposed to conserve the identified species habitats and priorities for implementing such actions.* The Priority Conservation Actions in the *SWAP: Texas* plan aims to improve the conditions for priority species and habitats while reducing the adverse effects of priority conservation threats. To measure progress and effectiveness, the *SWAP: Texas* recommends applying full-cycle management from *Open Standards of Conservation Practice, Measuring the Effectiveness of State Wildlife Grants* (2020). The toolkit in *Measuring the Effectiveness of State Wildlife Grants* (AFWA 2011) is also strongly recommended to assist project coordinators in defining projects, identifying their target audiences and partners, collecting the correct data to report conservation achievements, and demonstrating the positive impact of projects on species and habitats.

To achieve the highest benefits to SGCN, priority communities, and their habitats, the following actions are recommended to counter the effects of Priority Conservation Threats. The list is not exhaustive but represents the actions identified by local and state-level conservation practitioners, private landowners, academicians, and other stakeholders. This list is intended to be refined and revised in subsequent plan revisions. The *SWAP: Texas* adopts the definitions and hierarchical classification standard of NatureServe, and according to that format, the Priority Actions are organized based on scale, topic, and feasibility. In the 2023 revision, suggested actions from all ecological regions in the 2013 TCAP were compiled, and redundant or obsolete actions were removed. Conservation actions are divided into the following categories:

1. Land/Water Protection
2. Land/Water Management
3. Species Management
4. Education and awareness
5. Law and policy
6. Livelihood, economic, and other incentives
7. External capacity building

Further descriptions, subcategories, and examples of each action category can be found in *Supplement 6.1, "Unified language describing conservation threats and priority actions for fish and wildlife conservation"* (often referred to as the "standard" or "common lexicon"). Within each category, actions are generally in order from most general with most extensive geographic applications to most specific with the most precise geographic applications. For example, an action that could be taken anywhere in the state will be listed before an action most specifically tailored to a playa lake in northwest Texas. Because the *2013 TCAP* had not yet adopted the standard lexicon, priority conservation actions identified in that edition were compiled into the new standard lexicon in the *2023 SWAP: Texas* whenever possible and numbered according to the structure of that lexicon (e.g., "**Site/Area Protection (1.1)**").

This list represents the best available knowledge of the time and is intended to be expanded and refined with time.

Priority Conservation Actions

1.0 Land and Water Protection

Land and Water Protection are actions to identify, establish, or expand parks and other legally protected areas and to preserve resource rights.

Site and area protection (1.1)

The Texas Ecosystem Analytical Mapper has identified critical rare habitats that must be defined, ground-truthed, monitored, and updated. To preserve these habitats, we must locate high-quality large blocks of the Priority Habitats and focus on individual technical guidance. We can use the National Wetlands Inventory, Texas Ecosystem Analytical Mapper data, and other imaging resources to identify intact, remaining priority habitats and create a data layer that can be used to help conserve these features during project development and conservation planning efforts.

We should work with industry partners to protect habitats and mitigate industry practices when necessary. Some industries, such as oil and gas development, water management and desalination, and mining, have been identified as potentially harmful to habitats. We need to determine the effects of these practices on waterways, groundwater, and terrestrial habitats and take appropriate measures to avoid potential groundwater contamination, remediate when necessary, and restore the habitats to their native conditions post-operations.

We should also find creative solutions to minimize and mitigate industry impacts on listed species, especially small fossorial and limited-range mammals, reptiles, and rare plants. For transportation planning and protection, we must take protective measures for water quality at important crossings and upstream of aquatic populations and identify significant riparian corridors for conservation.

Maintenance dredging recommendations by waterway must be crafted based on navigation districts' needs to widen or deepen channels or add capacity to port facilities and channels based on ecologically desired conditions, avoidance areas, and mitigation measures before projects come to USACE and other entities' environmental review.

For power development and transmission, we should avoid migration corridors for raptors, neotropical migrants, nocturnal migrants, stopover habitats for Whooping Cranes, concentrations of black-capped vireo and other vital habitats, and bat concentrations.

Agriculture must retain streamside and field-side buffers of native dense vegetation to assist with runoff control and treatment before "discharge" into any waterway. We should also consider conservation practice incentives to encourage the use of stormwater pollution prevention practices and identify areas in windrows, crop corners, and fenceline habitats where management could benefit grassland or shrubland-dependent birds, contribute to riparian conservation through streamside buffers and conserve rare plants and communities. Finally, we should work with local landowners and planning partners to identify and designate Important Bird Areas, primarily for grasslands.

Resource and habitat protection (1.2)

To ensure the resiliency of Texas' ecosystem in the face of climate change, it is crucial to use available data and locally adapted modeling tools, such as the Texas Ecosystem Analytical Mapper, to identify the potential effects of climate change. These effects can include sea level rise, shoreline erosion, saltwater incursion, loss of cold-water habitats, increase in and more frequent stand-replacing fires, among others. By identifying the priority habitats in Texas that are most vulnerable to these effects, we can develop strategies to conserve them and mitigate the impact of climate change.

To conserve existing biodiversity in Texas, we can take several steps. Firstly, we can protect high-quality habitats, including protected areas, and the range and ecological variability of habitats and species. Secondly, we can build replication within protected-area networks. Finally, we can develop ecologically resilient and varied landscapes by identifying and protecting relatively intact landscapes that will serve as core conservation actions, establishing buffers through a variety of conservation activities along rivers and coasts to facilitate natural migration of watercourses, improving management and restoration of existing protected areas to enhance resilience, and establishing ecological corridors through habitat restoration and conservation.

We need to implement an adaptive management framework to ensure that our conservation efforts remain effective. This framework should respond to changing conservation priorities as new information is collected and analyzed and establish long-term monitoring objectives that will serve as the basis of adaptive management.

Use information discovered through the Texas Native Fish Conservation Areas Network (Figure 6.1) (Birdsong et al., 2019) to identify and protect vulnerable and ecologically essential waterways.

The protection of riparian areas in and around priority Native Fish Conservation Areas is crucial. It involves restoring and maintaining functional watershed processes, freshwater habitats, and native species while also supporting human necessities like flood control, municipal and agricultural water supply, water quality protection, and water-based recreation.

It is important to develop specific water quality standards for estuaries. Current standards are based on freshwater rivers and streams and do not account for unique estuarine processes like tides and seasonal stratification which can significantly impact the quality of estuary water.

To protect serpulid reefs, we should designate them as a conservation area or state scientific area using the International Union of Concerned Scientists' Conservation Area Designation effectiveness measures.

The wintering range of the Whooping Crane must be protected. By doing so, we can also benefit other species like the Reddish Egret, Brown Pelican, White-faced Ibis, Wood Stork, Bald Eagle, White-tailed Hawk, and Peregrine Falcon by preserving their habitat complexes.

2.0 Land and Water Management

Land and Water Management actions are directed at conserving or restoring sites, habitats, and the wider environment.

Site and area management (2.1)

The Ecological Mapping Systems of Texas geospatial analysis tool is a crucial project that needs to be created and maintained. This tool is a 398 class, 10-meter spatial resolution current vegetation map of the state of Texas. It can be utilized by a wide variety of partners in Texas for conservation planning and management. These include species habitat modeling, habitat mitigation, landowner incentive programs, urban planning, and habitat mitigation. The current efforts are focused on incorporating higher resolution satellite Sentinel 2 imagery, Lidar, and additional ground data.

To protect vulnerable ecological communities from the negative effects of climate change, the development of site-specific climate change models is necessary. These models should be used to predict the effects of climate change on isolated habitats, riparian areas, springs/groundwater resources grasslands, and shrublands. The information gathered from these models should be utilized to develop climate resiliency plans. The efforts should be focused on areas identified as SGCN conservation opportunities via the Texas Ecological Mapping System (TPWD 2023).

The conservation efforts in urban and suburban areas should include technical guidance, education, outreach, interpretation, and original research and discovery. The urban wildlife biologist's technical guidance should aim to assist city planners, boards, councils of government, corporations, and other entities charged with land development planning and land management. Urban community science such as iNaturalist.org and TexasInvasives.org should also be included. Partnerships with urban scholarship, science, and ecological advocacy and education organizations should be established to increase understanding and participation in local conservation issues and opportunities. Examples include Texas Master Naturalists, iNaturalist City Nature Challenge, Historically Black Colleges and Universities (HBCUs), Hispanic-Serving Institutions (HSIs), community colleges, and other institutions specifically serving local residents, and Bird City USA / Texas Bird Cities.

To prioritize habitats identified in the Texas Native Fish Conservation Areas Network, resources, and management attention should be given. The threats identified in "Conservation of Texas Freshwater Fish Diversity Selection of Species of Greatest Conservation Need" should also be addressed.

The Environmental Flows Advisory Group should have the most up-to-date information related to fish and wildlife needs for public hearings and public policy implications for balancing the demands on the water resources of Texas. Public land managers should also be supported to create site-specific "action plans" to hone management. Collaboration with willing landowners, land trusts, and other potential partners to connect important habitats and resources across ownerships is necessary. Public properties for which natural resources management is a component of their mission should be the best demonstration sites for natural resources management, conservation, and recovery practices, and interpretation, based on the best science available. The evaluation of infrastructure and development impacts to SGCN, especially SGCN plants and rare plant communities, water quality, and work with TPWD technical guidance biologists to identify conservation opportunities, prescribe habitat management, and demonstrate habitat monitoring processes is important.

The public should have access to information on priority conservation on the SWAP Portal. Conservation-based, scientifically supported Best Management Practices for priority habitats identified in this plan should be posted on a TPWD Portal that is connected to Technical Guidance, Landowner Outreach, Specific Resources internet pages, and Environmental Review.

A multi-disciplinary ecology committee should be created to identify three to five years of highest-priority research projects of importance at the local level. These projects can be presented to universities and colleges to collect the most needed information at the practical level for management and conservation improvement on the ground.

Brush management (native problematic species): Identify Best Management Practices by ecoregion for ecologically acceptable brush management, accounting for impacts to priority habitats and SGCN in this plan.

Improve water quality during construction and in the final structures through better building practices and materials.

When developing Total Maximum Daily Load (TMDL) recommendations, ensure that natural resources needs are included. Include recommendations for both in-stream and stream-adjacent springs, seeps, and other tributaries.

Protect shorelines by establishing development setbacks from dunes, beaches, rookeries, and floodways.

Park and open space development: Plan for habitat connectivity, with consideration of daily and seasonal movements. Prioritize grassland restoration (coastal prairie, short grass prairie, etc), riparian and streamside protection, water quality protection, floodplain conservation, and mitigation banks for in-jurisdiction projects.

Water quality protection through stormwater-pollution prevention plans, vegetation improvement (natural water slowing, recharge, flood prevention, erosion control), and facilities rather than armoring, leaving natural floodways intact.

Invasive species spread prevention and removal in public land, rights of way, planned developments (e.g. encourage native plant use in new housing areas, incentives for landscape conversion to natives especially in areas near waterways)

Agricultural: Provide access to technical guidance for habitat conservation. Habitat management prescriptions may include:

- Recommend alternating crops in the same field to reduce erosion and build soil fertility.
- Planting row crops followed by wheat or other small grains the next year provides habitat diversity for quail.
- Farmland “rest” incentives should promote the installation of native grasses and forbs.
- More permanent conservation options should be incentivized and documented.
- Remove dense sod-forming monoculture grasses. Thick mats of grass hinder native wildlife movement (quail, Houston toad) and make feeding and burrowing difficult or impossible. Native warm-season grasses, properly managed, provide cover and food. Mixing legumes with grasses improves the habitat for young quail.
- Leave brushy or grassy borders around fields/orchards. These borders can help with erosion and if left un-mowed can provide nesting areas.
- Encourage remediation and open space sites to focus on native grassland restoration. More public grasslands, especially those in urban “demonstration” areas at a large enough scale to be ecologically viable should be promoted.

Where wildlife and fisheries management are not the primary objective and where livestock production is the primary objective, refer landowners to partners who can assist them with best management practices for rotational and site-appropriate grazing management.

Protect fishery nursery habitat (e.g. eastern arm of Matagorda Bay); document the relationship of commercial fishing practices and changes to SGCN resiliency and recovery. Use regulation and outreach effectiveness measures.

Energy production: Develop a short list of best management practices for site assessment prior to operations (e.g. karst connectivity to the aquifer, surface, and karst interior rare species survey), water quality protection, and aquatic feature adjacent vegetation protection for oil and gas operators.

Invasive/nuisance species control (2.2)
The Texas Ecological Systems Mapping Invasive Species Distribution Project (visit http://www.texasinvasives.org/i101/ecoalert.php) can be used to identify and prioritize the most critical habitats for conservation and restoration. Here are some industrial partnerships that can help achieve this goal:

1. Power Transmission / ROW Maintenance: Develop ROW maintenance recommendations that are specific to each ecoregion.

2. Invasive Species Removal (Volunteers): Coordinate with regional conservation service providers, Texas Master Naturalist chapters, and local volunteer groups. Focus on habitats and watersheds that are most significant for invasive species. Monitor the sites for habitat restoration.

3. Address and manage known Invasive (Exotic) or Problematic (Native) Priorities according to established best manaagement practices (BMPs):

a. White-nose Syndrome: Monitor bat colonies for white-nose syndrome and support inoculation and other related research. Provide technical assistance to landowners, cave explorers, property managers, transportation officials, city officials, and others to prevent the spread of Pseudogymnoascus destructans, the fungus that causes white-nose syndrome.

b. Golden Algae: Document and map golden algal blooms across water bodies, especially where SGCN fishes are known to occur. Develop a community science golden algal bloom tracking network.

c. Native Problematic Brush (for example: honey mesquite, retama, greenbriar): Remove invasive native brush appropriately with the least ecological collateral damage to promote healthy native grasslands. This will benefit grassland-obligate birds, shortgrass prairie species such as burrowing owl and black-tailed prairie dog, and pronghorn. Support prescribed fire as a tool to increase grassland health when appropriate and monitor habitat health and recovery over time.

d. Tawny Crazy Ants: Support management and control of tawny (Rasberry) crazy ants in the context of critical habitat and wildlife management and conservation. Recent management actions in a controlled environment have been successful in managing crazy ants at through the use of infection by a microsporidian pathogen. This work was supported by grants by Texas Parks and Wildlife Department and US Fish and Wildlife Service, among other funding sources (LeBrun, Powes, and Gilbert 2022).

e. Introduced Aquatic Predators: Monitor introduced aquatic predators in free-flowing river sections where they have the potential to affect native rare freshwater minnows, shiners, pupfish, and other SGCN aquatics of spring-fed rivers and streams.

f. Tamarisk: Monitor bank stability, native vegetation recovery, and native animal use in areas treated with Tamarisk removal (various means/methods/timing).

g. Feral Hog: Reduce feral hog populations, taking into account the species' recruitment rate and its ability to rebound after culling. Provide technical guidance and educational programs about the impact and management of feral hogs to benefit ground-nesting birds, small mammals, and aquatic species.

h. Oak Wilt: In areas with a high concentration of oak wilt or oak decline vulnerable species, support best management practices to slow/prevent the spread of this disease. Document areas of oak wilt or oak decline with the Texas Forest Service to help them concentrate their outreach and incentive programs on this front.

i. Cactoblastus (Cactus Moth): Monitor and manage Cactoblastus distribution in Texas in the context of habitat or SGCN management. Participate in citizen science efforts to document species occurrences (iNaturalist and TexasInvasives.org).

j. Ips Beetle: Monitor infestation centers of Ips sp. beetles in various species of Ponderosa pine in the region and western pine beetles (Dendroctonus brevicomis) in the context of habitat, community, or SGCN management.

Habitat and natural process restoration (2.3)
Industry Partners: Work with industry partners to restore habitat and mitigate industry practices when negative impact occurs. Specific industries identified by participants include:

Oil and Gas Development: use best management practices, and address reclamation to native conditions post-operations. Review and revise Best Management Practices for pad and road development, runoff and spill containment, and ecoregion-appropriate remediation guidelines, with recommended native seed mixes and sources, including estimated costs for full remediation. Provide with other planning tools (SWAP Portal, Texas Natural Diversity Database, Texas Ecosystem Mapping Tool).

Mining: restore land impacted by mining with native soils and vegetation. Use best management practices in restoration, such as TCEQ regulatory guidance Best Management Practices (BMPs) for Sand Mining Operations in the San Jacinto River Watershed. Mine reclamation: Identify native reseeding and replanting mixtures, sources, and habitat-specific techniques. Monitor restoration and suppressing nonnative invasive species until the site fully recovers to native conditions and does not require ongoing management.

Transportation planning and protection: Revegetate transportation corridors with native seeds of species that both control erosion and contribute to habitat value. Select species that are resilient to modeled climate conditions.

Power Development and Transmission: Revegetate transportation corridors with native seeds of species that both control erosion and contribute to habitat value. Select species that are resilient to modeled climate conditions.

Agriculture: Retain streamside and field side buffers of native dense vegetation to assist with runoff control and treatment before “discharge” into any waterway. Consider conservation practice incentives to encourage the use of stormwater pollution prevention practices.

Identify areas in windrows, crop corners, and fence line habitats where management could benefit grassland or shrubland-dependent birds, contribute to riparian conservation through streamside buffers and conserve rare plants and communities. Work with local landowners and planning partners to identify and designate Important Bird Areas, primarily for grasslands.

Freshwater and marine habitats:

Impoundment and Dam Operations. Environmental Flow working groups, TPWD River Studies, and Estuary Ecosystem Leaders need to coordinate recommendations and work directly with River Authorities, US Army Corps of Engineers, Drainage Districts, and other reservoir managers to understand their release schedule needs (amount, timing, seasonality) and identify specific changes by facility (dam, reservoir, power plant, saltwater barrier, etc.) which could benefit priority habitats and SGCN identified in this plan.

Riparian and Floodplains. Texas Ecological Mapping System Data Riparian Quality Index Analysis: Develop Riparian Quality Index at the river basin level based on Texas Ecological Mapping Systems Data in conjunction with data developed by the National Fish Habitat Action Plan, Ecologically Significant Stream Segments, FEMA Floodplain maps, TXNDD, and local knowledge Identify highest priority areas for connectivity and community protection or restoration conservation actions. Designate mussel sanctuaries in areas where large sustainable populations of state-threatened species (or even small populations of the very rare species) are found. In river basins identified through prioritization tools, provide resources to restore instream flow, water quality, and intensity management; riparian restoration; and specific work to increase resiliency to climate change; work with adjacent ecoregions as needed.

Estuaries and the Gulf of Mexico. Map extent of tidal marsh and swamp system based on salinity regime Artificial reefs, when used, should function to: 1) redistribute biomass; 2) increase exploitable biomass by aggregating previously unexploited biomass; and 3) improve aspects of survival and growth, creating new production. Continue the artificial reefs program at TPWD with the aim of improving resiliency to climate change effects.

Grasslands: Prioritize mapping Native Grasslands in Texas Ecological Mapping Systems analytical mapper. Make publicly available so partners can work to identify the best locations for functional grassland conservation/restoration in contiguous blocks. Prioritize landowner incentives for the restoration of native grasslands, including the conversion of non-native grasses to native grasslands. Long-term monitoring of regional scale summer wildfire sites to document vegetation community and animal assemblage recovery or shift and trends over time.

Colonial Habitats. Map various kinds of colonial habitats information every two years.

Caves and Karst. Map karst landscapes with their vegetation community contexts, create an index of vulnerability and rarity based on SGCN presence and knowledge to date, evaluate surface habitat needs to protect the feature(s) functions, and prioritize areas for landowner incentives and stewardship with grassland, forest, woodland, riparian and other conservation programs.

Connectivity of all habitats: Develop, restore, or conserve seasonal and daily movement corridors and stopovers. Identify key stopover patch areas, connectivity corridors for migratory birds, wide-ranging animals, and trans-border populations.

Restoration after invasive or problematic vegetation removal: Promote the use of native grasses in landowner incentive programs for wildlife and fish resource improvement (e.g. Farm Bill, SWG, LIP, and others). Sod-forming exotic grasses and cultivars should not be used in any restoration or enhancement project as these are known to be detrimental to native habitats and the wildlife on which they depend.

3.0 Species Management

Species Management actions are those that are directed at managing or restoring species, focused on the species of concern itself.

Species management (3.1)
The following are some important conservation strategies and goals that need to be addressed in Texas:

1. Specific Species Management: The Species of Greatest Conservation Need spreadsheet, provided in Supplement 1 and on the SWAP: Texas website, includes threats to specific SGCN.

2. Community Science: Use platforms like iNaturalist and Urban Wildlife Information Network to document and raise awareness about data-deficient species. This will help counter "false rarity" determinations and contribute to the conservation of sensitive habitats. Montezuma Quail, Common Black-Hawk, Gray Hawk, Yellow-billed Cuckoo, Spotted Owl, Colima Warbler, Summer Tanager, pronghorn, mountain lion, black bear, Sprague's pipit, mountain plover, wintering grassland birds, Houston daisy, and dune umbrella-sedge need to be prioritized.

3. Bird Conservation Goals: Use information on current population estimates, research on area sensitivity or acreage required for minimum viable populations, and daily metabolic requirements for breeding and wintering species to set high priority bird species conservation goals.

4. Freshwater Mussels: In the Gulf Coast Prairies and Marshes and the Western Great Coastal Plain, additional distribution and habitat requirements information is needed to identify instream flow standards, recommend water conservation areas, protect sites from reservoir development, prevent zebra mussel spread, and provide greater water quality protections in mussel watersheds.

5. Warbler Conservation: Identify high priority conservation areas for bottomland hardwoods. Increase conservation lands protecting intact bottomland hardwoods in northeast Texas. Promote BMPs for this habitat among agencies and cooperators.

6. Obligate Grassland Species Conservation: Prioritize resources on native grassland management to support grassland bird conservation. According to National Audubon Society's North American Grasslands and Birds Report (Wilsey, et al., 2019), Texas grasslands are critical in connecting breeding and wintering grounds.

7. Monitor the status of key suite of breeding and wintering coastal prairie birds, shorebirds and waterfowl, and grassland and savanna birds.

8. Identify key areas to promote netwire fencing replacement (with strand barbed wire) for pronghorn antelope benefits.

9. Gather more information on Shortgrass dependent species, including those not specifically obligate to black-tailed prairie dog (e.g. ferruginous hawk, swift fox) presence and status.

10. Monitor Haemonchus (barber pole worm, a parasite) distribution in pronghorn populations and avenues for containment and recovery if needed (Weaver, 2013).

11. Riverine Species: Research the effects of managed flows (dam releases), including sediment dynamics and water quality, and their effects on SGCN fishes and aquatic invertebrates, especially those in vulnerable watersheds and coastal sites.

12. Determine specific levels of impact of groundwater withdrawals on spring and cienega habitats that support rare and endemic species (e.g., Phantom Lake, Diamond Y, Balmorhea, others). Refine the ranges and relatedness of Dionda argentosa, Dionda serena, and Dionda episcopa to help identify threats and conservation needed for the various populations.

13. Predators: Evaluate the role of predators (coyotes, mountain lion, rattlesnake spp.) in priority habitats and the effects of predator control activities on the stability of certain predators' populations and their contribution to natural system function. Identify community-supported solutions to relate predator control effects with ecological needs.

14. Pollinators: Conduct phenology studies related to insect fauna, particularly pollinators, in rare plants/communities and document the documented and potential effects of climate change in grassland, wetland, shrubland, wetland various marsh types, and geologically isolated plant communities.

15. Industry Partnerships:

a. Mining: Identify areas where Terlingua Creek cat's-eye, an endemic endangered plant, is potentially adversely affected by local mining. Concentrate outreach efforts on prevention of impacts.

b. Communications: Identify non-compliant communications towers and provide incentives to bring them into compliance (lighting, height). Conduct outreach to communications companies about the local hazards of communication towers and provide recommendations to improve practice.

c. Wind Energy: Find opportunities to study wind turbine operations related to direct strike incidence and barotrauma to document operational changes and recommendations which may be helpful to minimize or avoid these impacts.

Species recovery (3.2)
Priority species communities include:

All Species of Greatest Conservation Need

Grassland birds, including Northern Bobwhite, Dickcissel, Eastern Meadowlark, LeConte's Sparrow, Short-eared Owl, Loggerhead Shrike, Northern Harrier, Swainson's Hawk, Henslows Sparrow

In the Southwest Tablelands and High Plains ecoregions, black-tailed prairie dog, burrowing owl, black-footed ferret communities are in special need of actions like re-introductions, habitat improvement, and management recommendations for compatible land uses.

Freshwater Mussels communities. Texas Administrative Code Title 31 TAC Section 57.157 designates segments of various waterways in Texas as sanctuaries for freshwater mussels. Mussel sanctuaries protect populations of both rare and commercially valuable species from harvest. Although this designation protects mussels from harvest only, designated waterways are selected because they support populations of rare and endemic mussel species, or are important for maintaining, repopulating, or allowing recovery of mussels in watersheds where they have been depleted. These sanctuaries manage mussels by providing for repopulation after harvest or other use, or loss due to environmental conditions. Projects that cross or are located in close proximity to a waterway designated as a freshwater mussel sanctuary should avoid disturbing the streambed to protect species that reside in the streambed. Water quality should be protected from any project related water pollution, including runoff, erosion and sedimentation.

Aplomado falcon population restoration in Cameron and Willacy counties. Lesser prairie chicken communities regional restoration

Species reintroduction (3.3)
Reintroduction efforts may sometimes be warranted. IUCN Guidelines for Reintroductions and other Conservation Translocations (2013) can provide guidance for determining whether and when a species might be a canditate for reintroduction.

Through partnerships with zoos (Houston Zoo, Fort Worth Zoo) and Texas State University, Houston Toad tadpoles and young adults have been reared and released to protected sites within their historic range in Bastop County. Conservation is further assisted by implementing best management practices and long-term conservation within critical habitats that are permenantly protected. Ongoing monitoring and surveying are done for known and new locations, including private lands.

Ex situ conservation (3.4)
Native seed collection and storage, especially of species with limited species distribution and under immediate threat. Collections of local genotype seeds of Loblolly pine were instrumental in Lost Pines recovery after a catastrophic wildfire.

4.0 Education and awareness

Education and awareness actions are those directed at people to improve understanding and skills, and influence behavior.

Formal education (4.1)
Workshops in areas of human population growth (also known as “Wildland-Urban Interface”) In and near urban and outlying “bedroom” developments, provide workshops for landscape design and installation service providers, local and “big box” nurseries’ producers and buyers, city planning boards for landscaping, managers for urban parks and recreation sites, Home Owners Associations, Texas Master Gardener classes, and garden clubs.

Training (4.2)

Train conservation professionals: Texas Natural Diversity Database and associated products to plan and carry out conservation with emphasis on SGCN. A public-facing portal should be provided with information on SGCN, priority habitats, and suggestions on action.

Environmental justice, focusing on equitable access to clean air and water and opportunities to experience natural habitats. Urban and rural supporters of environmental justice should be strong advocates and partners for conservation, but this can only happen if concerns related to environmental health are not dismissed or ignored. Conservationists must be aware of and trained in these challenges and solutions.

Instruction on the use of conservation tools like conservation easements, Purchase of Development Rights, fee title, donations, mitigation banking, Safe Harbor, Candidate Conservation Agreements, Candidate Conservation Agreements with Assurances, stewardship/management incentive programs), prescribed fire, grassland restoration, and riparian restoration.

Regarding prescribed fire, training should cover technical requirements, time, and costs for an effective program, how to develop a program and what partner resources are available, how to engage private landowners in Rx fire application, how to deal with urban-wildland interface issues, what stakeholders need to be involved, how to generate interest in burn cooperatives to enhance the scale of fire application, and how to measure the effectiveness of Rx Fire application (site-specific and programmatically).

Renewable energy sector training: Coordinate with the TPWD Habitat Assessment Program and local conservation delivery professionals to conduct a workshop for current and future wind power providers focused on the amount and type of avoidance, minimization and mitigation information that is available for free from the TPWD Habitat Assessment service group, to encourage voluntary consultation.

Regional communications providers to inform them of areas of highest significance for avoidance – migratory bird pathways (especially nocturnal; also known impacted species such as Yellow- billed Cuckoo, Painted Bunting, Summer Tanager), adjacency to pronghorn herd patterns -- and potential areas to concentrate mitigation dollars and projects in the event avoidance is not feasible or prudent.

Law enforcement Provide annual workshops for regional law enforcement related to updates in nongame collection, possession and sale regulations; include identification section in curricula; create a voluntary monitoring program to determine effectiveness of the technical guidance/training related to the efficacy of nongame enforcement, decrease in adverse SGCN population impacts (especially to resources on public lands).

Regulatory agencies: training on setting Total Maximum Daily Load (TMDL) standards for water bodies. Priorities include Texas Commission on Environmental Quality Texas Water Development Board, Metropolitan Planning Organizations, Councils of Government, transportation planners, Regional Surface Water Planning Region groups, Groundwater Management Districts, consultants, and other planning providers with messaging specific to their needs, using the National Fish Habitat Action Plan data viewer and ongoing threat and resource-based assessments from Environmental Flows findings. Monitor the use of that information in the stakeholders' evolving discussions and plans.

Power developers and providers, especially those interested in solar and biofuels, to inform them of the importance of native grasslands to regional wildlife and fish resources, areas of highest significance for avoidance, and potential areas to concentrate mitigation dollars and projects in the event avoidance is not feasible or prudent.

Landowners / land managers: Host landowner workshops on conservation instruments – Safe Harbor Agreements, Candidate Conservation Agreements, others – to dispel myths about regulatory constraints. Showcase specific studies and examples from the region (or adjacent ecoregions) for better relationship building.

Host local and absentee landowner workshop series related to SGCN and habitat "target areas" and add a focus module on conservation instruments – Safe Harbor Agreements, Candidate Conservation Agreements, conservation easements – to dispel myths about regulatory constraints and promote benefits in preventing the need to list and promoting recovery.

Showcase specific studies and examples from the region (or adjacent ecoregions) for better relationship building.

Training on prescribed fire technical requirements, time, and costs for an effective program; how to develop a program and what partner resources are available; how to engage private landowners in prescribed fire application; how to best deal with urban – wildland interface issues (what stakeholders need to be involved); burn cooperatives that enhance the scale of fire application; lessons learned over time in this region; how to measure effectiveness of prescribed fire application (site specific and programmatically).

Non-native vegetation mitigation: Identify watershed-specific and ecoregionally appropriate seed and plant material sources for restoration projects following invasive species removal. Distribute this information to plant nurseries, conservation service providers, recreation and trail grant recipients, urban planning organizations and TXDOT Districts.

In areas upstream and adjacent to high priority streams and water courses, conservation projects and wildlands to deter the promotion or use of Bermuda grass, KR Bluestem, other nonnative grasses, Chinese tallow, Chinaberry, Tree of heaven, Japanese honeysuckle, Ligustrum, Nandina and state-prohibited species.

Awareness and communications (4.3)
SWAP information portal: Provide the most current SGCN, habitats, threats, and actions information.

Link to the Texas Ecosystem Mapping Systems and Texas Natural Diversity Database.

Public SWAP outreach: Target outreach programs to address priority habitats and relevant issues in this plan.

SWAP: Texas information portal: As the primary source for SGCN and habitats information, revise the TPWD website to make it easier for the public to find thematic information and more accessible for staff to maintain.

Technical guidance information on habitat management:

Urban Wildlife Interface best management practices: target outreach to urban areas, emerging communities, and adjacent larger ranches with desirable habitats focused on the significance of native grasslands and shrublands, intact floodplain-extent riparian habitat, sensitive hydrologic features including non-jurisdictional wetlands which host SGCN rare plants and communities, drainage and floodway protection, and water use conservation related to SGCN specific to their community.

Use of prescribed fire: Initiate and publish post-wildfire studies to document vegetation community and target SGCN responses.

Unintentional bycatch: Provide guidelines for trotline construction and use in line with the conservation of nontargeted species, identify target audiences, conduct outreach, and monitor implementation related to marking and removing abandoned trotlines. Refer to crab trap awareness programs on the coast.

Brush control: In woodland ecoregions, the flat floodplain, and other suitable soils suitable for ranching practices, occasionally, "brush control" projects adversely impact native climax woodland communities. Working with landowners and other conservation practitioners to identify and define suitable characteristics for brush control activities specific to this ecoregion would be helpful in a written guide for technical assistance providers and landowners.

Host local and absentee landowner workshop series on conservation instruments – Safe Harbor Agreements, Candidate Conservation Agreements, conservation easements – to dispel myths about regulatory constraints and promote benefits in preventing the need to list and promoting recovery. Showcase specific studies and examples from the region (or adjacent ecoregions) for better relationship building. Document through conservation practice and partner surveys over three to five years whether the workshops increase opportunities for these tools and the SPECIFIC barriers to their use. Share lessons learned in an annual conference through the Land Trust community.

Unintentional spread of non-native species: General technical guidance and educational programs about the impact of invasive species (feral hog, nutria, axis, and aoudad) and management to benefit ground-nesting birds, small mammals, and aquatic species.

Oak wilt prevention: In areas with a high concentration of oak wilt, oak decline, Red Bay decline, and other vulnerable species and a lot of tree trimming activity (urban areas, parklands) to deter the inappropriate timing or disposal of oak trimming to slow and prevent the spread of this disease.

Aquatic invasives – plants, mollusks (especially zebra mollusks), and bait fishes. At coastal, lake, and river and boat ramps and ports: Intensify outreach and public education efforts to reduce or eliminate the introduction, especially near boat ramps and high-traffic fishing tournament areas.

Target outreach for red imported fire ant (RIFA) and native beneficial ant species in conjunction with other habitat restoration recommendations, especially where grassland birds, native prairie, amphibians, and smaller ground-dwelling SGCN are the conservation targets. Partner with Texas AgriLife Extension outreach efforts where possible.

White-nose syndrome: especially those sites with traversable caves, increase outreach to promote appropriate preventative protocols to help prevent the introduction of White-nose syndrome in caves and karst roosts in this region. Also, post protocols near cavern entrances for public and commercial caves with known roost areas, even if those roosts are only seasonal, and provide signs for the public to purchase at cost.

Working with partners:

Pursue cross-training opportunities with urban entities such as Metropolitan Planning Organizations, Councils of Government, Regional Transportation authorities, International Boundary Water

Commission, and other planning entities to include SGCN, rare communities, and habitat priorities as part of their first-round constraints process in development, zoning, and permitting.

Support urban conservation with volunteer assistance: Identify sources of volunteers and funding that could help municipalities employ conservation practices.

Mining: Provide conservation outreach to mining company operators, especially those in the sand and gravel field, to inform them of the new regulations requiring a TCEQ permit for river and stream operations.

TCEQ permitting coordination: include information about the sensitivity and importance of instream gravel bars, riparian areas, springs, seeps, and other water features, including non-jurisdictional wetlands and swales, to encourage best practices (avoidance of nesting/roosting islands, stormwater pollution prevention and water quality improvement, minimal damage to vegetation and restoration to native conditions).

Oil and gas: Provide best reclamation practices in written guidance for oil and gas companies operating in this region, posted to the TPWD Habitat Assessment (Environmental Review) website; emphasize containment of potentially hazardous runoff, reclamation of cleared sites to native grasses, and reclamation of wetland and swale areas to natural conditions which could again support wetland communities.

5.0 Law and Policy

Law and policy actions develop, change, influence, and help implement formal legislation, regulations, and voluntary standards.

Legislation (5.1)

Conservation Funding: Provide agency support for Recovering America's Wildlife Act or other federally allocated permanent funding source, dedicated to funding all conservation priority actions for species identified as Species of greatest Conservation Need.

County authority: Support county authority to require stormwater pollution prevention, floodplain buyouts, appropriate road development, conservation of non-jurisdictional wetlands, open space planning, or water or other conservation measures from developers.

Policies and regulations (5.2)

Water Planning and Policies: Groundwater, Surface Water, Estuaries

To ensure effective planning and management of water resources, it is important to establish regional water planning stakeholder conservation working groups. These groups will review specific regional resource issues and identify key recommendations that should be considered during the planning processes. They will also advise each of the entities involved and share delegation participation. To ensure that this information is included in the planning processes, it is crucial to provide specific guidance to the water planning stakeholder groups and explain why it is important.

To accurately and completely account for surface water resources, it is recommended to participate in Regional Surface Water Planning meetings and plan projects with additional recommendations.

To support scientific management of fisheries and establish appropriate fishing regulations, conservation effectiveness measures should be used for regulation to document progress, adapt management as needed, and share lessons learned.

In habitat-related policies, it is important to consider habitat-level protections for disappearing or imperiled communities or habitat types that are important to a wide variety of SGCN.

To improve the effectiveness of the Coastal Zone Management Program, it is important to craft and promote specific measures from the Office of Ocean and Coastal Resource Management.

To effectively deal with invasive problems, agencies should develop official guidelines and/or regulations that are more effective than the existing laws.

Private sector standards and codes (5.3)
The Environmental Review MOU aims to provide information and mechanisms for the full implementation of a revised TPWD-Texas Department of Transportation MOU. This will use the Texas Ecological Systems Mapping Project Data, Texas Natural Diversity Database, Environmental Review processes, and emerging information from the State Wildlife Action Plan-related projects to protect state-threatened species, SGCN, and important habitats during the planning and project implementation processes.

To evaluate the effectiveness of transportation mitigation, one small watershed within one TxDOT District or a couple of counties with the potential for the presence of SGCN will be impacted by bridge, culvert, and/or riprap barriers for fish and wildlife passage. The first step is to develop an initial assessment of the site, including completeness of the barrier, aquatic and terrestrial fauna, roadkill statistics, and habitat quality. After modifications, the site will be reassessed to document changes and at frequent enough intervals to demonstrate improvement in aquatic and riparian habitat, increased diversity in the aquatic ecosystem and reduction of local roadkill, as well as the effectiveness of the riparian corridor.

Voluntary conservation guidance for solar development will also be developed. This will encourage coordination with TPWD's Habitat Assessment section for environmental review of impacts, potential avoidance strategies, and mitigation opportunities for the highest ecological value. Planners can avoid areas of highest ecological significance through coordination with the Texas Ecosystem Analytical Mapping System.

In addition, water quality projects will set voluntary conservation measures for non-jurisdictional wetlands. Recommended actions may include site-appropriate buffer protection recommendations, restoration options, and desired ecological conditions for mitigation.

Voluntary stormwater pollution prevention control measures will be developed to catch field runoff in treatment wetlands, native streamside buffers, or catchment with filtration substrates prior to discharge to local waterways. Compliance and efficacy of this approach will be documented in waterway segments with SGCN (fishes, invertebrates, amphibians) where farmland runoff has adversely impacted water quality (sedimentation, turbidity, chemical).

Finally, the establishment of east Texas groundwater conservation districts that align most closely with the aquifer boundaries will be supported. This will help in using areas in and out of these basins to support management for conservation, preservation, recharging, and prevention of waste of groundwater resources. Support and contribution to the processes and outcomes of the area Recovery Implementation Plans which affects environmental water flows through and downstream will also continue.

Compliance and enforcement (5.4)
State Wildlife Action Plan tracking: Document State Wildlife Action Plan implementation activities, research projects on SGCN and priority habitats, working group plans and activities that support conservation in Texas and make the information available to the public. Example: Colorado Conservation Dashboard.

Conservation regulation effectiveness evaluation: Evaluate current and new proposed regulations for conservation effectiveness and assess cost-benefit ratio. Use Technical Committees including members from ecological regions, relevant partners, and relevant natural resource agency programs to advise on research priorities and present science-based recommendations to executive management and the Texas Parks and Wildlife Commission.

Illegal sales law enforcement: More enforcement is needed to curb the sale and the introduction of prohibited species that are SGCN.

Increase law enforcement value:

Evaluate the effectiveness of deterrents (signage, law enforcement presence) on the protection of rookeries, barrier and spoil islands, and other colonial waterbird sites and implement findings.

Prevent aquatic invasive species spread through focused enforcement at problematic sites.

Increase education and outreach efforts at these sites as well.

Reduce unintentional loss of non-target SGCN by updating TPWD policies and regulations on the trapping of furbearers and non-game species. Potential solutions include increasing trap inspection intervals from every 36 hours to every 24 hours for furbearers and requiring 24-hour trap checks for non-furbearing target species would potentially reduce the number of non-target losses.

Increase enforcement of shipping traffic laws to reduce shoreline erosion, saltwater intrusion, loss of vegetation, and creation of open water by illegal shipping traffic.

Improve Environmental Review and Consultation for voluntary practices (wind, solar, communications, transportation):

Encourage voluntary compliance with the USFWS Wind Power Development Guidelines and coordination with TPWD's Ecological & Environmental Planning Program and Landscape Ecology Program for environmental review of impacts, potential avoidance strategies, and mitigation opportunities for the highest ecological value. Map sensitive sites within well-identified migratory pathways for hawks and other raptors, neotropical migrants, and waterfowl potentially impacted by wind tower siting and operations. Provide this information to the TPWD Ecological & Environmental Planning Program so that they can better assess wind tower and operational impacts, and propose avoidance and mitigation measures. Support the development of an online resources mapper for developers to use to avoid areas of the highest ecological significance.

Use Site Renewables Right and publicly accessible mapping Information Portal to supplement renewable energy placement and planning.

Identify timing and intensity of barotrauma and impact hazards from wind turbines and encourage wind generation companies to modify practices.

Share this information with existing and developing wind operations managers, and encourage wind generation companies to modify practices to avoid or minimize impacts. Study avoidance and minimization based on practices' modifications and then publish results. Adjust management and development recommendations as needed for best practices.

6.0 Livelihood, economic, and other incentives

Livelihood, economic, and other incentive actions are those that use economic and other incentives to influence behavior.

Linked enterprises and livelihood alternatives (6.1)

The Wildlife Tax Valuation tool can be used to help preserve Species of Greatest Conservation Need (SGCN) and priority habitats. Additionally, the Index of Conservation Practice Incentives can help determine market values that drive agricultural and livestock production, hunting, recreation, and land sales in a specific area. Based on this information, a recommendation can be crafted to index conservation practice incentives in different ecoregions.

Substitution (6.2)

Efforts should be made to cater to the needs of off-road vehicle enthusiasts while still protecting vulnerable species and habitats. This can be achieved by identifying suitable locations and adopting best management practices to prevent erosion, riparian degradation, and rare plant loss.

It is recommended to promote water conservation as a more economically viable option in human development. By comparing the water usage and rates paid in larger urban areas to the long-term ecological loss from reservoirs or other water development projects, we can make a strong case for the benefits of water conservation. We should also safeguard the instream uses by transferring unused water rights to the Texas Water Trust for funding purposes.

Market forces (6.3)

The following are some important conservation tools that can help preserve natural habitats and biodiversity across different regions.

- Voluntary Conservation Instruments: A feasibility study should be conducted to determine the most effective methods and incentives for encouraging voluntary conservation easement participation in each ecoregion. These easements can benefit both conservation practices and landowners, but they are not well-utilized throughout the state.

- Conservation Easements: A comprehensive study should be conducted to evaluate various conservation easement types from different entities and periods to determine their effectiveness in promoting conservation. Recommendations for improvements should be proposed to enhance long-term effectiveness.

- Land Conservation Tools: Different tools such as conservation easements, fee titles, donations, mitigation banking, Safe Harbor, Candidate Conservation Agreements, Candidate Conservation Agreements with Assurances, and stewardship/management incentive programs should be used and monitored for success. Recommendations should also be revised accordingly.

Conservation payments (6.4)

Analyze the market forces that impact large ranchlands with conservation possibilities. The focus will be on identifying incentive packages and tools that encourage landowners to preserve the site and its features for future generations. The area in question should be near established conservation lands, land trusts, water trusts, and public lands.

For mitigation banks, it is necessary to identify the top keystone regulated species for each broad habitat type that is most affected by development, such as wetlands, shrublands, and hardwood woodlands. Landowner incentives should be provided to encourage participation in these areas.

Conservation incentives should be targeted at willing landowners, especially those adjacent to and in corridors between well-managed public lands. The aim is to restore and manage forest communities in large single-ownership or smaller acreage cooperatives. This will create opportunities to connect and improve historically fragmented management.

Intact priority habitats in high-value timber areas should be prioritized for restoration, especially those contiguous with public and private lands employing conservation practices or on sites mapped as potential intact remnants. Landowners should be willing to manage streamside vegetation as native riparian buffer and to floodplain extent as practicable. Rare wetland communities like acidic bogs and baygalls should also be prioritized.

The focus along riparian areas should be on promoting the restoration of floodplains, bottomlands, and tributary confluences.

Wetlands, especially springs, seeps, bogs, and other isolated wetlands, and bottomland hardwood and mixed hardwood woodlands should be protected from livestock access. The surrounding wetland fringe vegetation should be restored, and data about the location and condition of these sensitive resources should be collected.

To incentivize landowners to permanently protect and restore playas with ecologically-determined native grassland buffers to slow or halt sedimentation, appropriate Natural Resource Conservation Service Farm Bill, US Fish and Wildlife Service Partners, Playa Lakes Joint Venture, and other technical guidance and grant programs should be utilized.

Grasslands like swale wetlands, native grasslands (especially short grass and midgrass prairies), and mature native mesquite savanna on appropriate sites should be given further incentives. Landowners should also share data about SGCN to better manage and recover these species to prevent listing.

Incentivize gating and stabilization for conservation of bat roosts and colonies.

For urban and suburban landowners, specific programs should be created to encourage them to participate in native wildland resource conservation efforts outside of urban areas, thereby maximizing conservation benefits.

Nonmonetary values (6.5)
No nonmonetary recommendations were made.

7.0 External capacity building

External capacity building actions are those to build the infrastructure to do better conservation.

Institutional and civil society development (7.1)
Encourage all public land managers to participate in the Non-Native Invasive Species Community Science Program in a coordinated way with the TexasInvasives.org mapping project. This will help to identify and map invasive species within their boundaries and identify those that are most harmful to priority habitats in this plan, tapping into community science and regional experts. Additionally, it is recommended to initiate a Short-leaf Pine Savanna Restoration Alliance, similar to the Long Leaf Pine Alliance. The alliance will help to identify suitable ecologically functional areas for restoration efforts, project partners, and potential plant resources. To promote awareness of White-Nose Syndrome, it is suggested to develop private landowner outreach and community science documentation programs with Texas Master Naturalist. Lastly, a Natural Resources Data Working Group for Texas should be formed. The group will be made up of database managers and database users and will be coordinated with conservation delivery. Its main objective will be to promote data accessibility for all practitioners from agency to land trust, and to connect data with practice in a web-based format for all to access.

Alliance and partnership development (7.2)
Partnership support: Support the efforts of local land trusts, American Farmland Trust, and conservation NGOs to identify and conserve larger contiguous acreages willing to work toward SGCN and priority habitat conservation.

Water Quality Control/Improvement: Work with local planning and state regulatory entities to identify specific high-priority areas to prevent development in floodplains and riparian areas, encourage natural floodwater conveyances, and improve implementation of voluntary stormwater controls where not regulatorily required. Where directly related to improving SGCN habitat, work with construction providers to understand better building practices and materials to improve water quality during construction and in the final structures.

Municipal planning and partnerships: Form regional conservation working groups of conservation practitioners and experts who work in or near metropolitan and urban areas (including emerging areas) to review specific regional natural resources issues that should be considered during MPO, COG, transportation, and other urban and emerging urban planning processes.

Come to the table with information to share, maps and data, recommendations, and specific ways to incorporate your needs.

Partner with LEED industry green building, and green energy guidance development to include SGCN issues in Development Planning.

NatureServe and Texas Natural Diversity Database: identify ways to input incoming data to the Texas Natural Diversity Database in a more efficient manner to ease bottlenecks.

Continent-wide partnerships: Conduct joint capacity building with partners from Mexico and other Latin American countries seeking partnership with TPWD, focused specifically on priority habitats identified in this plan.

Border fence issues: Form a working group of conservation practitioners and landowners adjacent to the border fence and potential border fence.

River rehabilitation working groups: Form a working group with adjacent ecoregions aquatic and terrestrial ecologists to identify river rehabilitation goals in/adjacent to undammed stretches below the last impoundment to the estuaries to evaluate/implement instream flow recommendations: improve the quality, timing, and seasonality of releases, improve riparian restoration, and increase connectivity to improve resilience to climate.

Regional invasives mapping task force emphasizing cooperation and contributions in funding and people from regional land trusts, Master Naturalists, state and federal landholders in the region, nongovernmental organizations, volunteers, and other professionals to ground truth invasive mapping and participate in the TexasInvasives.org mapping program.

Use community science to monitor golden alga in conjunction with SGCN monitoring and management.

Ecology Advisory Committee: Create a multi-disciplinary ecology committee to identify three to five years of highest priority research projects of importance at the local level that can be presented to universities and colleges to collect the information most needed at the practical level for management and conservation improvement on the ground. Establish a regional lands management experience cooperative to identify restoration needs and sites for connectivity, invasive species removal priorities, trail development and recreation planning improvement, and management practice improvement opportunities.

Form multi-partner working group(s) to establish and publish scientifically sound best management practices for:

Chemical/mechanical brush control for the ecoregion and specific watersheds (slope, aspect, soils, targets, methods, rates, proximity to water features).

Native riparian restoration, including timing, water needs, reasonable recommendations for initial planting diversity, ways to encourage full complement of the desired ecological condition of the community, how to prevent or control specific invasives without negatively impacting restoration, locally sourced seed and plant materials for the ecoregion (and finer scales if needed).

Prescribed fire application for the ecoregion (timing/season, period/duration, intensity, parameters for prescriptions, how often to mimic natural fire occurrences) for the restoration of SGCN-specific habitats (long-term health and sustainability of desired ecological conditions); work with Rx fire technical experts, SGCN and rare communities experts to identify concerns, barriers, and solutions. Identify a suite of key species to monitor post-burn to determine the effectiveness of the applied practices.

Blackland prairie priority conservation areas for long-term rotating and/or perpetual conservation that have high native prairie species diversity, are large functional blocks that could be networked for system function, could serve as a seed source for local restoration projects, and are adjacent to existing managed conservation lands.

Thornscrub restoration for the ecoregion and Mexico (timing/season, period/duration, intensity, parameters for RX) for the restoration of prairie grasslands in appropriate areas (not areas where the desired ecological condition is brushland or riparian corridors.

Native Prairies Association's ongoing current effort to identify scientifically sound best management practices for coastal prairie restoration, including timing, water needs, reasonable recommendations for initial planting diversity, ways to encourage full complement of the desired ecological condition of the community, how to prevent or control specific invasives without negatively impacting restoration, locally sourced seed and plant materials for the ecoregion (and finer scales if needed).

Urban partnerships: Conservation service providers and ecologists must engage with urban biologists to convey conservation needs and priorities to urban planning efforts through Metropolitan Planning Organizations, Councils of Government, Regional Transportation Authorities, Parks Boards, Counties, and others in current and emerging urban areas.

Park and open space planning for specific regional habitat connectivity (daily and seasonal movements), riparian and streamside protection, water quality protection, floodplain set-asides, and mitigation banks for in-jurisdiction projects.

Prairie conservation and mowing practices.

Karst, cliff, spring, and other sensitive feature protections.

The resaca system needs a better understanding of the effects of certain human activities, and protection.

Water quality protection through stormwater pollution prevention plans and facilities even where not required by regulation, leaving natural floodways intact rather than armoring.

Water conservation practices and direct relationship to benefits for humans and SGCN in their areas.

Invasive species prevention and removal in public land, rights of way, planned developments (e.g. encourage native plant use in new housing areas, incentives for landscape conversion to natives especially in areas near waterways.

Collaboration with counties for environmental protections, stormwater management, invasive species control, ecological reclamation, dumping and other pollution, and other ecologically important factors.

Tax incentives for open land conversion, restoration, conservation planning

Identify sources of volunteers and/or funding that could help municipalities employ conservation practices. As with any outreach program, these efforts need to have reporting objectives and monitoring of sorts to determine effectiveness, share lessons learned, and hone approaches for future and emerging areas that will be experiencing these issues in the future.

Increase capacity for municipalities to engage in conservation practices.

Reduce human-induced pollution risks and increase water conservation by working with city and/or regional planners in the high to very high-risk HUC 12 watersheds identified in the National Fish Habitat Action Plan; identify specific measures that can be implemented and establish monitoring to determine if outreach and coordination with planning entities is effective.

Conservation finance (7.3)
Provide agency support for Recovering America's Wildlife Act, or other federally allocated permanent funding source, dedicated to funding all conservation priority actions for species that are identified as Species of greatest Conservation Need, including plants and all vertebrates and invertebrates animals.

Statewide Conservation Delivery working group: Form a Statewide Conservation Delivery working group that includes entities that fund and receive conservation grants to review existing web-based conservation data collection and practice sharing websites and implement "state of the practice" effectiveness reporting in Texas, using the measures method in the AFWA TWW 2011 Measuring the Effectiveness of State Wildlife Grants. Coordinate with the Natural Resources Data Working Group or all natural resources database managers.

State Scientific Areas: Find conservation grants for incentives and regulatory assurances for data collection on private lands in State Scientific Areas for priority habitat data collection and Best Management Practices development.

Chapter 6 List of Figures

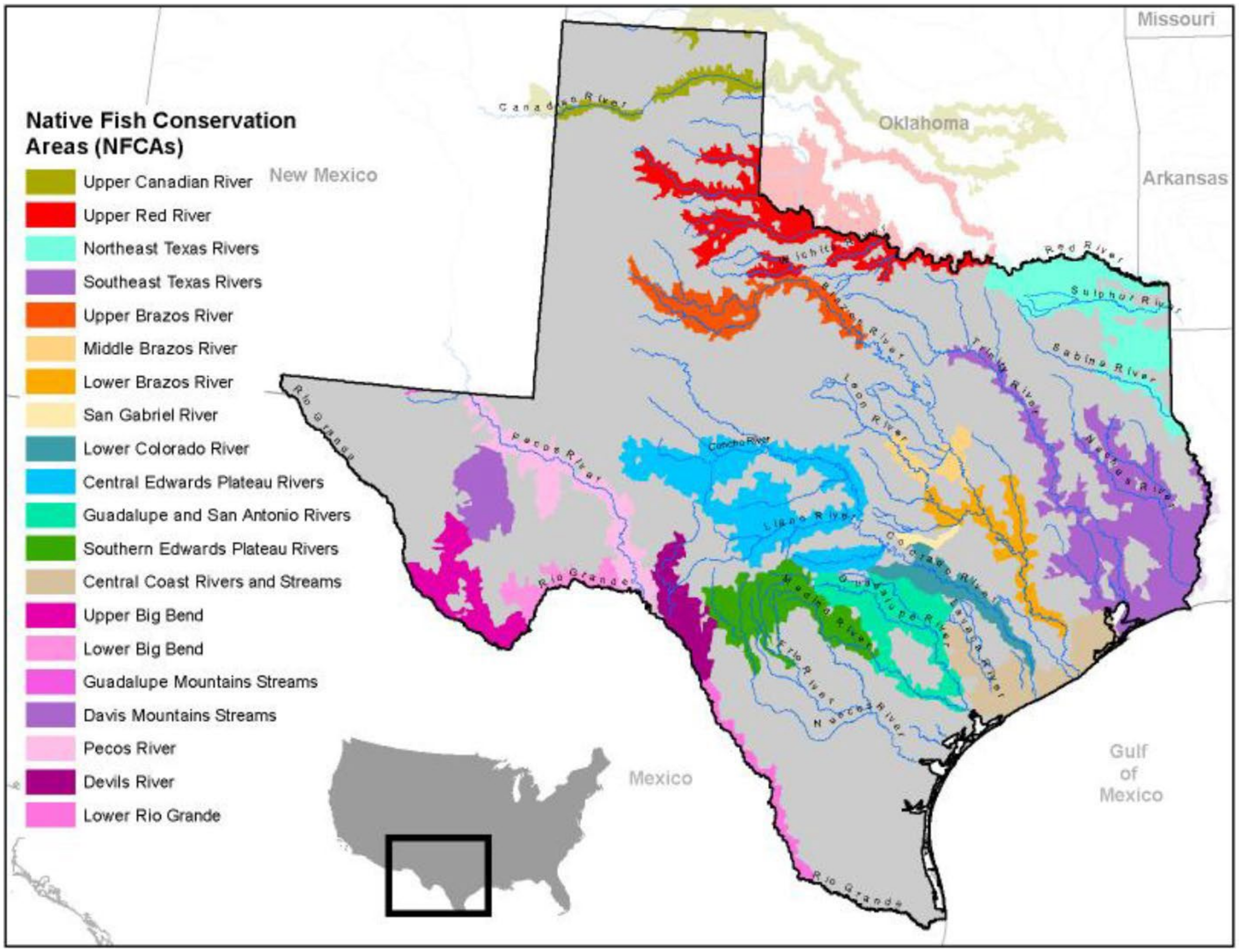

Figure 6.1 Native Fish Conservation Areas.
Texas Native Fish Conservation Areas Network: Strategic Investments in Restoration and Preservation of Freshwater Fish Diversity. Map of Native Fish Conservation Areas. Used with permission.

Supplement 6.1

Unified Language Describing Priority Conservation Actions for Fish and Wildlife Conservation.

Priority Actions (Element 4, Chapter 6) is organized according to the World Conservation Union-Conservation Measures Partnership (IUCN-CMP) classification of conservation actions (Salafsky, et al., 2008). Unified language classifying and describing conservation actions assists conservation practitioners in communication and therefore advances knowledge more efficiently.

1.0 Land/water protection: Actions to identify, establish or expand parks and other legally protected areas, and to protect resource rights.

1.1 Site/area protection: Establishing or expanding public or private parks, reserves, and other protected areas roughly equivalent to IUCN categories I-VI. National parks, town wildlife sanctuaries, private reserves, tribally owned hunting grounds.

1.2 Resource and habitat protection: Establishing protection or easements of some specific aspect of the resource on public or private lands outside of IUCN categories I-VI. Easements, development rights, water rights, instream flow rights, wild and scenic river designation, securing resource rights.

2.0 Land/water management: Actions directed at conserving or restoring sites, habitats and the wider environment.

2.1 Site/area management: Management of protected areas and other resource lands for conservation. Site design, demarcating borders, putting up fences, training park staff, control of poachers.

2.2 Invasive/problematic species control. Eradicating, controlling and/or preventing invasive and/or other problematic plants, animals, and pathogens. Cutting vines off trees, preventing ballast water discharge.

2.3 Habitat and natural process restoration: Enhancing degraded or restoring missing habitats and ecosystem functions. Dealing with pollution, creating forest corridors, prairie re-creation, riparian tree plantings, coral reef restoration, proscribed burns, breaching levees, dam removal, fish ladders, liming acid lakes, cleaning up oil spills.

3.0 Species management: Actions directed at managing or restoring species, focused on the species of concern itself.

3.1 Species management: Managing specific plant and animal populations of concern. Harvest management of wild mushrooms, culling buffalo to keep population size within park carrying capacity, controlling fishing effort.

3.2 Species recovery: Manipulating, enhancing or restoring specific plant and animal populations. Vaccination programs manual pollination of trees, artificial nesting boxes, clutch manipulation, supplementary feeding, disease/parasite management.

3.3 Species reintroduction: Reintroducing species to places where they formally occurred or benign introductions. Reintroduction of wolves.

3.4 Ex situ conservation: Protecting biodiversity out of its native habitats. Captive breeding, artificial propagation, gene banking.

4.0 Education and awareness: Actions directed at people to improve understanding and skills, and influence behavior.

4.1 Formal education: Enhancing knowledge and skills of students in a formal degree program. Public schools, colleges and universities, continuing education.

4.2 Training: Enhancing knowledge, skills and information exchange for practitioners, stakeholders, and other relevant individuals in structured settings outside of degree programs. Monitoring workshops or training courses in reserve design for park managers, learning networks or writing how-to manuals for project managers, stakeholder education on specific issues.

4.3 Awareness and communications: Raising environmental awareness and providing information through various media or through civil disobedience. Radio soap operas, environmental publishing, Web blogs, puppet shows, door-to-door canvassing, tree sitting, protest marches.

5.0 Law and policy: Actions to develop, change, influence, and help implement formal legislation, regulations, and voluntary standards.

5.1 Legislation: Making, implementing, changing, influencing, or providing input into formal government sector legislation or polices at all levels: international, national, state/provincial, local, tribal global. Promoting conventions on biodiversity, wildlife trade laws like CITES National: work for or against government laws such as the US Endangered Species Act, influencing legislative appropriations State/Provincial: state ballot initiatives, providing data to state policy makers, developing pollution permitting systems, dam relicensing Local: developing zoning regulations, countryside laws, species protection laws, hunting bans Tribal: creating tribal laws.

5.2 Policies and regulations: Making, implementing, changing, influencing, or providing input into policies and regulations affecting the implementation of laws at all levels: international, national, state/provincial, local/community, tribal. Input into agency plans regulating certain species or resources, working with local governments or communities to implement zoning regulations, promoting sustainable harvest on state forest lands.

5.3 Private sector standards and codes: Setting, implementing, changing, influencing, or providing input into voluntary standards and professional codes that govern private sector. Practice Marine and Forest Stewardship Councils, Conservation Measures Partnership (CMP) Open Standards, corporate adoption of forestry best management practices, sustainable grazing by a rancher.

5.4 Compliance and enforcement: Monitoring and enforcing compliance with laws, policies and regulations, and standards and codes at all levels. Water quality standard monitoring, initiating criminal and civil litigation.

6.0 Livelihood, economic and other incentives: Actions to use economic and other incentives to influence behavior.

6.1 Linked enterprises and livelihood alternatives: Developing enterprises that directly depend on the maintenance of natural resources or provide substitute livelihoods as a means of changing behaviors and attitudes. Ecotourism, nontimber forest product harvesting, harvesting wild salmon to create value for wild population.

6.2 Substitution: Promoting alternative products and services that substitute for environmentally damaging ones. Viagra for rhino horn, farmed salmon as a replacement for pressure on wild populations, prom

6.3 Market forces: Using market mechanisms to change behaviors and attitudes. Certification, positive incentives, boycotts, negative incentives, grass and forest banking, valuation of ecosystem services such as flood control.

6.4 Conservation payments: Using direct or indirect payments to change behaviors and attitudes. Quid-pro-quo performance payments, resource tenure incentives.

6.5 Nonmonetary values: Using intangible values to change behaviors and attitudes. Spiritual, cultural, links to human health.

7.0 External capacity building: Actions to build the infrastructure to do better conservation

7.1 Institutional and civil society development: Creating or providing nonfinancial support and capacity building for nonprofits, government agencies, communities, and for-profits. Creating new local land trusts, providing circuit riders to help develop organizational capacity.

7.2 Alliance and partnership: Development forming and facilitating partnerships, alliances, and networks of organizations. Country networks, Conservation Measures Partnership (CMP).

7.3 Conservation finance: Raising and providing funds for conservation work. Private foundations, debt-for-nature swaps.

Chapter 7

Element 5: Monitoring

The fifth element required in SWAPs is *Element 5*: *Plans for monitoring species and habitats, and plans for monitoring the effectiveness of the conservation actions and for adapting these conservation actions to respond to new information*. This element is commonly referred to as "Monitoring." In Texas, the Monitoring element is fulfilled primarily through the activities of projects funded through State Wildlife Grant (SWG) projects. SWG projects can be internal, such as the SWAP development and implementation process, and external, such as pass-through grants that are used to support SWAP-prioritized research and conservation action. This chapter identifies specific activities that fulfill the Monitoring element, divided into two main parts: (1) Monitoring Species of Greatest Conservation Need (SGCN) and habitat status and (2) monitoring the effectiveness of the conservation actions and adapting conservation actions to respond to new information.

Current activities fulfilling Element 5 requirements can be divided into three categories: Monitoring the status of SGCN and their habitats, monitoring the effectiveness of conservation actions, and adapting conservation actions to respond to new information gained through monitoring.

Monitoring SGCN and habitat status is accomplished through

1. State Wildlife Grant (SWG) project prioritization process, as detailed below in sections labeled "Process of SWG Prioritization" for Wildlife, Inland Fisheries, and Coastal Fisheries divisions.
2. Review of SGCN and state Threatened and Endangered ranks in proscribed intervals (Rank Review).

Monitoring effectiveness and adapting conservation actions in response to new information is accomplished through

1. Maintaining the Texas Natural Diversity Database (TxNDD),
2. Performing Knowledge Gap Analyses on SGCN,
3. Creating S-rank improvement plans based on new information gained through SWG and other research and analysis of TxNDD content.

Monitoring SGCN

Monitoring species and habitats

SWG Review and Prioritization Processes by Natural Resource Division

Upon apportionment by USFWS, TPWD divides SWG funding responsibility among natural resource divisions (Wildlife Division 40%, Inland Fisheries 30%, and Coastal Fisheries 30%). Funding priorities follow SWAP priorities, but Divisions refine prioritization of the limited SWG resources according to internal processes.

The annual State Wildlife Grant process for Texas is found online at https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/grants-research/state-wildlife-grants.phtml/.

The processes are summarized below.

Wildlife

Timeline

- **November**: Review of the SWG process at the Wildlife Diversity Program meeting.
- **December:** Priority topics and Request for Proposals (RFP) edits finalized, as funding allows.
- **January:** RFP issued, as funding allows.
- **March:** Draft proposals due to TPWD.
- **April**: SWG Review Committee meets to assess and rank proposals.
- **May:** Deadline to alert applicants of funding decisions. Successful grant applicants will be notified, and a TPWD biologist will be assigned to the project. The TPWD lead biologist, or Project Coordinator (PC), will work with TPWD's Federal Aid office to guide the proposal through the process of becoming a federal grant (i.e. creation of the grant's project statement using the U.S. Fish and Wildlife Service's online system, creation of required environmental compliance documentation, etc.).
- **June:** Final proposals and budgets submitted to Rare and Listed Species Grant Coordinator. The project is subject to final approval by the U.S. Fish and Wildlife Service. Once the federal award is received, TPWD will enter into a contractual agreement with the sub-recipient and ultimately issue a purchase order to fund the project.
- **June 31, 2023**: submissions must be in the FWS

To make better prioritization decisions, biologists use the following tools

a. *Tools and Data:* Some taxa have more data-rich species than others. Data provides the basis for structured decision-making that will lead to effective conservation.
    i. Data used:
        1. eBird (range/distribution, seasonal abundance, predicted % of population found in TX by season);
        2. iNaturalist (local-scale observations, image-based data like nests);
        3. NatureServe/Biotics (global ranks, state ranks where recent and available);
        4. Breeding Bird Survey & Christmas Bird Count (seasonal long-term trend data)
    ii. Tools used:
        1. PIF Watchlist (species of concern, both range-wide and by BCR);
        2. Conservation Opportunity Area analysis (when complete)
        3. Species Distribution Modeling (when complete)
        4. Geographic threats analysis (example: WREN)
        5. Regional geospatial information (Southeast Conservation Blueprint)

b. *Questions asked to support structured decision-making*
    i. Knowledge Gap Analysis: Is the SGCN data-deficient ("Science Need") or Conservation Ready?
        1. Science Need identified: If there is a lack of research on the species, data gathering is prioritized and critical Knowledge Gaps are identified.
        2. Conservation Ready: For data-rich species, conservation action-oriented projects are prioritized. Conservation rank improvement plans ("S-rank Improvement Plans") are prepared for Conservation Ready SGCN, and

SWG projects are designed to address S-rank improvement actions identified by the S-Rank Improvement Plans.

ii. Upcoming USFWS listing decisions: Pending federal Threatened or Endangered designations influence prioritization, particularly if there is sufficient time to inform a Species Status Assessment (SSA) meaningfully.
iii. Federal recovery plans: does SSA indicate the proposed action?
iv. Are there compliance requirements of potential projects, including Section 106 (cultural resources) compliance? High compliance requirements increase the time and cost of a project and may lower priority rank.
v. Is the species endemic? Endemics receive higher priority.
vi. If not endemic, how much of the species' current and historic range is in Texas? Is Texas a stronghold for the species (do we have a high stewardship responsibility for the species)?
vii. Is the species highly specialized or range-restricted? If so, does this specialization decrease the likelihood of meaningful conservation and recovery? A decreased likelihood of meaningful conservation will decrease priority. If a species is specialized but conservation and recovery is practical, species priority is increased.
viii. How much of the population occurs on private vs. public land? If we don't have access to populations, can we generate interest by private landowners in conservation actions or research (as appropriate)? The more likely access can be granted, the higher the priority.
ix. Is the species part of a rare community? Specifically, is a plant part of a rare plant community? Does that community support SGCN wildlife species? Increasing connections increases priority.
x. Is the species vulnerable to climate change? If so, is there a reasonable way to mitigate it? A decreased likelihood of meaningful conservation will decrease priority. If species is vulnerable but conservation and recovery is achievable, species priority is increased.
xi. Do efforts in Texas fit within the broader conservation efforts happening regionally? Are there other states and tribes to partner with to address needs at a population or landscape scale? More connections increase priority.
xii. What is the potential for conservation actions if knowledge gaps were closed? Do we have a chance to conserve it, or would it become a resource sink?
xiii. What are threats to survival, and how imminent are they? If threats are known and conservationists can address them, priority is increased.
xiv. Is there local knowledge about the species that can increase the potential success of conservation?
xv. Opportunistic considerations: Is expertise available? Is there good public engagement? More connections and support increase priority.
xvi. Availability / Opportunity for funding from other sources: Non-bird and Non-mammal species receive higher priority in SWG since they don't receive PR funding. However, species that have opportunities for supplemental funding through outside sources may receive higher priority because of the potential for leveraging funding.

Workflow: The Rare and Listed Species Grant Specialist in the Research and Administration Branch defines timelines and deadlines and maintains prioritization criteria and scoring. A Program Leader and

Program Director leads nongame and Rare Species taxa biologists. This team performs foundational prioritization analysis and decision-making, especially of science-need species identified by the Knowledge Gap Analysis (KGA). The KGA process is detailed below in the **Adaptation to New Information** section. Some of the data-rich taxa biologists (herps, birds, mammals) also prioritize conservation action projects. Wildlife Diversity regional field staff provide information on potential site availability; local expertise and access, conservation actions, threats, and funding opportunities; current and potential public engagement; and landscape and habitat experience. The Rare and Listed Species Grant Coordinator compares funding requests to funding allocation and evaluates the budget, administrative burden, and current project load for the respective taxa specialists who will serve as project coordinators. Final decisions on project priorities are made by a committee comprised of taxa biologists and coordinated by the Rare and Listed Species Grant Specialist.

Inland Fisheries

Timeline:

- **February**: Request for Proposals issued.
- **April**: Proposals due to TPWD. Copies will be made of all proposals, and these will be distributed to the internal SWG review committee.
- **April**: SWG Review Committee meets to assess and rank proposals. Successful grant applicants will be notified, and a TPWD biologist will be assigned to the project. The TPWD lead biologist, or Project Coordinator, will work with TPWD's Federal Aid office to guide the proposal through the process of becoming a federal grant (i.e. creation of the grant's project statement using the U.S. Fish and Wildlife Service's online system, creation of required environmental compliance documentations, etc.).
- **May**: Deadline to alert applicants of funding decisions.
- **June**: Final proposals and budgets submitted to Federal Grant Coordinator. The project is subject to final approval by the U.S. Fish and Wildlife Service. Once the federal award is received, TPWD will enter into a contractual agreement with the sub-recipient and ultimately issue a purchase order to fund the project.

Review Process:

Inland Fisheries members volunteer to be on the review panel. The following are used to review each proposal objectively.

1. Is the project time-sensitive or urgent? (e.g. addresses imminent threats, regulatory actions, conservation opportunities, etc.) Scaled as 1, 2, 3, 4, 5 where 1 = No specific timeline or urgency place for study and 5 = Study should be funded during this funding cycle or unique opportunity will be missed.
2. Is the project a defined priority for the Division or Department? (e.g., informs important initiative/agreement; project influence/impact; existing progress/momentum; pure value judgment based on understood importance, knowledge, and experience for each participant) Scaled as 1, 2, 3, 4, 5 where 1=Somewhat important to 5=Very important.
3. Does the project inform on-the-ground management? (e.g., research directly leads to management or intervention; identifies specific management strategies; conservation/management actions address specific threats to stabilize/recover populations) where 1 = project would better inform life history or some other information gap of

the species, 3= Applied research or conservation focus, 5 = research to develop new or evaluate the effectiveness of management or conservation actions

4. Does the project have a high value-to-cost ratio? (return on investment, leveraging resources, value of information/data, and study quality). Scaled as 1, 2, 3, 4, 5 where 1 = project delivers information/utility of lesser value than expected given cost, 5= project delivers information/utility of greater value than expected given cost.
5. Is the project likely to influence the listing status (Threatened, SGCN, etc.) of the species? (i.e., will the project fill data gaps to better inform listing status or otherwise lead to an impact on the species designation as an SGCN). 1= Will provide limited information to inform status, 3 = Will provide useful, but not critical information to inform status, 5=Will provide critical information to improve status (e.g., delist/downlist)

After the proposals are ranked, the list is discussed and reviewed by the Inland Fisheries leadership team.

Coastal Fisheries

The complete Request for Proposals for Coastal Fisheries projects can be found online. https://tpwd.texas.gov/fishboat/fish/Grant-Research/swg-rfp-guide.phtml#appendix1

Because the funding pool is relatively limited, the time frame for each proposal may not exceed four years and funding should not exceed $100,000.

To be considered for the award, proposals must be received by the deadline electronically at Diana.Isabel@tpwd.texas.gov. A 35% non-federal match will be required. Funds will be made available to the grantee on a reimbursement basis. The time frame for each proposal may not exceed four years and shall not request more than $100,000 of federal SWG funding. Capital equipment requests outside these funding parameters might be considered based on the statement of work submitted.

Project Scope

The Coastal Fisheries Division of the Texas Parks and Wildlife Department (TPWD) requests proposals from organizations and agencies interested in partnering with the TPWD to implement high-priority portions of the State Wildlife Action Plan. TPWD will make funding available to support cooperative, cost-share projects that will further the conservation of wildlife species designated as “Species of Greatest Conservation Need” in the Texas SWAP. The origin of this funding is the State Wildlife Grants (SWG) program, a federal assistance program for state wildlife conservation agencies. The purpose of the SWG program is to support proactive conservation efforts. The areas of focus for research should be in the following areas:

- Flounder – Research that addresses hatchery challenges, stocking success, or movement/survival in estuaries
- Tarpon, Snook – Research that addresses life history, movement and distribution in Texas, and population trends
- Blue Crabs – Research that addresses population declines and informs management actions
- Sharks – Research that improves understanding of the shore-based shark fishery, and harvest utilization by anglers.

- Habitat Restoration, Creation, and Cultivation – Research that can inform adaptive management for habitat restoration, creation, and cultivation practices
- Habitat Assessment – Research, monitoring, and mapping that assess changes in estuarine habitat distribution and impacts to SGCN

We desire to fund well-designed projects that provide conservation benefits for one or more species of greatest conservation need and that address one or more of the conservation issues outlined in the State Wildlife Action Plan of Texas. Beneficial conservation actions include habitat restoration or enhancement activities, and field studies that seek to fill information gaps that will enable Texas to develop more effective conservation programs for rare and declining species. The State Wildlife Action Plan is the guiding document for how SWG funding may be spent in Texas and applicants should review the relevant sections of this strategic plan before preparing their proposal.

SWG Partnerships

Texas Parks and Wildlife recognizes the benefit of engaging with partners when prioritizing potential conservation research and actions. The following partnerships have been shown to increase the efficacy of specific projects and are valued when making prioritization decisions. This is not a comprehensive list of valued partnerships, and some of these partnerships are required by Federal or State statutes, agency policy, or administrative code.

- Government: Examples include USFWS, especially if required for Section 7 of the Endangered Species Act. Other examples of government partners include the Natural Resource Conservation Service and National Park Service.
- Universities and research institutions: These institutions produce research proposals to be considered. They assume the responsibilities of day-to-day operations of their successfully funded projects.
- Non-Governmental Organizations (NGOs) generally partner in implementing conservation actions. Examples include Bird Conservancy of the Rockies, Rio Grande Joint Venture, and University Lands.
- Conservancies and land trusts. These organizations help with the establishment of conservation easements and acquisitions, which serve as a foundation for implementing conservation measures and conducting field-based research. Examples include The Nature Conservancy, Texas Hill Country Conservancy, Lost Pines Conservancy, and Texas Land Trust Conference.
- Private landowners, including corporate/industrial landowners. Partnerships with private landowners can allow access to habitat on private land for research or conservation actions. Sometimes there are cost-share or mutually beneficial partnerships, like CCAA, EQIP, and Farm Bill conservation programs.
- Landscape-scale partnerships. Regional conservation initiatives bring together a variety of stakeholders to accomplish conservation priorities at a regional scale. These regional partnerships may include state and federal agencies, nonprofit organizations, private landowners and businesses, tribes, partnerships, and universities. Examples include Southeastern Conservation Adaptation Strategy Blueprint and the Western Crucial Habitat Assessment Tool (CHAT).

- Internal partnerships with taxa and ecoregional specialists to implement conservation actions and develop local relationships that will facilitate conservation research and action.

Rank Review

S-Rank Review: SGCN conservation status assessments are reviewed by Wildlife Diversity Program Nongame and Rare Species taxonomic specialists continuously. Using the NatureServe Rank process staff have scheduled a review for each SGCN on a 20-year cycle so that each SGCN rank is reviewed within 20 years of it's previous review. Updated s-ranks are submitted to NatureServe to be updated on Biotics and any other NatureServe publication, and published in-state with the next minor or comprehensive SWAP review.

State-listed Threatened or Endangered Species: All state-listed threatened or endangered species' conservation statuses are reviewed every 2-4 years and the results are presented to TPWD Commissioners at a regularly scheduled public meeting.

Adaptation to new information

Plans for monitoring effectiveness and adapting conservation actions in response to new information.

Knowledge Gap Analysis and S-Rank Improvement Plans: Monitoring is also accomplished by combining SWG-funded research and analysis of species status. Using these tools, A Knowledge Gap Analysis (KGA) is carried out to determine if SGCN require further scientific research or if they are ready for conservation efforts. The methodology used for conducting SGCN KGAs is outlined in Supplement 7.1. SGCN that are identified as "Science Need" in the KGA have their specific research needs, or "Knowledge Gaps," identified. To be eligible for SWG funding, proposed projects must identify the specific Knowledge Gaps that will be addressed through the proposed analyses.

Species that are determined to be "Conservation Ready" in the KGA process are eligible for SWG projects that propose conservation action rather than knowledge gap-reducing research. Biologists use previous research, including SWG-funded research and analysis, to prepare state conservation rank improvement plans, or "S-Rank improvement plans." The goal of these plans is to support conservation that will meaningfully affect the species population health and result in an improvement in State Conservation Rank (S-rank) of the species, eventually qualifying the species for non-SGCN status because of improved population health.

Future Needs:

We recognize there are key needs and roadblocks to conservation progress in Texas. Future prioritization processes should address the needs identified below.

Need: Conservationists are limited by a lack of comprehensive mapped species distribution and threat data. A comprehensive database that provides our current knowledge on species, habitats, threats across taxa including both aquatic and terrestrial species is needed. "Inland Fisheries did this with *Fishes of Texas* in 2011 and it allowed them to develop a multi-species watershed level priority structure to their conservation efforts in 2019."

Roadblock: Staff and time.
Potential Solution: Support initiatives that increase data availability through natural heritage programs and landscape analysis tools.

Need: Removal of impediments not directly related to conservation delivery.

Roadblock: Conservation initiatives that require cultural clearances become a lower priority because of higher financial and time costs.
Potential solution: Add internal cultural resources staff with the capacity to fulfill compliance requirements such as Section 106 cultural assessment requirements.

Need: SWG-funded research final reports are not easily available or searchable.

Roadblock: ADA Accessibility requirements have been cited as a roadblock for publishing on the TPWD website.
Potential Solution: Staff time and resources to develop a process that ensures reports are delivered in a format that fulfills ADA Accessibility requirements.

Need: Conservation initiatives and research should be directed where the benefit would be greatest.

Roadblock: It is a current priority to prevent the State from listing species as threatened or endangered if possible, and prioritizing these species pulls limited resources away from initiatives that could advance meaningful conservation for less imperiled SGCN.
Potential Solution: Separate petition and listing decisions from the conservation initiatives.

Need: The resources to methodically address conservation needs and actions are insufficient. Low resources drive inefficient conservation and current actions are too broadly dispersed to be effective.

Roadblocks: Projects that are more likely to be successful are prioritized because of extremely limited funding. Long-term funding relationships, even those with slightly misaligned priorities, are highly valued since they are more likely to produce successful projects.
Potential Solution: Longer-term funding cycles focused on fewer priorities that are more strictly bound to approved projects. For example, focus effort on 1-3 species over 10 years, or move to an ecoregion or habitat type approach to conserve suites of species across taxa. Maintain independent, science-bound conservation priorities and initiatives using Knowledge Gap Analysis (KGA) and State-rank improvement plans.
Roadblock: Understanding of the SWG process, or how SWG, T&E, and other conservation targets were prioritized or implemented, is limited.
Potential Solution: Written guidance or policy (SWAP) that informs our conservation prioritization, planning, and implementation processes, and programmatic training on that policy. Maybe regular SWAP segments at future monthly program meetings.

Need: Access to species and the land they occupy for research and conservation action.

Roadblock: Texas is a private property state, therefore most SGCN populations and their habitats are on private property.
Potential Solution: Coordinated and negotiated efforts to gain access to private land.

Planned or in-progress activities fulfilling Element 5 requirements

These activities have been recognized as needs and are prioritized for completion when resources allow.

A. Monitoring SGCN and habitat status
    a. Provide a web-enabled SWAP available to the public
    b. Plans for obtaining, using, or developing SWG process tools identified as a need in the SWG Prioritization Survey
    c. Scientific Permit for Research data for annual reports and applications being digitized and made available for review (in progress, available May 2025)
    d. Species Distribution Modeling (in progress)
    e. Conservation Opportunity Areas (in progress, Beta available October 2024)
    f. Increase participation in the Southeast Conservation Adaptation Strategy Blueprint (in progress; next collaboration project planned for 2023 Blueprint update)
B. Monitoring the effectiveness of conservation actions
    - Evaluate SWG project success with long-term Conservation Opportunity Area mapping.
C. Adapting conservation actions to respond to new information.
    a. Include COA in the SWG and RAWA prioritization process.
    b. SWAP planning tools (S-Rank improvement plans linked to COA)

Chapter 7 List of Supplements

7.1 Knowledge Gap Analysis process

7.2 S-Rank Improvement Plan sample: Houston Toad

7.3 S-Rank Improvement Plan sample: Kit Fox

Supplement 7.1

Knowledge Gap Analysis

Proposed Framework for Prioritizing SGCN Conservation Research Necessary for Management Actions

February 22, 2022

Summary

There are 1488 Species and Communities of Greatest Conservation Need currently in the Texas Conservation Action Plan. However, we lack the basic research needed to improve the conservation status for most of these species. Alternatively, some SGCN have benefitted from adequate research, and therefore conservation actions could be implemented. Here we propose a process for identifying when to transition from prioritizing research to management for a species and how to track progress.

Project Goals

The goals of this effort are to 1) prioritize and enable on-the-ground conservation to better achieve our mission of species conservation, 2) track progress towards recovery to demonstrate program effectiveness, and 3) optimize use of limited resources.

A Proposed Solution

We propose we strategically prioritize critical conservation management actions while focusing research on removing barriers to conservation management. To achieve this, we recommend a 3 step process: 1) Identify Barriers to Conservation Management, 2) Track Research Progress, and 3) Track Conservation Progress (still under development).

1) Identify Barriers to Conservation Management: We selected 7 information categories important for conservation to occur: Taxonomic certainty, Condition of populations, Distribution well defined, Individual needs, Population needs, Threats known, and Effective conservation possible. These are roughly based on a document from USFWS entitled: *"USFWS Rapid Assessment for the Species Status Assessment".* We then applied a 5-point scale to evaluate the current state of knowledge for each category. (See full descriptions below.)

2) Tracking Research Progress: We identified AirTable (a simple to use online database) as a useful tool for tracking these data. Once the baseline knowledge assessment has been conducted, the AirTable database can be used to track the status for each species. The information in the database can then be used to quickly identify research gaps and develop future RFPs and track progress in removing barriers to conservation action.

COMMON_NAME	Taxonomic certainty	Occurrence viability	Distribution well defined	Individual needs	Population needs	Threats known	Conservation possi...
Swift fox	4	4	5	3	3	3	4
Texas kangaroo rat	5	3	5	3	3	3	4
Ocelot	5	4	3	4	4	4	3
Tricolored bat	5	3	3	3	3	4	3
Eastern spotted skunk	5	2	4	3	2	1	2

Ultimately, program effectiveness could be measured by the number of species which have improvements in the species' ranks. However, as an intermediate step, for the species lacking sufficient information, program effectiveness can be measured by the increases in the information status across all species (knowledge gaps filled necessary for conservation).

Tracking Conservation Progress: TPWD has long relied on the NatureServe ranking methodology to determine the conservation status of SGCN species. The rank calculator categorizes species status data based on: range extent, area of occupancy, abundance/condition, environmental specificity, threat impact, intrinsic vulnerability, short term trends, and long term trends. It may be possible to inspect a species most recent rank to identify conservation actions most likely to result in an improved rank. This is a work in progress and while it may help TPWD focus on the actions likely to have the greatest impact, the rank calculator is an imperfect tool and may not be appropriate for this use.

The qualitative Likert-style 5-point scale to Identify Barriers to Conservation Management and evaluate/track progress.

This structure is designed make the desired "target" information status between values of 3 and 5. Values of 1 or 2 indicate that insufficient information is currently available to know what the appropriate conservation actions are. A value of 3 across the various factors indicates that sufficient information is available to no longer be a barrier to prevent conservation action. Values of 4 and 5 indicate increasing confidence in the information.

Factor A - Taxonomic clarity

Is the taxonomic nomenclature for the species well accepted?

1- Uncertain

2- Some progress made towards understanding, but significant uncertainties remain whether the species designation is accurate and an appropriate conservation unit for management action.

3- Stable with no specific concerns or reasons for questioning the current nomenclature. However, a thorough taxonomic review has not been conducted.

4- Some specific taxonomy work has been done, few uncertainties remain, and additional changes are unlikely.

5- Fully resolved through a comprehensive and specific assessment.

Factor B – Distribution well defined

Is the current distribution well documented in TX?

1- Unknown

2- Some historic location information exists, but significant uncertainties remain about current distribution.

3- Lack of recent surveys/location info but boundaries well-defined from historic data and some uncertainties remain about current distribution.

4- Some recent survey work has been done and few uncertainties remain about the distribution.

5- Fully defined through a recent comprehensive assessment.

Factor C – Condition of populations (population status and trends)

Current Condition of Populations in TX? Do we have survey or monitoring data available for the populations (population sizes, abundance, density or trends)? Do we know if the populations are functioning as needed?

1- Unknown

2- Some limited population status information available, however reliability may be poor or in question and need for conservation action is unclear. Very little survey effort. Don't know where the populations are or not. Probably need more survey effort before conservation is necessary. May be more common than thought.

3- Although limited data exists, there is sufficient survey/monitoring effort so that a population status can be inferred; enough knowledge exists to understand whether conservation is needed.

4- Repeated population surveying/monitoring has occurred and conservation status is reasonably well known for populations across most of the range.

5- With reliable statistical population estimates exist with reasonable confidence intervals across the majority of the species distribution. Short-term trend data is available.

Factor D – Individual needs (life cycle, food needs, shelter, habitat, home range, reproductive age, etc.)

Do we know what things are most important to ensure persistence/ survival of individuals (e.g., reproduction, life cycle, food needs, shelter needs, migratory, max age, microhabitat needs, feeding habitat, home range/distribution, pollinators, soil type/geology, etc.)?

1- Unknown

2- Insufficient information exists for specific individual needs to ensure persistence/survival of individuals identified to be important for implementing conservation action.

3- Basic elements of life history known sufficiently enough to proceed with some specific conservation measures.

4- Some specific work has been done and the individual needs are reasonably well known enough to proceed with conservation measures.

5- All individual needs and life history information needed for conservation work to occur are thoroughly researched and understood.

Factor E – Population needs (fecundity, survival rate, recruitment, genetic structure, sex ratio, minimum viable population, patch size connectivity, seasonal-habitat use)

Do we know the natural population functions (e.g., sex ratio, fecundity, survival rate, recruitment, genetic structure, mortality rate, minimum viable population, seed bank) and habitat needs of a population (e.g., patch size, connectivity, minimum habitat size, wintering/migratory/breeding range)?

1- Unknown

2- There is uncertainty and concern about our understanding of population biology, habitat needs, and dynamics and therefore effective conservation measures are not well understood.

3- Basic elements of population needs known sufficiently enough to proceed with some specific conservation measures.

4- Some specific work has been done and the population needs are reasonably well known enough to proceed with conservation measures.

5- All population needs required for conservation work to occur are thoroughly researched and understood.

Factor F – Threats known

Do we know the current threat(s) to the species in TX? Do we know which of these threats will continue into the future?

1- Unknown

2- Some threats identified; however, severity, scope, and timing are unknown or poorly understood.

3- At least one significant threat identified with severity, scope, and timing mostly understood.

4- Most significant threats have been identified and investigated with severity, scope, and timing mostly understood.

5- All threats identified, investigated and prioritized with severity, scope, and timing of each well understood.

Factor G – Effective conservation possible

Are effective conservation measures known and feasible in TX?

1- No effective conservation measures are known/feasible.

2- The conservation actions are poorly understood, and outcome is uncertain.

3- Sufficient information exists to reasonably expect at least one conservation action to produce a benefit for the species. Monitoring needed to ensure project success.

4- Some specific studies have been completed and the outcomes of action are reasonably likely to succeed. More monitoring may be needed to ensure project success.

5- Conservation actions are tested and have proven history of success.

Supplement 7.2

EXAMPLE 1

FY22 S-Rank Improvement Plan For species: Houston toad (Anaxyrus houstonensis)

Status

G-Rank	G1
S-Rank	S1
S-Rank Review Date	7/1/2019 LE
Federal Status	E
State Listed Status	SGCN
State Status	Y
Endemic	Very high
Threat Impact	Decline of
Short Term Trend	50-70%

Knowledge Gaps

Taxonomic certainty	3
Distribution well defined	4
Condition of Populations	2
Threats known	4
Individual needs	4
Population needs	3
Conservation possible	5

Specific Knowledge Gap Research Needed

In FY22, "condition of population" will be targeted for research. Once it improves from 2 to 3, all knowledge gap categories will be above 3. Specifically, we do not know the status of populations outside of Bastrop County. Some counties haven't been surveyed for >10 years.

Future knowledge gap research will focus on…

Steps to Improve S-Rank

To improve the rank from S1 to S2, the following actions are recommended:

- Reduce Threat Impact from "Very High" to "High" by reducing the scope of fire suppression from pervasive to small through the implementation of prescribed fire programs…
- Raise area of occupancy from "E = 26-125" 4km2 to "F = 126-500". The current estimate is 89, meaning only 37 4km2 grids need to be added.
- Improve Number of Occurrences with Good Viability from "Very Few" to "Few." This will require…

Alternatively, solely reducing Threat Impact from "Very High" to "Medium" results in improving the rank from S1 to S2. Though this may not be achievable.

Supplement 7.3

EXAMPLE 2

FY22 S-Rank Improvement Plan For species: Swift fox (Vulpes velox)

Taxa Group: MAMMAL Species Type: RESEARCH

Status

G-Rank G3
S-Rank S1?
S-Rank Review Date 20211020
Federal Status
State Listed Status
State Status SGCN
Endemic N
Threat Impact High - medium
Short Term Trend Decline 10-30%

Knowledge Gaps

Taxonomic certainty 4
Distribution well defined 5
Condition of Populations 4
Threats known 3
Individual needs 3
Population needs 3
Conservation possible 4

Specific Knowledge Gap Research Needed

1. Evaluation of Swift Fox Management Actions
2. Evaluation of Strategies to Reduce Predation and Road Mortality (livestock guardian dogs, artificial dens; road signs, exclusion fences)
3. Evaluation of Habitat Restoration and Management (grazing, burning, grass planting, and brush management)
4. Human Dimensions – Landowner and Hunter Attitudes towards Swift Fox in the High Plains of Texas: The Need for Effective Outreach for Swift Fox Conservation (surveys, interviews, -> produce outreach strategy and educational materials)
5. Direct and indirect impacts of diseases on Swift Fox Populations in Texas (parvo, distemper, plague, etc)

Steps to Improve S-Rank

1. Species goals: Increase population size from 50 – 250 individuals to 250 – 1,000 individuals;

2. 250 individuals = 50 occupied grids (average 2 adults + 3 pups/grid) to improve S-Rank from
3. S1? to S2 in 15 years. Long term goal (25 years) is to recover swift foxes to a NatureServe
4. Rank of at least S3.

GOAL A: SECURE EXISTING POPULATIONS

Dallam county has the only known functional swift fox population remaining in Texas.

Securing this population should take top priority. Goal is to sustain at least 250 occupied

territories in order for this population to be suitable as a source for future translocations into

other areas of Texas.

OBJECTIVE A.1: ASSESS CURRENT STATUS OF EXISTING POPULATION

A.1.1. STRATEGY: Conduct studies to identify threats, trends, etc.

A.1.2. STRATEGY: Conduct regular monitoring to determine number of occupied/unoccupied

territories within suitable habitat.

OBJECTIVE A.2: MINIMIZE HUMAN CAUSES OF MORTALITY

A.2.1. STRATEGY: Close harvest season for swift fox in Texas.

A.2.2. STRATEGY: Conduct public outreach and education efforts

OBJECTIVE A.3: CONDUCT MANAGEMENT ACTIONS WHEN NEEDED AND SUPPORTED BY RESEARCH

A.3.1. STRATEGY: Habitat management (brush control, prescribed fire/grazing).

A.3.2. STRATEGY: Reduce predation on swift foxes

GOAL B: EXPAND EXISTING POPULATIONS

OBJECTIVE B.1: INCREASE AND IMPROVE SUITABLE HABITAT ADJACENT TO ACTIVE FOX POPULATIONS

B.1.1. STRATEGY: Identify landowners in appropriate areas for LIP/PUB funding for habitat improvement

GOAL C: ESTABLISH 1 NEW SWIFT FOX POPULATION INTO SUITABLE HABITAT WHERE NATURAL RECOLONIZATION IS UNLIKELY TO OCCUR

OBJECTIVE C.1: EVALUATE POTENTIAL RELEASE SITES

C.1.1. STRATEGY: Identify areas with enough suitable habitat to sustain a functional swift fox population (50 pairs).

C.1.2. STRATEGY: Identify willing landowners within suitable habitats

Future Monitoring Plan

Annual occupancy modeling via camera trapping of 4 x 4 km grid to determine percentage of available territories occupied from year-to-year

As of 4/11/2022 – 18 occupied grids (40 detection locations) between 2017-18 (Schwalm) and 2020-21 (Castro) surveys

Chapter 8

State Wildlife Action Plan Development (Elements 6, 7, and 8)

Element 6: *Descriptions of procedures to review the plan at intervals not to exceed ten years*.

Element 7: *Plans for coordinating the development, implementation, review, and revision of the plan with Federal, State, and local agencies and Indian tribes that manage significant land and water areas within the State or administer programs that significantly affect the conservation of identified species and habitats.*

Element 8: *Congress also affirmed through this legislation, that broad public participation is an essential element of developing and implementing these plans, the projects that are carried out while these plans are developed, and the Species in Greatest Need of Conservation that Congress has indicated such programs and projects are intended to emphasize.*

Plan Review and Revision (Element 6)

This *SWAP: Texas* edition is submitted to fulfill a Comprehensive Review required by the United States Fish and Wildlife Department, which administers the State Wildlife Grants. A Comprehensive Review/Revision reviews the entire plan content and supporting materials and is required at 10-year intervals. The previous edition of Texas' state wildlife action plan (Texas Parks and Wildlife Department, 2013) was approved in 2013.

This plan represents a comprehensive review with the following goals:

- Complete review and update of the methods of establishing and prioritizing SGCN, and reanalysis of SGCN prioritized based on the resulting methodology.
- Combine the previous edition, published in multiple handbooks, into one easy-to-use and understandable document.
- Remove duplicative content, streamline content, and ensure the document is presented to enhance the user's ability to use the document.

The State Wildlife Action Plan (SWAP) of Texas is scheduled for a comprehensive review and revision in 2025. The aim is to leverage the latest advancements in technology and conservation tools to bring Texas in line with other states' review and revision cycles.

Preview of the SWAP: Texas 2025 Process

The revision process for the Texas SWAP will begin immediately after the approval of the 2023 revision. The focus of the 2025 effort will be on:

1. Identifying priority conservation habitats, their threats, and potential conservation actions (Elements 2, 3, and 4). We will do this with analytical tools and public forums. Relevant input will include the concentration of SGCN populations, vulnerability to conservation threats, and the likelihood of conservation success based on project feasibility through available science, financial support, and involvement by community and conservation partners.
2. Creating a living document that incorporates processes and methodologies that enable it to be used as a tool for iterative conservation projects and project monitoring, increasing our

effectiveness and efficiency while avoiding the temptation of a “laundry list” approach to conservation planning.

Because a thoroughly comprehensive review was conducted of SGCN for the *SWAP: Texas 2023* revision process, updates will be made to that list only as necessary because of taxonomic or listing status changes. Following is the proposed structure of the upcoming revision process:

1. Assemble internal project management and element work teams from all natural resource divisions.
2. Develop external partnerships and build assets, including the new Conservation Opportunity Areas tool (Texas Parks and Wildlife). Collaborating organizations provide assets like the Southern Wings Annual Cycle Conservation Resources for SWAPS, the revised Southeast Conservation Blueprint, climate impact maps, community science data on fish and wildlife populations, and renewable energy impact maps.
3. Produce a preliminary Conservation Opportunity Area map to identify geographic areas with potential as priority conservation areas.
4. Develop stakeholder engagement throughout Texas, particularly in potential priority conservation areas. Build relationships in communities adjacent to potential priority conservation areas. (Field staff will be critical in this step – The project manager will coordinate and facilitate, but field staff will introduce landowners, potential collaborators, and general stakeholders in staff counties.
5. TPWD will host facilitated conversations with communities near potential priority conservation areas. During these discussions, relevant local SGCN will be presented, and potential priority habitats will be described. The objective is to develop a mutual understanding of the threats to area fish and wildlife SGCN conservation and to develop possible conservation actions based on available interest and resources. The potential for conducting effective conservation action in that geographical area will also be discussed. After the discussion, staff will develop a report that records the decisions made by meeting participants. Reports generated through these meetings will be available for review and comment.
6. The SWAP Project Management Team will assess feedback from the community and recommend priority conservation habitats and their possible conservation action projects to the Division Directors of TPWD's natural resource divisions. The community and stakeholders' input will be considered along with the TPWD Conservation Opportunity Area analysis. The team's recommendations will prioritize landowner participation and local support.
7. After reviewing the suggestions, a preliminary draft of SWAP: Texas 2025 will be created. The draft will include documentation of the prioritization and conservation action project development process, along with the recommended priority conservation action projects. The draft will be presented for review to stakeholders, TPWD Advisory Committees, and TPWD Executive Office. Responses will be documented based on the feedback received and necessary revisions will be made. Finally, the SWAP: Texas 2025 will be presented to the U.S. Fish and Wildlife Service for final approval.

While this process will yield some priority habitats and species combinations, the focus will be on developing a strategy of analysis and consensus-building that produces **conservation action projects**. An example of a **conservation action project** might be a combination of SWG-funded research or habitat enhancement, landowner incentives, and voluntary conservation easements to restore specific communities of SGCN within a priority habitat. When we're successful in one of the projects, we should be able to offer the next project developed through this process as a minor revision. This way, we create a living, actionable plan rather than a reference book of possible actions.

SWAP development begins in late fall of 2023. Use the QR Code to register your interest, or email the State Wildlife Action Plan coordinator at Kelly.simon@tpwd.texas.gov to receive a registration form.

Public Participation (Element 8)

A public survey was used to guide the development of *SWAP: Texas* 2023.

A public participation survey was issued in November 2022 that helped to guide the Threats prioritization, formatting, and delivery method of *SWAP: Texas.*

The survey was distributed:

- via social media and direct email communications of TPWD biologists and administrators geographically distributed throughout the state, and with the assistance of our partners, including Texas Master Naturalists chapters throughout the state, and
- through internal communications distribution throughout the agency.

Responses were collected for five weeks during three temporally separated campaigns. One hundred seventy-one responses were received inside and outside the agency (Figure 8.1). Of those who worked outside the agency, about half (48%) were engaged in work that included natural resource management duties (Figure 8.2).

Over half of respondents (67%) believed they could use the State Wildlife Action Plan for personal or professional benefit. The top five anticipated uses of the *SWAP: Texas* are presented in Figure 8.3.

When asked how participants would prefer accessing the information in the SWAP, the majority responded that they would explore all content online. Very few answered that they would like to access a complete printed document, though many wanted to be able to print at least some of the content and then access the rest online (Figure 8.4).

The 2023 State Wildlife Action Plan: Texas is presented in 100% electronic format, formatted to print on most standard home and office printers. This will allow most users to access the *SWAP: Texas* online, as requested. However, many conservation action priorities listed in Chapter 6 also included a request for a "SWAP portal." A SWAP portal is a priority project for the 2025 comprehensive revision.

In the Texas Conservation Action Plan (2013), conservation threats to ecosystem health (element 3) and conservation actions (element 4) were identified by participants in extensive ecoregional conservation workshops and follow-up surveys (Texas Parks and Wildlife Department, 2013). The 2023 Comprehensive Revision aimed to retain these conservation threats and potential actions provided by public engagement while reviewing and consolidating where possible. Additionally, the reviewed threats and actions were translated into the common Conservation Threats and Actions lexicon (Salafsky et al., 2008). The 2022 Public Survey was then used to assess the importance that the public now places on each of the categories of threat, and the results guided the design and presentation of conservation threats in the 2023 State Wildlife Action Plan: Texas. These results do not represent the actual impact of each threat category on our ecosystems but were reviewed to ensure that the current Conservation threats ranked in relative order of perceived impact by survey respondents. The relative impact of ecosystem threats as rated by the public are shown in Figure 8.5.

Coordinating with Partners (Element 7)

Element 7 required of State Wildlife Action Plans is to provide a plan for coordinating the development, implementation, review, and revision of the plan with Federal, State, and local agencies and Indian tribes that manage significant land and water areas within the State. The *SWAP: Texas* team fulfilled this requirement by engaging in the following:

1. Maintained previous partnerships and relationships as described in the last edition of the Texas Conservation Action Plan (Texas Parks and Wildlife Department, 2013).
2. Actively participated in the Association of Fish and Wildlife Agencies SWAP learning series, ensuring that best practices of SWAP development were employed in the *SWAP: Texas* development.
3. Coordinated with multi-state cross-border SWAP collaborators organized through the Western Association of Fish and Wildlife Agencies to provide regional conservation and efficiently use resources.
4. Participated in a SWAP development workshop hosted by Wildlife Diversity Program Managers and the Association of Fish and Wildlife Agencies to efficiently plan, use resources, and ensure plan development following best practices.
5. Began communications with the Native American Wildlife Fish and Wildlife Society to establish connections that may lead to future partnerships in fish and wildlife conservation between the Native American tribes located adjacent to or within Texas's current borders.
6. Established a Regional Review Team relationship with the Arizona Department of Game and Fish.

List of Figures

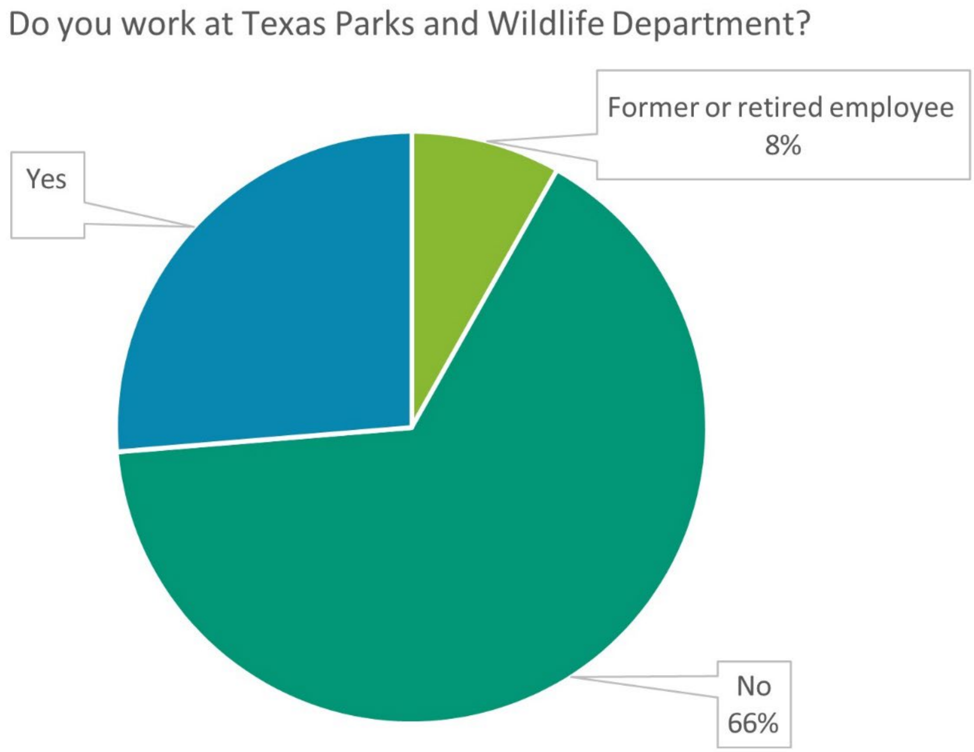

Figure 8.1 Responses to the question: "Do you work at Texas Parks and Wildlife Department

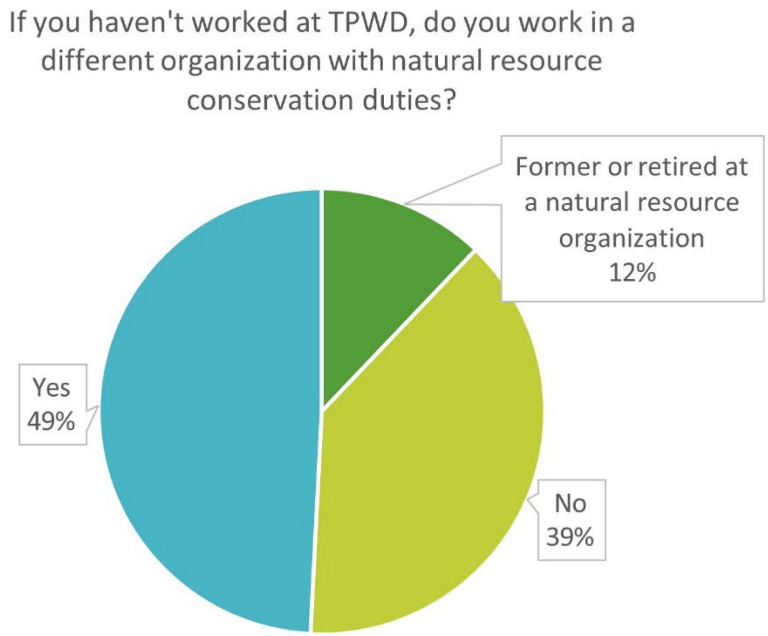

Figure 8.2 Responses to the question: “If you haven’t worked at TPWD, do you work in a different organization with natural resource conservation duties?”

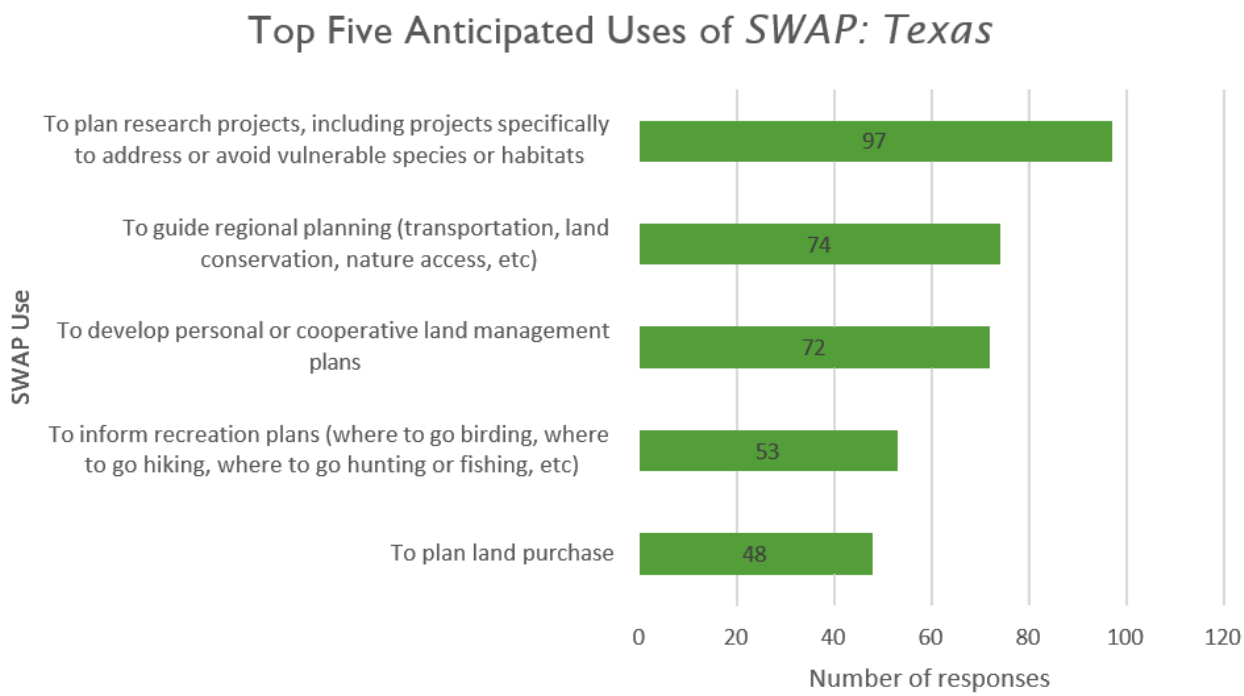

Figure 8.3 Top five anticipated uses of *SWAP: Texas* by survey respondents.

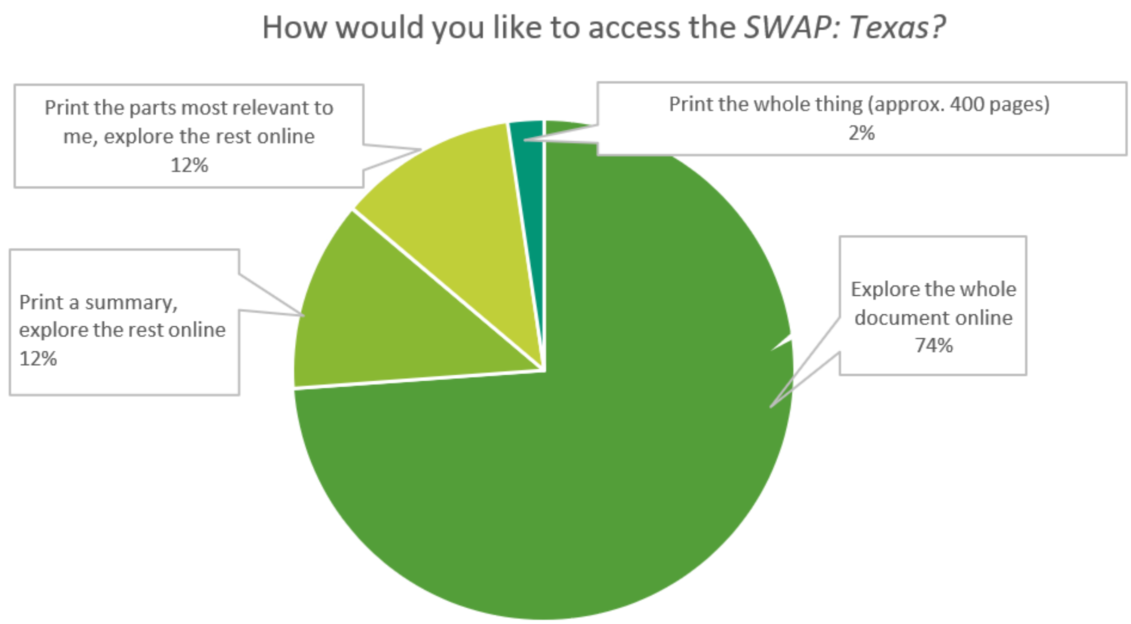

Figure 8.4. Responses to the question: "How would you like to access the *SWAP: Texas*?"

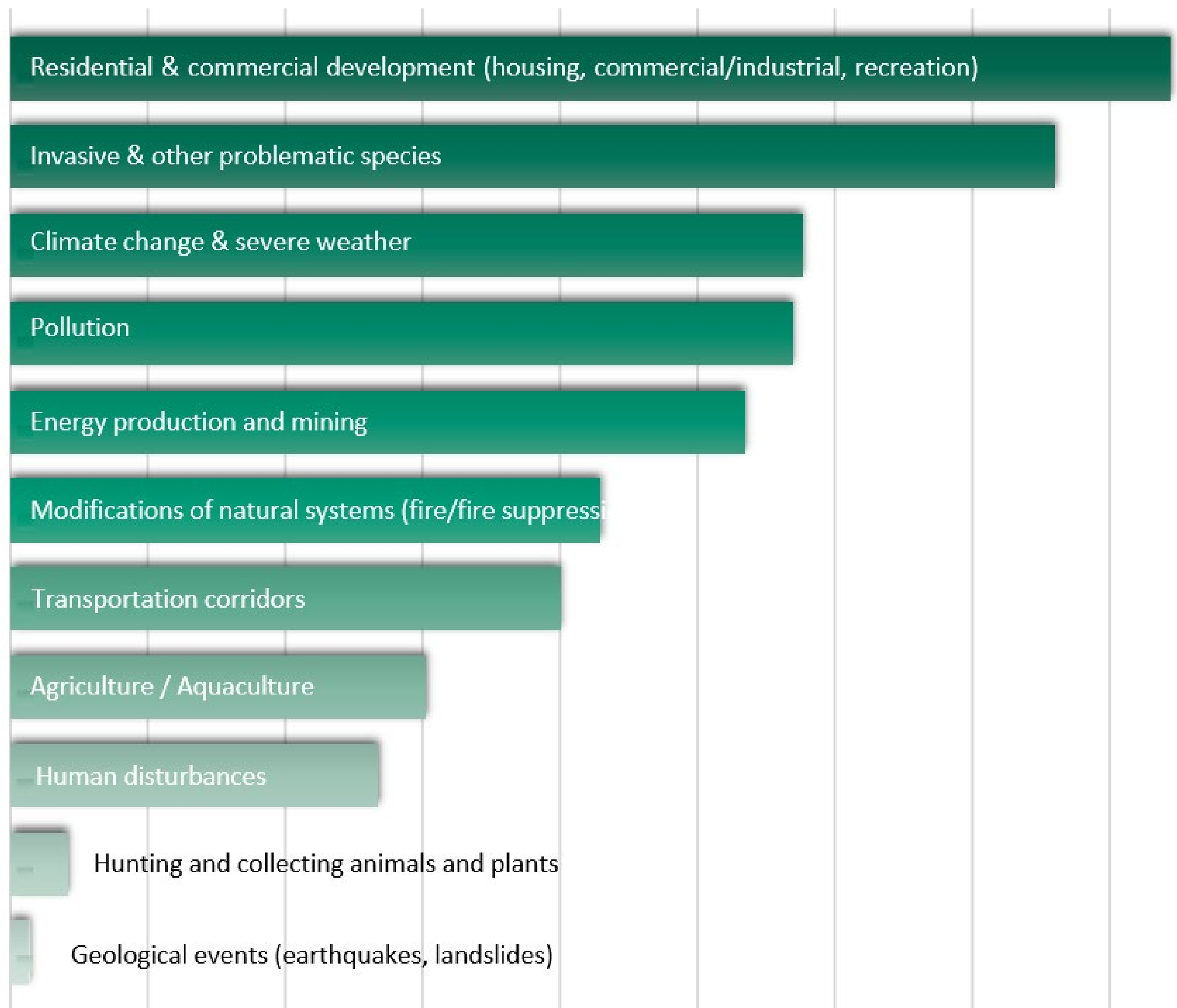

Figure 8.5. Relative impacts of ecosystem threats as rated by the public.

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