Conservation Assessment for the

BIG BEND-RÍO BRAVO REGION

A Binational Collaborative Approach to Conservation

Commission for Environmental Cooperation

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BIG BEND-RÍO BRAVO REGION

A Binational Collaborative Approach to Conservation

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See the full list of the Experts' Meeting participants in the Appendix.

Foreword

On behalf of the US Department of the Interior (DOI), I would like to personally congratulate everyone who contributed to the development of the "Conservation Assessment for the Big Bend-Río Bravo Region: A Binational Collaborative Approach to Conservation." I am confident that the Assessment will be used to guide and inform important conservation decisions for years to come and I am hopeful that this unique and cooperative approach to conservation will be replicated elsewhere. By implementing the Recommendations outlined in the Assessment, we can collectively work to protect the extraordinary biological diversity of this shared desert ecosystem for current and future generations. I would also like to recognize the tireless efforts of Jeff Bennett at the National Park Service and Carlos Sifuentes at *Comisión Nacional de Áreas Naturales Protegidas,* who graciously volunteered to serve as the co-chairs for the Big Bend-Río Bravo Steering Committee. Finally, I would like to thank the Commission for Environmental Cooperation (CEC) for its generous technical and financial support, without which this project would not have been possible. When Big Bend National Park was established on 12 June 1944, President Franklin Delano Roosevelt of the United States of America wrote to President Manuel Ávila Camacho of Mexico, "I do not believe that this undertaking in the Big Bend will be complete until the entire park area in this region on both sides of the Rio Grande forms one great international park." Almost 70 years later, we celebrate the latest step in the long and productive history of bilateral cooperation in the conservation of natural and cultural resources between the United States and Mexico with the publication of this robust and scientifically-grounded Conservation Assessment.

Lori Faeth
Deputy Assistant Secretary for Policy and International Affairs
US Department of the Interior

The Big Bend-Río Bravo natural area of binational interest builds on nearly 70 years of purposeful efforts between the governments of Mexico and the United States, aimed at conserving more than 1.3 million hectares of unique and highly diverse landscapes and ecosystems. This initiative strengthens our common objective of transboundary conservation in one of the most diverse areas among the world's arid and semi-arid ecosystems. The CEC project, "Big Bend-Río Bravo Collaboration for Transboundary Landscape Conservation," has brought about a renewed agenda for binational conservation; it has fostered effective partnerships among various stakeholders and supported crucial restoration actions. For Mexico, this project sets an important precedent for future binational conservation efforts along the country's northern and southern borders.

The present publication is the fruit of the work of the project and represents a cornerstone for conservation policies between the two countries, based on assessments from multiple actors, and will define conservation and restoration priorities for years to come. It is Conanp's wish that the strategic binational efforts embodied in this Assessment be promoted and strengthened in future conservation policies for this exceptional landscape—a vital part of the natural heritage of our two countries.

Luis Fueyo Mac Donald
National Commissioner of Natural Protected Areas (Mexico)

Desert bighorn sheep
Photo: Marieke Ijsendoorn-Kuijpers

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Wax production from candelilla in Jaboncillos, Coahuila
Photo: María Dolores Wesson

Executive Summary

The borderlands of the Chihuahuan Desert, in the Big Bend-Río Bravo (BBRB; the Rio Grande is known as the Río Bravo in Mexico) region, have one of the highest levels of diversity and endemic species among the world's arid and semiarid ecosystems. This large binational area, comprised by a total of eleven protected areas in Texas, Coahuila, and Chihuahua, offers a unique opportunity for conservation because of its isolation from human settlements and the unfragmented nature of its landscape. Connectivity of habitats in these borderlands is essential to maintain and restore biodiversity, particularly in the face of a changing climate. Private land conservation efforts underway in both countries add an important dimension to these efforts by extending the region's conservation potential to include essential habitat for mammals, birds, aquatic and other species from the Davis Mountains and Marfa in the north, to the Sierra de Hechiceros and Lagunas de Sanchez y de Montoya in the west, the Devils River to the east, and the Sierra de Santa Rosa to the south.

On 29 January 2012, a binational Steering Committee convened for the purpose of implementing a project entitled *Big Bend-Río Bravo Collaboration for Transboundary Landscape Conservation*. One of five activities undertaken as part of this project was the development of a Binational Conservation Assessment (the Assessment) for the region that would provide an analytical framework and methodology for reaching agreement on protection and restoration priorities within this large landscape.

The Experts' Meeting

To that end, 60 experts from federal and state governments and civil society from Mexico and the United States were convened in Mexico City on 5–7 September 2012, by the CEC. The meeting was preceded by a preparation phase consisting of gathering regional data and information on ecological zones, species, habitats, and processes across the BBRB region. At the meeting, scientists, managers and ranchers were grouped by expertise to identify conservation targets, important ecosystem services and functions, areas of special interest, threats and opportunities, conservation and restoration tools, and site-specific monitoring and research needs. The groups were provided with detailed maps and preliminary lists of targets that facilitated their focus on priority in the region. This analysis was used to compile a list of recommendations applicable to the entire region of interest, and to identify 29 priority conservation areas (PCA), which are areas of importance due to their ecological significance, threatened nature and opportunities for conservation, that are in urgent need of protection and restoration actions (see map on page 1).

After the meeting, the experts were tasked with drafting segments of the Assessment, based on their expertise, over a period of three months. The draft document was assembled and edited by the CEC Secretariat and a smaller group of governmental, academic, and nongovernmental organization (NGO) representatives. The Assessment was presented to and shared with local stakeholders for their review and comment in Manuel Benavides, Chihuahua, on 19 October 2012, in Múzquiz, Coahuila, on 26 October 2012, and in Alpine, Texas, on 20 December 2012, and their recommendations were integrated in the final draft before it was peer reviewed.

The Assessment is meant to provide a binational and comprehensive regional approach to conservation based on the best available scientific information and expert opinion. It does not in any way override the priorities, activities, and work plans of any of the partner agencies and private efforts underway throughout the region. Its goal is to assist local stakeholders in identifying opportunities, strengthening existing partnerships, and reaching out to build new cooperative initiatives across the BBRB landscape.

General Recommendations

1. Use this Conservation Assessment as a foundation to develop strategies for implementing Adaptive Management for priority ecosystems, such as grasslands and the Rio Grande, that consider priority or representative conservation targets. Such strategies should address the following questions:
   a. What are the most urgent and strategic management actions needed?
   b. Where there is uncertainty in how to accomplish conservation goals and objectives, what are the essential things to monitor to evaluate the effects of climate change and other ecosystem drivers on conservation targets?

Pecos River Bridge at Langtry, Texas. Photo: Marcus Calderon

2. Use tools like vulnerability assessments and future scenario planning with climate change projections to help managers and landowners plan for uncertainty; choosing conservation actions which promote adaptation and build resilience to climatic changes that would favor increased drought, extreme weather, changes in wildfire and hydrologic regimes, and the spread of exotic species and diseases.
3. Define conservation goals and objectives for each conservation target, starting with those that are of the highest priority.
4. Evaluate the status of the Transboundary Aquifer Assessment Program.
5. Create an institutional framework to facilitate binational conservation and restoration projects intended to address invasive species, sustainable livestock practices, restoration of degraded rangeland and habitats, ecotourism, and alternative land uses, among others.
6. Assist the Big Bend Cooperative, which represents a number of state and federal agencies in the region, to be an effective mechanism in promoting and supporting landowner-driven conservation efforts and local initiatives, particularly with regard to grasslands and range management.
7. In both the US and Mexico, continue to promote and implement government programs that provide assistance, cost-share, incentives, and property rights protection to private landowners related to the conservation of natural resources.
8. Improve environmental health and promote sustainable economic development of border communities by continuing to support the development of conservation-related jobs and ecotourism and providing assistance in developing programs for refuse and waste management.
9. Build capacity within academia, state and federal agencies as well as civil society to conduct the inventory and monitoring recommendations from each Priority Conservation Area (PCA) in a coordinated manner across the region. Cross-border academic partnerships can be useful in addressing the need for addressing the scientific and monitoring needs outlined in this document.
10. Access remote sensing data, such as land use and vegetation cover, for the region. Local efforts and initiatives should take advantage of broader data collection initiatives at the national and international levels to enhance data efforts collected in PCAs and throughout the region.
11. Promote water quality data collection, monitoring, and modeling. Coordinate with International Boundary and Water Commission (IBWC) the hosting of binational datasets. Encourage the Texas Commission on Environmental Quality (TCEQ) to analyze past water quality data, in particular water salinity and nutrients.
12. Encourage development of binational ecotourism routes on both sides of the border that foster healthy and sustainable livelihoods as well as address conservation objectives.
13. Facilitate raising the language competency of the partners in planning and allocating funds for international travel, and for learning Spanish and English in state and federal agencies, as well as civil society.
14. Use the Conservation Assessment as an instrument to support and justify funding at the international, national, and local levels in both Mexico and the United States.

Background

The Rio Grande, from its confluence with the Río Conchos to Amistad Dam, is the centerpiece of a transboundary landscape of unique conservation value that encompasses public and private lands. Protected lands on both sides of the US-Mexico border within the greater Big Bend ecosystem approach 12,000 square kilometers (3 million acres). This region includes grasslands that are globally important for migratory birds, scattered montane sky islands, vast tracts of arid shrubland, rare desert plants, and springs, rivers, and streams. In this arid land, aquatic resources are rare and support a rich diversity of species.

These large transboundary ecosystems are steadily degrading, due to human activities and climate-induced changes. Channel narrowing—due to the current hydrologic regime, sediment accumulation, and exotic riparian plant species—has resulted in increased frequency of flooding of riverside communities, degraded water quality, decreased diversity of habitats available for fish and wildlife, and decreased riverine and riparian ecosystem resiliency to large-scale stressors such as climate change. The degradation of these riparian habitats, coupled with the loss of springs because of aquifer depletion and the diversion of water for irrigation throughout the entire watershed, has had a great impact on wildlife. Over the past 150 years, grasslands have progressively degraded into less productive shrublands. Pressure from livestock overgrazing and increased drought frequency has contributed to soil erosion, desertification, contamination of springs and seeps, and decreased biodiversity. Montane forest habitats in the region are isolated from each other by broad valleys of desert habitat, creating "sky islands" that often harbor endemic species and unusual ecological assemblages. High intensity wildfires, climate change (e.g., increased heat waves and summer drought, increased temperatures in the winter, and extreme rainfall events), invasive species, and overgrazing are causing montane forest degradation across the region.

The significance of transboundary conservation efforts along the US-Mexico border in the Big Bend-Río Bravo (BBRB) region of the northern Chihuahuan Desert is reflected in recent declarations by Presidents Obama and Calderón (2010) that recognize the fragility and uniqueness of this region and its conservation value for both nations. In May 2009, United States Secretary of the Interior Ken Salazar and Mexican Secretary of Environment and Natural Resources Juan Rafael Elvira Quesada announced their commitment to strengthen transboundary conservation efforts throughout the region. Recommendations made in this Assessment for binational conservation actions offer a unique opportunity to unify conservation partners, from government, civil society, academia, and the public sector, for the purpose of providing leadership in strategic conservation science, planning, design, and implementation at a broad, transboundary scale.

In recent years, Mexico and the US have renewed their commitment to binational cooperation in this region. The Big Bend Conservation Cooperative (BBCC) was formally created by the National Park Service (NPS—Big Bend National Park), US Fish and Wildlife Service (USFWS), Region 2, the US Geological Survey (USGS), and the Texas Parks and Wildlife Department (TPWD). Together with a number of agencies in Mexico, including the *Comisión Nacional de Áreas Naturales Protegidas* (Conanp), *Comisión Nacional de Agua* (Conagua), *Instituto Nacional de Ecología y Cambio Climático* (INECC), and *Comisión Internacional de Límites y Aguas* (CILA) under the Big Bend-Río Bravo Initiative, led by the Department of Interior (DOI) and the *Secretaría de Medio Ambiente y Recursos Naturales* (Semarnat), are working together to strengthen binational cooperation in the BBRB region. Support of these efforts has been provided by Environment Canada, Semarnat, and the US Environmental Protection Agency, through the Commission for Environmental Cooperation (CEC), which has facilitated, funded and implemented this project through its 2011–2012 Operational Plan.

Purpose

The objective of this Conservation Assessment is to gather the best available scientific information and expert opinion, as well as input from stakeholders in the region to provide a common framework for transboundary stewardship of natural resources in the region. Many of these agencies, private landowners and *ejidos* share the common and supportive goals of protecting both the ecological services and functions of these ecosystems, fish and wildlife habitats, and maintaining economically productive activities on these lands. This document serves as a basis for greater awareness for the public, interested agencies, and the international community as well as a starting point for regional conservation planning. Drafted and reviewed by a binational group of conservation experts, managers, and stakeholders, this document provides an analytical framework for protection and restoration priorities within the Big Bend-Río Bravo landscape.

It should be noted that there are significant opportunities and ongoing projects to restore or protect priority ecosystems on both public and private lands that are not included in the priority conservation areas (PCA) described in this document. These areas where conservation activities are occurring or have the potential to be

successful, should not be overlooked as potential priorities for action. The successful restoration of degraded ecosystems, or the protection of important habitats, will benefit local communities and native plant and wildlife species and contribute to the development and dissemination of beneficial management practices throughout the region, whether or not these areas are identified as PCAs.

Scope of the Assessment

All recommendations with a binational focus provided in this Assessment will need to be vetted and agreed upon within the framework and jurisdiction of existing international treaties and relevant federal and international agencies, such as the IBWC and CILA. All matters related to water quantity monitoring and planning in the Rio Grande and its Mexican tributaries lie within the jurisdiction of IBWC/CILA for international matters, and with Conagua, the US Bureau of Reclamation, and TCEQ for domestic matters. Any comment regarding the need to provide water flows for maintaining habitats does not imply the responsibility or commitment of the Mexican government to provide that flow. Any binational evaluation of transboundary aquifers mentioned in this project should be understood to be undertaken in the framework of the IBWC.

Recommendations shall not include any form of water management not specified in international treaties. Sections *Research and Monitoring Needs* for the PCAs located in Mexico shall be limited to water quality. The scope of this project does not include water quantity in the Rio Grande and Mexican tributaries, like water rights, water use, water management, water flows, transboundary aquifers, and other topics related to water quantity.

Process

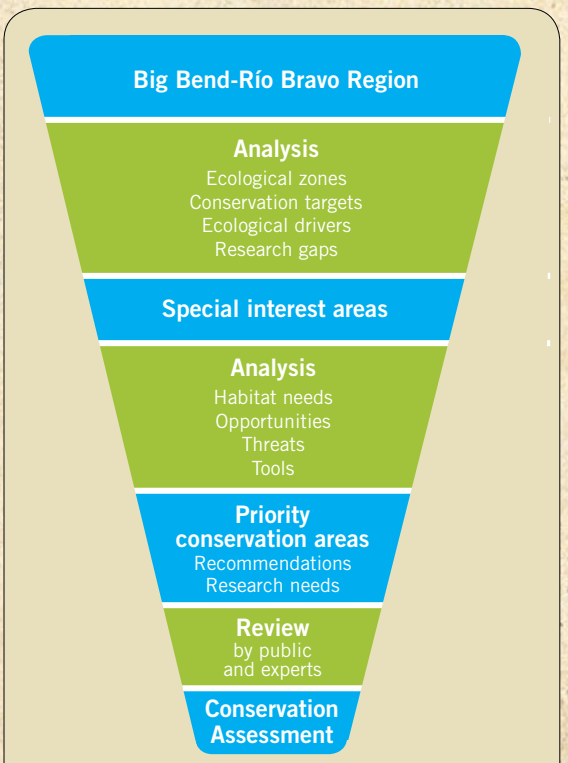
In September 2012, the CEC convened 60 experts from federal and state governments and civil society from Mexico and the United States in Mexico City to identify conservation targets, PCAs, research and monitoring needs, and general recommendations for improved binational stewardship of public and private lands in the Big Bend-Río Bravo region.

The meeting was preceded by a preparation phase consisting of gathering regional data and information on ecological zones, species, habitats and processes into a Preparation Document. During the meeting, scientists, managers and ranchers, were grouped by expertise to identify conservation targets (see the section on Conservation Targets), important ecosystem services and functions provided by the region's ecological zones, areas of special interest, threats and opportunities, conservation and restoration tools, monitoring and research needs, and priorities for the region (Figure 1).

The meeting resulted in the identification of 29 PCAs, which were defined as areas of importance due to their ecological significance, as well as threats and opportunities for conservation, protection, and restoration actions. The process was driven by consensus during plenary sessions guided by a facilitator and the CEC Secretariat. A detailed description of the process is provided in Figure 2.

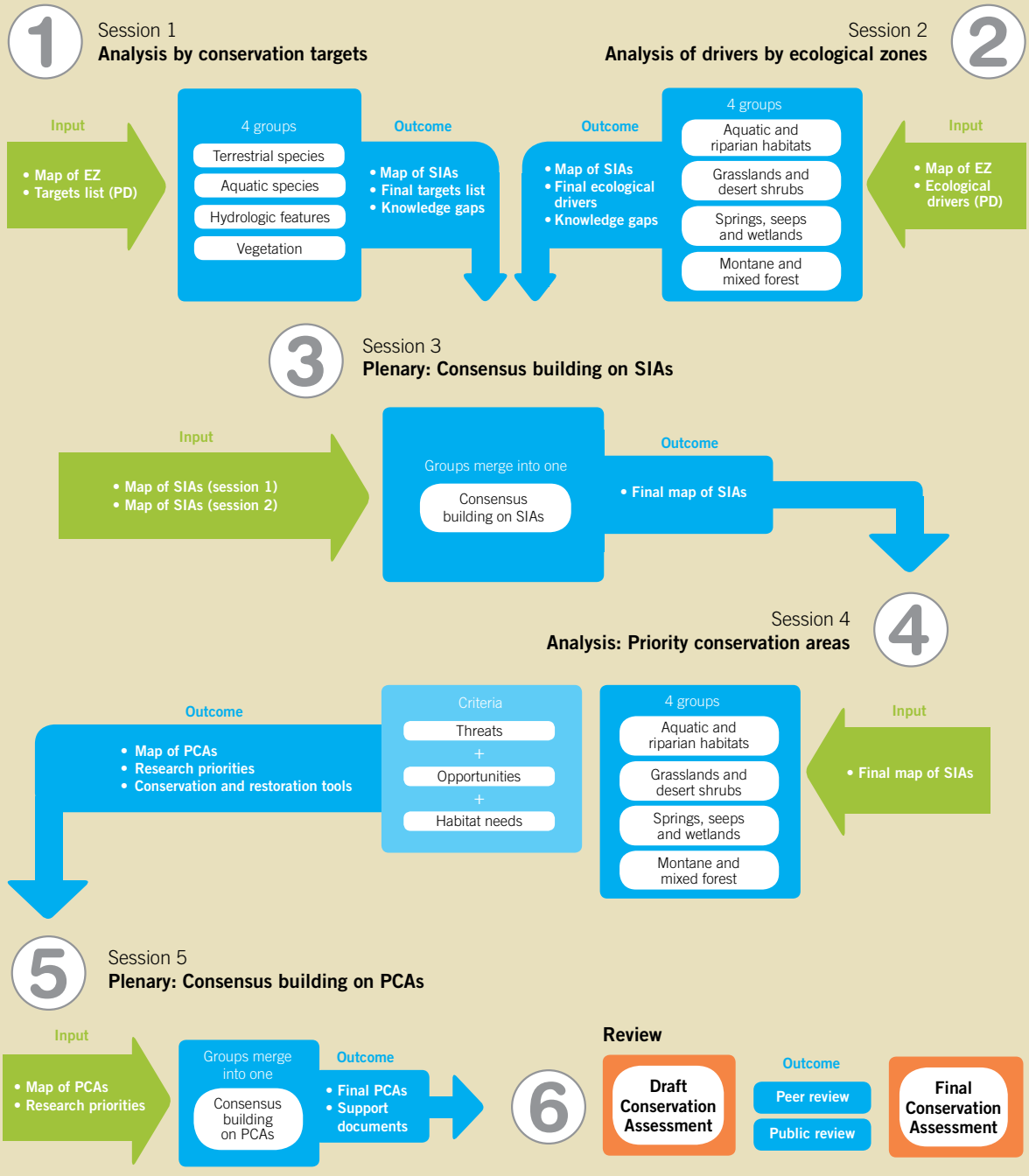
The Conservation Assessment was drafted and reviewed by the same expert group, with the assistance of several additional experts. Once completed, the first draft document was presented to communities living in and around protected areas in Mexico and the US. In Mexico, two meetings were held with the advisory councils of the Área de Protección de Flora y Fauna (APFF) Cañon de Santa Elena in Manuel Benavides, Chihuahua, and Maderas del Carmen in Múzquiz, Coahuila, on 19 October and 26 October 2012, respectively. In the United States, the Assessment was presented at the Open House on Big Bend Region Conservation in Alpine, Texas, on 20 December 2012. All comments received during those consultations were incorporated into the document. Finally, the document was peer-reviewed by experts and managers in early 2013 prior to final approval and publication.

Figure 1: Overview of the process followed to develop the Conservation Assessment



Prepared by María Dolores Wesson and Catherine Hallmich for the Experts' Meeting (July 14, 2012)

Figure 2: Detailed description of the process for the development of the Conservation Assessment, including the Experts' Meeting (steps 1-5), and the public review and peer review (step 6) leading up to the final Conservation Assessment



Acronyms: **EZ** Ecological zones; **PCAs** Priority Conservation Areas; **PD** Preparation document; **SIAs** Special Interest Areas

Prepared by María Dolores Wesson and Catherine Hallmich. July 14, 2012

Priority Conservation Areas

Priority Conservation Area		Integrity	Risk
Aquatic and riparian habitats			
1	River Corridor	Medium	High
2	San Antonio Creek	Medium	Medium
3	San Carlos Creek	Medium	Medium
4	Terlingua Creek	Medium	Medium
5	Alamito Creek	Medium	Medium
6	Devils River	High	High
7	Pecos River	High	High
8	Balmorhea Springs Complex	High	Medium
9	Big Bend Ranch State Park Springs	Medium	Low
10	San Carlos Springs	High	Medium
11	Boquillas Hot Springs	Medium	Low
12	Gambusia Springs	Medium	Medium
Grasslands			
13	Sierra de Hechiceros y Lagunas de Sanchez y de Montoya Grasslands	Medium	High
14	Marfa Grasslands	Medium	High
15	Alpine Grasslands	Medium	High
16	Marathon Grasslands	Medium	High
17	Morelos - Los Lirios Grasslands	Low	High
18	Valle de Colombia Grasslands	Medium	Medium
19	Serranías del Burro Grasslands	High	Medium
Mountains			
20	Chinati Mountains	High	Medium
21	Glass Mountains	Unknown	Medium
22	Davis Moutains	Medium	Medium
23	Chisos Mountains	High	Medium
24	Dead Horse Mountains	High	Low
25	Sierra Rica	Medium	Medium
26	Sierra del Carmen	Medium	High
27	Mountains of the Serranías del Burro	Medium	High
28	Sierra la Encantada	Medium	High
29	Sierra de Santa Rosa	Medium	High

Protected areas in Mexico and the US

Priority Conservation Areas in the Big Bend-Río Bravo Region

8
22
Fort Davis
14
21
Alpine
Marfa
16
Marathon
Candelaria
15
7
Pecos River
Devils River
Sanderson
Ruidosa
20
6
5
Río Grande - Río Bravo
Ochoa
Langtry
Presidio
Ojinaga
Amistad Reservoir
Redford
4
24
1
9
Terlingua
23
11
Boquillas
25
10
Nuevo Lajitas
Castolon
12
2
3
Jaboncillos
26
27
17
Manuel Benavides
13
19
San Miguel
28
18
29
Múzquiz
Río Sabinas

Conservation Targets

Conservation targets, as defined in this document, are biological and/or physical features that represent the biodiversity of the region, the conservation of which increases the chances of conserving other living resources. Targets can be individual species, communities, ecosystems, or physical aspects of the landscape, such as important hydrological features. Conservation targets were identified throughout the BBRB region as part of the analysis for identifying PCAs. Conservation targets in the table below are grouped by taxonomy.

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
INVERTEBRATES						
Phantom cave snail *(Pyrgulopsis texana)*	Balmorhea Springs Complex	Restore and/or enhance habitat, including control of invasive species.	Low	Proposed Endangered (US) Not listed (MX)	Population threatened by diminished spring flows.	Yes
Phantom springsnail *(Tryonia cheatumi)*	Balmorhea Springs Complex	Restore and/or enhance habitat, including control of invasive species.	Low	Proposed Endangered (US) Not listed (MX)	Population threatened by diminished spring flows.	Yes
Salina mucket *(Potamilus metnecktayi)*	Rio Grande	Monitor and Inventory population status and genetic integrity.	Low	Under review (US) Not listed (MX)	Rare but present to occasional in the Rio Grande from Boquillas canyon to lake Amistad. Population threatened by loss of natural flow regime and perhaps diminished water quality, and loss or alteration of preferred substrate.	No
Tampico pearlymussel *(Cyrtonaias tampicoensis)*	Rio Grande	Inventory. Restore and/or enhance habitat.	Low	Not listed (US) Not listed (MX)	Occasional between Mariscal and La Linda, becoming more common in Lower Canyons, to Amistad lake. Population threatened by loss of natural flow regime and perhaps diminished water quality. Loss or alteration of preferred substrate.	No
Texas hornshell *(Popenaias popeii)*	Rio Grande	Improve inventory protocol. Restore and/or enhance habitat.	Low	Candidate (US) Not listed (MX)	Rare but present in Rio Grande from Boquillas Canyon to Amistad Reservoir. Unknown distribution. Historically in the Rio Grande down to Amistad dam and below. Indicator species. Population threatened by loss of natural flow regime and perhaps diminished water quality. Loss or alteration of preferred substrate.	No
Diminutive amphipod (*Gammarus hyalleloides)*	Balmorhea Springs Complex	Restore and/or enhance habitat, including control of invasive species.	Low	Proposed Endangered (US) Not listed (MX)	Present in some springs in Jeff Davis County. Population threatened by diminished spring flows.	Yes
Invertebrate species	Devils River	US tributaries Inventory and distribution.	Low	Not listed (US) Not listed (MX)		
Monarch butterfly *(Danaus plexippus)*	Sierra del Carmen, Sierra Rica	Monitoring.	Low	Not listed (US) Threatened (MX)	Iconic species. Lives in riparian and montane woodlands.	No
AMPHIBIANS						
Amphibian species (general)	Devils River - only the spring salamander *(Eurycea spp.),* US tributaries	Inventory and distribution. Restore and/or enhance habitat, including control of invasive species. Assure quality and quantity of spring outflow discharge in the case of the salamander.	Low	Not listed (US)	Populations of native frogs threatened by non-native bull frogs and green tree frog, decreased water quality, parasites, and climate change.	No

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
Canyon tree frog *(Hyla arenicolor)*	Sierra del Carmen, Davis Mountains, Chisos Mountains	Mesic habitat protection.	Low	Not listed (US) Not listed (MX)	Found in Sierra del Carmen. Lives in oak-chaparral in semi-arid to arid canyons from 1,300 m (4,300 ft) elevation upward. Threatened by drought. Populations depend on rainfall for reproduction. Lives in riparian and montane woodlands.	No
Woodhouse's toad *(Bufo woodhousii)*	Rio Grande	Restore and/or enhance habitat, including control of invasive species.	Low	Not listed (US) Not listed (MX)	Present historically in the flood and backwater pools of the Rio Grande.	No
REPTILES						
Big Bend rough-footed mud turtle *(Kinosternon hirtipes murrayi)*	US tributaries	Inventory and population status in Alamito Creek. Restore and/or enhance habitat, occurs only on private lands.	Low	Not listed (US) Protected (MX)	Unknown distribution. Historically in the US only in the Alamito Creek drainage. Population threatened by loss of habitat and reduced spring flows.	No
Big Bend slider *(Trachemys gaigeae)*	Gambusia Springs, River Corridor	Restore and/or enhance habitat, including control of invasive species.	Low	Not listed (US) Not listed (MX)	Present historically in the Rio Grande. Native to Texas and Chihuahua. Population threatened by exotic elegant slider competition, invasive alien plant species, and by loss of natural flow regime and perhaps diminished water quality.	Yes
Rio Grande cooter *(Pseudemys gorzugi)*	Balmorhea Springs Complex, Pecos River, Devils River	Restore and/or enhance habitat, including control of invasive species. Provide for bankside nesting habitat and predator control on nest and hatchlings.	Low	Not listed (US) Not listed (MX)	Presumed moderately stable because of existence and persistence.	Yes
Gray-checkered whiptail *(Aspidoscelis dixoni)*	Chinati Mountains	None recommended.	Low	Not listed (US) Not listed (MX)	No conservation action recommended, as much of its known range is on protected lands.	Yes
Merriam's canyon lizard *(Sceloporus merriami merriami)*	Rio Grande, Coahuila	None recommended.	Low	Not listed (US) Not listed (MX)	Scattered populations known throughout the state of Coahuila. Occurs throughout the Rio Grande basin, from Presidio, TX, to east of Val Verde County, TX.	No
Desert massasauga *(Sistrurus catenatus edwardsii)*	All grasslands	Conservation of grassland and savanna.	Low	Not listed (US) protected (MX)		No
FISH						
Mexican stoneroller *(Campostoma ornatum)*	Rio Grande, Río Conchos	Increased inventory in the Rio Grande.	Low	Threatened (TX) Not listed (US) Not listed (MX)	Present in Alamito and Terlingua creeks. Presence unknown in the Río Conchos. Population is dependent upon the tributaries, and threatened by diminished surface and spring flows.	No
Red shiner *(Cyprinella lutrensis)*	Rio Grande and tributaries	Restore and/or enhance habitat.	Good	Not listed (US) Threatened (MX)	Abundant in a variety of habitats and tolerant to environmental extremes.	No
Conchos shiner *(Cyprinella panarcys)*	Río Conchos (upper basin), MX tributaries	Inventory, distribution and trend. Restore and/or enhance habitat.	Low	Endangered (MX)	Population threatened by reduced surface and spring flows.	Yes
Proserpine shiner *(Cyprinella proserpina)*	Devils River, Pecos River, MX tributaries	Inventory. Protect spring flows. Restore and/or enhance habitat.	Medium	Threatened (TX) Not listed (US) Threatened (MX)	Population threatened by reduced surface and spring flows.	Yes
Manantial roundnose minnow *(Dionda argentosa)*	Devils River, Pecos River	Monitor population status and genetic integrity. Protect spring flows. Restore and/or enhance habitat.	Low	Not listed (US) Not listed (MX)	Population threatened by diminished spring flows.	Yes

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
Devils River minnow *(Dionda diaboli)*	Devils River, Río Sabinas	Inventory and distribution.	Medium	Threatened (TX) Threatened (US) Endangered (MX)	Population status in Mexico unknown. Population threatened by diminished spring flows.	Yes
Roundnose minnow *(Dionda episcopa)*	Rio Grande, tributaries in BBNP, MX tributaries, Balmorhea Springs Complex	Inventory and distribution. Restore and/or enhance habitat.	Low	Endangered (MX)	Population threatened by loss of natural flow regime and perhaps diminished water quality.	No
Rio Grande chub *(Gila pandora)*	Davis Mountains	Inventory. Protect spring flows. Restore and/or enhance habitat.	Low	Threatened (TX) Not listed (US) Threatened (MX)	Present in springs located in the Davis Mountains and upper reaches of the Pecos River. Population threatened by diminished spring flows.	No
Rio Grande silvery minnow *(Hybognathus amarus)*	Rio Grande	Inventory in the Rio Grande. Restore and/or enhance habitat, including control of invasive species.	Low	Endangered (US) Extinct (MX)	Reintroduced in the Rio Grande in 2008. Population threatened by loss of natural flow regime and perhaps diminished water quality.	No
Speckled chub *(Macrhybopsis aestivalis)*	Rio Grande and tributaries	Inventory, distribution and trend. Restore and/or enhance habitat.	Low	Not listed (US) Threatened (MX)	Population threatened by loss of natural flow regime and perhaps diminished water quality.	Yes
Tamaulipas shiner *(Notropis braytoni)*	Lower Pecos River	Inventory, distribution and trend. Restore and/or enhance habitat.	Low	Not listed (US) Threatened (MX)	Population threatened by loss of natural flow regime and perhaps diminished water quality.	Yes
Chihuahua shiner *(Notropis chihuahua)*	Río Conchos, Rio Grande, tributaries (from the Río Conchos to eastern BBNP), Rio Grande (occasionally)	Inventory, distribution and trend. Restore and/or enhance habitat, including control of invasive species.	Low	Threatened (TX) Not listed (US) Threatened (MX)	Population dependent on tributaries.	Yes
Rio Grande shiner *(Notropis jemezanus)*	Rio Grande	Inventory, distribution and trend. Restore and/or enhance habitat.	Low	Not listed (US) Threatened (MX)	Population threatened by loss of natural flow regime and perhaps diminished water quality.	Yes
Longnose dace *(Rhinichthys cataractae)*	Rio Grande	Inventory, distribution and trend. Restore and/or enhance habitat, including control of invasive species.	Low	Not listed (US) Not listed (MX)	Population threatened by loss of natural flow regime and perhaps diminished water quality.	No
Blue sucker *(Cycleptus elongatus)*	Rio Grande, MX tributaries, Pecos River, Río Conchos	Monitor population status and genetic status. Restore and/or enhance habitat, including control of invasive species.	Low	Threatened (TX) Not listed (US) Threatened (MX)	Indicator species. Evidence suggests this is a new, undescribed species. Population dependent on flows and threatened by loss of natural flow regime and perhaps diminished water quality.	Yes
Mexican redhorse *(Moxostoma austrinum)*	Rio Grande	Monitor population status and genetic integrity. Restore and/or enhance habitat.	Low	Not listed (US) Not listed (MX)	Population threatened by loss of natural flow regime and perhaps diminished water quality.	No
Headwater catfish *(Ictalurus lupus)*	Balmorhea Springs Complex, Pecos River	Monitor population status and genetic integrity. Restore and/or enhance habitat, including control of invasive species.	Low	Not listed (US) protected (MX)	Historically in the Rio Grande. Population threatened by diminished spring flows.	No
Rio Grande cutthroat trout *(Oncorhynchus clarki virginalis)*	Montane headwater reaches of the Rio Grande and Pecos River.	Restore and/or enhance habitat, including control of invasive species. Restore population in the Davis Mountains.	Medium	Candidate (US) Not listed (MX)	Population extirpated from the Davis Mountains due to absence of spring flows. Persists in upper reaches of the Rio Grande and Pecos River.	No

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
Big Bend gambusia *(Gambusia gaigei)*	Boquillas Hot Springs, Gambusia Springs	Monitor population status and genetic integrity. Evaluate similar springs and streams in adjacent Mexico for existence and/or introduction possibilities. Restore and/or enhance habitat, including control of invasive congeneric species.	Good	Endangered (US) None (MX)	Present in the Rio Grande at Rio Grande Village. Almost extinct. Population threatened by reduced spring flows, invasive alien species (giant cane and saltcedar), nutria, Gambusia affinis, and potentially by exotic green tree frog.	Yes
Pecos gambusia *(Gambusia nobilis)*	Balmorhea Springs Complex	Inventory. Protect spring flows. Restore and/or enhance habitat.	Medium	Endangered (TX) Endangered (US) Not listed (MX)	Population threatened by diminished spring flows.	No
Blotched gambusia *(Gambusia senilis)*	Río Conchos	Maintain current populations and re-establish in historic range. Protect spring flows. Restore and/or enhance habitat, including control of invasive species.	Low	Threatened (TX) Not listed (US) Threatened (MX)	Extirpated from Satan Canyon (Devils River). Population threatened by diminished spring flows.	Yes
Marbled swordtail *(Xiphophorus meyeri)*	Río Sabinas	Inventory, distribution and trend. Restore and/or enhance habitat.	Low	Endangered (MX)	Population threatened by loss of natural flow regime and perhaps diminished water quality.	Yes
Comanche Springs pupfish *(Cyprinodon elegans)*	Balmorhea Springs Complex	Inventory, distribution, trend, and genetic integrity. Restore and/or enhance habitat, including control of invasive species.	Medium	Endangered (TX) Endangered (US) Not listed (MX)	Population threatened by diminished spring flows.	Yes
Conchos pupfish (Cyprinodon eximius)	Rio Grande, Devils River, Río Conchos	Inventory, distribution, trend, and genetic integrity. Restore and/or enhance habitat, including control of invasive species.	Low	Threatened (TX) Not listed (US) Threatened (MX)	Population threatened by diminished spring flows.	No
Conchos darter *(Etheostoma australe)*	Upper Río Conchos basin, MX tributaries	Inventory, distribution and trend.Restore and/or enhance habitat.	Low	Endangered (MX)	Population threatened by reduced surface and spring flows.	Yes
Rio Grande darter *(Etheostoma grahami)*	Rio Grande, Devils River, Pecos River, US tributaries	Inventory, distribution and trend. Restore and/or enhance habitat.	Medium	Threatened (TX) Not listed (US) Threatened (MX)	Population threatened by loss of natural flow regime and perhaps diminished water quality.	Yes
Bigscale logperch *(Percina macrolepida)*	Devils River MX tributaries	Inventory, distribution and trend. Restore and/or enhance habitat.	Low	Not listed (US) Not listed (MX)	Distribution and microhabitat requirements are probably poorly known in the region.	No
BIRDS						
Water birds	Wetlands and marshes throughout the region	Protection of water availability.	Low	Not listed (US) Not listed (MX)		No
Gray hawk *(Buteo nitidus)*	Davis Mountains, Big Bend National Park (periodically)	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)	Probably low density nesting species along wooded riparian corridors.	No

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
Common black-hawk *(Buteogallus anthracinus)*	Gambusia Springs, Davis Mountains, Big Bend Ranch State Park, Riparian gallery woodlands and forest throughout mountain forests	Inventory, distribution and trend in Coahuila.	Medium	Not listed (US) protected (MX)	Present throughout the region, but abundance unknown. Can be found in Sierra del Carmen from 1,460 m (4,800 ft) in semi-arid canyon with some riparian areas to over 1,800 m (6,000 ft) in pine-oak woodland with riparian areas nearby. Priority species for the Rio Grande Joint Venture (RGJV). Abundant information on the ecology of this species.	No
Ferruginous hawk *(Buteo regalis)*	All Grasslands	Inventory, distribution and trend.	Medium	Not listed (US) protected (MX)	Winter resident only, does not breed in the region. Populations declining throughout the region. Threatened by degraded wintering grasslands. Priority species for the RGJV.	No
Golden eagle *(Aquila chrysaetos)*	Chinati Mountains, Sierra La Encantada, Serranías del Burro Grasslands, Sierra de Santa Rosa, Valle de Colombia Grasslands, Sierra de Hechiceros Grasslands, Marfa Grasslands, Morelos-Los Lirios Grasslands, Sierra del Carmen, Sierra Rica, Davis Mountains	Inventory, distribution and trend.	Medium	Not listed (US) Threatened (MX)	Lives in Sierra del Carmen and adjacent mountains. Threatened by habitat loss in the former grasslands. Has become rare in the region. Population nests on cliffs and steep escarpments in grassland, chaparral, shrubland, forest, and other vegetated areas.	No
Solitary eagle *(Harpyhaliaetus solitarius)*	Maderas del Carmen	Protect montane forest.	Low	Not listed (US) Not listed (MX)	Very sparse records from the Maderas del Carmen.	No
Peregrine falcon *(Falco peregrinus anatum)*	Chinati Mountains, Sierra La Encantada, Chisos Mountains, Sierra del Carmen, Sierra Rica, Rio Grande canyon cliffs	Inventory, distribution and trend.	Low/Medium	Delisted due to recovery (US) protected (MX)		No
Northern aplomado falcon *(Falco femoralis septentrionalis)*	Valle de Colombia Grasslands, Sierra de Hechiceros Grasslands, Marathon Grasslands, Marfa Grasslands, Sierra de Hechiceros Grasslands	Inventory, distribution and trend.	Low	Endangered (US) Threatened (MX)	Species at northern boundary of historic range. Population at risk due to specific needs for nesting (e.g., specific shrub structure). Ongoing efforts for re-introduction in West Texas. Indicator species. Population in nearby grasslands in Chihuahua may be at risk too.	No
Mountain plover *(Charadrius montanus)*	All grasslands	Inventory, distribution and trend.	Low	Not listed (US) Threatened (MX)	Rare in the region and very difficult to find or confirm in such small numbers over vast grassland expanses. Priority species for the RGJV.	No
Upland sandpiper *(Bartramia longicauda)*	All grasslands (mid-continental migrant)	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)	Population at risk. Priority species for the RGJV.	No
Long-billed curlew *(Numenius americanus)*	Alpine Grasslands, Marfa Grasslands, Valle de Colombia Grasslands, Sierra de Hechiceros Grasslands	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)	Fall migrant in northern Coahuila and western Texas. Threatened by habitat loss (fragmented and degraded former grasslands), and water sources depletion. Indicator species. Considered priority grasslands species for the RGJV. Roost sites and foraging habitat are crucial to population survival, which have shown evidence of disruption.	No

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
Montezuma quail *(Cyrtonyx montezumae)*	Chinati Mountains, Serranías del Burro Grasslands, Morelos-Los Lirios Grasslands, Serranías del Burro Mountains, Glass Mountains, Sierra Rica, Sierra del Carmen, Davis Mountains	Inventory, distribution and trend.	Low	Not listed (US) Protected (MX)	Fairly common from 1,200-1,800 m (4,000-6,000 ft) in scattered oak-ponderosa with patches of open grasslands, pine-oak woodland and pine-fir-oak woodlands. Population possibly declining.	No
Gambel's quail *(Callipepla gambelii ignoscens)*	Rio Grande (terrace shrublands)	None recommended.	Good	Not listed (US) Not listed (MX)	Small and perhaps declining populations in the lower BBRB region. Lives in riparian and arroyo shrublands, and low desert habitat along the Rio Grande corridor in West Texas. Game species important for local communities. Considered priority for grasslands in the RGJV.	No
Wild turkey *(Meleagris gallopavo intermedia)*	Serranías del Burro Grasslands, Sierra del Carmen, Davis Mountains, Chisos Mountains	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)	Lives in creeks in desert shrub habitat to pine-oak woodlands. Game species important for locals.	No
Burrowing owl *(Athene cunicularia)*	Valle de Colombia Grasslands, Sierra de Hechiceros Grasslands, Serranías del Burro Grasslands, Alpine Grasslands, Marfa Grasslands, Marathon Grasslands, Sierra del Carmen (west and east side in lower desert elevations and restored grasslands)	Inventory, distribution and trend. Restoration of grasslands.	Medium	Not listed (US) Threatened (MX)	Population is small and declining in many areas from habitat loss. Threatened by degraded grasslands condition of lower elevation lands in northern Mexico. Priority species for the RGJV. Lives in burrows created by other species, usually mammals. Collision with cars is a major source of mortality.	No
Great horned owl *(Bubo virginianus)*	Sierra La Encantada, Sierra de Santa Rosa, Sierra Rica	Monitoring.	Low	Not listed (US) Not listed (MX)	Species is stable and abundant throughout the region.	No
hummingbirds (up to approx. 16 possible species in region)	All mountain ranges, and several desert species	Inventory, distribution and trend.	Medium	Not listed (US) Not listed (MX)	Large guild with some specific species' habitat requirements. Diverse habitat availability. Limited information on needs.	No
Loggerhead shrike *(Lanius ludovicianus)*	Valle de Colombia Grasslands, Sierra de Hechiceros Grasslands, Marathon Grasslands, Marfa Grasslands, open plains throughout Sierra del Carmen (lower elevations)	Inventory, distribution and trend. Conservation of grassland and savanna.	Medium	Not listed (US) Not listed (MX)	Population declining locally. Present in northern Coahuila, and in grasslands and desert lowlands. Moderate information on distribution but limited on trends.	No

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
Black-capped vireo *(Vireo atricapilla)*	Sierra Rica, Sierra del Carmen/ Maderas del Carmen, Chisos Mountains, Pecos River, Serranías del Burro Mountains	Inventory, distribution and trend, especially in northern Coahuila, including other foothills and mountain ranges.	Medium	Endangered (US) Endangered (MX)	Inhabits Serranías del Burro, Sierra del Carmen and La Encantada from elevations at 1,160–>1,200 m (3,800–>4,000 ft). Frequents oak chaparral at the lower edges of pine-oak, will nest in semi-arid canyons. Priority species for the RGJV. Lives in deciduous and evergreen shrubland.	No
Sprague's pipit *(Anthus spragueii)*	Valle de Colombia Grasslands, Sierra de Hechiceros Grasslands, Grasslands in Brewster County, Texas	Inventory, distribution and trend.	Low	Candidate (US) Not listed (MX)	Population at high risk. Priority species for the RGJV. Indicator species for grasslands. Lives in montane and mixed forests.	No
Colima warbler *(Oreothlypis crissalis)*	Sierra Rica, Chisos Mountains, Sierra del Carmen	Inventory, distribution and trend.	Low	Not listed (US) protected (MX)	Lives in pine-oak woodland, such as in Sierra del Carmen and the Chisos Mountains. One of the least-studied warblers. Priority species for the RGJV. Iconic species for the Chisos Mountains. Neotropical migrant.	No
Cassin's sparrow *(Peucaea cassinii)*	Valle de Colombia Grasslands,Sierra de Hechiceros Grasslands, Marathon Grasslands, Grasslands throughout Sierra del Carmen (lower elevations)	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)		No
Vesper sparrow *(Pooecetes gramineus)*	All grasslands	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)	Population at risk. Priority species for the RGJV. Population declining. Lives in grasslands. Reasons for their decline are poorly understood and very little is known about their wintering ecology.	No
Lark bunting *(Calamospiza melanocorys)*	Valle de Colombia Grasslands, Sierra de Hechiceros Grasslands	Maintain/improve grassland integrity and conservation.	Low	Not listed (US) Not listed (MX)		No
Baird's sparrow *(Ammodramus bairdii)*	Marfa Grasslands	Inventory, distribution and trend.	Medium	Not listed (US) Not listed (MX)	Winters in the region. Priority species for the RGJV. Located in sites with Texas persimmon (*Diospirus texana*) and evergreen sumac (*Rhus virens*), or in oak shrubland. Indicator species.	No
Grasshopper sparrow *(Ammodramus savannarum)*	Marathon Grasslands, Cañon de Santa Elena	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)		No
Chestnut-collared longspur *(Calcarius ornatus)*	Grasslands of Valle de Colombia, Grasslands Sierra de Hechiceros	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)		No
Eastern meadowlark *(Sturnella magna lilianae)*	Grasslands throughout	Conservation of grassland and savanna.	Low	Not listed (US) Not listed (MX)		No
MAMMALS						
Miller's shrew/Carmen Mountain shrew *(Sorex milleri)*	Sierra del Carmen	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)	Populations in pine-fir-oak forests 1,900-2,700 m (6,200-8,850 ft) in Maderas del Carmen. Nesting documented.	Yes
Coahuila mole *(Scalopus aquaticus montanus)*	Sierra del Carmen	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)	Endemic to Maderas del Carmen. Lives in pine-oak woodland above 1,400 m (4,800 ft).	Yes
Presidio mole *(Scalopus aquaticus texana)*	Unknown	Inventory, distribution and trend.	Low	Not listed (US) Endangered (MX)	Current status in the region is unknown and appears to be declining.	Yes

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
Mexican long-nosed bat *(Leptonycteris nivalis)*	Sierra Rica, Sierra del Carmen, Chinati Mountains, Chisos Mountains, Morelos-Los Lirios Grasslands	Inventory, distribution and trend, particularly throughout sky island ranges. Inventory and monitoring of flowering agave plants (primary food source). Protect roosts.	Low	Endangered (US) Endangered (MX)	Lives in subtropical dry areas at medium and high elevations. Population possibly declining. Affected by overharvest of wild agave plants along migratory corridor. More information is needed about roost sites in Mexico and yearly fluctuations in food availability across the region.	No
Kit fox *(Vulpes macrotis)*	Valle de Colombia Grasslands, Serranías del Burro Grasslands, Sierra de Hechiceros Grasslands, Morelos-Los Lirios Grasslands, Marathon Grasslands, Marfa Grasslands, Alpine Grasslands, Sierra del Carmen	Inventory, distribution and trend.	Low	Not listed (US) Threatened (MX)	Lives in desert lowlands. Limited information. Anecdotal reports from landowners suggest that the population may be declining.	No
American black bear *(Ursus americanus)*	Chinati Mountains, Chisos Mountains, Davis Mountains, Dead Horse Mountain, Sierra La Encantada, Glass Mountains, Serranías del Burro Grasslands, Morelos-Los Lirios Grasslands, Sierra de Santa Rosa, Serranías del Burro Mountains, Sierra del Carmen, Sierra Rica	Protect corridors for natural dispersal. Protect large tracts of habitat for currently sustainable or naturally colonizing populations. Education and outreach to prevent killing.	Good	Threatened (TX) Not listed (US) Endangered (MX) - except in Serranías del Burro.	Iconic and indicator species. Beginning to move back into historic range in Santa Rosa and Sierra La Encantada. Bears are poached for meat and are also shot on sight in many of the ejidos and private lands in northern Coahuila. The connecting lands of desert shrub are vitally important for black bear dispersal from sky island to sky island and as dispersal corridors and feeding areas.	No
Puma/mountain lion *(Puma concolor)*	Sierra Rica	Inventory, distribution and trend.	Low	Not listed (US) Not listed (MX)	Mountain lion harvest is not regulated in Texas and populations are not monitored. Without monitoring, overexploitation of the population is possible.	No
Arizona black-tailed prairie dog *(Cynomys ludovicianus arizonensis)*	Marathon basin, Brewster County	Reintroduction to suitable habitats.	Low	Not listed (US) Not listed (MX)	Efforts to reintroduce this species are ongoing in Brewster County in addition to existing colonies. Keystone species in grasslands.	No
Cliff chipmunk *(Tamias dorsalis carminis)*	Sierra Rica, Sierra del Carmen	Protect montane pine forests.	Low	Not listed (US) Not listed (MX)	Lives in pine-oak to pine-fir forest above 1,800 m (6,000 ft). Population in Sierra del Carmen/Maderas del Carmen. The biggest threat to 'sky island' species in the region is habitat loss due to climate change.	No
Kangaroo rat *(Dipodomys spp.)*	Serranías del Burro Grasslands, Morelos-Los Lirios Grasslands, Valle de Colombia Grasslands, Sierra de Hechiceros Grasslands, Marathon Grasslands, Marfa Grasslands, Alpine Grasslands, Sierra del Carmen (west and east sides in lower elevations)	Monitor population.	Good	Endangered (US) Threatened (MX)	Common in lower desert elevations, in grasslands and shrublands. Keystone species.	No

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
American beaver *(Castor canadensis)*	US tributaries, MX tributaries, Devils River, Pecos River, Gambusia Springs	Restore and/or enhance habitat, including control of invasive species.	Low	Not listed (US) Endangered (MX)	Population threatened by loss of natural flow regime, competition with nutria, and invasive alien plant species (giant cane and saltcedar).	No
Pecos River muskrat *(Ondrata zibethicus ripensis)*	Rio Grande near El Paso, New Mexico reaches of the Pecos River	Identify suitable habitat and study feasibility for reintroductions.	Low	Not listed (US) Not listed (MX)	Formerly widely distributed throughout the Rio Grande and Pecos River. The main cause of decline is presumably over-trapping, irrigation canal maintenance, and habitat degradation. A near-endemic population extends some distance from the subject region.	Not entirely
Davis Mountains cottontail *(Sylvilagus robustus)*	Davis Mountains, Chisos Mountains, Elephant Mountain, Sierra del Carmen	Monitor population. Determine distribution and taxonomic status of rabbits of the *Sylvilagus* genus in Mexican mountain ranges.	Medium	Not listed (US) Not listed (MX)	Found in montane and mixed forests, evergreen montane shrublands and thickets, and pine-oak woodlands. While its habitat is limited, there are very few immediate threats to this species. The biggest threat to 'sky island' species in the region is habitat loss due to climate change, and perhaps small isolated population factors.	Yes
Desert bighorn sheep *(Ovis canadensis)*	Big Bend Ranch, State Park Springs, Chinati Mountains, Sierra del Carmen, Dead Horse Mountain, Sierra del Mulato and Sierra del Matadero	None recommended.	Good	Not listed (US protected (MX))	Ongoing efforts to re-establish or augment local population. CEMEX reintroduced this species to viable levels in the Sierra del Carmen. Iconic species. Population is at high risk from transmitted diseases from domestic goats and sheep, and from poaching for their horns.	No
Mule deer/ black-tailed deer *(Odocoileus hemionus)*	Valle de Colombia Grasslands, Sierra de Hechiceros Grasslands, Sierra Rica, Sierra La Encantada, Marfa Grasslands, Morelos-Los Lirios Grasslands, Sierra del Carmen	Monitor population. Improve habitat.	Low	Not listed (US) Not listed (MX)	Game species important for locals. Viable population in Sierra del Carmen.	Yes
White-tailed deer *(Odocoileus virginianus carminis)*	Chisos Mountains, Sierra Rica,Sierra de Santa Rosa, Sierra del Carmen	Habitat protection.	Good	Not listed (US) Not listed (MX)	The biggest threat to 'sky island' species in the region is habitat loss due to climate change.	No
Pronghorn *(Antilocapra americana)*	Serranías del Burro Grasslands, Marathon Grasslands, Marfa Grasslands, Alpine Grasslands, Sierra del Carmen	Improve habitat and fences.	Low	Not listed (US) Endangered (MX)	TPWD is involved in ongoing reintroductions of pronghorn from Texas Panhandle into the region. Population is declining drastically in the region. Population is threatened by fencing (genetics and predation), drought, habitat degradation, parasites, coyote (when fawns), and vehicle collisions. Reintroduced population in Sierra del Carmen in 2009-2010 is viable and growing.	No
VEGETATION						
Aquatic, emergent, rare, and wetland plants (non-tree)	Boquillas Hot Springs, Rio Grande and tributaries upland water sources	Protect water sources (springs), aquifers, and recharge zones.	Medium	Most Not listed	Indicator species. Native riparian herbaceous and aquatic communities. Species inventories exist for some land management units.	No
Athel *(Tamarix aphylla)*	Rio Grande and tributaries	Protect shade-and landscaping trees from damage by saltcedar leaf beetle *(Diorhabda* spp.).	Good	Not listed (US) Not listed (MX)	Of economic and social/heritage importance in the region. Threatened by the saltcedar leaf beetle in along the Rio Grande corridor. However, once escaped from cultivation, athel can be an undesirable invasive plant.	No

Conservation Target	PCA where the target is found	Conservation action	State of information	Legal status	Condition and threats	Target endemic?
Economically-important plants	desert grasslands and shrublands	None recommended.	Good	Medium	Species include Brahea berlandieri, lechuguilla, ocotillo, lippia, candellila, Yucca spp., and sotol. These are found region-wide. Economic and social importance in the region, for shade and windbreak. Vegetation inventory maps exist in several land management units.	No
Endemic but unlisted cactuses	desert grasslands and shrublands	Inventory and distribution in Mexico.	Medium		Endemic species.	Yes
Endemic but unlisted oaks	Chisos Mountains, Davis Mountains, Sierra del Carmen	Inventory and distribution in Mexico, susceptibility to climate change.	Medium		Some are more drought-tolerant than others. Endemic species. Location and habitat maps exist for many species in Texas.	Yes
High elevation forests (species include Pinus, Abies, Pseudotsuga, Cupressus, and Populus tremuloides)	Chisos Mountains, Davis Mountains, Sierra del Carmen, Sierra La Encantada	Investigate and implement fire management practices. Promote healthy soils and water retention capacity.	Good		Heavy tree regeneration under fire suppression, high fuel loads due to fire suppression in all ranges and remnant logging slash in the Sierra del Carmen. Very rare and regionally biodiverse habitats. Vertical stacking of biotic communities due to complex physiography. Knowledge of historical fire regimes, current forest stand structure and fuel loads.	
Limestone-dependent plants	Dead Horse Mountain	Protect habitats from human disturbance (e.g. livestock grazing, mining).	Good	Some listed	Geologic maps for most areas, listed species inventoried and mapped.	Some are endemic
Listed plant species	various habitats region-wide	Varies	Varies	Listed (US) Listed (MX)	Legally protected, rare and endemic species.	Some are endemic
Mixed coniferous and oak forests (species include Quercus, Juniperus, Pinus cembroides woodland, some Cupressus, and Arbutus)	Davis Mountains, Sierra del Carmen, Chisos Mountains, Sierra Rica, Sierra del Carmen	Investigate and implement fire management practices. Promote healthy soils and water retention capacity.	Good		Large, relatively intact expanses of this forest type at lower elevations of forest cover. Some are keystone species. Knowledge of forest stand structure and oak ecophysiology.	
Native grasses	Marfa grasslands, Ejido Alamos San Antonio, Canyon del Diablo, El Jardin, Mesa de los Fresnos, Rancho La Palma, Rancho Cimmaron, Valle de Colombia Grasslands	Protect grassland expanses and integrity.	Good		Keystone and indicator species for management activities.	No
Native riparian trees	Boquillas Hot Springs, Rio Grande and tributaries	Inventory and distribution in tributaries.	Good		Genera include *Salix, Populus, Sapindus, Fraxinus, Taxodium*, and *Platanus*. Limited knowledge on the effect of exotic species, geomorphology, and river flow on riparian communities. Some historic accounts, some current inventory.	No
Orchids	Chisos Mountains, Davis Mountains, Sierra del Carmen	Inventory. Protect montane forests. Fuel and fire management.	Medium		Populations in mixed coniferous and oaks forests, and in high elevation forests. Indicator species and endemic.	Some are endemic
Oyamel fir forests	Sierra del Carmen					
Pecos sunflower *(Helianthus paradoxus)*	Balmorhea Springs complex	Protect alkaline ciénagas.	Medium	Threatened (US) Not listed (MX)	Most alkaline ciénagas occur on protected lands.	No
Pine species *(Pinus remota, Pinus strobiformis, Pinus arizonica, and Pinus cembroides)*	Sierra del Carmen, Chisos Mountains, Serranías del Burro	Tree ecophysiology studies and range shift modeling under climate change.		Protected (MX) -remota and strobiformis	Forests are altered by fire suppression. Heavy tree regeneration under fire suppression, high fuel loads due to fire suppression and remnant logging slash in areas not dominated by pinon pine. Keystone species. At risk because of climate change.	Remota: Yes
Prickly pear *(Opuntia spp.)*	Desert grasslands and shrublands	Protect habitats from human disturbance (e.g. livestock grazing, mining).	Medium	Not listed (US) Not listed (MX)	Keystone species found region-wide. Important for many other species.	No

Conservation Target	Location	Conservation action	State of information	Condition and threats
AQUATIC ENVIRONMENTS				
Alluvial reaches	Rio Grande	Inventory of species' distribution and habitat characteristics. Key aquatic species and habitat requirements. Add permanent ecological cross section(s) in Colorado canyon. Establish binational program to describe the nature and occurrence of aquatic habitats. Determine watershed dynamics that govern erosion and sediment transport.	Low	Alluvial reaches are the wide open reaches between canyons. They are generally not bound by bedrock and have the potential for wide riparian areas. Because the channel is wide and water velocities generally slower, channel sedimentation is greatest in the alluvial reaches. The alluvial reaches of the Rio Grande provide habitat for many native species, including the endangered Rio Grande silvery minnow. As with all of the Rio Grande, the alluvial reaches are adversely affected by the interaction between reduced flow and invasive riparian plant species, which impact the quality of aquatic and riparian habitats, as well as recreational opportunities.
Canyon reaches	Colorado, Santa Elena, Mariscal, Boquillas, Lower Canyons on the Rio Grande	Inventory of species' distribution and habitat characteristics. Key aquatic species and habitat requirements. Add ecological cross section(s). Establish binational program to describe the nature and occurrence of aquatic habitats.	Low	As with all of the Rio Grande, the canyon reaches are adversely affected by the interaction between reduced flow and invasive riparian plant species, which impact the quality of aquatic and riparian habitats, as well as recreational opportunities. The canyon reaches of the Rio Grande are valued for recreational use, primarily boating and some hiking. Low flows adversely affect river conditions, at times to the degree that the river becomes unnavigable. In some cases, invasive species have impacted camp and rest sites to the degree that they are no longer usable.
Ephemeral upland rain pools	Scattered and ephemeral	Inventory of species' distribution and habitat characteristics.	Low	Key habitat for most amphibian species.
Oxbows	Candelaria, Presidio, Redford, and Ojinaga	Water quality monitoring. Monitor for impacts of sedimentation on habitat quality. Monitor for migratory bird and wildlife use.	Low	Limited information is available related to riparian species composition, wildlife use, role in invasive species, migratory birds, or water quality. The interaction between an altered sediment regime and oxbow occurrence has not been studied. There are ongoing efforts to restore historic oxbows within the Rio Grande floodplain on private land near Presidio, Texas. These include annual and seasonal variability of macro invertebrates as an indicator of river quality and health, level of endemism in the river, and factors that determine distribution of invasives, particularly giant cane and saltcedar and others.
Upland springs: Rheocrene springs (emerge within river channels)	Boquillas Springs Outlaw Flats Springs complex	Inventory, assessment and monitoring, and aquifer characteristics.	Variable, low to medium	At risk from groundwater pumping and climate change. Freshwater supply for local communities and native species.
Upland springs: Limnocrene springs (springs with pools)	Gambusia Springs Balmorhea Springs complex Phantom Springs, The Post	Inventory, assessment and monitoring, and aquifer characteristics.	Variable, low to medium	Risks for limnocrene springs are similar to rheocrene springs, with the addition of threats to biological communities that occupy and depend upon surface pools. Large riparian communities that support migratory birds and wildlife surround many of these springs. Aquatic communities sometimes contain endemic fish. These systems can be subjected to surface development or disturbance by invasive species.

Conservation Target	Location	Conservation action	State of information	Condition and threats
Upland springs: Hanging Gardens	Dripping Springs, BBNP	Inventory, assessment and monitoring, and aquifer characteristics.	Variable, low to medium	Similar threats associated with other spring types. Because these springs are often suspended and out of reach of livestock or human disturbance, they often have intact vegetation.
High water quality	Río Grande and tributaries, Springs, Sierra de Santa Rosa	Conserving and/or improving high quality conditions.	Low	The Big Bend Reach of the Rio Grande does not meet Texas water quality standards (TCEQ 2010). Salinity is increasing at many Texas Clear Rivers Stations (Bennett et al. 2012). Limited information is available related to groundwater quality and how it can be managed.
Multi-threaded channel	Río Grande	Restoration of a multi-threaded channel.	Medium	Multi-threaded channels provide topographic diversity necessary for a wide range of aquatic habitat types. Backwaters, side channels, glides, and runs occupy a greater relative position in a multi-threaded channel rather than a single channel dominated by pools and riffles. Channel sedimentation buries these diverse topographic features. The flooding of 2008 widened the channel and increased habitat diversity. Channel sedimentation since then is beginning to fill in the channel thereby diminishing habitat diversity.
Base flows	Sierra de Santa Rosa, Rio Grande	Maintain aquatic habitat.	Medium	Base flows contribute to improving water quality moving downstream, and are likely the prime factor in the survival of a largely intact Chihuahuan desert fish community. Base flows in the lower canyons of the Rio Grande are supported by groundwater and springs that are generally in good condition. Primary threats are groundwater extraction and development. More information is needed about other potential threats.

Wall paintings in APFF Cañon de Santa Elena, Chihuahua
Photo: Catherine Hallmich

Cañón de Santa Elena and Maderas del Carmen (Mexico)

The *Áreas de Protección de Flora y Fauna* (APFF) Cañón de Santa Elena and Maderas del Carmen, both created on November 7, 1994, are managed by Conanp, which has overseen since June 2012 the implementation of their respective *Programas de Manejo del Área Natural Protegida*. These plans constitute an instrument for planning and regulation, and establish the basic principles, activities, and actions for the management and administration of the APFFs. Specific objectives of the management plans include: establishing policies, strategies and programs focused on conservation, protection, restoration, training, education and sustainable development in the APFFs, through alternative projects and the promotion of sustainable development activities; dissemination of knowledge, practices, and technologies which allow for the conservation and sustainable use of biodiversity; fostering the active participation of rural communities and promoting the value of ecological services and of conservation of biodiversity specific to this area; and establishing a framework for the management of the APFFs, and the mechanisms that will allow the participation of government agencies, individuals and adjoining communities, as well as of other groups and organizations interested in their conservation and sustainable use (DOF 2012a, DOF 2012b).

Ocampo (Mexico)

The APFF Ocampo was created by Semarnat in June 2009 to conserve ecosystems specific to the Chihuahuan Desert, which connect the Rio Grande basin with the natural protected areas of Maderas del Carmen and Cañon de Santa Elena in Mexico and with protected areas in the US (DOF 2009a). The management plan is currently being developed as well as a public consultation process involving rural communities and private land owners to guide activities specific to sustainable use of the area's natural resources.

Monumento Natural Río Bravo (Mexico)

The area known as the *Río Bravo del Norte* was declared by Semarnat in October 2009 as a natural protected area and *Monumento Natural (*DOF 2009b). A management program (*Programa de Manejo del Monumento Natural Río Bravo del Norte*) prepared in January 2012 is under review. This management program is intended to be an adaptive instrument to plan and regulate activities related to ecosystems and sustainable resource use, based on the short, medium and long term needs and requirements set forth by policy and regulation.

Don Martín Irrigation District 004 (Mexico)

In 1949 Mexico established a decree to protect the upper watersheds of irrigation districts, including the Río Sabinas basin, as Forestry Protection and Repopulation Zones, and banned resource use in these basins. Half a century later, in a ruling issued in 2002, the federal government recategorized these areas as Protected Natural Resource Areas. This change assured the conservation of 802,500 hectares (2,000,000 acres), a significant portion of the Chihuahuan Desert, and transition zone to Tamaulipan shrublands. This area is now under the stewardship of Conanp, and encompasses the upper watershed of the Río Sabinas, and the Sierras of Santa Rosa, la Encantada, and the Serranías del Burro. The introduction of Annual Operating Programs fosters the development of conservation programs and the participation of inhabitants, landowners and local authorities in education and awareness endeavors.

Big Bend National Park (US)

Big Bend National Park (BBNP) was created June 12, 1944, to preserve and protect a representative area of the Chihuahuan Desert along the Rio Grande. The park includes rich biological and geological diversity, cultural history, recreational resources, and outstanding opportunities for the protection of natural and cultural heritage. The park has a dual mission to provide visitors with an interesting experience while preserving rare and fragile ecosystems. As stated in its General Management Plan/Environmental Impact Statement adopted in 2004, BBNP faces key issues such as water quality and quantity concerns, air quality degradation, invasion of exotic species, management of endangered species, and degradation of natural ecosystems (NPS 2012a). The plan is maintained by the NPS and ensures that park managers have a longer-term management philosophy and framework for decision-making and problem solving, and a clearly defined direction for preserving resources and managing tourism (NPS 2012b).

Rio Grande Wild and Scenic River (US)

The Rio Grande Wild and Scenic River, designated by the US Congress in 1978, is managed by BBNP staff with the goal to preserve and protect the natural, cultural, and scenic conditions of the river and its immediate environment for the benefit of present and future generations (NPS 2012a). Conservation activities follow the direction established in 2004 by the General Management Plan/Environmental Impact Statement for Rio Grande Wild and Scenic River, developed in

coordination with the Big Bend National Park General Management Plan. In addition to ensuring a balance between protecting the natural and cultural resources with tourist activities, the plan aims to encourage activities on adjacent lands that minimize adverse impacts on the river (NPS 2004). In 2011, the NPS published *Outstandingly Remarkable Values for the Rio Grande Wild and Scenic River*. This document provides a strong foundation for future management and protection of the river.

Black Gap Wildlife Management Area (WMA) (US)

The Black Gap WMA borders BBNP on the northeastern border and shares 40 kilometers (25 miles) of the Rio Grande with the Mexican State of Coahuila (TPWD 2012a). Its management is guided by the goals adopted by the TPWD in 1989, which include developing and managing wildlife habitats and populations of indigenous wildlife species; providing areas that can serve as model to landowners and other interested groups in terms of habitat development and wildlife management practices; providing natural environments suitable to educational and research activities; protecting populations of threatened and endangered species and their related habitats; and, ensuring that public hunting and appreciative use of wildlife are done in a manner compatible with the resource (TPWD 2012a).

Elephant Mountain WMA (US)

The Elephant Mountain WMA, located 42 kilometers (26 miles) south of Alpine, TX, was private land donated to the state in 1985 for the purpose of "conservation and development of desert bighorn and large game animals, wildlife-oriented research, and other compatible recreational uses including public hunting" (TPWD 2012c). Management principles, like in the Black Gap WMA, follow the general goals adopted by the TPWD in 1989 (TPWD 2012a).

Big Bend Ranch State Park (US)

The Big Bend Ranch State Park (BBRSP), located west of BBNP and across the river from the APFF Cañon de Santa Elena, was acquired in 1988, doubling the state park acreage at that time, and opened to the public in 1991 (Bengston et al. n.d.). Conservation activities in BBRSP are guided by the Texas Conservation Action Plan (TCAP), which provides a general strategy and roadmap for research, restoration, management and recovery projects addressing Species of Greatest Conservation Need (SGCN) and important habitats across Texas. This conservation plan focuses on resources that are most at risk, and its main purpose is to foster collective activities to prevent species from becoming endangered, and to preserve Texas' natural heritage.

Davis Mountains State Park (US)

The Davis Mountains State Park is located 6.5 kilometers (4 miles) northwest of Fort Davis, Texas. The Park was opened to the public in the late 1930s (TPWD 2012d), and follows the management principles of the TCAP (TPWD 2012b). Activities in the park must also comply with the laws and regulations established by TPWD, and follow land and water management practices outlined in the Land and Water Resources Conservation and Recreation Plan (LWRCRP) adopted by the TPWD Commission (TPWD 2005).

Balmorhea State Park (US)

Located approximately 6.5 kilometers (4 miles) west of Balmorhea, Texas, the park was built by the Civilian Conservation Corps (CCC) in the early 1930s, and was opened to the public in 1968 (TPWD 2012e). Like other State Parks in Texas, conservation activities in the Balmorhea State Park follow management principles of the TCAP (TPWD 2012b). Activities in the Park must also comply with the laws and regulations established by TPWD, and follow land and water management practices outlined in the LWRCRP adopted by the TPWD Commission (TPWD 2005).

Chinati Mountains State Natural Area (SNA) (US)

The Chinati Mountains State Park/Natural Area is located near Presidio, Texas. The park is currently closed to the public due to lack of funds. It is managed by the Big Bend Ranch State Park ("Take in Texas" 2011).

Fort Davis Natural Historic Site (US)

Fort Davis was authorized in 1961 as a national historic site and a unit of the NPS (NPS 2012c). The site preserves the historic buildings, ruins, and landscape associated with two forts belonging to the US Army in the late 19th century. Like all national park units, Fort Davis is managed following a General Management Plan that provides general guidance for the projects and activities conducted in the area. The plan consists of various components setting the vision, desired futures conditions, and management prescriptions for each park. Management prescriptions are based on the character and conditions specific to the park, and also take into consideration factors from areas outside the park boundaries (NPS n.d.).

Devils River SNA (US)

Devils River SNA, in Val Verde County north of Del Rio, was officially acquired by the TPWD in May 1988. The TPWD is developing a General Management Plan for the SNA, and is working with stakeholders and the public to develop public-use plans to allow for sustainable, resource-based recreation across this 15,000-hectare area (37,000-acre).

International Treaties and Commitments in the Big Bend-Río Bravo Region

Water management of the Rio Grande is governed by two US-Mexico treaties: the 1906 Rio Grande Convention,[1] and the 1944 Water Utilization Treaty,[2] both implemented by IBWC (CEC 2001). The 1906 convention establishes water entitlements for the Rio Grande from the Acequia Madre (Old Mexican Canal) above Ciudad Juárez, Mexico, to Fort Quitman, Texas, approximately 120 km (75 miles) downstream of Ciudad Juárez. The 1944 treaty establishes water entitlements for the Colorado and Tijuana Rivers, and the Rio Grande from Fort Quitman, Texas, to the Gulf of Mexico, and addresses governance matters related to the boundary between US and Mexico. Compliance with these international treaties is not qualified nor limited by any comment made in this document.

Under Article 3 of the Treaty, this following hierarchy of uses is established: 1) domestic and municipal uses; 2) agriculture and stockraising; 3) electric power; 4) other industrial uses; 5) navigation; 6) Fishing and hunting; and finally, any other beneficial uses. Any other beneficial uses are to be determined by the CILA/IBWC, and are subject to sanitary measures or works mutually agreed upon by the two governments, with preferential attention given to solving border sanitation problems.

Bilateral conservation activities focusing on the Chihuahuan Desert and the Big Bend region have been supported by a series of agreements between US and Mexico. One such agreement is the Letter of Intent signed in May 1997 by the US State Department and Mexico's *Secretaría de Medio Ambiente, Recursos Naturales y Pesca* (currently Semarnat), which committed the two countries to collaborating towards the conservation goals in the national parks and protected areas along the US–Mexico border. This document states that "Cooperation under this Letter of Intent is subject to the existing laws and regulations in effect in each country, and should serve to harmonize activities directed at conservation of biological diversity, cultural resources and balance of the ecosystems that are shared along the border between the countries" (DOI and Semarnat 1997).

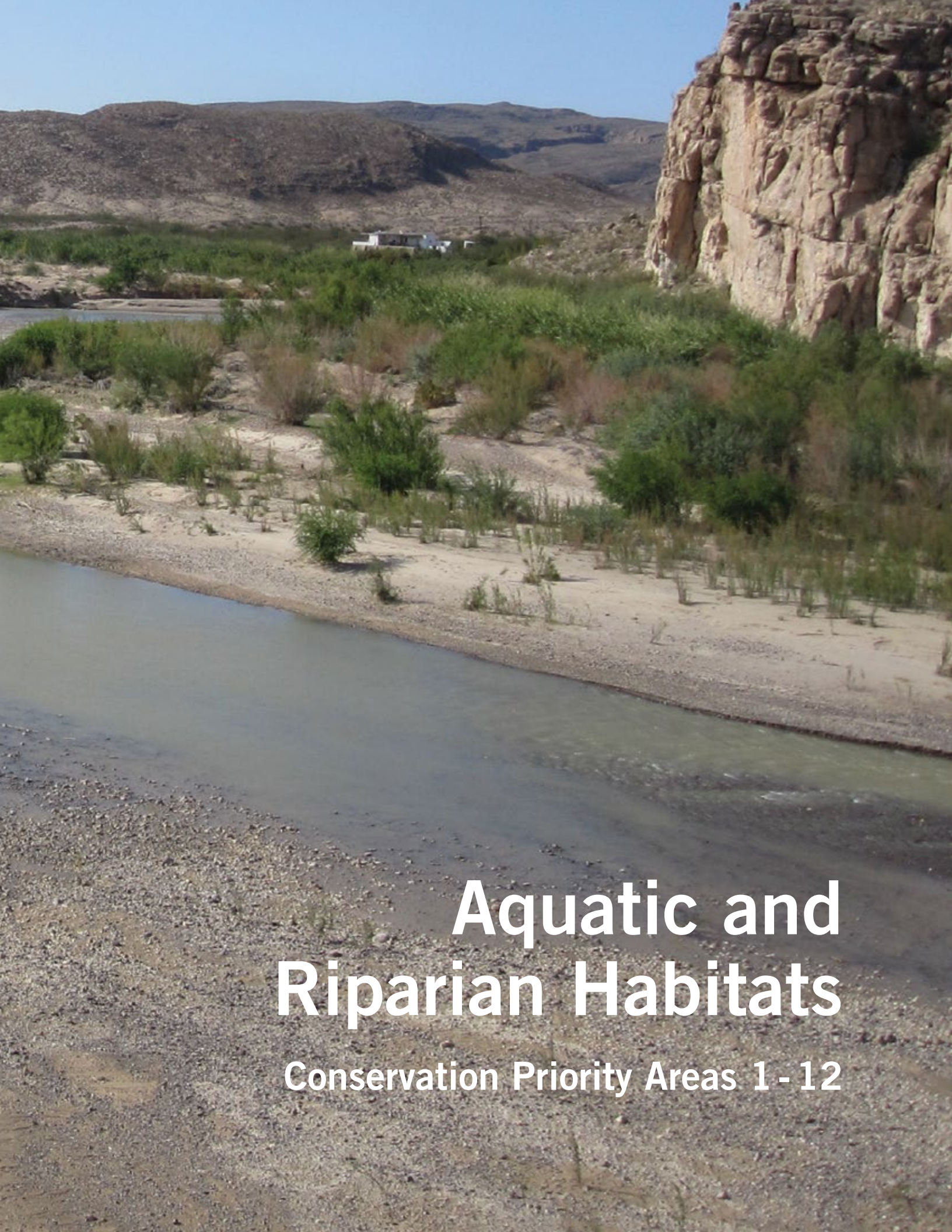
In May 2010, Presidents Obama and Calderón released a joint statement identifying the Big Bend-Río Bravo region as a "natural area of binational interest." They expressed support for the efforts of DOI and Semarnat agencies to strengthen cooperation in the region.

In October 2011, US Secretary of the Interior Ken Salazar and Mexican Environment and Natural Resources Secretary Juan Rafael Elvira Quesada announced next steps for a binational working plan to protect the Rio Grande in the Big Bend region, which includes the following objectives: restoration of riparian ecosystems; management and control of exotic, invasive riparian vegetation; restoration of the Rio Grande silvery minnow; and coordination of binational programs for the protection and restoration of threatened species (ENS 2011).

American beaver. Photo: Rick Derevan

1. Full title: *Convention between the United States and Mexico, Equitable Distribution of the Waters of the Rio Grande* (signed 21 May 1906). See ‹http://www.tceq.texas.gov/assets/public/border/1906conv.pdf›.
2. Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (signed 14 November 1944). See ‹http://www.usbr.gov/lc/region/pao/pdfiles/mextrety.pdf›.

Rio Grande
Photo: Catherine Hallmich



Aquatic and Riparian Habitats

Conservation Priority Areas 1 - 12

Monumento del Río Bravo (left)/ Rio Grande Wild and Scenic River (right)
Photo: Jeffery Bennett

Priority Conservation Area

1

Rio Grande – Río Bravo River Corridor

Authors: Jeffery Bennett, Mark Briggs, and Samuel Sandoval Solís

Rio Grande River Corridor.
Photo: Matthew Humke

Mexican stoneroller.
Photo: Kevin Conway

The Rio Grande corridor between Redford, Texas, and Amistad Reservoir is one of the most remote stream segments in North America and one of the least studied. The northern branch of the Rio Grande upstream of the confluence with the Río Conchos drains the southern Rocky Mountains in Colorado and New Mexico and much of the western half of New Mexico. Water diversions for irrigation and municipal use consume most of its flow. The southern branch, the Río Conchos, drains the Sierra Madre Occidental in Chihuahua, Mexico, and provides up to 75 percent of the flow downstream of Presidio, Texas, and Ojinaga, Chihuahua. Dams and diversions throughout the basin, in addition to the long-term regional drought, have put extreme pressure on the Rio Grande's aquatic ecology. Fortunately, the Rio Grande receives considerable groundwater inputs downstream of Mariscal Canyon, positively affecting the ecology and water quality in this reach; ecologic conditions above Mariscal Canyon are declining, possibly due to poor water quality and the lack of local groundwater inputs (Basin and Bay Expert Science Team 2012).

The Upper Rio Grande Basin and Bay Expert Science Teams (BBEST), comprised of federal and state agencies, universities and regional nongovernmental organizations, defines a sound ecological environment as one that sustains the full complement of the current suite of native species in perpetuity, supports the reintroduction of extirpated species, sustains key habitat features required by these species, retains key features of the natural flow regime required by these species to complete their life cycles, and sustains key ecosystem processes and services. The team classified the Lower Canyons as a Sound Ecological Environment (SEE) based largely on improved water quality, quantity, and environmental conditions provided by the springs. These conditions have allowed certain species, such as mussels (NPS survey), and algal communities to persist (Porter and Longley 2011).

Conservation goals along this reach include enhancing socio-economic conditions of riverside towns and improving habitat for native wildlife. On the socio-economic side, the focus is on potable water quality and reducing the frequency at which riverside towns are flooded. On the environmental side, focus is on maintaining an ecology that supports a full complement of native species (see Conservation Targets list) that are dependent on a suite of habitat features, including high water quality and habitat diversity. The current state of knowledge suggests that this is best achieved by maintaining a wandering, laterally unstable river channel that is wide and shallow and includes multi-threaded segments, and where water, sediment and nutrients are actively exchanged between floodplain and channel habitats.

Conservation targets

Conservation targets identified in this area include vertebrate species such as blue sucker (*Cycleptus elongatus*), Rio Grande darter (*Etheostoma grahami*), Rio Grande silvery minnow (*Hybognathus amarus*), speckled chub (*Macrhybopsis aestivalis*), Mexican redhorse (*Moxostoma austrinum*), Tamaulipas shiner (*Notropis braytoni*), Rio Grande shiner (*Notropis jemezanus*), longnose dace (*Rhinichthys cataractae*), and Big Bend slider (*Trachemys gaigeae*). Targets also include mussels such as Texas hornshell (*Popenaias popeii*), Salina mucket (*Potamilus metnecktayi*), and Tampico pearlymussel (*Cyrtonaias tampicoensis*). In addition, an important river feature identified as conservation target is the multi-threaded nature of the river channel.

Threats

The threats to the aquatic natural resources of the river corridor include channel narrowing and sediment accumulation (Dean and Schmidt 2011; Dean et al. 2011), deteriorating aquatic habitat, invasive and exotic species (Everitt 1998), increasing mercury concentrations in fish (Heard et al. 2012), continued water-quality deterioration

(Sandoval-Solis et al. 2010; Bennett et al. 2012), groundwater extraction (Donnelly 2007), and climate change (Ingol-Blanco 2011). Large-scale regional water management and the invasion of non-native riparian species have changed stream flow, sediment dynamics, and near-channel vegetation cover (Everitt 1998; Schmidt et al. 2003; Dean and Schmidt 2011). As a result, a once wide and shallow channel is now filled with sediment and has become narrow and deep. Non-native riparian plants provide a feedback mechanism for channel sediment retention, negatively affecting the aquatic habitat and riverside communities by covering up and eliminating backwaters and side channels, diminishing channel conveyance capacity, and increasing flooding frequency (Hubbs et al. 2008; Dean and Schmidt 2011).

Threats to the river corridor's riparian natural resources include exotic and invasive riparian plants and animals. Non-native giant river cane (*Arundo donax*) and saltcedar (*Tamarix* spp.) occupy much of the riparian zone, displacing native willows (*Salix* spp.), cottonwoods (*Populus* spp.), and other riparian plants. Non-native feral livestock are negatively impacting natural resources. Feral pigs (*Sus scrofa*), burros (*Equus africanus asinus*), horses (*Equus ferus caballus*), and cows (*Bos* spp.) are all found in the river corridor. Trails leading from riverside *vegas*, or fertile flood plains, onto fragile desert soils, manure, and disturbance to springs all commonly occur throughout the river corridor.

The Rio Grande corridor is deemed to have a 'high' risk status due to the deterioration of hydroecologic conditions and associated declines in native aquatic and riparian species along upper segment of this reach. The integrity of the reach as a whole is 'medium', however, because natural processes along the lower reach still support a high diversity of native aquatic species. In the context of scoring this reach, the river remains largely intact within the lower reach.

It is important to note that the Rio Grande corridor can be divided into two distinct segments characterized by differences in base flow, sediment movement, and water quality: (i) Redford to Mariscal Canyon (characterized by reduced base flow and water quality issues); and (ii) Mariscal Canyon to lower segment (with canyons), where base flow is augmented considerably by spring input (see *Lower Canyons Springs* section). If considered separately, risk and integrity evaluations for the upper and lower segments would probably produce distinctly different results. For example, as compared to the lower segment, the lack of significant groundwater input along the upper segment of the Rio Grande corridor raises concerns regarding the persistence of base flow as we look to a future that may be significantly warmer, and which appears to have a favorable affect on sediment evacuation and water quality.

Partnerships and socioeconomic factors

Land ownership and natural resource management along the corridor are complex owing to the river's binational nature and the variety of agency and private land ownership. On the US side of the river, national and state parks and private owners manage the land. Similarly, on the Mexican side, the land is managed by three federal protected areas, a national monument, private owners, and *ejidos*.

Ongoing conservation efforts in this binational area include: 1) control of saltcedar (*Tamarix* spp.) and giant river cane (*Arundo donax*); 2) hydrologic investigations; 3) monitoring near-channel vegetation and channel morphologic conditions; 4) analyses of sediment dynamics of the present flow regime; and 5) reintroduction of the Rio Grande silvery minnow (*Hybognathus amarus*) in the United States.

Research and monitoring needs

- Continue to develop a scientific understanding of the relationship between flow regime, sediment dynamics, and water quality.
- Identify and map key springs to understand their source.
- Develop a scientific understanding of the role riparian vegetation management can play in sediment dynamics.
- Develop ecological monitoring protocols that can determine trends in ecological change associated with channel narrowing.
- Investigate the fate and transport of herbicides used in riparian vegetation management.
- Develop a binational monitoring program for the saltcedar biological control agent, saltcedar leaf beetle (*Diorhabda sublineata).*
- Assess flow-dependent habitat-use relationships for key aquatic species and map their extent and distribution.
- Study the distribution of mussel and fish habitat and populations.
- Quantify the benefits that ecosystem services provide to riverside communities.

Recommendations

- Establish a binational team to investigate trends and trajectories of ecological health within the Rio Grande, and to develop an Adaptive Management framework for guiding conservation activities.
- Develop strategies that minimize the negative impacts of flooding and strengthen the understanding of flood frequency, cost of reparation, and how conservation efforts may affect both variables.
- Better integrate flood and environmental management to support the resilience of ecosystem services as an effective climate adaption response.
- Develop an index of biotic integrity for the area.
- Maintain native aquatic fauna; increase the distribution of native mussel species and beavers (*Castor canadensis*).
- Establish a sustainable population of Rio Grande silvery minnow.
- Effectively control feral pigs *(Sus scrofa)* along both sides of the river and expand control efforts of giant river cane (*Arundo donax).*
- Identify and pursue innovative funding mechanisms that link conservation efforts in other parts of the watershed with those being conducted along the Rio Grande corridor.
- Continue to strengthen binational conservation partnerships.

Hot springs in the Lower Canyons. Photo: Jeffery Bennett

Priority Conservation Area

1

Springs of the Lower Canyons

Authors: Jeffery Bennett and Kevin Urbanczyk

In the Lower Canyons reach of the Rio Grande, numerous springs issue within the channel and at rivers edge from a transboundary cretaceous limestone aquifer (Bennett et al. 2009; Brauch et al. 2011; Bennett et al. 2012). On the Texas side, the Cretaceous-hosted Edwards-Trinity Plateau aquifer (ETPA) is extensive. On the Mexican side, two aquifers in Coahuila have been delineated: Cerro Colorado-La Partida and Serranías del Burro.

Running through the Lower Canyons, the Rio Grande gains a significant amount of water from warm-water springs. Springs along the Rio Grande generally occur within the channel and below the mean gradient line. IBWC gage data indicate that base flow progressively increases by as much as 60 percent. High base flows of good quality water maintain a relatively intact Chihuahuan Desert fish and invertebrate community (Heard et al. 2012). The Texas State Water Plan notes the ecological significance of thermal springs along the Rio Grande and adjacent to public lands, largely due to the role groundwater plays in improving water quality in the river. Likewise, freshwater springs improve water quality within the Lower Canyons through dilution. The estimated annual water yield from springs ranges from 185,000 to 247,000 cubic meter per year (150,000 to 200,000 acre-feet per year). These freshwater inputs are important in maintaining the Amistad Reservoir's water quality (Miyamoto 2006). Water quality in the reach above BBNP, however, is so poor that Texas added this segment to the state's list of impaired water bodies in 2010 (TCEQ 2010).

Rio Grande
Photo: Jonathan Putnam

Threats

The risk status of the springs in the Lower Canyons is deemed to be 'high' due to inconsistent management mechanisms and authorities on the US side for the groundwater system supporting them. Groundwater extraction has depleted spring systems all over the world and effective management mechanisms are necessary to protect flows and ecological integrity, particularly given the changing climate. The integrity of the spring system as a whole is 'medium' because groundwater development has not yet affected spring discharge.

Partnerships and socioeconomic factors

Land on the US side below BBNP is privately owned, except for the Black Gap WMA. On the Mexican side, the *Monumento del Río Bravo del Norte* extends through the entire reach. The Lower Canyon Springs represents a unique opportunity for proactive conservation management for both the US and Mexico.

Research and monitoring needs

- Conduct hydrogeologic investigations to refine and complement current knowledge about recharge, flow path, and discharge on those springs fed by the ETPA in the United States.
- Conduct ecological studies to characterize the role spring discharge plays in maintaining fish, invertebrate, and algal populations.
- Determine the impact of exotics on general aquatic resources associated with the springs.

Recommendations

- Create a groundwater management district within Val Verde County.
- Establish a binational team of experts to determine and monitor the ecological health of the springs and the nature and extent of the ETPA that supports them.

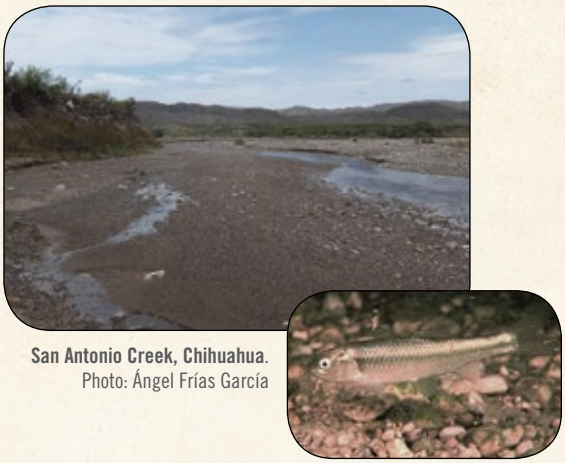
Priority Conservation Areas

2 + 3

Mexican Tributaries

(San Carlos and San Antonio creeks)

Authors: Ángel Frías García and César Alberto González-Zuarth



San Antonio Creek, Chihuahua. Photo: Ángel Frías García

Proserpine shiner. Photo: Garold Sneegas

San Carlos and San Antonio creeks in the APFF Cañón de Santa Elena are part of the San Antonio sub-watershed. In addition to their ecological importance, they have high social and economic value for local communities. Run-off flows into the Rio Grande, helping to stabilize climate by regulating the water cycle, humidity, and air temperature. The riparian system in the corridor formed by San Carlos Creek is listed as a *special habitat* within the APFF Cañón de Santa Elena because of its high biological value, stressing the importance of preserving and conserving associated wildlife and native vegetation (Conanp 1997). The canyons associated with these creeks are also known for their outstanding scenic beauty and recreational opportunities.

Conservation goals

Conservation goals include improving water quality, reducing the distribution and extent of exotic riparian vegetation, restoring and maintaining native grasslands and stands of riparian vegetation, and maintaining native aquatic fauna as well as a healthy beaver population (*Castor canadensis*) in the Rio Grande. Aquatic target species considered endangered, threatened, or under special protection in Mexico include blue sucker (*Cycleptus elongatus*), red shiner (*Cyprinella lutrensis*), Conchos shiner (*Cyprinella panarcys*), proserpine shiner (*Cyprinella proserpina*), roundnose minnow (*Dionda episcopa*), Conchos darter (*Etheostoma australe*), Chihuahua shiner (*Notropis chihuahua*), and bigscale logperch (*Percina macrolepida*).

Threats

Climate change is a key ecological driver and its potential impact on tributaries is considered greater than that of invasive vegetation in the main stem of the Rio Grande. Declining soil stability and increasing erosion surrounding San Carlos Creek, where overgrazing and drought is causing significant soil loss, is a growing concern. Threats to the San Carlos Creek include point-source pollution from the municipality of Manuel Benavides released into the aquifer from septic tanks; solid waste from urban areas, visitors, and livestock inside the arroyos; and increasing water use for agriculture. Potential future conservation threats include groundwater extraction, mining (especially at San Antonio Creek), declining watershed conditions, vegetation loss, extreme climatic events, and lack of data.

Water quality conditions within San Carlos Creek are unknown. According to park management, the water may contain arsenic, although levels are not toxic to humans or wildlife (Frías, A. pers. comm.). Water quality analysis is pending to verify an allegation that in 2000, discharges into the creek from the San Carlos mine killed fish populations in the Rio Grande. Additionally, the 2010–2011 drought noticeably reduced water volumes (although there is no water-level monitoring). The integrity of the San Carlos and San Antonio tributaries is 'medium,' because of healthy native fish populations. Risk levels are also 'medium' due to reduced environmental flows, drought, and climate change.

Partnerships and socioeconomic factors

San Carlos and San Antonio Creeks are federally owned. About 60 percent of the lands in the APFF Cañón de Santa Elena are *ejido* lands, 35 percent is private property, and the remaining is under urban use or owned by rancher's associations. The creeks' socioeconomic benefits, particularly those of the San Carlos Creek, include water for agriculture—livestock, pasture, corn, and beans—and domestic and recreational purposes (Conanp 1997).

Some preliminary and historical conservation work has been done but there are no comprehensive studies of San Carlos and San Antonio creeks. The

Conanp is reforesting with native species to reduce soil loss and manages solid waste and drainage in collaboration with local communities to control water pollution. The Conanp and Profauna collaborate to control the expansion of saltcedar (*Tamarix* spp.) along the San Carlos Creek. In 2004, the USGS monitored habitat quality along Rio Grande corridor segments in Cañón de Santa Elena and Maderas del Carmen, and invited the APFF managers to participate.

There are considerable opportunities for public-private projects and many landowners wish to improve their property's conservation value. Recreational opportunities include hiking, bird watching, mountain biking, and other outdoor activities. Current conservation and restoration tools include exotic vegetation control, revegetation with native riparian species, brush removal, environmental education, and public outreach.

Research and monitoring needs

- Establish a monitoring program to assess water quality in San Carlos Creek. It is particularly important to monitor heavy metals given the proximity of an abandoned mine in the Sierra Azul.
- Establish a monitoring program for San Carlos and San Antonio creeks to assess native riparian vegetation, and limiting factors.
- Complete the inventory of fishes for the creeks.
- Carry out fish monitoring programs based on biomarkers and/or behavioral studies to assess the impact of pollutants on the health of fish populations.
- Monitor key species such as Chihuahua shiner (*Notropis chihuahua*). Edwards et al. (2002) reported that water depletion severely threatens the tributary creeks critical to breeding and rearing young.
- Monitor aquatic native vegetation species such as pondweed (*Potamogeton* spp.), cattail (*Typha* spp.) and Najas (*Hydrocharitaceae* spp.).
- Continue collaborative habitat monitoring along the Rio Grande to assess flow regimes and their impact, like the 2004 USGS collaborative effort with the APFFs Maderas del Carmen and Cañón de Santa Elena.

Recommendations

- Continue efforts to control the expansion of saltcedar (*Tamarix* spp.) into the San Carlos and San Antonio creeks.
- Build a water treatment plant in Manuel Benavides that makes use of the already existing but still unused drainage network, or *acequias*.

San Carlos Creek, Chihuahua
Photo: Catherine Hallmich

Priority Conservation Areas

4 + 5

US Tributaries

Authors: Jeffery Bennett and Gary P. Garrett

Alamito Creek, Texas.
Photo: John Karges

Big Bend rough-footed mud turtle.
Photo: Paul Freed

Tributaries between the confluence of the Río Conchos with the Rio Grande and Amistad Reservoir include dry arroyos, and intermittent and perennial streams. Unencumbered by significant impoundment and diversions, these tributaries to the Rio Grande provide ecological and hydrological functions by moving water, nutrients, and sediment throughout the watershed (Levick et al. 2008). Ecosystem services include filtering and storing water, recharging and discharging groundwater, transporting sediment, providing habitat and migration corridors, supplying nesting and cover areas for year-round and migrating birds, and supporting vegetation communities. These streams are the dominant hydrologic feature of arid watersheds and serve the vital function of protecting and maintaining natural resources and the human communities dependent on them.

Ecological drivers include groundwater systems that support base flows and healthy watershed conditions. Aquifer characteristics reflect underlying geology. In the western portion, mountain building processes and volcanism created a groundwater system made up of small, poorly connected aquifers—the West Texas Igneous and Bolson aquifer—that has received little scientific study. Some reports describe regional recharge and other aquifer characteristics, but detailed information on discreet flow paths between recharge and discharge areas is lacking. Consequently, land managers cannot make decisions about water, mining, or hydrocarbon development that consider potential impacts on tributary base flows and ecosystem services.

Further to the east, the ETPA supports tributary base flows. This is a large, regional, primarily limestone aquifer extending from the Lower Canyons of the Rio Grande to Midland, Texas, and eastward to the Hill Country. The ETPA is well known for large springs, such as Comanche Springs in Fort Stockton and the spring-fed portions of the Pecos and Devils rivers. The aquifer's karst features means that the flow paths (recharge, storage, and discharge) that support tributaries and springs are discreet and poorly connected. The groundwater supporting these systems maintains base and subsistence flows in the Rio Grande.

Perennial reaches, like Terlingua and Alamito creeks, support extensive, but not continuous, riparian woodland dominated by cottonwoods. Others, like Tornillo Creek, may only have short perennial runs at the confluence with the main stem. These perennial segments are particularly important in providing local refuge for important main-stem species like the Rio Grande silvery minnow (*Hybognathus amarus*) and migratory birds. Terlingua and Alamito creeks also provide habitat for several endangered species in the US and Mexico. Also, these segments often have well developed riparian areas or are good candidates for riparian restoration.

Conservation targets

Conservation goals include improving water quality, reducing the distribution and extent of exotic riparian vegetation, maintaining native aquatic fauna, and restoring and maintaining native grasslands and riparian vegetation. Conservation targets include amphibian and invertebrate species, roundnose minnow (*Dionda* spp.), speckled chub (*Macrhybopsis aestivalis*), Conchos pupfish (*Cyprinodon eximius*), Mexican stoneroller (*Campostoma ornatum*), beaver (*Castor canadensis*), freshwater shrimp (*Palaemonetes kadiakensis*), Mexican redhorse (*Moxostoma austrinum*), Rio Grande darter (*Etheostoma grahami*), Tamaulipas shiner (*Notropis braytoni*), Chihuahua shiner (*Notropis chihuahua*), and Big Bend rough-footed mud turtle (*Kinosternon hirtipes murrayi),* whose historic occurrence in Alamito Creek has been documented only.

Threats

Far West Texas, one of the most unpopulated and remote areas in the lower 48 states, has not been extensively subdivided and developed. Urban sprawl has had a minimal effect and most of the area is comprised of large intact ranches that have contributed positively to the unfragmented nature of the landscape.

Threats to these streams include groundwater extraction, mining, invasive plants and animals, and data gaps. The primary, irreversible disturbance to west Texas watersheds comes from a few small and ongoing mining operations. Mining for bentonite, a clay mineral important for many industrial uses including drilling technologies, occurs in southern Brewster County and zeolites are mined in southern Presidio County. A silver shaft mine currently operating in Shafter, Texas, is an underground facility and will not create a large surface disturbance. It requires a pumping program to dewater the shafts, however, since the silver ore lies beneath the water table. This water will be discharged into a nearby dry *arroyo* changing it in the short term and potentially altering aquifer storage. None of these features have been analyzed for their potential impacts on stream health or groundwater flow. A larger open-pit copper mine is planned for an area adjacent to the silver mine.

Climate change is also a threat to these systems, particularly with regard to forecasted warming trends that describe droughts of greater severity, frequency and duration. This is particularly worrisome for tributaries whose flow regime is highly dependent on precipitation runoff. With the majority of precipitation in the Big Bend region falling during the warm season, precipitation-driven surface flow in these tributaries will increasingly depend on cool season precipitation, which is typically infrequent in this region. Another potential climate change impact is the increase severity of summer convectional storms, which could affect tributary sediment input and sediment balances along the Rio Grande.

The integrity status of the Rio Grande perennial tributaries is generally 'medium,' since the groundwater systems that support base flows are intact and development is minimal. The risk status is also 'medium' due to the threats described here.

Partnerships and socioeconomic factors

Most of the land surrounding Alamito and Terlingua creeks is privately owned. The perennial reach of Terlingua Creek adjacent to the Rio Grande is the only segment that traverses mostly public land. Many landowners wish to improve their property's conservation value and there is considerable opportunity for public-private projects, such as the USFWS Partners for Fish and Wildlife program and the Desert Fish Habitat Partnership. The Dixon Water Foundation owns and operates the Alamito Creek Preserve and several public-private partnership restoration projects are underway.

The lower perennial segment of Alamito Creek is within the BBRSP. The USFWS and TPWD are partners in grassland and riparian restoration projects in the Alamito and Terlingua creek watersheds. The NPS has invasive vegetation control projects and follow-up revegetation activities in Terlingua and Tornillo creeks. Conservation and restoration tools already in use or with potential benefits include exotic vegetation control, revegetation, brush removal, and public outreach.

Some preliminary and historical biological work has been carried out in Terlingua, Alamito, and Tornillo creeks, such as fish (e.g., Edwards et al. 2002) and invertebrate studies, but no broad-based ecohydrological studies have been undertaken. Historical accounts of the area indicate that mining and agricultural activities harvested large cottonwood (*Populus* spp.) gallery forests that once existed along the creeks.

Research and monitoring needs

- Monitor discreet flow paths to discharge areas in the West Texas Igneous and Bolsons aquifer in order to support decision-making about water, mining, or hydrocarbon development that consider potential impacts on tributary base flows and ecosystem services.
- Investigate the effects of potentially irreversible disturbance from mining operations on stream health or groundwater flow of west Texas watersheds.
- Conduct broad-based ecohydrological studies of Alamito, Terlingua, and Tornillo creeks.

Recommendations

- Promote state recognition of the conservation value of the lower portion of Terlingua Creek through the regional water planning processes.
- Expand public-private partnerships and invest in additional conservation and restoration projects along tributaries.

Priority Conservation Area

6

Devils River

Author: Gary P. Garrett, John Karges, and Elizabeth Verdecchia

Devils River, Texas.
Photo: Nicolas Henderson

Conchos pupfish.
Photo: Garold Sneegas

The Devils River flows from Pecan Springs in Val Verde County, Texas, and traverses about 105 kilometers (66 miles) before discharging into the Rio Grande's Amistad International Reservoir. Various seeps, basal springs, and tributaries, including spring-fed Dolan Creek, contribute to its 10 cubic meters per second flow (nearly 350 cubic feet). The ETPA recharges the river (BBEST 2012).

The Devils River is located in an ecological transition zone at the confluence of three ecoregions: Edwards Plateau, Tamaulipan Thornscrub, and Chihuahuan Desert (BBEST 2012). This habitat has excellent water quality with low salinity levels (IBWC 2011) and supports high aquatic biodiversity (De La Cruz 2004), including several localized endemic species and several federally and state-listed threatened or endangered aquatic species (Garrett et al. 1992; BBEST 2012).

Conservation goals

Conservation targets in the river basin include many freshwater species threatened by diminished spring flows, such as Conchos pupfish (*Cyprinodon eximius*), speckled chub (*Macrhybopsis aestivalis*), Devils River minnow (*Dionda diaboli*), manantial roundnose minnow (*Dionda argentosa*), Tamaulipas shiner (*Notropis braytoni*), Gray redhorse (*Moxostoma congestum*), Rio Grande darter (*Etheostoma grahami*), proserpine shiner (*Cyprinella proserpina*), Rio Grande cooter (*Pseudemys gorzugi*), spring salamander (*Eurycea* spp.), endemic spring invertebrates, and extirpated river prawns (*Macrobrachium* spp.). Beaver populations (*Castor canadensis*) also inhabit the river, but suffer from habitat loss, changes to the natural hydrological regime, competition with the nutria (*Myocastor coypus*), decreased food supply, and the presence of the invasive and exotic giant river cane and saltcedar plant species. Amphibian and invertebrate species throughout the Rio Grande and its tributaries were also identified as conservation targets since they are important indicators species and have yet to be inventoried.

Threats

This healthy ecosystem, generally considered to be the cleanest river in Texas, is subject to various ecological stressors, such as increased groundwater extraction in the ETPA, ranchland subdivision and housing developments, and invasive riparian plant species, although these are not yet dense or in abundant quantities (BBEST 2012). In addition, the effects of climate change are likely to be severe, diminishing recharge and replenishment and reducing or even stemming spring discharge, which will threaten endemic spring dependent aquatic animals in particular (BBEST 2012). Current conservation efforts and objectives to address some of these threats include maintaining good water quality, reducing the distribution and extent of non-native species, maintaining native aquatic fauna (fish, turtles, spring salamanders, and invertebrates), and protecting base flows. Although the integrity status of Devils River is currently 'high', potential threats make this ecosystem a high-risk area. The river's high integrity is also important for maintaining the water quality in Amistad International Reservoir (Miyamoto 2006).

Partnerships and socioeconomic factors

Although most of the Devils River flows through private property, several conservation areas and initiatives exist along the river channel within the basin. The TPWD currently protects 15,000 hectares (37,000 acres) at the Devils River State Natural Area (DRSNA, 2 distinct units), with visitor access to several recreational activities. In addition, The Nature Conservancy owns and manages the Dolan Falls Preserve, a 1,900-hectare (4,800-acre) property adjacent to the DRSNA (BBEST 2012), and a total of 63,000 hectares (156,000 acres) of private and

public lands are currently under conservation easements, thereby protecting the valuable spring water that feeds the river. There are opportunities to expand these conservation efforts in partnership with State and local entities and in collaboration with private landowners. There is also the potential to combine efforts to conserve the ecosystem's environmental features with those conserving cultural heritage, since the area also harbors cultural resources of ancient Native American artifacts.

Research and monitoring needs

- Continue water quantity and water quality monitoring, which is being carried out by the IBWC, the USGS, and the Texas Commission on Environmental Quality (TCEQ).
- Conduct regular biodiversity studies to ensure that biodiversity and community assemblages are being maintained.
- Study the potential impact of regional hydrocarbon development on aquifer characteristics and dynamics that support groundwater discharge to the Devils River.
- Inventory amphibian and invertebrate species and investigate their utility as indicators of ecosystem health.

Recommendations

- Conserve the intact system that exists on the Devils River, including maintaining current flows.
- Consider employing instream flow and/or spring flow standards in groundwater management, such as setting desired conditions for the aquifer, as well as standards in drought management plans (BBEST 2012).
- Maintain present levels of biodiversity to protect currently thriving resources.
- Maintain water quality and reduce the distribution and extent of invasive exotic plant species.
- Increase visitors' awareness of the area's uniqueness and importance.

Devils River, Texas
Photo: Nicolas Henderson

Priority Conservation Area

7 Pecos River

Author: John Karges

Rapids on the Lower Pecos River, Texas.
Photo: John Karges

Rio Grande darter.
Photo: Garold Sneegas

The Pecos River is a large tributary of the Rio Grande with its headwaters in northern New Mexico. When it reaches West Texas, agricultural and municipal diversions and evaporation have diminished the river so much that its flow is barely noticeable and salinity approaches that of seawater. High salinity has resulted in the loss of many fish species and the repeated occurrence of a highly dangerous golden alga bloom (*Prymnesium parvum*). This Pecos River PCA refers to the lower Pecos River, from downstream of Sheffield, TX, to Amistad Reservoir, a perennial spring-fed stream (BBEST 2012). A large spring-fed tributary, Independence Creek, designated as an Ecologically Significant Stream Segment by the TPWD, contributes greatly to the Pecos River, increasing water volume by 42 percent at their confluence and reducing total dissolved solids by 50 percent (BBEST 2012). More springs downstream of the Independence Creek confluence further increase river flow and dilution, improving water quality in this lowermost reach of the Pecos River. These freshwater inputs are important in maintaining the Amistad Reservoir's water quality (Miyamoto 2006).

This area supports warm-water native and non-native fish species, a diverse benthic macro-invertebrate community, and aquatic endemic spring invertebrates. Conservation targets in the river basin include many freshwater species threatened by diminished spring flows, including the manantial roundnose minnow (*Dionda argentosa*), headwater catfish (*Ictalurus lupus*), Rio Grande darter (*Etheostoma grahami*), blue sucker (*Cycleptus elongatus*), Rio Grande cooter (*Pseudemys gorzugi*), and proserpine shiner (*Cyprinella proserpina*). Beavers (*Castor canadensis*) also inhabit the river and seem to be increasing, but may have declined historically from habitat loss, changes to the natural hydrological regime, competition with nutria (*Myocastor coypus*), decreased food supply, and the presence of invasive and exotic giant river cane (*Arundo donax*) and saltcedar (*Tamarix* spp.). Suitable terrestrial habitat throughout the Pecos River watershed also supports the black-capped vireo (*Vireo atricapilla*).

Threats

Threats to the Lower Pecos River include groundwater extraction, oil and gas development, and invasive species/exotic introductions. Because groundwater discharge is of high quality, water quality in the stream improves in the spring's area. Groundwater development, however, threatens both the quantity and quality of these springs and so endangers the ecological integrity of Independence Creek and the lower Pecos River. The loss of spring water quantity or quality would result in increased salinity in the Pecos River, native species loss, and potentially more widespread golden alga blooms (*Prymnesium parvum*). Increasing salinity also favors invasive exotic fish species, of which there

Pecos River Bridge in Langtry, Texas
Photo: Marcus Calderón

Pecos River, Texas. Photo: Kirk Kittell

are numerous species in the system, including common carp (*Cyprinus carpio*), sheepshead minnow (*Cyprinodon variegatus*), Gulf killifish (*Fundulus grandis*), and introduced freshwater mussels including the Asiatic clam (*Corbicula fluminea*). Current conservation efforts and objectives to address some of these threats include hydrogeologic investigations to identify critical recharge areas and flow paths, reducing the distribution and extent of non-native species, maintaining or reintroducing native aquatic fauna (fish, turtles, and invertebrates), and protecting base flows.

Despite the severely degraded conditions further upstream, this area is considered to have a 'high' integrity status due to its fairly intact native fish populations and good water quality. Outside threats, however, make this ecosystem a high-risk area.

Partnerships and socioeconomic factors

All of the land along the lower Pecos River is privately owned above Amistad National Recreation Area and the Rio Grande confluence. The Nature Conservancy (TNC) owns an 8,000- hectare (19,740-acre) preserve along Independence Creek, adjacent to an additional 280 hectares (702 acres) under conservation easement. Ongoing efforts and opportunities for conservation include landowner collaboration, and the increased incentive for conservation due to the region's high recreational value. Conservation work continues to focus on restoring brush-encroached ranch pastures to native grass species, riparian habitat management and restoration, and conducting a multiyear hydrology study to help understand the lower Pecos River's hydrologic processes. Sul Ross State University, collaborating with National Park Service, initiated a study on the role of groundwater in maintaining base flow, finding it provides refuge for aquatic communities and improves water quality. Additionally, as in various PCAs bordering the Rio Grande, the lower Pecos canyons contain more than 2,000 recorded archeological sites, spanning approximately 10,000 years of cultural occupation.

Research and monitoring needs

- Study the aquifer's characteristics and dynamics, and its relationship to spring discharge and river volume along the reach.
- Categorize (and map as appropriate) the ecological impacts of terrestrial and aquatic invasive species.
- The USFWS could evaluate the potential to re-establish the Rio Grande silvery minnow (*Hybognathus amarus*) and the Rio Grande Fishes Recovery Team (group composed of federal, state and private representatives), and agency partners might assess the restoration potential for the Rio Grande shiner (*Notropis jemezanus*) as an extirpated element of the native fish fauna.
- Continue monitoring vital signs of the aquifer and spring discharge volumes, and the river's health and integrity, threats, and thresholds.

Recommendations

- Possibly establish Groundwater Management Districts in adjacent counties that lack them (Terrell and Val Verde) or have no representation within regional groundwater management authorities.
- Encourage best management practices in both land management and resource development, and in managing water uses and surface effects related to oil and gas exploration and extraction operations.

Priority Conservation Area

8

Balmorhea Springs Complex

Author: John Karges

San Salomon Springs, Texas.
Photo: 12-Foot Hedgehog Productions

Comanche pupfish. Photo: Garold Sneegas

Located in West Texas near the foot of the Davis and Barrilla mountains, the Balmorhea Springs Complex consists of several springs fed by groundwater discharge. This area is considered one of the largest and most important of the remaining desert spring systems in West Texas. The main springs include Phantom Lake, San Solomon, Giffin, Saragoza, Toyah Creek, East Sandia, West Sandia Springs, and Toyah Creek (White et al. 1940).

The current Balmorhea valley was historically an extensive *ciénaga*, created by spring outflows of 76,000 cubic meters (20 million gallons) of water a day, creating a dynamic mosaic of shallow aquatic habitats. During droughts, aquatic populations would persist as isolated subunits near springheads. Periods of high spring flow and low-level flooding created new aquatic habitats, and permitted migration between *ciénagas*. Since the early 1900s, however, ciénagas have been drained for irrigation, and spring flow has declined due to groundwater pumping.

Conservation targets

The conservation targets in this Springs Complex include the Comanche Springs pupfish (*Cyprinodon elegans*), Pecos gambusia (*Gambusia nobilis*), roundnose minnow (*Dionda episcopa*), headwater catfish (*Ictalurus lupus*), aquatic invertebrates including the diminutive amphipod (*Gammarus hyalleloides*), Phantom cave snail (*Pyrgulopsis texana*)[3], Phantom springsnail (*Tryonia cheatumi*), Rio Grande cooter (*Pseudemys gorzugi*), and the Pecos sunflower (*Helianthus paradoxus)*.

Threats

Biological and physical processes in the Balmorhea Springs Complex rely heavily on the health and persistence of spring discharges, which sustain the associated open waters and marshlands. The availability of groundwater sources is the major driver of these conditions. Historically, water delivery canal systems have distributed spring outflow to agricultural fields, which decreased wetlands and species migration opportunities, resulting in declining habitat and health among fish populations (Winemiller and Anderson 1997). Groundwater extraction is the primary threat to these springs. Additional threats include habitat destruction and competition from invasive plants, fish, and aquatic mollusks. Despite these changing conditions, the integrity of this area remains 'high', and it is subjected to 'moderate' environmental and anthropogenic risks.

Partnerships and socioeconomic factors

The Balmorhea springs are located within Balmorhea State Park, an 18-hectare (45-acre) park managed by the TPWD. In addition, the US Bureau of Reclamation owns the 7-hectare (17-acre) Phantom Lake Spring and The Nature Conservancy (TNC) protects 100 hectares (246 acres) of land located over East and West Sandia springs (WWF 2000). The TPWD, the US Bureau of Reclamation, and TNC collaborate to restore springs and wetlands, create surrogate refuge for aquatic species, and control saltcedar.

The local economy depends heavily on irrigation water withdrawn from Phantom Lake Springs, San Solomon Springs, and the underground aquifer associated with them. Thus, it is important to maintain the quantity and quality of these springs' outflow (Winemiller and Anderson 1997). Projects that reallocate water rights to conservation projects, and groundwater protection stimulated by the Endangered Species Act (ESA) to protect listed species and associated ecosystems simultaneously benefit the ecosystem and agricultural irrigation-water guarantees.

Considerable research has been conducted on the fishes and aquatic invertebrates of the valley's accessible protected springs, and some ecological inventories have been conducted at the remaining private springs. Academic, agency, and NGO scientists are conducting ongoing research, including studies on behavior, genetics, the effects of invasive species on natives, and ecohydrological characterizations.

3. A recent paper modified the taxonimical classification of this species from *Cochliopa texana* to *Pyrgulopsis texana*. See: Robert Hershler, Hsiu-Ping Liu, and Brian K. Lang. (2010) Transfer of Cochliopa texana to Pyrgulopsis (Hydrobiidae) and description of a third congener from the lower Pecos River basinJ. Mollus. Stud. 76(3): 245-256 doi:10.1093/mollus/eyq002

Research and monitoring needs

- Continue research on aquatic species, their ecological needs and the impacts of invasive species.
- Conduct regular biodiversity studies to ensure that biodiversity and community assemblages are being maintained.
- Study the potential impact of groundwater development and regional hydrocarbon development on aquifer characteristics and dynamics that support groundwater discharge to the Balmorhea Springs Complex.

Recommendations

- Conserve additional springs permanently, either as easements, purchases, or conservation agreements.

Priority Conservation Area

9

Big Bend Ranch State Park Springs

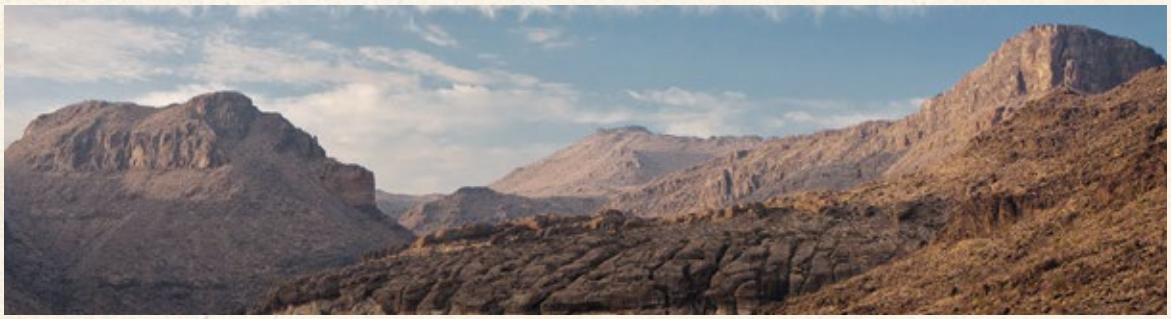
Authors: Mark Lockwood and Kevin Urbanczyk

Mayan setwing. Photo: Tripp Davenport

Yellow columbine. Photo: Gary Nored

The Bofecillos Plateau is the hydrologic and physiographic center of the BBRSP. There are approximately 120 active springs within the BBRSP, with six large spring systems that supported extensive riparian gallery woodlands. Most of the springs are located around the Bofecillos Plateau. The woodlands contain cottonwoods (*Populus fremontii* and *Populus deltoides*), velvet ash (*Fraxinus velutina*), Goodding willow (*Salix gooddingii*), netleaf hackberry (*Celtis reticulata*), little walnut (*Juglans microcarpa*), buttonbush (*Cephalanthus occidentalis*), and Mexican buckeye (*Ungnadia speciosa*). Rare plant species associated with these communities include a yellow columbine (*Aquilegia* spp.) that needs additional research to determine its affinities, and fringed monkeyflower (*Mimulus dentilobus*), among others.

The spring systems, as well and many smaller springs, provide important habitat for the canyon tree frog (*Hyla arenicolor*) and Rio Grande leopard frog (*Rana berlandieri*), along with a very diverse group of reptiles that includes several limited-range species such as canyon lizard (*Sceloporus merriami*), Trans-Pecos rat snake (*Bogertophis subocularis*), gray-banded kingsnake (*Lampropeltis alterna*), New Mexico milksnake (*Lampropeltis triangulum celanops*), Trans-Pecos black-headed snake (*Tantilla cucullata*), Texas lyre snake (*Trimorphodon biscutatus*), and Trans-Pecos copperhead (*Agkistrodon contortrix pictogaster*). There is also a very important suite of bird species found here, including such species of conservation concern as common black hawk (*Buteogallus anthracinus*), zone-tailed hawk (*Buteo albonotatus*), yellow-billed cuckoo (*Coccyzus americanus*), and Bell's vireo (*Vireo bellii*).



Bofecillos Mountains, Texas. Photo: Gary Nored

Conservation targets

Conservation targets include grassland restoration on the Bofecillos Plateau, riparian vegetation, desert bighorn sheep (*Ovis canadensis*), rare plants, migratory birds, and fish that live in spring-fed streams. The Mayan setwing (*Dythemis maya*), a dragonfly relatively rare in the US but widespread in Mexico, is associated with these springs.

Threats

Small perched aquifers, formed by local precipitation trapped in layers of ancient volcanic and volcaniclastic rocks, feed the springs. This hydrogeologic system overlies or is adjacent to two more regional aquifer systems; a Cretaceous limestone aquifer underlies the area and a separate volcaniclastic aquifer surrounds the Bofecillos system. It is likely that all these aquifers contribute significant base flow to springs that occur in the area's major tributaries, such as Alamito and Fresno creeks. The connection between the two aquifers is not well understood, but the main springs in the volcanic Bofecillos Mountains are not likely to be affected by changes that might occur in the carbonate aquifer.

Water condition of the aquifers is a main ecological driver in BBRSP springs. Threats to the springs include erosion, overgrazing, and the encroachment of exotic species. Feral burros (*Equus africanus asinus*), Barbary sheep (*Ammotragus lervia*), and cattle and other domestic livestock are likely to cause direct damage to the springs, though this has not been quantified.

Beginning in the late 1880s, the Bofecillos Plateau was the center of ranching activities within what is now the state park. These activities began initially with white-faced cattle but rapidly shifted to large concentrations of sheep. Predictably, this had a detrimental effect on the upper plateau's sensitive black grama (*Bouteloua eriopoda*) grasslands. There has been a continuous, fairly intense livestock operation in this area since about 1930. Since the state park acquisition in 1987 and through to early 2012, a Texas longhorn herd grazed the Bofecillos uplands. The TPWD is reducing that herd with a long-term goal of maintaining a small exhibit herd. The long-term effect has been the transition from a desert-plains grassland to a creosote-bush (*Larrea tridentata*) dominated disturbance community. This change in vegetation type has contributed to higher levels of sheet-flow erosion across the plateau and resulted in channel erosion that allows water to escape the hydrologic center and flow into various Rio Grande tributaries. The end result has been reduced recharge to the local aquifers that are the source for the many springs in the Bofecillos.

Mining activities to the west of the park in the vicinity of Shafter, Texas, will reportedly include the extraction of significant amounts of groundwater from the limestone aquifer. There is a legitimate concern that this extraction could impact the base flow contributions from this aquifer to Alamito Creek, and possibly Fresno Creek.

The integrity level of these springs is 'medium,' due to surface damage by trespass livestock and invasion by exotic plants. Given that the source aquifer for the majority of springs is wholly contained within the park, the risk level is low, although there is uncertainty about the reliability of base flows within the area's creeks.

Partnerships and socioeconomic factors

Conservation opportunities include managing exotic animals, controlling riparian exotic plants at the spring sources, and restoring grasslands in the Bofecillos Plateau's uplands. The TPWD manages resource conservation in the BBRSP. In addition to reducing the state-owned livestock herd, other conservation actions have helped to protect the active springs, among other goals. These include controlling trespass and feral livestock and exotic ungulates, which have greatly reduced the populations of these non-native animals and reduced their impact on springs. Management of burros and feral horses is a socially sensitive issue, however, and management agencies must proceed with caution and engage both local and international constituencies that seek to protect wild burros and horses.

Research and monitoring needs

- Update the inventory of springs and apply the recently developed Spring Monitoring Protocols (NPS initiative) to all of them.
- Develop a hydrogeochemical database of all springs and a general model with a water budget for recharge, groundwater flow, and discharge.
- Quantify damage caused by feral burros and other exotic/invasive species.

Recommendations

- Work with partners to manage exotic plant and animal species.
- Obtain funding to complete the research and monitoring needs described above.

Priority Conservation Area

10

San Carlos Springs

Authors: Claudia N. Castillo Jiménez and Ángel Frías García

Cottonwoods at Rancheria Springs, Chihuahua. Photo: Gary Nored

San Carlos Creek runs through San Carlos canyon, located in the center of the APFF Cañón de Santa Elena. In addition, run-off from the Sierra Rica creates natural springs within the Canyon. These sources provide water for the communities of Manuel Benavides and Nuevo Lajitas and for agriculture in the Nuevo Lajitas and San Carlos *ejidos*. The area's only conservation target is its riparian vegetation. Important tree species along the river, including cottonwood (*Populus* spp.), willow (*Salix* spp.), ash (*Fraxinus* spp.), and walnut (*Juglans* spp.), are suffering from water scarcity.

Threats

The main ecological drivers include drought, the source aquifer's characteristics (recharge, storage, discharge), and human water use. Since nearly all the water is used for human activities, this driver determines current conservation threats to the riverine ecosystems downstream from the natural springs. Threats include solid waste disposal, municipal wastewater pollution in the Piélago spring downstream from Manuel Benavides, exotic plants, livestock impacts, and lack of knowledge about the aquifer's characteristics. Solid waste levels vary with visitor use and can peak over holidays such as Easter Week when two tons of trash can accumulate over two days (Sifuentes Lugo, pers. comm.). Exotic species such as saltcedar (*Tamarix* spp.) and loose or feral livestock can foul conditions and displace native species. While integrity at the San Carlos springs is considered to be 'high', the impact of drought makes the risk level also 'high'.

San Carlos Springs, Chihuahua. Photo: Catherine Hallmich

Partnerships and socioeconomic factors

Both the San Carlos canyon and its natural springs are located in *ejido* San Carlos, the only community where water is free; *ejido* Nuevo Lajitas is located lower down the slope. The Alamos de San Antonio Springs are important for the *ejido* Paso de San Antonio. Springs born on the private Naboreño and Matadero properties belong to the Arroyo Ventanas and are important for agricultural use. The construction of gabions to prevent the loss of riverbank soil in San Carlos Creek is an example of cooperation efforts between Conanp and the *ejido* communities. The main conservation opportunity is to maintain and restore riparian vegetation and aquatic species.

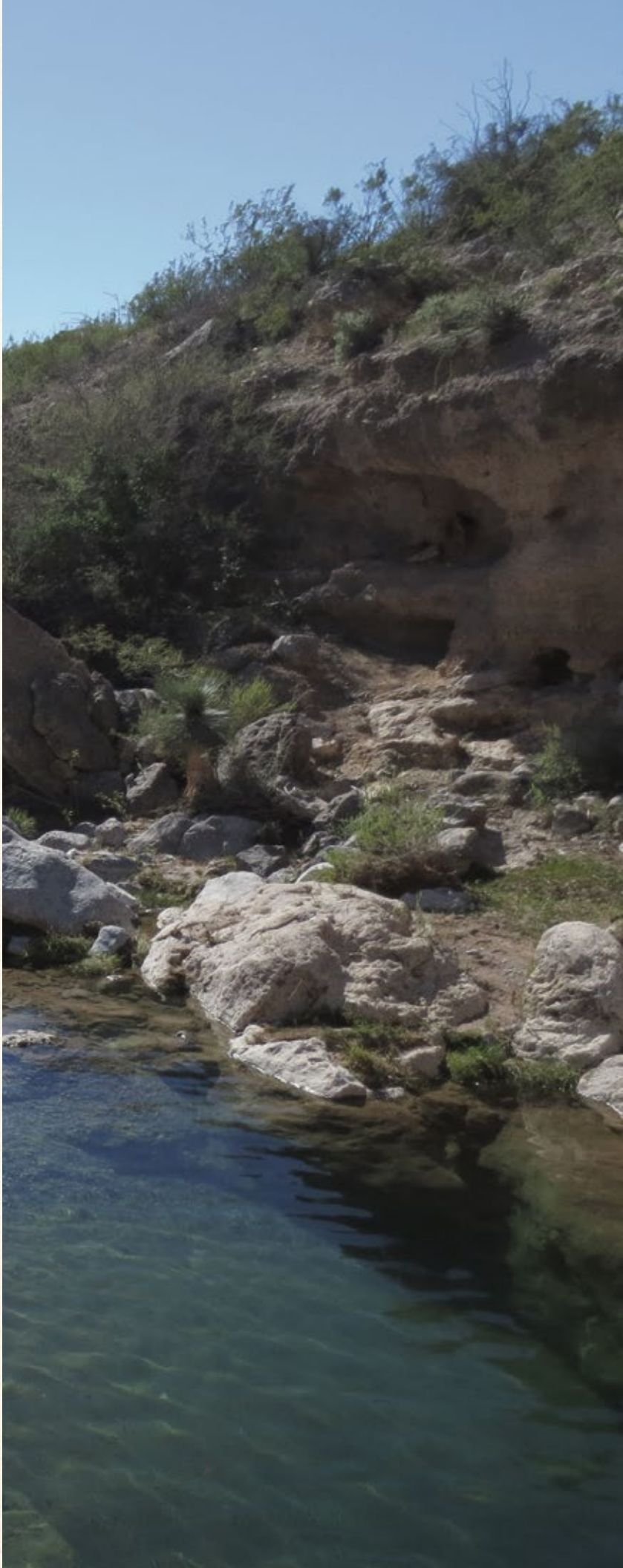
San Carlos Springs, Chihuahua. Photo: Catherine Hallmich

Research and monitoring needs

- Conduct an inventory of all springs, including permanent springs such as Cañón del Naboreño, El Piélago, and Manantial del Matadero.
- Conduct a diagnostic assessment of riparian environments and determine the species present and their conservation needs.
- Assess management options for reducing riverbank soil loss in San Carlos Creek.
- Develop an Index of Biotic Integrity based on aquatic fauna.

Recommendations

- Develop an outreach program to promote awareness and best water-use practices.
- Consider creating a water fee dedicated to water conservation and public works with positive environmental impacts, such as soil stability and water retention. This recommendation was strongly supported by the community as part of the public consultation process for this document.
- Increase public participation in conservation and trash management in Manuel Benavides and increase law enforcement to prevent graffiti.
- Maintain vegetation diversity and cover around the springs and its runoff, especially by keeping livestock at a distance; this will help build resilience and the capacity to adapt to climate change.
- Establish a metered water service and a program to detect leakage.
- Establish a system so the Manuel Benavides community can pay the owners and landholders in Sierra Rica in the upper part of the watershed for hydrological services that benefit them.
- Invite the Comisión Nacional Forestal (Conafor) to incorporate the Sierra Rica and Sierra Azul areas that recharge the San Carlos springs in their payment for environmental services program.



San Carlos Springs, Chihuahua.
Photo: Catherine Hallmich

Priority Conservation Area

11

Boquillas Hot Springs

Authors: Jeffery Bennett and Joseph Sirotnak

Boquillas Hot Springs, Coahuila. Photo: Aimee Michelle Roberson

Big Bend gambusia. Photo: Robert J. Edwards

The Boquillas Hot Springs emerge along an 18-kilometer (11 miles) reach of the Rio Grande from a short distance upstream of San Vicente, Coahuila, to the upstream end of Boquillas Canyon. In a few locations—Gambusia Spring, Ojo Caliente, and Fortino Creek—the springs emerge far enough from the river to create a distinct spring-fed ecosystem. Arising largely within or immediately adjacent to the river channel, this group of approximately two dozen hot springs is thermal to semi-thermal (41°C, 106°F) and contributes approximately 946 cubic meter per day (250,000 gallons per day) of clean water to the river flow. This clean water supports small wetland and spring habitats and makes a significant contribution to water quality and quantity in the Rio Grande, as shown by the significant improvement in several water quality parameters below this reach. These springs are probably fed by surface-recharged water circulating some 700 meters (2,300 feet) underground where it is heated before returning to the surface along faults and emerging from the Cretaceous limestone. Recent geochemical evidence from springs on the Texas side indicates that the system's recharge area lies primarily in the Dead Horse Mountains to the north, although the transboundary extent of this aquifer has not yet been established. According to Brune (1981), the flow rate has been falling since the early twentieth century.

Conservation targets

Conservation targets in Boquillas Hot Springs include the endangered Big Bend gambusia (*Gambusia gaigei*), native riparian vegetation, aquatic emergent wetland vegetation, and inflows of high quality water to the Rio Grande. The principal ecological drivers are related to the regional aquifer and recharge zone; they include invasive exotic plants and animals, and human land uses such as developments and grazing that degrade local ecological conditions. A small number of wells currently exploit the aquifer, including a deep well supplying Rio Grande Village and a shallow well at Boquillas village.

Threats

No significant threats to the groundwater system that supports Boquillas Hot Springs have been identified. However, there is uncertainty about the location of recharge areas and the flow path of water moving to the springs. Additionally, the impact of climate change and altered precipitation patterns is poorly understood. The most notable threats include solid waste accumulation from visitors, contamination by cattle, and the presence of exotic species such as giant river cane (*Arundo donax*), nutria (*Myocastor coypu*), and numerous non-native fishes. The threats from invasive plants and animals create a condition of 'medium' integrity, while the level of risk is 'low' due to ambiguous knowledge about the source aquifer's recharge and flow path.

Town of Boquillas, Coahuila. Photo: Matthew Humke

Partnerships and socioeconomic factors

The Boquillas Hot Spring's source is protected within the Big Bend National Park on the US side and the Maderas del Carmen and Ocampo APFFs on the Mexican side. In addition, springs on the Rio Grande are within the designated Wild and Scenic (US) and *Monumento Río Bravo* (Mexico) reaches. *Ejiditarios* in Boquillas and surrounding communities use some spring water for domestic uses, irrigating small, non-commercial farmland, and watering livestock. Locals also use the springs for bathing, which must be respected while exploring and developing capacity for recreational activities.

The National Park Service and conservation partners, such as the Far West Texas Water Planning Group, have designated Boquillas Hot Springs as 'ecologically significant'. BBEST recommends protecting these springs following a thorough biological and physical assessment of this reach. Conservation efforts to date include the removal of exotic giant cane and saltcedar and riparian habitat restoration. A hydrogeologic investigation to determine recharge areas and flow path is currently underway. These data are useful for planning groups and in updating groundwater flow models.

Research and monitoring needs

- Conduct additional research on recharge dynamics and effects of aquifer exploitation.
- Continue studies of aquifer recharge and assessments of threats to aquifer.
- Monitor rare and listed species.

Recommendations

- Continue to control exotic species.
- Begin restoring native riparian and wetland vegetation where hydrology, soil, and river flow conditions are favorable. In addition to the Gambusia Springs, restoration candidates include the springs at Ojo Caliente village and the springs emanating at Arroyo de Fortino on the Mexican side just upstream of Boquillas canyon.
- Protect and restore watersheds in the recharge zone.
- Work with groundwater planning and conservation organizations to prevent aquifer exploitation.

Priority Conservation Area

12

Gambusia Springs

Author: Raymond Skiles

Gambusia Springs are located within Big Bend National Park; they include several warm springs near the Big Bend National Park Rio Grande Village. Ojo Caliente is a similar spring run in neighboring Mexico. These springs are a subset of the Boquillas Hot Springs Complex. Unlike others in the complex, the Gambusia Springs emerge onto the floodplain well away from the river, producing stream runs, wetland and riparian habitats, and a beaver pond. The aquatic and riparian habitat hosts diverse bird, amphibian, and reptile populations.

Beaver Pond at Rio Grande Village, Texas. Photo: Raymond Skiles

Big Bend slider. Photo: J. N. Stewart

Conservation targets

Conservation targets include the endangered Big Bend gambusia (*Gambusia gaigei*), Big Bend slider (*Trachemys gaigeae*), beavers (*Castor canadensis*), the common

black-hawk (*Buteogallus anthracinus*), migratory and breeding birds, water birds, and riparian and wetland vegetation. The Rio Grande river cooter (*Pseudemys gorzugi*), a native turtle, has only ever been recorded in Beaver pond and the aquatic habitat supports the most robust known population of crayfish in the park. Although less studied, the adjacent Ojo Caliente represents an opportunity for cross-border conservation, including the potential to introduce the Big Bend gambusia.

Threats

The primary ecological drivers are the source aquifer; the beaver (*Castor canadensis*), which creates rare and important ponds in the Chihuahuan desert; the floodplain's capacity to provide aquatic habitat; and exotic invasive species that disrupt ecosystem function.

Although located within a protected area, the springs' proximity to the NPS development represents one of the major threats to the area due to the impact of visitors and associated administrative facilities. Rio Grande Village also uses water from the aquifer that supplies the springs. Concrete spring boxes contain two of the springs. Spring 1 supplies water to an artificial refugia pond for the Big Bend gambusia. Until recently, Spring 4, the other contained spring, was the development's main water supply, but it is now maintained as a backup for domestic water. The system consists of a spring box, a pump, and a pipeline. To decrease the impact of pumping on the spring habitats, BBNP drilled a new well into the same aquifer further away. It also maintains and regularly monitors several observation wells.

The other major threat is from exotic species that have colonized the hospitable stream and pond habitat. These include nutria (*Myocastor coypus*), elegant slider (*Trachemys scripta elegans*), green tree frog (*Hyla cinerea)*, bullfrog (*Rana catesbeiana*), common mosquitofish (*Gambusia affinis),* and blue tilapia (*Oreochromis aureus*). The 100-site Rio Grande Village campground is adjacent to the Gambusia Springs and visitors are likely responsible for the introduction of these species. Potential spills from the powerlines, pipelines, and roads that cross the area threaten to contaminate it. Restoration options include removing pre-park earthen dams and diversions, and relocating a campground loop and utility/service corridors that currently impinge on the area, as called for in the Big Bend gambusia (*Gambusia gaigei*) recovery plan. The integrity level of Gambusia Springs is deemed to be 'medium', as is the level of risk.

Partnerships and socioeconomic factors

Various restoration projects have reduced the threats from the park; some administrative facilities have been removed while others remain. The adjacent Mexican springs are within *ejido* property and are cultivated. A NPS project aims to remove several earthen berms and restore natural soil contours and hydrologic conditions in part of the US area. The USFWS Rio Grande Fishes Recovery team also works on Big Bend gambusia (*Gambusia gaigei*).

Research and monitoring needs

- Establish a strategy to monitor spring flow.
- Collate and interpret observation-well monitoring data.
- Measure and monitor water extraction from the aquifer and spring heads for human use.
- Survey Mexico's adjacent springs for Big Bend gambusia (*Gambusia gaigei*).
- Determine the impact of exotic species, such as nutria (*Myocastor coypus*), on aquatic and riparian resources and native species, including Big Bend gambusia (*Gambusia gaigei*).
- Monitor for other exotic species, including feral pig (*Sus scrofa*).
- Monitor spring flows and fluctuations and determine the relationship to groundwater pumping from the NPS water-supply well.
- Further investigate and document the spring-recharge zone's characteristics and dynamics.

Recommendations

- Evaluate strategies to control the exotic bullfrog (*Rana catesbeiana*), nutria (*Myocastor coypus*), and elegant sliders (*Trachemys scripta elegans*).
- Evaluate the removal of spring containment structures from the spring heads.
- Plan to relocate the campground loop that impinges on wetland habitat.
- Create a binational plan to enhance the natural resource values of both the US Gambusia Springs and the adjacent Ojo Caliente spring runs. Any such plan would be subject to the authorization of relevant agencies.

Llano las Amapolas, Chihuahua
Photo: Raymond Skiles

Grasslands

Conservation Priority Areas 13 - 19

Priority Conservation Area

13

Sierra de Hechiceros y Lagunas de Sanchez y de Montoya Grasslands

Authors: Gerardo Arturo Bezanilla Enriquez and José Roberto Rodríguez Salazar

Llano las Amapolas, Chihuahua. Photo: Raymond Skiles

Loggerhead shrike. Photo: Kenneth Cole Schneider

The Grasslands of Sierra de Hechiceros y Lagunas de Sanchez y de Montoya are located in the Mexican state of Chihuahua, in the southern part of the Manual Benavides municipality. The area is grassland and shrubland-covered hills dominated primarily by grasses such as blue grama species (*Bouteloua gracilis, Bouteloua eriopoda, and Bouteloua curtipendula*), tobosa (*Pleuraphis mutica*), and alkali sacaton (*Sporobolus airoides*). The main shrub species include creosote bush (*Larrea tridentata*) and cane cholla (*Cylindropuntia imbricata*), in addition to some yuccas (*Yucca elata* and *Yucca torreyi*).

Conservation targets

The bird conservation targets include loggerhead shrike (*Lanius ludovicianus*), lark bunting (*Calamospiza melanocorys*), Cassin's sparrow (*Peucaea cassinii*), long-billed curlew (*Numenius americanus*), ferruginous hawk (*Buteo regalis*), golden eagle (*Aquila chrysaetos*), aplomado falcon (*Falco femoralis septentrionalis*), burrowing owl (*Athene cunicularia*), chestnut-collared longspur (*Calcarius ornatus*), and Sprague's pipit (*Anthus spragueii*). Mammal target species include pronghorn (*Antilocapra americana*) (in the southern part only), kangaroo rats (*Dipodomys* spp.), kit fox (*Vulpes macrotis*), and mule deer (*Odocoileus hemionus*).

Feral pigs. Photo: Hernando Cabral Perdomo

Threats

Drivers in these grasslands include weather extremes and climate change, and invasive and exotic species, such as feral pigs (*Sus scrofa*), Barbary sheep (*Ammotragus lervia*), buffelgrass (*Pennisetum ciliare*), and natal grass (*Melinis repens*). Lack of awareness of conservation issues may also be an important driver. The main threats are related to the destruction, fragmentation, and overgrazing of grasslands, primarily due to unsustainable grazing practices, groundwater pumping, soil salinization, wildlife poaching, and land conversion to agriculture. For example, the ideal habitat for the Sprague's pipit requires a plant cover of 80 percent grasses and 5 percent shrubs, with a height of between 20 and 30 centimeters (Pool et al. 2012). Constant high levels of grazing and other causes, such as the absence of fires, prevent these habitat conditions from forming. Another key threat is the limited interest of landowners in natural resources conservation. The grasslands' ecological condition gives them a 'medium' level of integrity, while the threats mean the risk level is 'high.'

Partnerships and socioeconomic factors

This area is primarily privately owned, with some *ejidos*, which results in various grazing and grassland management practices. Small private landowners use primarily pasture-rotation systems, while extensive/continuous grazing is mainly used in the *ejidos*. The APFF Cañón de Santa Elena at the northeastern part of this area may be a strategic ally for recommending sustainable livestock production activities. Key conservation partners include the Universidad Autónoma de Chihuahua and the Rocky Mountain Bird Observatory (RMBO). The latter, in association with the CEC, described this area as Grassland Priority Conservation Area (GPCA), and named it "Llano las Amapolas" (Pool et al. 2011).

Research and monitoring needs

- Continue the monitoring of wintering grassland birds that the RMBO, in coordination with the Universidad Autónoma de Nuevo Leon, began in 2009.
- Monitor the distribution of northern aplomado falcon (*Falco femoralis septentrionalis*) and pronghorn (*Antilocapra americana*).
- Continually assess range condition.
- Monitor wildlife.
- Assess agricultural producers' attitudes toward conservation.
- Generate more information about soil types.

Recommendations

- Assess how different groups use resources, to provide a foundation for ensuring the success of conservation planning.
- Work with landowners to improve grasslands condition. Grassland management practices should be oriented toward achieving the type of plants native wildlife species in this area require.

Priority Conservation Area

14+15+16

Marfa, Alpine, and Marathon Grasslands

Authors: Louis Harveson, John Karges, and Aimee Michelle Roberson

Marfa, Texas. Photo: Catherine Hallmich

Long billed curlew. Photo: Ingrid Taylar

The grasslands throughout the Chihuahuan Desert are critical wintering areas for grassland bird species breeding in the western Great Plains of the US and Canada, and they are regionally important for a number of bird species with conservation concerns. The Marfa, Alpine, and Marathon grasslands are semi-contiguous, nearly adjacent grasslands within Presidio and Brewster counties in Texas. Like other semi-arid grasslands within the northern Chihuahuan Desert, these grasslands are globally important for migratory birds, as well as pronghorn and a diverse suite of other native species. Typically, winters in this area are moderately dry with relatively mild temperature extremes, the spring season is dry and warm, and early summer weather brings drought. The rainy season occurs from mid-summer to mid-fall with monsoonal, locally intense convection storms.

Prairie dog. Photo: Jürgen Hoth

Marfa Grasslands

The Marfa Grasslands are characterized by private cattle ranching and abundant wildlife. They are rich in biodiversity, with the ecological components of functionally intact Chihuahuan Desert grasslands. This area is still primarily open rangeland in a relatively natural and undisturbed condition, composed of midgrass-dominated semi-desert and plains grassland at moderate elevations of 1,500 meters (5,000 feet). Although land use and soil loss has degraded some portions of these grasslands since settlement, there remain large tracts of viable and/or recoverable sideoats grama (*Bouteloua curtipendula*) and blue grama (*Bouteloua gracilis*) grasslands and associations, including interspersed xeromorphic shrublands and yucca grasslands.

Conservation targets

Conservation targets include the golden eagle (*Aquila chrysaetos*), kangaroo rat (*Dipodomys merriami*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), kit fox (*Vulpes macrotis*), burrowing owl (*Athene cunicularia*), and aplomado falcon (*Falco femoralis septentrionalis*); the latter has been the focus of reintroduction efforts. Conservation targets also include wintering grassland birds, such as sparrows and longspurs, wintering raptor assemblages, nesting raptor species, as well as migratory and nesting sites for two migratory shorebirds, mountain plover (*Charadrius montanus*) and long-billed curlew (*Numenius americanus*), which use arid interior upland shortgrass plains. Community representatives of ecological intactness include mixed plains grassland, tobosa (*Pleuraphis mutica*) grasslands, black grama (*Bouteloua eriopoda*) grasslands, and riparian herbaceous woody communities.

Partnerships and socioeconomic factors

Land in the Marfa Grasslands is entirely privately owned; individual ranches operate different livestock productions or recreational hunting or both. Range management is ranch-specific, using sustainability and adaptive responses to local conditions, frequently under the guidance and assistance of the Natural Resources Conservation Service (NRCS). Sul Ross State University is conducting research on pronghorns, and some range management research is being carried out on a private ranch. The Peregrine Fund has led the aplomado falcon (*Falco femoralis septentrionalis*) population restoration work in this area.

Alpine Grasslands

The Alpine Grasslands surround Alpine, extending north-northeast of the town, primarily in Brewster County, Texas, eastward to the contiguous and ecologically indistinct Marathon Grasslands at the elevated watershed divide of Altuda Pass. To the northeast, the grasslands slope downward into desert shrublands of creosote bush and recumbent mesquite. To the west, the grasslands historically extended to Paisano Pass on the shallow slopes and plains interspersed with rocky uplands, and may have continued to the Marfa Grasslands in the late 1800s.

Cassin's sparrow. Photo: Jason Forbes

Conservation targets

Conservation targets include pronghorn (*Antilocapra americana*), kit fox (*Vulpes macrotis*), and kangaroo rats (*Dipodomys* spp.). Grassland bird conservation targets include raptors, burrowing owls (*Athene cunicularia*), longspurs and pipits, and shorebirds, notably including long-billed curlews (*Numenius americanus*) and mountain plovers (*Charadrius montanus*), although documentation of the latter species is rare.

Partnerships and socioeconomic factors

Individual ranch operations, with some land management and planning guidance and support from the NRCS range specialists and the TPWD wildlife biologists, have undertaken the primary conservation actions through range-management strategies and techniques. Important on some ranches are conservation measures, herd health, and sustainability of pronghorn and mule deer, an important game species that can be a source of substantial revenue. Some rangeland rehabilitation has occurred at the northern portion of the Alpine Grasslands where non-native forage grasses have been introduced for livestock production and groundcover to prevent soil erosion and loss. Although this grassland is not totally comprised of native species, it may provide sufficient vertical structure, forage, and cover for prairie animal species of conservation concern.

Valentine, Texas. Photo: Maria Dolores Wesson

Marathon Grasslands

The Marathon Grasslands, around Marathon in Brewster County, Texas, are the third-largest desert grasslands in the state. The area is bordered by Altuda Pass in the west, the Glass Mountains to the north, the Del Norte Mountains to the south and west, and Lemon's Gap in the east. These relatively intact grasslands occur in the intermontane plains, and adjacent to rugged rocky outcrops. The area is underlain by a thick sequence of folded and faulted Paleozoic strata with proven hydrocarbon reserves. Ephemeral streams are the dominant hydrologic feature on the landscape. There are historical accounts of several springs, of which only a few remain.

The Marathon Grasslands are dominated by sideoats (*Bouteloua curtipendula*) and blue grama (*Bouteloua gracilis*), but contain a diversity of other native grasses, forbs, shrubs, cacti, and some trees along drainage courses. Conservation targets include pronghorn (*Antilocapra americana*), kit fox (*Vulpes macrotis*), kangaroo rats (*Dipodomys* spp.), and wintering grasslands birds, including Eastern (Lilian's) meadowlark (*Sturnella magna lilianae*), loggerhead shrike (*Lanius ludovicianus*), aplomado falcon (*Falco femoralis septentrionalis*), Cassin's sparrow (*Peucaea cassinii*), and burrowing owl (*Athene cunicularia*). Other residents include mule deer (*Odocoileus hemionus*), coyote (*Canis latrans*), lagomorphs (hares and rabbits), black-tailed prairie dog (*Cynomys ludovicianus*) and other rodents, scaled quail (*Callipepla squamata*), greater roadrunner (*Geococcyx californianus*), and several raptor species of conservation concern.

Partnerships and socioeconomic factors

The Marathon Grasslands are owned exclusively by private landowners, with a small leased public park south of the town of Marathon. Most land use is focused on livestock grazing and recreational hunting operations, although recent trends in land ownership suggest that many ranches may have reduced grazing pressure. There has been no adequate mapping of this extensive grassland.

Threats

As with other desert grasslands in the region, the primary ecological drivers for the Marfa, Alpine, and Marathon grasslands are the cumulative effects of drought and climate change, altered fire regime and frequency, pressure from livestock grazing, and land use change and fragmentation. These drivers have resulted in the encroachment of woody species, including creosote (*Larrea tridentata*), mesquite (*Prosopis glandulosa*), Mormon tea (*Ephedra antisyphilitica*), sacahuiste (or foothill beargrass, *Nolina erumpens*), and broomweed (*Amphiachyris* spp.). Some invasion occurs with juniper from the higher slopes, and with sacahuista (*Nolina texana*) and ephedra (*Ephedra antisyphilitica*) expansion and encroachment throughout. Exotic feral pigs (*Sus scrofa*) are causing habitat degradation and exotic Barbary sheep (*Ammotragus lervia*) compete with native species for habitat. And perhaps most significantly, climate change is likely to be an increasingly important driver of vegetation change, given predictions of higher temperatures, prolonged droughts, and increased storm intensity—a combination that is likely to result in increased erosion of topsoil. As a result, the integrity level of these areas is 'medium', and the risk level is 'high'.

Currently, there is a parasitic epidemic among pronghorns that is causing some die-offs, and many of the historic fences are woven-wire that impedes pronghorn movement and can sever gene flow within pronghorn populations and family bands. Some fences entrap or create an escape barrier for pronghorns, particularly fawns and yearlings fleeing such predators as coyotes (*Canis latrans*) or bobcats (*Lynx rufus*). Additionally, ranchland pastures taken out of livestock production frequently do not have water available for wildlife because wells are not operated or maintained.

Research and monitoring needs

- Conduct aerial mapping of the Marfa, Alpine, and Marathon Grasslands to define the area of contemporary grasslands and to measure intactness and connectivity.
- Monitor pronghorn herd sizes and distribution, and conduct productivity assessments to determine whether this population is changing and sharing genetic exchange with adjacent grassland herds.
- Continue to monitor breeding and wintering birds.
- Seek to understand community dynamics in response to the water cycle.
- Study the effects of climate change on ecosystem community dynamics.
- Conduct research on soil microbiology, including cycling and sequestration of carbon and other nutrients.
- Study the role of riparian areas within grasslands and their importance as habitat corridors for bears, birds, or other species.
- Address the following management questions through research, monitoring, and adaptive management (also relevant to other grassland PCAs):
  - What is the current condition of the grassland and what is its potential for restoration?
  - What are the most appropriate management techniques for restoring or enhancing grassland habitats (e.g., mechanical or chemical brush control, banded brush treatments, roller-chopping, etc.) given specific conservation objectives and site-specific conditions such as soil type, precipitation, elevation, and slope?
  - What is the role of fire as a restoration tool in arid grasslands?
  - What are the most appropriate management techniques for riparian areas within grasslands?

Recommendations

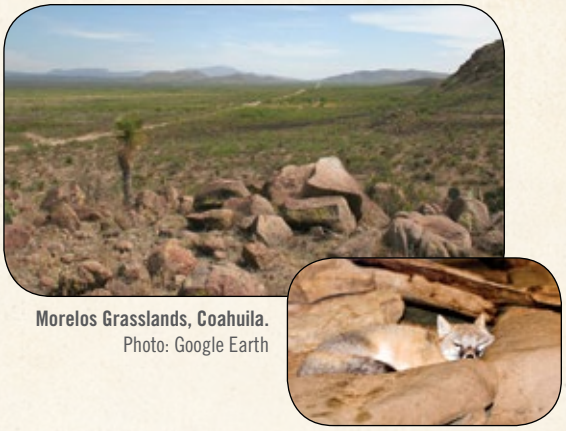
- Conservation actions in these grasslands are at the discretion of individual landowners and must be designed within their operational needs and capacities. Several agencies working in the area have private lands assistance programs, including various programs of the NRCS, the USFWS Partners for Fish and Wildlife program, and the TPWD Landowner Incentive Program and Watershed Management program. These agencies plan to continue to reach out to private landowners with cooperative conservation opportunities, including technical and financial assistance, aimed at increasing rangeland health and abating threats to grassland productivity.
- Continue to use conservation initiatives and agency conservation program incentives across and within private ownerships to contribute to watershed health by maintaining key ecological processes that sustain grassland communities and the species dependent upon functioning mid-grass and short-grass prairies. The suite of conservation practices used may include re-vegetation tracts to slow soil loss and erosion, shrub control, appropriate application of prescribed fire, prevention of altered hydrologic function, and use of sustainable rangeland grazing practices.
- As described above under Research and Monitoring Needs, conservation partners should work together to develop and implement inter-disciplinary, adaptive management frameworks to better understand what the most appropriate management techniques are for restoring or enhancing grassland habitats (e.g., mechanical or chemical brush control, banded brush treatments, roller-chopping, prescribed fire, etc.) and the riparian corridors within them given specific conservation objectives and site-specific conditions such as soil type, precipitation, elevation, and slope.
- In the Big Bend region, there are significant opportunities and ongoing projects to restore degraded grasslands on both public and private lands. Although some of the areas where this work is occurring or has the potential to be successful are not included in the PCAs described here, they should not be overlooked as management priorities. The successful restoration of degraded grasslands will benefit native plant and wildlife species, slow erosion of topsoil, and contribute to the development and dissemination of Beneficial Management Practices for grassland restoration.
- To accommodate pronghorn movement, natural resource agencies should continue to work with landowners to modify or remove existing woven-wire fences and encourage new or replacement fences to be built following pronghorn conservation recommendation standards.
- Maintain reliable and accessible water sources to benefit pronghorns and other native species.
- Maintain wildlife migration corridors, including riparian areas and other intact, contiguous habitats for large mammals and migratory, breeding, and wintering birds.

Priority Conservation Area

17

Morelos - Los Lirios Grasslands

Authors: Rogelio Carrera and Francisco Torralba González



Morelos Grasslands, Coahuila. Photo: Google Earth

Kit fox. Photo: D. Barronoss

These grasslands are found in the State of Coahuila, north of Múzquiz municipality, and south of the municipality of Acuña, between 900 and 1,500 meters (3,000–5,000 feet) above sea level. The area comprises the *ejidos* of Los Lirios, San Francisco, Hacienda Santo Domingo, and Hacienda Guadalupe in the municipality of Múzquiz, and *ejido* Morelos in the municipality of Acuña. Its various plant communities include midgrass-dominated grasslands composed of blue grama and tobosa grass, as in the Mesa de los Fresnos; canyons with oak, juniper and pine stands; and submontane and succulent scrub with *izotal* dominated by yuccas. Proportionally less important are sotol (*Dasylirion* spp.), thorny microphyllous shrubs, and associations of grassland shrubs. Around one-third of this area lies within the APFF Maderas del Carmen, with the rest extending eastward outside of the APFF and including private land and *ejidos*. Some locations are very productive but erosion and soil compaction is also very common.

Grazing pressure and possible changes in precipitation regime have deteriorated large areas within the *ejidos*. As a result, some opportunistic plant species have emerged. In some locations, such as Los Venados in *ejido* Los Lirios, water and wind erosion have created highly degraded areas that are now covered by dog cholla (*Grusonia bulbispina*), and by exotic weeds like Russian thistle (*Salsola ibérica*). Shrub encroachment with mesquite (*Prosopis glandulosa*), tarbush (*Flourensia cernua*) and creosotebush (*Larrea tridentata*) is also common in overgrazed locations, particularly in *ejidos*. Many locations in degraded areas can be restored to native grasslands with appropriate range improvement techniques and range management.

Conservation targets

Conservation targets in the grasslands of Morelos include black bear (*Ursus americanus*), kit fox (*Vulpes macrotis*), kangaroo rats (*Dipodomys* spp.), mule deer (*Odocoileus hemionus*), golden eagle (*Aquila chrysaetos*), Montezuma Quail (*Cyrtonyx montezumae*), Mexican long-nosed bat (*Leptonycteris nivalis*), as well as a great number of grassland birds. Tobosa grass (*Pleuraphis mutica*), mariola (*Parthenium incanum*), burrograss (*Scleropogon brevifolius*), tarbush (*Flourensia cernua*), and whitethorn acacia (*Acacia constricta*) dominate the plant cover. The plant checklist is long, with 74 families, 275 genera, and 422 species (Cabral-Cordero 2003).

Morelos Grasslands, Coahuila. Photo: Google Earth

Threats

The region's main ecological drivers are livestock overgrazing, weather extremes in the form of drought, and the introduction and spread of exotic species such as feral pigs and non-native grasses. Poor land management practices, poaching, and lack of environmental education are also important drivers.

Overgrazing is severe in some parts of the *ejidos,* where soil loss and shrub encroachment is a major concern. In some cases, private landowners are seeding pastures with exotic grasses for livestock. Poaching and predator control by landowners is also of concern.

The entire area has 'low' ecological integrity, although on some private lands, integrity may be 'medium' to 'high'. The area's risk status is considered to be 'high' because drought and current land practices, including overgrazing, have led to continuous soil degradation in most of the area.

Partnerships and socioeconomic factors

Most of the area is under *ejido* land ownership, although there is some private land as well. In the last few decades, *ejidos* have gone through deep social changes as families move to the region's cities. The residential centers of the Morelos and Carranza *ejidos* have been abandoned and no longer have elementary schools. San Francisco and Los Lirios have no urban centers and there are no permanent resident families living on the *ejido*. *Ejidos* have gone through partitioning and now function like small independent private land units managed by families who now live mostly in Muzquiz and Acuña. Conservation strategies in *ejidos*, considering these social changes, should aim to work with families who manage single land units individually, as do traditional private ranch owners. Existing conservation efforts have been localized and should be extended.

The recent drought has affected local communities; ranchers have been forced to reduce the stocking rate by up to 40 percent in most cases. These communities have implemented soil conservation projects, such as seeding native grasses and installing gabions. They have first-hand experience with the effects of fire, drought, and the progression from grasslands to shrublands. As a result, they are willing partners in soil conservation projects. Expanding existing partnerships with NGOs, academic institutions, and local government agencies will strengthen conservation goals in this area.

The APFF Maderas del Carmen continues to implement soil retention projects, sustainable range management, animal health initiatives, and land management education. These efforts have focused on Los Lirios and San Francisco *ejidos*, but they have not extended to other *ejidos* in the area. The Universidad Autónoma Agraria Antonio Narro (UAAAN), based in Saltillo, Coahuila, maintains an experimental range at Las Norias Ranch located at the area's northern end. There is limited activity at this experimental range, however, which has no permanent technical staff on site and is only used for occasional research activities in animal and range sciences. Activities at the APFF Maderas del Carmen and the UAAAN experimental range present opportunities to extend conservation programs to *ejidos* and private lands in the area.

Research and monitoring needs

Research in this area has been limited to some descriptive studies on plant communities at Las Norias experimental range. Research needs include:

- Inventories of focal groups of interest (e.g., grassland birds);
- Studies on the distribution of exotic species;
- Research on the effects of prescribed fire and climate change on grassland ecosystems;
- Monitoring of grassland birds; and
- Gathering additional information on soil types.

Recommendations

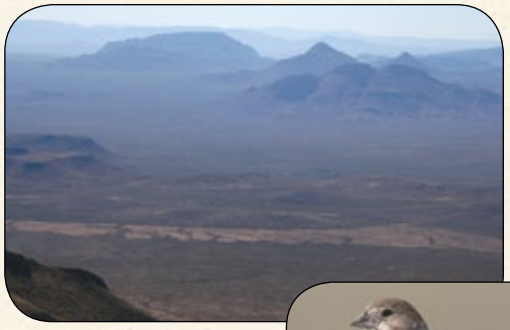
- Build on the lessons learned from past projects within the APFF Maderas del Carmen. For example, working with local *ejidatario*s may be difficult since they no longer live in the area and have to be reached through *ejido* associations and their representatives.
- Gather more information on *ejido* partitioning, and produce maps as well as a database of landowners, which are important tools for planning and conservation strategies.
- Promote coordination between different government agencies and stakeholders in the area to align conservation objectives. For example, Conanp is focused on sustainable cattle practices, while the *Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación* (Sagarpa) may incentivize habitat transformation and introduction of exotic grasses.
- Build on local ranchers' awareness of the beneficial effects of replanting native grasses to prevent soil erosion, particularly after severe wildfire events. Tap into current community support for projects to implement native seeding, as well as water retention projects such as the construction of gabions.

Priority Conservation Area

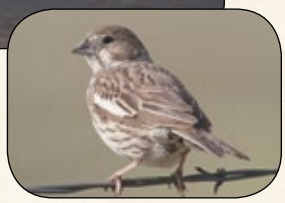
18

Valle de Colombia Grasslands

Authors: Carlos Alberto Sifuentes Lugo and Francisco Torralba González



Valle de Colombia, Coahuila. Photo: Google Earth



Lark bunting. Photo: Jason Forbes

Recent surveys by Panjabi et al. (2010) rank the Valle de Colombia grasslands among the Chihuahuan Desert's highest priority GPCAs because they host some of the highest grassland bird densities. The Valle de Colombia is located in northern Coahuila, East of the Sierra del Carmen, at an altitude of 1,200 meters (3,900 feet); it encompasses 445,000 hectares (1,100,000 acres) of Chihuahuan Desert grasslands and shrublands. Characteristic grass species include blue grama (*Bouteluoa gracilis*), sideoats grama (*Bouteloa curtipendula*), tobosagrass (*Pleuraphis mutica*), and alkaline grass (*Sporobolus airoides*). Some areas feature various shrub species such as mesquite (*Prosopis glandulosa*), creosote bush (*Larrea tridentata*), tarbush (*Flourensia cernua*), and yuccas (e.g., *Yucca carnerosana*) in rolling hills.

Conservation targets

Conservation targets in these grasslands include several grassland obligate species, such as loggerhead shrike (*Lanius ludovicianus*), lark bunting (*Calamospiza melanocorys*), Cassin's sparrow (*Peucaea cassinii*), long-billed curlew (*Numenius americanus*), ferruginous hawk (*Buteo regalis),* burrowing owl (*Athene cunicularia*), Sprague's pipit (*Anthus spragueii*), chestnut-collared longspur (*Calcarius ornatus*), golden eagle (*Aquila chrysaetos*), and vesper sparrow (*Pooecetes gramineus*). Mammal targets include pronghorn (*Antilocapra americana*), Mexican long-nosed bat (*Leptonycteris nivalis*), kit fox *(Vulpes macrotis),* kangaroo rat (*Dipodomys* spp.), and mule deer (*Odocoileus hemionus*). The area is also black bear (*Ursus americanus*) and mountain lion (*Puma concolor*) habitat. In 2012, Conanp identified 38 different bird species, of which the following were considered of special importance: Northern Mockingbird (*Mimus polyglottos*), Cassin´s sparrow (*Peucaea cassinii*), brown-headed cowbird (*Molothrus ater*), black-throated sparrow (*Amphispiza bilineata*), and lark sparrow (*Chondestes grammacus*).

Threats

Important ecological drivers include weather extremes and climate change, exotic species such as the European wild pigs (*Sus scrofa*), and landowner attitudes towards predators, which include the use of poison to stop livestock depredation. Conservation threats are related primarily to localized overgrazing and erosion, and potentially to the encroachment of woody plants. Other threats include wildlife poaching. The area's integrity and risk levels are both considered as 'medium'.

Partnerships and socioeconomic factors

Grassland ownership in Valle de Colombia is entirely private. Conservation and restoration tools in use include sustainable grazing practices, such as holistic range management; water distribution; prescribed fire; outreach and education about predators; soil conservation and erosion control; control of exotic species (feral pigs, Barbary sheep, non-native grasses); using pronghorn friendly fences; enforcing laws to stem poaching; and reintroducing native charismatic species, such as American bison (*Bison bison*) and pronghorn (*Antilocapra americana*).

Research and monitoring needs

- Continue to monitor grassland birds.
- Gather more information on soil types.
- Determine the effects of prescribed fire.
- Assess ranchers' attitudes toward conservation.

Ferruginous hawk. Photo: Samuel J. Barry

Recommendations

- Establish contacts with landowners and producers to develop an information network related to grassland bird monitoring.
- Implement a monitoring system based on key species such as the golden eagle and grassland birds.
- Implement research projects related to native grass species.
- Carry out an educational campaign on invasive species aimed at landowners and producers.
- Consolidate partnerships between government agencies and nongovernmental organizations aimed at restoring areas degraded by erosion.

Priority Conservation Area

19

Serranías del Burro Grasslands

Author: Hernando Cabral Perdomo

This section describes the grasslands in Serranías del Burro. See Conservation Priority Area 27 for a description of the mountains in Serranías del Burro.

Serranías del Burro, Coahuila.
Photo: Hernando Cabral Perdomo

Kangaroo rat.
Photo: USFWS Pacific Southwest Region

The Serranías del Burro in northwestern Coahuila covers just over 300,000 hectares (740,000 acres), and is partially located within Conanp's Protected Area Irrigation District 004 Don Martín. Together with the APFFs Maderas del Carmen and Ocampo, the *Monumento Natural Río Bravo del Norte*, and BBNP, it forms an important biological corridor. The unusually complex topography, with canyons punctuating the low relief and greater intermontane valleys connecting it to neighboring mountains, allow the coexistence of a wide variety of plants and animals. The predominant vegetation throughout the Serranías del Burro includes Tamaulipan thorn scrub, submontane scrub, scrub oak, and as the altitude increases, cedar forest.

Conservation targets

In the grasslands of Serranías del Burro the conservation targets include black bear (*Ursus americanus*), wild turkey (*Meleagris gallopavo intermedia*), golden eagle (*Aquila chrysaetos*), Montezuma quail (*Cyrtonyx montezumae*), kit fox (*Vulpes macrotis*), kangaroo rat (*Dipodomys* spp.), pronghorn (*Antilocapra americana*), and other grassland birds.

Threats

Ecological drivers in the grasslands of Serranías del Burro include overgrazing and altered fire regimes, in terms of fire intensity, quantity, and timing. Forest fires are a permanent feature of this area, but lately they have become more frequent, with a return period of three years. The risk of major forest fires has risen due to low precipitation and the lack of a fuel management program. The latter has led to an accumulation of grass, which is unpalatable to livestock. The area's low population density, long travel distances for fire-management personnel, and limited access to private property constrain the ability to manage fires.

Threats include the possible fragmentation of private property over generations and the risk of forest fires fed by exotic grasses, which increases temperatures and in turn leads to more wildfires. Threats to the conservation of these grasslands include extreme meteorological events caused by climate variability, the invasion—and gradual substitution—of grasslands by shrub species such as the thorntree (*Acacia* spp.) and honey mesquite (*Prosopis glandulosa*), as well as too-frequent fires. The ecosystem is generally in good condition due to its large unfragmented area, good management, and stable land ownership, which means the area's integrity is deemed to be deemed 'high'; the level of risk, however, is 'medium' due to the threats.

Partnerships and socioeconomic factors

The Serranías del Burro region is mostly privately-owned land. In 2014, the Serranías del Burro Fund, a partnership between *Fondo Mexicano para la Conservación de la Naturaleza, A.C.,* the Rainmaker Trust, and the Botanical Research Institute of Texas, is putting into place innovative funding mechanisms to ensure conservation and management of over 48,500 hectares (120,000 acres) of one of Mexico's last wildlands in the Chihuahuan Desert. The Rainmaker Trust is a fund originally begun by a small number of landowners to create an ecological easements system and a set of incentives to avoid further land fragmentation. There are various conservation programs in the area, including organically certified holistic breeding, ecotourism-oriented forest conservation management units (UMAs), bow hunting tourism, comprehensive fire management on the Las Pilas Ranch, and a long-term black bear (*Ursus americanus)* conservation project. The Serranías del Burro is designated as Priority Terrestrial Region *Sierra del Burro-Río San Rodrigo* (RTP-73) and Priority Terrestrial Region *Cuenca del Río Sabinas* (RTP-152) by Conabio, and as IBA *Sierra del Burro* (AICA no. 5) by BirdLife International. This area also has payment for ecosystem services (PES) programs. For example, in 2007 and 2008, Conafor paid approximately US$157,000 to protect 72,000 hectares (180,000 acres), directly benefiting owners. In 2009, more than 540,000 hectares (1,300,000 acres) or 65 percent of the municipality of Melchor Múzquiz (located in Serranías del Burro) were deemed eligible for PES, based on biodiversity conservation considerations.

Research and monitoring needs

- Establish a database enabling updates on species monitoring.
- Monitor climate conditions and record electrical storms in the area.
- Assess and monitor exotic species.

Recommendations

- Maintain high deer populations, as the species helps to control shrubs by browsing.
- Continue current practices and try new alternatives to collect and store water to benefit various ranch production activities and wildlife.
- Implement a comprehensive fire management program to regularize fire regimes and ensure a healthy grassland ecosystem.
- Establish prescribed fire demonstration units as the basis to justify an inter-institutional regional program of controlled burning.
- Develop and apply a forest health program.
- Strengthen initial firefighting with an Airlift Brigade that operates during critical fire periods.
- Distribute outreach materials and undertake environmental education campaigns with ranchers, communal farmers, and neighboring small communities to foster good waste management practices and avoid conflicts with bears.

Chinati Mountains, Texas
Photo: Charlie Llewellin

Mountains

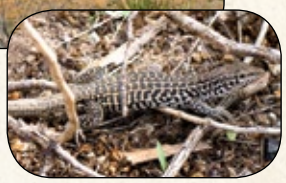
Conservation Priority Areas 20-29

Priority Conservation Area

20 Chinati Mountains

Authors: John Karges and Helen M. Poulos

Chinati Mountains, Texas.
Photo: John Karges



Gray-checkered whiptail.
Photo: Jason Penney

The Chinati Mountains, which exceed 2,347 meters (7,700 feet) in elevation, are located in southwestern Presidio County, Texas. Its woodland vegetation and the presence of a number of endemics (including several endemic plant species and terrestrial mollusks) qualify the range as a sky island. The primary conservation targets for mammals include the Mexican long-nosed bat (*Leptonycteris nivalis*), desert bighorn sheep (*Ovis canadensis*), and black bear (*Ursus americanus*). Two Mexican long-nosed bats have been found in the Pinto Canyon on the north side of Chinati Peak; otherwise the only other place they occur in Texas is in the nearby Chisos Mountains. Desert bighorns have been introduced to the area and may be colonizing the mountains, and occasional vagrant black bears are known. Another conservation target is the near-endemic gray-checkered whiptail (*Aspidoscelis dixoni*), which is also found in SW New Mexico. The primary bird targets include the golden eagle (*Aquila chrysaetos*), peregrine falcon (*Falco peregrinus anatum*), and Montezuma quail (*Cyrtonyx montezumae*). More information is needed to confirm their presence; the two raptors may occupy the higher elevations intermittently during migration and/or breeding, and the Montezuma quail may be found in the open woodland/savanna communities. The plant communities include woodland/savanna matrices, riparian woodlands, some springs and perennial reaches of watercourses, and rock bluffs and barren substrates.

Threats

Ecological drivers include climatic events such as prolonged droughts and high-intensity rainfall, and wild fire. Climate change is the overarching threat; rising aridity and the expected increase in the intensity of storm events will affect vegetative cover.

Land uses include some livestock production on a number of ranches, wildlife harvesting, mining, and recreational activities on some lands. Resource extraction, mining and/or water withdrawals, present a new and emerging issue for the region. A silver mining operation near Shafter, Texas, and on the eastern edge of the Chinati Mountains will need to dewater the mineralized zone to extract the ore. The mining company plans to discharge that water into a nearby dry arroyo, permanently removing it from the aquifer. A more desirable, albeit more expensive, option is to store it in the same aquifer at a reasonable distance from the project site. An open-pit copper mine is planned for the mountain range's southeast portion. It is likely that some groundwater management will be required to operate the site, and the threat of disturbing groundwater dynamics may have a regional ecological impact. The ecological and anthropogenic threats mean the area's integrity status is likely 'high', and the risk status is 'medium-to-low'.

Partnerships and socioeconomic factors

Two portions of the Chinati Mountains are protected for conservation purposes: the Chinati Mountains State Natural Area (by the TPWD) and Pinto Canyon Ranch. These natural areas are managed to conserve biodiversity, natural communities, and ecological intactness. The Pinto Canyon Ranch is a privately-owned conservation easement of TNC, subject to its conservation terms, including protecting rare species. Because the two areas are adjacent, it increases the overall amount of contiguous land under conservation cooperation, thereby benefitting conservation goals. The TPWD has conducted floral, herpetological, and mammal inventories of the area, and TNC has sponsored a botanical survey on the Pinto Canyon easement. The remainder is private ranchland principally consisting of large undivided ranches with a few scattered housing developments. Individual landowners manage their properties to meet their own objectives, be they livestock production (currently cattle, but with a history of sheep and goat operations), wildlife management for hunting, or recreational uses. Any additional conservation partnerships will be initiated at landowners' discretion.

The Chinati Mountains and the adjacent and contiguous uplands of the Sierra Vieja to the northwest form an important potential corridor for migratory or highly mobile animals. While much of the area is managed for conservation, crucial portions are not, including Chinati Peak's summit, although as yet it is not threatened. Little is known about the biology and ecology of the remainder of the mountain's highest portions to the southeast.

Research and monitoring needs

- Categorize and map the entire mountain range's vegetation to assist in conservation planning and potential landowner engagement.
- Inventory biotic and hydrologic features.
- Conduct hydrogeologic investigations to determine groundwater dynamics and relationships with surface water availability.
- Inventory terrestrial invertebrates and vertebrates.
- Conduct ecological studies on the populations and needs of some rare species.

Recommendations

- Further expand conservation lands with willing landowners, either through cooperative partnerships or other tools like natural resource agency programs.
- Monitor the impacts of mining operations on groundwater quality and quantity, rare resources, and ecological integrity.
- Promote aquifer storage of water supplies that need to be managed as a result of mineral extraction (mining).

Priority Conservation Area

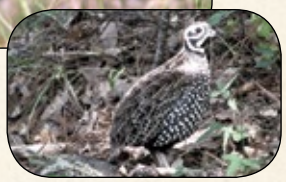
21 Glass Mountains

Authors: John Karges and Helen M. Poulos

The Glass Mountains are part of an ancient Permian reef consisting of limestone with a notable igneous intrusion, Iron Mountain, adjacent to the range. The elongated range trends southwest to northeast from northeastern Brewster County up into southwestern Pecos County, with an elevation generally below 1,980 meters (6,500 feet). The vegetation is primarily arid oak-juniper-piñon pine woodlands at the higher elevations, some mesic wooded canyons, and expanses of arid shrubland/grassland on slopes. Many endemic plant species occur on the limestone and the conservation community recognizes the Glass Mountains primarily for these endemic or rare known plant species, and maybe to some extent for its game animals. There is a dearth of literature summarizing or detailing the natural resources of the Glass Mountains.

The primary conservation targets are poorly known or publicized, but include Montezuma quail (*Cyrtonyx montezumae*) and black bear (*Ursus americanus*). The population status of the Montezuma quail is unknown, but it may be found in the woodlands and on grassland slopes. Wandering black bears certainly occur in the mountains at times and some may be residential.

American black bear.
Photo: Hernando Cabral Perdomo



Montezuma quail.
Photo: Bonnie R. McKinney

Threats

The area's principal ecological drivers include fire, herbivory, climate (i.e., seasonality, frequency, abundance, and punctuality of rainfall) and substrates. Substrates are soils derived from limestone in the mountains, relative to soil depth and topography, and barren exposed rock outcrops, cliffs, and bluffs. The pervasive threat is the changing climate and its influence on vegetation structure. The authors are unaware of the existence of any comprehensive assessments of range conditions or indicators of ecological health or intactness throughout the mountain range. Other known threats include exotic ungulates, such as introduced elk (*Cervus canadensis*) and Barbary sheep (*Ammotragus*

lervia), possibly groundwater extraction, and housing development. Oil and gas developments on the northern slopes may be of some relevance, but they are likely to have a greater impact on groundwater resources. Not enough information is known about the Glass Mountains to assess its integrity status. The risk status is 'medium' due to threats from groundwater extraction and nearby oil and gas exploration.

Partnerships and socioeconomic factors

The mountains are entirely privately owned; in many instances there are large tracts or undivided expanses of privately owned heritage ranches, which contribute to conservation value. Livestock producing enterprises in the range may enjoy governmental program assistance to sustain or enhance forage production, and the TPWD or academic wildlife management advisors may assist in improving rangeland conditions and wildlife resources. Whether or how a ranch employs such counsel is ranch-specific. There is no identified landscape-scale partnership or collaborative conservation effort in this area. Opportunities for conservation are at the discretion of landowners and managers to meet their individual operational objectives of livestock production or maintaining wildlife populations for recreational hunting revenue, or both.

Research and monitoring needs

- Conduct a biological inventory and habitat classification in the mountains, although whether such activity would be welcomed, allowed, or facilitated depends on the individual landowner.
- Study the role of fire and its ecological effects throughout the mountains, to assess its utility and the ecological and economic risks.

Recommendations

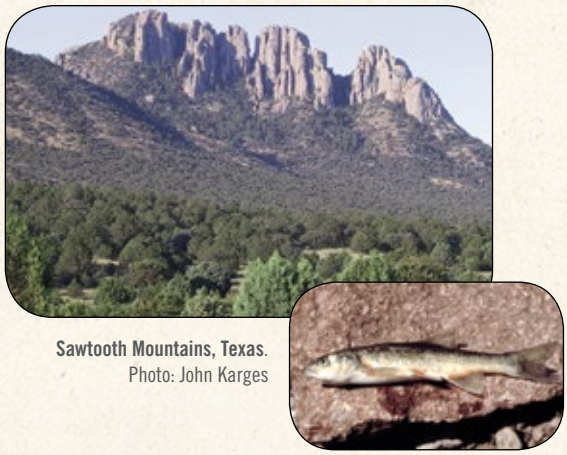
- Reach out to landowners for conservation opportunities.

Priority Conservation Area

22 Davis Mountains

Authors: John Karges and Helen M. Poulos

The Davis Mountains is the largest mountain range in Texas, rising from 1,524 to 2,560 meters (5,000–8,400 feet). Its vegetation cover is primarily comprised of piñon pine, juniper, mixed conifer species at higher elevations, and oak throughout. Dominant species include *Juniperus deppeana, Quercus grisea, Q. gravesii, Q. emoryi, Q. hypoleucoides, Pinus cembroides, P. strobiformis* and *P. ponderosa.* Chihuahuan desert grasslands bound the site at lower elevations, and relict montane conifer forests occur higher and in steep, relatively mesic canyons. With its well-represented woodlands, forests, and riparian gallery corridors, the Davis Mountains provide nesting habitat for neotropical migratory birds and support a diverse bat fauna (16 species), a diverse guild of hummingbirds (~15 species), raptors, and terrestrial animals of conservation importance, including endemic land snails and gophers, and rare snakes and other reptiles.



Sawtooth Mountains, Texas. Photo: John Karges

Rio Grande chub. Photo: David Propst

The Davis Mountains Springs Complex refers to springs, seeps, and *ciénagas* (marshy areas fed by seepage or springs) within the broader Davis Mountains physiography. There is an array of these important surface aquatic sites, including Limpia, Bridge, Tobe, Goat, and Barrel springs, among others, and Calamity Creek, Muzquiz Ciénaga, Big and Little Aguja Canyons, Cherry Canyon, Madera Canyon, and Limpia Canyon. Many springs within the mountainous areas may harbor rare

Gray hawk. Photo: Brian Snelson

or unique invertebrates, fish species, and endemic aquatic plants. Stream courses contain perennial reaches or pools that sustain aquatic obligates and are important to rare species. At least one stream has pools with a rare fish, the Rio Grande chub (*Gila pandora*), and streams here historically included Rio Grande cutthroat trout (*Oncorhynchus clarkii virginalis*), now extirpated.

Conservation targets in the Davis Mountains include black bear (*Ursus americanus*), Rio Grande chub (*Gila pandora*), Davis Mountains cottontail (*Sylvilagus robustus*), Mexican spotted owl (*Strix occidentalis*), high hummingbird and bat diversity, neotropical migratory birds, montane evergreen forest (including the north-facing slopes and the uppermost watershed drainages), and riparian woodlands/perennial stream courses. The latter are particularly important, as these woodlands indicate the availability and abundance of surface and shallow subsurface water.

Threats

Fire and livestock grazing are two major drivers of forest-stand structure and species composition. Historically, low intensity fires occurred frequently prior to the introduction of sheep and goats in the early 20th century. The mean fire-return interval was 11.2 years for the entire Davis Mountains Range and the point fire-return interval (interval between evidence of fire at the base of any one location on the landscape) was 75 years (Poulos et al. 2009). In the past, tree regeneration occurred during favorable climatic conditions following fire years; since 1926, fire suppression has stimulated widespread tree regeneration (Poulos et al. 2007). Three wildfires burned the majority of the uplands in 2011 and 2012, creating uncertainty about future trends in forest structure and tree-species' composition.

The primary hydro-ecological driver for the springs and their discharge flows is the reliability and viability of the local Igneous Aquifer Complex in maintaining surface waters. The aquifer consists of volcanic rocks and includes more than 40 different named units as much as 1,800 meters (6,000 feet) thick. The aquifer's hydrogeology is very complex due to the variable nature of the numerous individual water-bearing units. Recharge is from infiltrating precipitation, while discharge is to wells and more than 150 springs in the tri-county area (Brune 1981). The aquifer's water quality is very good, with low total dissolved solids (TDS), indicating a fairly rapid recharge and flow through. Aquifer characteristics, such as recharge rates and mechanics, flow path, and connectivity between flow paths, are poorly understood.

The major threats to the Davis Mountains include brush encroachment, feral pigs (*Sus scrofa*), fire (Poulos 2009; Poulos et al. 2009; Poulos et al. 2013) and large ranch subdivision, fragmentation, and development. Proximal threats to springs and spring-fed perennial pools include the impacts of exotic animals, notably feral pigs, which are abundant. They destroy or foul the waters, which negatively impacts habitat integrity and water quality. Other future potential threats to the Davis Mountains Spring Complex are likely to include increased groundwater extraction to meet the needs of an increasing population and a growing hydrocarbon industry. The level of both risk and integrity of the Davis Mountains is deemed to be 'medium' while in the Springs Complex, risk is 'low' and integrity is 'medium' to 'high.'

Partnerships and socioeconomic factors

This area has a number of private lands with a strong tradition of stewardship; there is a growing interest in working on conservation in partnership with local agencies and NGOs. The Davis Mountains State Park and Fort Davis National Historic Site are public lands dedicated to conservation. TNC has been working in the Davis Mountains since 1992 and has a 13,400 hectare (33,000 acre) preserve and another 28,300 hectares

(~70,000 acres) under contiguous conservation easements. The remainder of the Davis Mountains includes residential subdivisions, the University of Texas McDonald Observatory, and large ranches (with other private lands under conservation easement with other non-profit organizations in addition to TNC).

Agricultural ventures that rely on landscape productivity are invaluable conservation allies and can benefit from state and agency wildlife and land management guidance federally administered landowner incentive programs. If managed with the land's natural cycles and carrying capacity, grazing can be an important tool for maintaining healthy vegetative communities. Traditional land uses and beneficial management practices can also protect against landscape degradation and fragmentation.

Several state and federal cost-share programs are aimed at mitigating brush encroachment. Managers are working to control feral pigs through trapping and shooting. Researchers and managers are currently working to understand how recent fires in the Davis Mountains have affected the forests and to evaluate how prior fuel load mitigation projects (thinning and prescribed burning) influenced wildfire behavior (Poulos and Gatewood 2013). A number of approaches are also being employed to conserve springs and associated aquatic resources, including preserves, easements, exotic species control and management, and prescribed fire to increase infiltration by managing forest densities and grassland ground cover.

Research and monitoring needs

- Increase the understanding of how fire regulates the Davis Mountains' forests, the effects of wildfire on forest-stand structure, and how management activities influence fire behavior.
- Evaluate the risks of tree mortality due to climate change. Preliminary research suggests that contemporary tree distribution patterns are closely tied to tree-water relations (Poulos and Berlyn 2007; Schwilk unpublished data).
- Monitor the effect of future changes in climate on tree distribution and species composition to identify species at the greatest risk of extirpation due to future warmer temperatures.
- Increase the understanding of the role forests play in providing critical habitat for high-profile species including the spotted owl (*Strix occidentalis*), Davis Mountains cottontail (*Sylvilagus robustus*), and black bear (*Ursus americanus*).
- Identify critical recharge areas, flow paths, and other aquifer characteristics.
- Support groundwater characterization of spring discharges and well-level monitoring across a large network to improve the understanding of the hydrologic system.
- Monitor for signs of system decline, imperilment, and failure beyond the normal known and expected range of variation within the system.
- Monitor and assess the status of the rare fishes and stream hydrologic health where accessible on conservation lands and with willing private landowners.
- Map rare snail distribution throughout the mountain range, and snails and other invertebrates at springs.

Recommendations

- Assist private landowners with prescribed fire application to increase rangeland health and with sustainable production on livestock producing lands, which under good conservation management and stewardship also helps enhance wildlife and habitat.
- Establish working partnerships with local private owners to assist in characterizing local flora and fauna and identify joint conservation opportunities.
- Reach out to regional collaborative initiatives to access information-sharing and technical support.
- Investigate the role of fire in shaping forest-stand structure and species' composition.
- Explore the effectiveness of fuels-management activities in mitigating the risk of future high-intensity wildfires.
- Investigate the potential effects of climate change on forest structure and species' distribution patterns.
- Continue to expand permanent land protection as opportunity arises, particularly of crucial highland tracts, to abate threats of subdivision and development.
- Assess priority wildlife conservation species' population status, such as the black bear, Rio Grande chub, spotted owl, and other bird species, and their habitat use and needs, including wide-ranging wildlife species for corridors and connectivity.
- Continue exotic species' management activities and encourage private landowners to participate.

Priority Conservation Area

23

Chisos Mountains

Authors: David Larson, Helen M. Poulos, and Joseph Sirotnak

Chisos Mountains, Texas. Photo: Matthew High

Canyon tree frog. Photo: Brian & Jaclyn Drum

Located entirely within BBNP, the Chisos Mountains are a small rhyolitic mountain range that rises to over 2,300 meters (7,500 feet). The main wildlife conservation targets include black bear (*Ursus americanus*), peregrine falcon (*Falco peregrinus anatum*), Carmen white-tailed deer (*Odocoileus virginianus carminis*), black-capped vireo (*Vireo atricapilla*), Colima warbler (*Oreothlypis crissalis*), canyon tree frog (*Hyla arenicolor*), and Mexican long-nosed bat (*Leptonycteris nivalis*). The primary vegetation conservation targets focus on piñon-juniper-scrub oak woodlands, mixed coniferous/oak forests, and high elevation mixed conifer forests. Low elevations are primarily comprised of Mexican piñon (*Pinus cembroides*), Alligator juniper (*Juniperus deppeana*), Coahuila juniper (*Juniperus coahuilensis*), Emory oak (*Quercus emoryi*), gray oak (*Quercus grisea*), and Mexican juniper (*Juniperus flaccida*). North-facing slopes and mesic shady canyons harbor closed-canopy conifer forest dominated by Arizona pine (*Pinus arizonica*), Arizona cypress (*Cupressus arizonica*), Douglas fir (*Pseudotsuga menziesii*), and small relict stands of quaking aspen (*Populus tremuloides)*. Mixed piñon pine-oak juniper forest, which includes rare and endemic oak species, and the rare Mexican juniper (*Juniperus flaccida*) only known elsewhere in the Sierra del Carmen, dominates the more exposed areas above 1,800 meters (5,900 feet). These forests' shady understory consists of a diverse mix of shrubs, forbs, and grasses, including rare orchids and the only currently documented population of Guadalupe fescue (*Festuca ligulata*) in the United States.

Threats

Although the entire mountain range is protected within BBNP, there are both internal and external threats. The ecological drivers include fire, droughts, extreme frosts, and forest pests and diseases. Mean fire return intervals are 36.5 years across the entire Chisos range and point-fire return intervals are 150 years (Poulos et al. 2009). Historically, trees regenerated during favorable climatic conditions following fire years. Related anthropogenic drivers include altered fire regimes and climate change (Poulos et al. 2013).

This mesic habitat surrounded by more arid lowlands is sensitive to long-term climate change. Acute drought events are likely to occur with greater frequency as global mean temperatures rise in coming decades. This future climate regime combined with unusually high fuel loads make this ecosystem at risk for type-conversion. Thus, it is likely that many of the mesic-adapted forest species would not recover from stand-replacing fire or intense drought, and that these forests would be converted to shrub/chaparral, or at the least be relegated to small mesic microhabitats. The 2011 drought and five-day freezing event stimulated significant tree mortality across the Chisos (Poulos 2013) and the Mexican piñon (*P. cembroides*) was identified as a tree species particularly sensitive to mortality from drought coupled with freeze-thaw cycles. Subsequent drought events are likely to cause even greater damage to trees that survived this record drought in Texas, especially if they are coupled with freeze-thaw events. It is unlikely that forest plant and animal species will naturally re-colonize after such a catastrophic event because the range is isolated from similar habitat.

Infrastructure to serve visitors to the Chisos Basin, including a lodge, restaurant, store, visitor center, and campgrounds, and the high visitor use of the Basin and Chisos Mountains backcountry (over 200,000 visitors annually) increase anthropogenic stressors, such as unintentional fire ignition, the introduction of exotic species, and impacts on native species. Currently, ecological integrity is 'high' but maintaining this status will require managing fire, fuels, and visitor use, mitigating the impact of human activity on native species, and preventing the introduction of exotic species and plant and wildlife diseases. The threats described above make this region at 'medium' risk.

Partnerships and socioeconomic factors

Since the Chisos Mountains are located within a national park, they are protected from many anthropogenic threats, such as grazing, logging, and development that fragments habitat. High levels of tourism and the presence of significant developments already in the Basin can pit visitor needs against those of natural resource conservation. Existing conservation efforts include preventing the invasion of exotic animal species, and containing existing exotic plant infestations to the developed area. Wildlife management activities include efforts to reduce negative human-wildlife encounters with black bears (*Ursus americanus*) by improving sanitation, waste, and food management. Additionally, fire managers are working to understand the effects of prescribed fire and fire surrogates (thinning) on forest-stand structure and fuel loads (Poulos et al., unpublished data). Knowledge of fire effects on vegetation, however, is limited.

Research and monitoring needs

- Study the effect of fire and future climatic change on forest-stand structure and distribution patterns, and on flora and fauna species composition, distribution patterns, and habitat use to assist managers in targeting vulnerable species for conservation.
- Seek to understand how larger-scale fuel treatment activities alter the risk of future high-intensity fire. This is an important management goal since fire and thinning projects in the Chisos have been limited.
- Study and monitor human-use impacts on native ecosystems and species.

Recommendations

- Expand existing research on fire ecology and fuels management.
- Prevent exotic species from invading the higher Chisos.
- Mitigate visitor and park management effects on resources.
- Monitor rare, endemic, and listed species.

Priority Conservation Area

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Dead Horse Mountains

Author: John Karges

Dead Horse Mountains, Texas.
Photo: Raymond Skiles

Desert bighorn sheep.
Photo: Marieke Ijsendoorn-Kuijpers

The Dead Horse Mountains located in Brewster County, Texas, are a distinct linear upland limestone escarpment, geomorphically and ecologically connected to the higher and more massive Sierra del Carmen in adjacent Coahuila, Mexico. The main ecological setting is limestone bedrock and limestone-derived soils, with an arid climate and shrubland/desert scrub and succulent plant communities. There are areas of sparse high-desert grama grassland with yuccas (several species), common sotol (*Dasylirion wheeleri*), and lechuguilla *(Agave lechuguilla)*. Although not high enough to sustain much woodland community structure, the range supports isolated stands of remote piñon (*Pinus remota*) and wooded arroyos with a limited population of black-capped vireos (*Vireo atricapilla*). Surface water is virtually non-existent except during storm events when rain runoff is abrupt and short-lasting, filling bed-rock depressions for relatively short periods of time, with very few notable exceptions.

The primary conservation targets include habitat for desert bighorn sheep (*Ovis canadensis*) introduced to the Black Gap WMA, occasional semi-resident black bears (*Ursus americanus*), and habitat for a suite of range-restricted limestone-dependent plants and several reptile species.

Devils Den in Dead Horse Mountains, Texas. Photo: Mike Marvins

Threats

Ecological drivers in this area include climate change, drought, exotic plants (e.g., Old World grasses), and exotic animal species such as the Barbary sheep (*Ammotragus lervia*). Trespass livestock have also been common near the river. The threats to rare resources are moderately low, but include yucca harvest for the commercial landscape trade, some trespass and feral livestock, exotic plant invasion, and cactus and reptile poaching. The habitats are moderately stablefrom anthropogenic degradation throughout much of the range. There has been little focus on conservation management and land stewardship in the mountains even though much of the range is protected for conservation, a fact based as much on little need as it is on limited resources by the managing entity. As a result, the area's overall integrity status is 'high', with a 'low' risk of habitat deterioration.

Partnerships and socioeconomic factors

Much of the range is in conservation oversight and protection, including the BBNP (NPS) and the Black Gap WMA (TPWD). The Adams Ranch is under a conservation easement with Texas Parks and Wildlife Foundation, and TNC's former Brushy Canyon Preserve is now part of the Black Gap WMA under a TNC-held conservation easement. The remaining lands are private and the primary uses at any scale are yucca harvest for the landscaping trade in native plants and wildlife harvest through sport hunting for mule deer (*Odocoileus hemionus*) and perhaps some white-tailed deer (*Odocoileus virginianus*). In the recent past, the TPWD has used the Black Gap WMA as a black bear (*Ursus americanus*) relocation area. This has included relocating bears from as far away as Del Rio, Texas. A botanical survey of the Dead Horse Mountains has been completed and published. Rare plant inventories and black-capped vireo (*Vireo atricapilla*) surveys have been conducted; however, recent assessments of the current or contemporary status of vireos each breeding season have not been done. The TPWD conducts annual helicopter surveys of the northern half of the range for bighorns (*Ovis canadensis*) and Barbary sheep (*Ammotragus lervia*). Only a limited number of resource surveys have been conducted in the Dead Horse Mountains.

Research and monitoring needs

- Assess the current or contemporary status of the black-capped vireo (*Vireo atricapilla*) each breeding season.
- Map and conduct an inventory of the biology of cave features in the mountain range. Some caves may be extensive enough with multiple apertures to be 'breathing caves' with airflow through their apertures.
- Monitor the extent and spread of exotic species and feral/trespass livestock.

Recommendations

- As willing-seller opportunities arise, add more protected lands in the Dead Horse Mountains to already protected parks, preserves, and wildlife management areas.
- Coordinate management among private landowners, the NPS, the TWPD, and Cemex on agency-sponsored or supported conservation efforts.
- Reduce impacts from trespass livestock and exotic species.

Priority Conservation Area

25

Sierra Rica

Authors: Ángel Frías García and Pablo A. Lavín Murcio

Sierra Rica, Chihuahua. Photo: Ángel Frias García

Cliff chipmunk. Photo: Carla Kishinami

"*La Sierra Rica es como una flor que avienta agua para acá y para allá y para todos lados*" ("The Sierra Rica is like a flower that spills water here and there and everywhere")—Jesús José Villa Perches, President of the Advisory Committee of the APFF Cañón de Santa Elena.

The Sierra Rica is in the extreme northeastern part of the state of Chihuahua. The Manuel Benavides municipality is nestled in the mountains, in the middle of the APFF Cañón de Santa Elena bordered by the state of Coahuila and Conanp's *Monumento Natural Río Bravo del Norte*. This Sierra is a 'sky island' located at the upper reach of the water basin; it hosts important native habitat and a relict forest, and is characterized by steep slopes, shallow soils, open pine and pine-oak woodlands, numerous temporary streams or *arroyos,* and a temperate climate. The forest community plays an important conservation role in the ecosystem by retaining water and soils. These mountains are known locally as a 'water factory' due to the condensation of humidity that results from the mountain's high altitude—the highest in the region. Run-off flows into the Rio Grande, regulating the water cycle, humidity, and air temperature, and helping to stabilize the climate. Also, this area is one of the few remaining refuges for large fauna, a high percentage of which are threatened species. The area harbors wild deer, peccary, and puma and is a biological corridor for migratory birds.

The Sierra Rica helps to conserve the area's genetic and biological diversity. The APFF Cañón de Santa Elena's management program (Conanp 1997) contains objectives to conserve species at risk and it is important to establish mechanisms to support them. The conservation targets for mammals include black bear (*Ursus americanus*), Mexican long-nosed bat (*Leptonycteris nivalis*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), puma (*Puma concolor*), and potentially the cliff chipmunk (*Tamias dorsalis carminis*). Bird targets species include Montezuma quail (*Cyrtonyx montezumae*), golden eagle (*Aquila chrysaetos*), peregrine falcon (*Falco peregrinus*), black-capped vireo (*Vireo atricapilla*), and Colima warbler (*Oreothlypis crissalis*). Other target species include canyon tree frog (*Hyla arenicolor*), Monarch butterfly (*Danaus plexippus*), spiny lizards (*Sceloporus* spp.), and mixed coniferous/oak forests.

Threats

Natural ecological drivers in the Sierra Rica include fire, drought, extreme frost, and forest pests and diseases. The forests have high fuel loads that increase vulnerability to fires of high severity and intensity. In some places, livestock have destroyed the understory and there is a risk of massive erosion from rainwater torrents (*trombas).* In 2008, heavy rains in the Sierra Rica caused flooding in Nuevo Lajitas and Santa Elena—two communities in the Manuel Benavides municipality. Since 2008, there have been low-intensity fires in areas under 100 hectares (250 acres), but according to some estimates, a catastrophic fire could destroy as much as 2,000 hectares (4,950 acres). Capacity building is needed for fire fighters and first responders.

There are also places that are vulnerable to the direct impacts of climate change, which include diminished precipitation. Prolonged drought makes forests susceptible to pests; an outbreak of bark beetles (*Ips* spp. and *Dendroctonus* spp.) affected some 230 hectares (570 acres) of pine, and wood-boring insects have severely attacked juniper trees (*Juniperus* spp.). Grazing also occurs in the forests, making restoration a challenge. Vegetation loss and resulting soil deterioration threatens streams (*arroyos*); currently, only a few springs are still unexploited. There are six springs that feed what are known as *tinajas* (pools), which are essential to many of the conservation targets.

Although human activities have modified some of the vegetation cover and include water harvesting, the forests still provides habitat for wild fauna and migratory birds, so the state of the ecosystem's integrity is categorized as 'medium'. The risk status is 'high' in the mountains because of the small and isolated nature of the sky island and the high potential for wildfires and low recovery rate after severe fire events; on the other hand, the risk status in the Sierra Rica Springs is considered to be 'medium'.

Mountain lion. Photo: Reine Wonite

Partnerships and socioeconomic factors

Extensive livestock and low-yield seasonal agricultural activities take place within the APFF Cañón de Santa Elena, which is composed of federally-owned land, communal *ejidal* land (13 *ejidos*), and private property. Small landowners own most of the land, so there is a potential for schemes to rent land for conservation purposes and payment for environmental services. Three roads enter the mountain region and branch off toward the area's small settlements.

The Santa Elena management plan contains two specific objectives: 1) help conserve the area's genetic and biological diversity, and 2) establish specific mechanisms to conserve flora and fauna species, so they continue to thrive and increase in number. To achieve them, it is necessary to manage wildlife species and protect fragile ecosystems. Community participation is an important element and should be promoted. Conanp and some ranchers have collaborated in building infrastructure to obtain spring water for social and environmental purposes. Moreover, since 1994, Conanp has been conserving ecosystems, working with communities and promoting participation by other stakeholders such as TNC, the World Wildlife Fund (WWF), Protección de la Fauna Mexicana A.C. (Profauna), the Universidad Autónoma de Ciudad Juárez, and the Universidad Autónoma de Chihuahua (Semarnat/Conanp 2012).

Research and monitoring needs

- Develop models, including conceptual ecological models, for managing fuels and natural and prescribed fires.
- Design restoration strategies to reverse the effects of wildfires, and appropriate fire- management approaches for the ecosystem.
- Analyze the effects of wildfires that occurred over the last 20 years.
- Monitor rainfall regimes and conduct ecophysiological studies on plant vulnerability.
- Measure the effects of grazing on forests; carry out cost-benefit analysis, and establish the basis to promote better grazing systems and livestock management.
- Determine the natural dynamics of forested areas and carry out forest-health monitoring.
- Assess current water uses of wells (*norias*) used for livestock.
- Carry out an inventory of fish in water bodies in the mountains.

Recommendations

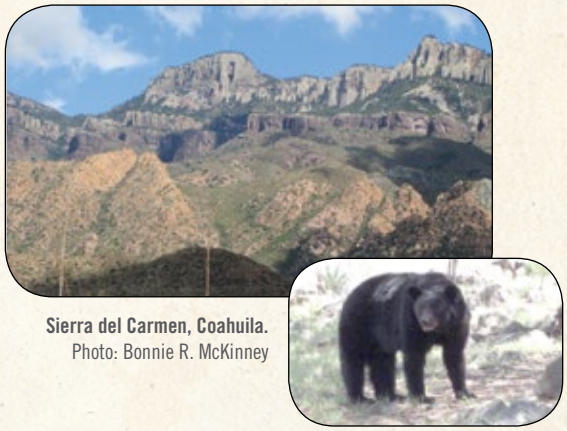
- Develop a vision to maintain water quality through soil conservation.
- Conduct a diagnostic assessment of the Sierra Rica's role in contributing water to the Cañón de Santa Elena Protected Natural Area.
- Promote the organization and involvement of communities in conservation actions within and surrounding the Sierra Rica (INE 1997).
- Establish PES programs to reduce pressure on natural resources.
- Establish schemes for renting land from owners who may become partners in conservation, and develop forest-management programs.
- Develop strategies to conserve water seepage and reduce soil loss.
- Work with ranchers and landowners to restore the forest's role in capturing water, preventing water contamination and retaining soil, and to restore grasslands.
- Improve communication with residents about the impacts and effects of the tamarisk beetle.
- Apply Conanp's *Programa de Conservación para el Desarollo Sostenible* (Procodes) to remove the fuel load and to protect soil.

Priority Conservation Area

26

Sierra del Carmen

Authors: Alejandro Espinosa Treviño and Carlos Alberto Sifuentes Lugo



Sierra del Carmen, Coahuila. Photo: Bonnie R. McKinney

American black bear. Photo: Bonnie R. McKinney

"Si tienes la suficiente paciencia para esperar la puesta de sol sobre la sierra del Carmen, las montañas siempre te sonreirán sonrojándose para darte la bienvenida." ("If you are patient enough to await the sunset on the Sierra del Carmen, the mountains will always blush and smile at you to bid you welcome.")—Don Julio Carrera

Located in the northeastern part of the Mexican state of Coahuila, the Sierra del Carmen is the largest island archipelago in the Rio Grande borderlands. Its high level of ecosystem diversity, characterized by a vertical stacking of biotic communities, is due to its highly variable physiography, long elevation gradient, ranging from 1,500 to 2,700 meters (4,920–8,860 feet), and rugged topography (Poulos and Camp 2010). Vegetation types include Chihuahuan Desert grasslands and scrub oak on the steeper mountain slopes, and piñon-juniper woodland and mixed conifer forests at the highest elevations.

Mexican piñon (*Pinus cembroides*), alligator juniper *(Juniperus deppeana*), Lacey oak (*Quercus laceyi*), and grey oak (*Quercus grisea*) dominate the piñon pine-juniper woodlands. Oak scrub contains a wide array of oak species, including shrub live oak (*Quercus turbinella*), scrub oak (*Quercus pungens*), and many other less common oak associates. Upper elevation mixed conifer forest is dominated by Arizona pine (*Pinus arizonica),* by Southwestern white pine (*Pinus strobiformis*) in drier high elevation sites, and by Arizona cypress *(Cupressus arizonica),* Douglas fir (*Pseudotsuga menziesii*), and Durango fir (*Abies durangensis coahuilensis)* in mesic high elevations (Poulos and Camp 2010). The Sierra del Carmen also supports endemic vegetation, primarily vascular plants, and is considered a high-priority site for conserving plants, birds, and mammals, and especially for the outstanding large vertebrate assemblages and functional predator-prey interactions that occur in the area (WWF et al. 2000).

Forest fires ignited during thunderstorms are an integral part of the ecosystem's natural dynamics. Periodic ground fires of low intensity and severity reduce of the amount of litter and other fuels and promote natural vegetation regeneration. The historical mean fire return interval prior to the 1950s was 7.7 years for the entire Carmen Range. The point-fire return interval (the number of years between a fire passing at the base of any one tree) was 24.7 years (Poulos et al. 2013). Land redistribution among *ejidos* in the 1940s, livestock introduction, and logging operations changed the abundance and continuity of fuels, leading to a decline in fire frequency in the Sierra del Carmen after the 1950s.

Jaboncillos Springs are located in Jaboncillos Grandes, Coahuila, inside the APFF Ocampo. The springs are an oasis of small and abundant streams and subsurface flow originating from the Sierra del Carmen, in an otherwise arid region. Its name comes from a riparian tree (*Sapindus saponaria*) once commonly found in wetlands, which has been harvested for many years to prepare soap given its high content in saponins. Jaboncillos Springs provide the community with high-quality water via domestic wells, and supports riparian vegetation and possibly some local fauna. The outflows from these springs do not reach any tributary of the Rio Grande.

The main conservation targets in the Sierra del Carmen include black bear (*Ursus americanus*), golden eagle (*Aquila chrysaetos*), peregrine falcon (*Falco peregrinus*), desert bighorn sheep (*Ovis canadensis*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odoicoleus virginianus carminis*), wild turkey (*Meleagris gallopavo intermedia*), Monarch butterfly (*Danaus plexippus*), black-capped vireo (*Vireo atricapilla*), Colima warbler (*Oreothlypis crissalis*), Coahuila mole (*Scalopus aquaticus montanus*), Miller's shrew/Carmen Mountain shrew (*Sorex milleri*), and cliff chipmunk (*Tamias dorsalis carminis*). The primary vegetation conservation targets are piñon pine-juniper (*Pinus-Juniperus* spp.), oak (*Quercus* spp.) woodlands, pine (*Pinus* spp.) forests, and Durango fir (*Abies durangensis coahuilensis)* forests.

Sierra del Carmen, Coahuila. Photo: Matthew Humke

Threats

Natural ecological drivers include fires, drought, extreme frost, and biotic pathogens. Anthropogenic drivers include alteration of the fire regime since the 1950s (Poulos et al. 2013), deforestation since the 1980s, and climate change.

Threats include fires of high severity/intensity due to high fuel loads (Poulos 2009), the potential for mining exploitation, and massive infestations of forest diseases and pests by bark beetles (*Dendroctonus* spp.), although spatial variation in the forest's vulnerability to pathogens is unknown. Because of their restricted distributions, the area's forests are generally vulnerable to the direct impacts of climate change, such as diminished precipitation and high temperatures. There is limited information, however, on the response of individual species to future climatic change. Invasive grass and shrubs partly associated with poor grazing practices threaten grasslands in the foothills. The large amount of felled timber (up to 120 ton/ha) left on the ground by forest extraction activities represents a potentially high fire risk, giving the area a 'high' risk rating; the level of integrity is 'medium', due to forest extraction activities since 1983.

Partnerships and socioeconomic factors

Land is owned by private livestock ranches and *ejidos*. *Ejidos* include Boquillas del Carmen, Norias, Jaboncillos, Los Lirios, San Francisco, José María Morelos, and Venustiano Carranza. This mountain range provides important socioeconomic benefits to these communities and serves as a water source for the entire area. The main watershed flows into Río Sabinas, Zaragoza de Acuña, and the Rio Grande. Conanp and Cemex have permanent personnel working on conservation in the area. Activities include firefighting and ongoing monitoring of forest health and that of high-priority species such as golden eagle (*Aquila chrysaetos*), black bear (*Ursus americanus*), peregrine falcon (*Falco peregrinus*), and bighorn sheep (*Ovis canadensis*).

Cemex and private owners, including the Maderas del Carmen Museum and Rancho Guadalupe, have collaborative agreements related to wildlife conservation and forest-fire fighting. Conanp, Cemex, the fire crews of the *Secretaría de Medio Ambiente del Estado de Coahuila* (Sema), Conafor, and the *Secretaría de la Defensa Nacional* (Sedena) all collaborate in fire operations. Conservation and management priorities include prescribed fires, fuel management, assessing fire effects, payment for environmental services, and management plans.

Research and monitoring needs

- Assess the impact and geographical area of forest extraction activities.
- Assess natural and prescribed fires as restoration tools, and develop fuel models and fuel management plans.
- Study the dynamics of forest pests in ecosystems.
- Monitor changes in species distribution due to climate change.
- Inventory natural springs.

Recommendations

- Identify existing and potential partners.
- Identify existing conservation efforts and management schemes.
- Include Cañón del Diablo and Mesa Los Fresnos as important sites for conservation.
- Promote soil conservation and restoration, especially at the headwaters of creeks and rivers.
- Evaluate legal, technical, and operative capacities to administer and regulate natural and prescribed fires as part of a forest fire management policy.

Río Sabinas Headwaters

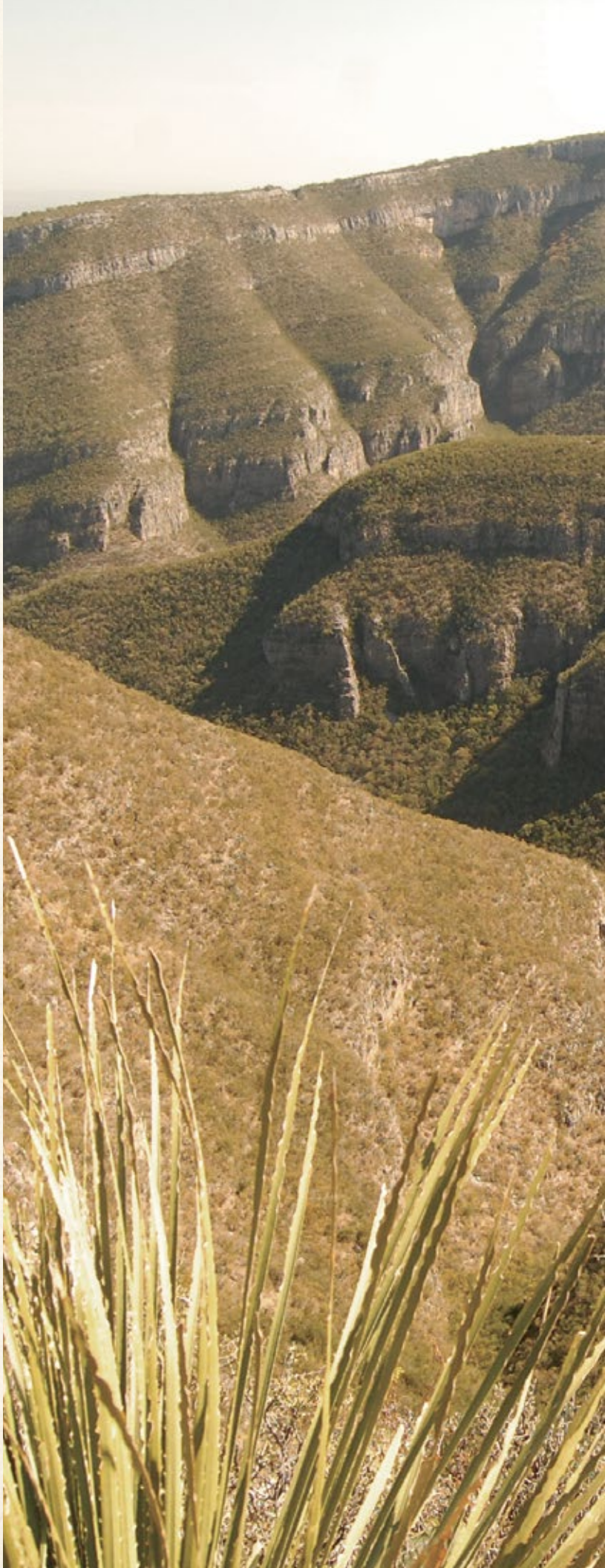
Author: José Antonio Dávila Paulin and Felix Lumbreras

The Río Sabinas is iconic of the State of Coahuila, given its importance for economic and ecological reasons. It is one of the few rivers in Coahuila with significant flow and length. A significant part of the upper watershed of the Río Sabinas is protected under the designation of Don Martín Irrigation District 004 (see page 15). The headwaters of the Río Sabinas include three PCAs as designated in this Assessment: the Serranías del Burro, and the Sierras de Santa Rosa and la Encantada.

The headwaters include four Conabio terrestrial and hydrological priority regions: 1) Priority Hydrological Region *Sierra de Santa Rosa* (RHP-47); 2) Priority Terrestrial Region *Sierras la Encantada-Santa Rosa* (RTP-71); 3) Priority Terrestrial Region *Sierra del Burro-Río San Rodrigo* (RTP-73); and 4) Priority Terrestrial Region *Cuenca del Río Sabinas* (RTP-152). Additionally, BirdLife International has designated two Important Bird Areas (IBA) within this same region: 1) *Sierra del Burro* (AICA no. 5); and 2) *Nacimiento Río Sabinas/ SE Sierra de Santa Rosa* (AICA no. 6). In 2008, the Río Sabinas sub-basin was designated as a Ramsar site.

The headwaters are threatened by several human activities, including coal mining, increased urbanization and landuse change, illegal solid waste disposal in the vicinity of population centers, untreated water discharges, unregulated storage of stone piles within the river corridor, over harvesting of firewood, mainly mesquite, for commercial and biofuel uses, and unsustainable rangeland and wildlife management, including poaching and illegal fishing.

The Río Sabinas flows through private and *ejido* lands. Conservation activities would benefit from determining land use to facilitate outreach and management of projects directly with landowners. Conagua manages the river corridor inside the protected area, and provides water concessions to water users along the river to support agricultural and livestock activities.



Sierra de Santa Rosa, Coahuila
Photo: Rodolfo López

Priority Conservation Area

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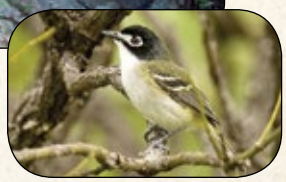
Mountains of the Serranías del Burro

Author: Hernando Cabral Perdomo

Serranías del Burro, Coahuila. Photo: Hernando Cabral Perdomo



Black capped vireo. Photo: Francesco Veronesi

The Serranías del Burro are a long, low mountains formation that extends about 125 km (78 miles) from the Rio Grande in the north to the Sierra del Carmen in the south, and are located inside Conanp's Protected Area Irrigation District 004 Don Martín. Supercell thunderstorms are characteristic of this area, bringing rain northward across the Rio Grande into Texas. The unusually complex topography, with canyons punctuating the low relief and greater intermontane valleys connecting it to neighboring mountains, is characterized by high species richness and interesting phytogeography, where species of the eastern deciduous forests, northern grasslands, and western pine forests converge. Montane pine-oak forests with Arizona pine (*Pinus arizonica*) and oak associates (Muller 1947) dominate the higher elevation forests and montane oak-piñon-juniper forest dominates lower ones.

The mountains of the Serranías del Burro provide particularly important habitats for black bear (*Ursus americanus*). They possibly harbor northern Mexico's highest black bear population density, which may have been fueling the recent recolonization of the Sierra del Carmen and the Chisos Mountains (Onorato and Hellgren 2001) and vagrant bears into Texas eastward to Laredo. Conservation targets in the mountains habitats of the Serranías del Burro include Montezuma quail (*Cyrtonyx montezumae*), black bear (*Ursus americanus*), black-capped vireo (*Vireo atricapilla*), and burrowing owl (*Athene cunicularia*).

Burrowing owl. Photo: Geoff Holroyd

Threats

The main ecological and anthropogenic drivers include altered forest-fire regimes, hurricanes, droughts, low temperatures, forest diseases, grazing practices, and climate change. The main threats to the Serranías del Burro mountains include decimation of isolated populations of black bear (*Ursus americanus*), human occupation and ranching, change in population distribution due to climate change, and recent alterations to forest-stand structure due to wildfire. In 2010, a high-intensity crown wildfire burned over the majority of the Serranías del Burro, destroying much of the aboveground vegetation. Also, large forest fires in 2011 burned thousands of hectares of pine and oak forests. The risk status is 'high' due to the potential for fires and habitat conversion. The integrity status is 'medium' due to human factors and recent fires.

Partnerships and socioeconomic factors

The entire mountain range is privately owned, consisting mainly of private ranchland, which was recently listed as a federal protected area. Banamex and Ecobanca are helping a private effort to promote conservation and sustainable agriculture in the area. The agencies involved hope this new land trust could be a model for private conservation in Mexico, although local communities have shown limited interest in past government-led conservation efforts. Doan- Crider *et al.* are currently producing burn-severity maps for the 2010 fire to relate burn severity to post-fire vegetation response. The Serranías del Burro is designated as Priority Terrestrial Region *Sierra del Burro-Río San Rodrigo* (RTP-73) and Priority Terrestrial Region *Cuenca del Río Sabinas* (RTP-152) by Conabio, and as IBA *Sierra del Burro* (AICA no. 5) by BirdLife International.

Research and monitoring needs

- Monitor the impact of fire severity on vegetation (in progress by D.L. Doan-Crider), forest-stand structure, and species composition related to wildlife habitat.
- Study wildfire impact on bear habitat availability and migration to other mountains in this ecoregion.
- Monitor bear population trends and meta-population dynamics against the area's carrying capacity, and establish population management strategies.
- Study supercell formation.
- Study exotic species distribution and impacts.

Recommendations

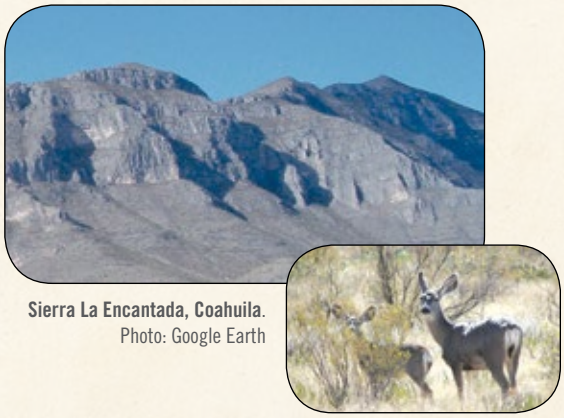
- Increase collaboration with private landowners in conservation activities.
- Raise awareness on the environmental, cultural, historical, and economic importance of the Río Sabinas for the community.

Priority Conservation Area

28

Sierra La Encantada

Authors: Juan Antonio Encina Domínguez and Andrés Nájera Díaz



Sierra La Encantada, Coahuila. Photo: Google Earth

Mule deer. Photo: Bonnie R. McKinney

The Sierra La Encantada is located in northern Coahuila, in Conanp's Protected Area Irrigation District 004 Don Martín. This mountain range, including the Santa Rosa, covers nearly 7,000 square kilometers (1,729,000 acres). The Sierra La Encantada and the Sierra de Santa Rosa form part of the Santa Rosa-Maderas del Carmen-Chisos Mountains biological corridor. Ecosystem diversity in the Sierra La Encantada ranges from submontane scrub in the foothills to oak and pine-oak forests at the highest elevations. The regional fauna is highly diverse, with large carnivorous and hoofed animals.

The conservation targets include black bear (*Ursus americanus*), golden eagle (*Aquila chrysaetos*), peregrine falcon (*Falco peregrinus*), great-horned owl (*Bubo virginianus*), and mule deer (*Odocoileus hemionus*).

Sierra La Encantada, Coahuila. Photo: Google Earth

Threats

Ecological drivers include fire, hurricanes, drought, extreme frost, and forest pests and diseases. Anthropogenic drivers include livestock activities, land-use change, and habitat fragmentation (building cabins and infrastructure for livestock, including fences, *aguajes*, and corrals, for example). Other human influences include the alteration of fire regimes, introduction of invasive species, domestic uses, and climate change. The risk status for potential fires is 'high' and the area's integrity status is 'medium' due to livestock and mining activities. The Conabio's earlier assessment (Arriaga et al. 2000) classified its integrity as 'high' because the vegetation is in good condition.

There is the potential threat of highly severe and intense fires in Sierra La Encantada due to high fuel loads, deforestation, the potential for massive erosion, and mining. The impacts of the catastrophic high severity/high intensity fires of 2011, which spanned over 500,000 hectares (1,235,500 acres), can be observed on vegetation throughout the range. This area is also susceptible to massive bark beetle (*Dendroctonus* spp.) pest and disease infestations, and to the impacts of climate change, such as diminished precipitation and increased temperature. According to Arriaga et al. (2000), other key threats include predator poaching and hunting, particularly of black bears (*Ursus americanus*).

Partnerships and socioeconomic factors

Land is generally owned communally as *ejidal* land, with some privately owned rangeland. Activities include livestock ranching (e.g., cattle, horses, and goats) and extensive unmanaged summer-pasture grazing. Conservation and restoration tools include prescribed forest fires, clearings, assessing the impact of fires on forest species distribution, ongoing forest-stand structure monitoring, payments for environmental services, and the implementation of Conanp's management plans. The Sierra La Encantada is designated as the Priority Terrestrial Region *Sierras la Encantada-Santa Rosa* (RTP-71) by Conabio.

Research and monitoring needs

- Assess fire effects on vegetation structure and grazing.
- Study the impact of natural and anthropogenic disturbances on forest communities' composition and structure.
- Update vegetation, land use, and ownership maps.
- Carry out dendrochronological studies to investigate conceptual ecological and fuel models, determine fuel loads, and apply fuel management methods.
- Support phytosanitary studies on the effects of pests and diseases.
- Monitor and assess the abundance and status of plant and animal species, including endemic, exotic or invasive, and wild species, particularly those most vulnerable or endangered, such as felines and cactus.
- Monitor arthropod and mollusc distribution in the creeks of the upper watershed.
- Monitor riparian vegetation.
- Study the impacts of exotic vegetation, and develop control methods.
- Study the relationship between flow, sediment dynamic, and water infrastructure in the headwaters of the Río Sabinas.
- Study the impacts of economic development, urbanization, and recreation on biodiversity and water quality.

Recommendations

- Identify existing and potential conservation partners.
- Identify existing conservation efforts and management schemes.
- Develop strategies for ecological restoration in areas impacted by forest fires.
- Establish a program of prescribed fires to manage forest fuel loads.
- Coordinate residents to form quick-response volunteer forest-fire brigades to prevent high intensity fires.
- Promote the reintroduction of native fish species in the upper watershed of the Río Sabinas.
- Determine land use in the Protected Area Irrigation District 004 Don Martín.
- Raise awareness on the environmental, cultural, historical, and economic importance of the Río Sabinas for the community.

Priority Conservation Area

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Sierra de Santa Rosa

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Sierra de Santa Rosa, Coahuila. Photo: Rodolfo Lopez

White-tailed deer. Photo: Becky Gregory

The Sierra de Santa Rosa is located in the center of the Mexican state of Coahuila in the Múzquiz municipality, in Conanp's Protected Area Irrigation District 004 Don Martín. The Río San Juan originates in the Sierra de Santa Rosa and is the main tributary of the Río Sabinas, which arises from natural springs in the mountains. Dominant plant communities are the rosette scrub on the southern side, which include lechuguilla (*Agave lechuguilla*), sotol (*Dasylirion cedrosanum*), and candelilla (*Euphorbia antisyphilitica*). The northern side hosts Tamaulipan and submontane scrub, with species such as blackbrush acacia (*Acacia rigidula*), ape's earring (*Pithecellobium pallens*), and Texas persimmon (*Diospyros texanus*). The most humid canyons support oak forests dominated by Lacey oak (*Quercus laceyi*), Chisos red oak, (*Quercus gravesii*), and isolated cases of Texas live oak (*Quercus fusiformis*) interspersed with coniferous species such as Arizona pine (*Pinus arizonica*) and cypress (*Cupressus* spp.). American sycamore (*Platanus occidentalis*) trees grow near watercourses.

The main conservation targets are various wildlife species, such as black bear (*Ursus americanus*), white-tailed deer (*Odocoileus virginianus*), golden eagle (*Aquila chrysaetos*), peregrine falcon (*Falco peregrinus*), and great-horned owl (*Bubo virginianus*). Important endemic plants include *Scutellaria muzquiziana, Ageratina riskindii* and *Ratibida coahuilensis*. Conservation goals specific to the headwaters include maintaining water quality, reducing the distribution and extent of non-native species, maintaining native aquatic habitat and fauna, and instilling a conservation ethic.

Threats

Ecological drivers include natural forest fires within altered fire regimes, drought, extreme frost, hurricanes, and forest pests and diseases. Anthropogenic drivers include altered fire regimes; livestock ranching; mining; climate change; and land-use change and infrastructure development, including fences and cattle corrals, which contribute to habitat fragmentation.

Forest fires represent a latent threat in the Sierra de Santa Rosa due to large fuel loads that may result in high intensity fires and associated impacts on vegetation. Other threats include the impacts of deforestation and hurricanes, including massive erosion; groundwater extraction; invasive fish and plant species; gas extraction; and mining activities, such as coal, ore, and fluorite extraction. Some areas are vulnerable to massive infestations of forest pests and diseases, including bark beetle (*Dendroctonus* spp.) and leafy mistletoe (*Phoradendron* spp.), and to direct impacts from climate change, including diminished precipitation and increased temperatures. In light of these changes and threats, the risk status in the Sierra de Santa Rosa is 'high' and the integrity status is 'medium'.

Partnerships and socioeconomic factors

Land ownership is generally communal *ejidal* land, with some privately owned rangeland. The area's current conservation and restoration tools include prescribed forest fires, clearings, impact assessment of fires on forest species distribution, ongoing forest-stand structure monitoring, Conafor's payments for environmental services, management plan implementation, as well as water capture projects carried out by Conanp in 2011. There remains a significant dearth of information regarding the effects of forest fires and grazing on vegetation structure in the Sierra de Santa Rosa. The Sierra de Santa Rosa is designated Priority Hydrological Region *Sierra de Santa Rosa* (RHP-47) and Priority Terrestrial Region *Sierras la Encantada-Santa Rosa* (RTP-71) by Conabio, and as IBA *Nacimiento Río Sabinas/SE Sierra de Santa Rosa* (AICA no. 6) by BirdLife International.

Town of Boquillas, Coahuila
Photo: Catherine Hallmich

Research and monitoring needs

- Identify areas where forest and species distribution are vulnerable to climate change.
- Conduct research on the impact of natural and anthropogenic disturbances on forest community composition and structure.
- Research the effects of pests and diseases on trees.
- Study the effects of fires and grazing on tree plantlets and shoots.
- Update vegetation, land use, and ownership cartography.
- Conduct studies on wild animal species abundance, particularly on the most vulnerable species.
- Monitor arthropod and mollusc distribution in the creeks of the upper watershed.
- Monitor rare and endemic plant and animal species.
- Monitor riparian vegetation.
- Study invasive exotic species, the impacts of exotic vegetation, and develop control methods.
- Monitor the climate.
- Assess surface and groundwater quality.
- Study the relationship between flow, sediment dynamic, and water infrastructure in the headwaters of the Río Sabinas.
- Update livestock inventory
- Monitor fuel load and fire return intervals
- Study the ecological effect of fire on the forest ecosystems of Sierra de Santa Rosa.
- Study the impacts of economic development, urbanization, and recreation on biodiversity and water quality.

Recommendations

- Identify potential partners.
- Promote social participation in conservation and management programs.
- Conduct fire and fuel load management using fuel management models.
- Develop ecological restoration strategies in areas affected by forest fires.
- Conduct studies to establish conceptual ecological models, apply fuel management methods, and conduct training in the Incident Command System (*Sistema de Mando de Incidentes*—SMI).
- Promote sustainable rangeland management with ranchers in order to ensure that the carrying capacity of the grasslands is not exceeded.
- Determine land use in the Protected Area Irrigation District 004 Don Martín.
- Raise awareness on the environmental, cultural, historical, and economic importance of the Río Sabinas for the community.

General Recommendations

1. As part of the continuing effort to strengthen and expand the binational, public-private network of conservation partners in the region, this Conservation Assessment should be used as a foundation to develop strategies for implementing conservation priorities, including creating Adaptive Management frameworks for priority ecosystems, such as grasslands and the Rio Grande, that consider priority or representative conservation targets. Because resources are limited and not all of the recommendations in this Assessment can be addressed immediately, strategies should be developed to answer and address the following questions:
   a) What are the most urgent and strategic management actions that are needed in the region?
   b) Where there is uncertainty in how to accomplish conservation goals and objectives, what are the essential things to monitor to evaluate the effects of management actions on conservation targets and to detect, predict, and respond to the effects of climate change and other ecosystem drivers?

2. Use decision-support tools such as vulnerability assessments and scenario planning using climate change projections to develop possible climate and ecological future scenarios that can guide managers and landowners in planning for uncertainty and choosing conservation actions most likely to be beneficial. Consider strategies in all management plans, as well as restoration and conservation actions throughout the region that promote adaptation and build resilience to climatic changes favoring increased drought, extreme weather events, changes in wildfire and hydrologic regimes, and the spread of exotic species and diseases.

3. Define conservation goals and objectives for each conservation target, starting with those that are of the highest priority. For species federally listed as threatened or endangered in the US, conservation goals and objectives can be found in recovery plans.

4. Evaluate the status of the Transboundary Aquifer Assessment Program established in 2004 by the US Congress to assess transboundary aquifers and provide the scientific foundation necessary to address water resource challenges along the United States-Mexico border and advocate its continuation and support in the region.

5. Create an institutional mechanism or framework to facilitate binational conservation and restoration projects that ensure the continuity of shared conservation objectives, including state and federal agencies that manage natural resources, as well as local stakeholders and, in particular, ranchers and farmers from both sides of the border. This framework should facilitate activities and efforts intended to address invasive species, sustainable livestock practices, restoration of degraded rangeland and habitats, ecotourism, and alternative land uses, among others.

6. Assist the Big Bend Conservation Cooperative, which represents a number of state and federal agencies in the region, to be an effective mechanism to promote and support landowner-driven conservation efforts and local initiatives, particularly with regard to grasslands and range management. Efforts should be made to use this mechanism to provide assistance and outreach to local ranchers through various government programs with the aim of supporting stewardship of natural resources and enhancing their ability to manage and conduct productive activities. Opportunities to share lessons learned across the border could also be explored through this group.

7. In both the US and Mexico, continue to promote and implement government programs that provide assistance, cost-share, incentives, and property rights protection to private landowners related to the conservation of natural resources. For example, in the US, such programs include the USFWS' Partners for Fish and Wildlife and Safe Harbors programs, various programs administered by NRCS, and TPWD's Landowner Incentive Program and Watershed Management program.

8. Improve environmental health and promote sustainable economic development of border communities by continuing to support the development of conservation-related jobs (e.g., invasive vegetation management, wildland fire management, etc.) and ecotourism and providing assistance in developing programs for refuse and waste management.

9. Build capacity within academia, state and federal agencies as well as civil society to conduct the inventory and monitoring recommendations from each PCA in a coordinated manner across the region. Advocate for a concerted binational academic program addressing larger ecosystem questions throughout the watershed of the Rio Grande that is implemented through local universities, and established and funded by the National Science Foundation (NSF) and the Consejo Nacional de Ciencia y Tecnología (Conacyt). The University of California Institute for Mexico and the United States (UC MEXUS) is one model of academic partnership that can be useful in creating cross-border academic partnerships to address the need for addressing the scientific and monitoring needs outlined in this document.

10. Access remote sensing data, such as land use and vegetation cover, for the region. Local efforts and initiatives should take advantage of broader data collection initiatives at the national and international levels to enhance data efforts collected in PCAs and throughout the region.

11. Promote water quality data collection, monitoring, and modeling. Coordinate with IBWC the hosting of binational datasets. Encourage TCEQ to analyze past water quality data, in particular, water salinity and nutrients.

12. Encourage development of binational ecotourism routes that foster healthy and sustainable livelihoods as well as address conservation objectives. Build on the work conducted in Boquillas, Las Norias, and Jaboncillos, and link these communities and their ecotourism providers to others in the region, from Marathon, Alpine, Marfa, and Fort Davis in the north, to Manuel Benavides and Múzquiz in the south.

13. Facilitate raising the language competency of the partners in planning and allocating funds for international travel, and for learning Spanish and English in state and federal agencies, as well as civil society. Cross-border conservation and binational collaboration requires understanding the institutions, cultures, and needs of communities on both sides of the border. Understanding the mandates of agencies involved in the priority conservation areas is essential to meet the challenges faced by this binational region.

14. Use the Conservation Assessment as an instrument to support and justify funding at the international, national, and local levels in both Mexico and the United States.

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Acronyms

APFF	*Área de Protección de Flora y Fauna*
BBCC	Big Bend Conservation Cooperative
BBNP	Big Bend National Park
BBEST	Basin and Bay Expert Science Teams
BBRB	Big Bend-Río Bravo
BBRSP	Big Bend Ranch State Park
CCC	Civilian Conservation Corps
CEC	Commission for Environmental Cooperation
CILA	*Comisión Internacional de Límites y Aguas entre México y Estados Unidos* (for US, see IBWC)
Conabio	*Comisión Nacional para el Conocimiento y Uso de la Biodiversidad*
Conacyt	*Consejo Nacional de Ciencia y Tecnología*
Conafor	*Comisión Nacional Forestal*
Conagua	*Comisión Nacional del Agua*
Conanp	*Comisión Nacional de Áreas Naturales Protegidas*
Coneco	*Conservadores de Ecosistemas del Puerto del Pinto*
DOF	*Diario Oficial de la Federación, México*
DOI	Department of the Interior
DRSNA	Devils River State Natural Area
ESA	Endangered Species Act
ETPA	Edwards-Trinity Plateau Aquifer
USFWS	US Fish and Wildlife Service
GPCA	Grassland Priority Conservation Area
IBA	Important Bird Area
IBWC	International Boundary and Water Commission
INECC	*Instituto Nacional de Ecología y Cambio Climático*
LWRCRP	Land and Water Resources Conservation and Recreation Plan
NGO	Nongovernmental organization
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
PCA	Priority conservation area
PES	Payment for Ecosystem Services
Profauna	*Protección de la Fauna Mexicana A.C.*
Procodes	Conservation program for sustainable development
RAMSAR	Convention on Wetlands (Ramsar, Iran, 1971) -- called the "Ramsar Convention"
RGJV	Rio Grande Joint Venture
RMBO	Rocky Mountain Bird Observatory
Sagarpa	*Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación*
Sedena	*Secretaría de la Defensa Nacional*
SEE	Sound Ecological Environment
SEMA	*Secretaría de Medio Ambiente del Estado de Coahuila*
Semarnat	*Secretaría de Medio Ambiente y Recursos Naturales*
SGCN	Species of Greatest Conservation Needs
SMI	*Sistema de Mando de Incidentes*
TCEQ	Texas Commission on Environmental Quality
TPCA	Texas Conservation Action Plan
TDS	Total dissolved solids
TNC	The Nature Conservancy
TPWD	Texas Parks and Wildlife Department
UAAAN	*Universidad Autónoma Agraria Antonio Narro*
UMA	*Unidad de Manejo para la Conservación de la Vida Silvestre*
USGS	US Geological Survey
WMA	Wildlife Management Area
WWF	World Wildlife Fund

Glossary

aguaje: watering trough.

aquatic obligates: species that depend on aquatic resources for food and cover.

arroyo: small, deep gully produced by flash flooding in arid and semiarid regions of the southwestern United States.

benthic: about the flora and fauna found on the bottom, or in the bottom sediments, of a sea, lake, or other body of water.

bentonite: clay formed by the alteration of minute glass particles derived from volcanic ash. It was named for Fort Benton, Mont., near which it was discovered. Used especially as a filler.

biomarker: a measurable substance in an organism whose presence is indicative of some phenomenon such as disease, infection, or environmental exposure.

ciénaga: marshy area at the foot of a mountain, in a canyon, or on the edge of a grassland where groundwater bubbles to the surface, fed by seepage or springs.

chaparral: type of plant community in which shrubs are dominant. It occurs usually in regions having from 10 to 20 in. (25–50 cm) of rainfall annually and with a Mediterranean-type climate. Where the rate of evaporation is high, chaparral may be found where the rainfall exceeds 50 cm/year. Generally, chaparral country receives most of its rainfall in the winter. The vegetation includes both evergreen and deciduous forms, the dominant species varying in different areas.

cholla: any cylindroid-jointed cactus of the genus *Cylindropuntia,* family *Cactaceae*, native to North and South America.

conservation target: conservation targets are biological and/or physical features that represent the biodiversity of the region, the conservation of which increases the chances of conserving other living resources. Targets can be individual species, communities, ecosystems, or physical aspects of the landscape, such as important hydrological features.

conveyance capacity: quantitative measure of the discharge capacity of a watercourse. It relates total discharge to a measure of the gradient or slope of the channel. It is derived from the channel properties, including channel roughness, channel shape (section and plan form) and cross-sectional area.

corral: (*North American)* a pen for livestock, especially cattle or horses, on a farm or ranch.

creosote bush: woody shrub species (*Larrea tridentata*).

dendrochronological: dendrochronology - The study of climate changes and past events by comparing the relative sizes of springwood and summerwood portions of successive annual growth rings of trees or old timber.

ecological drivers: element (biotic or abiotic) that induces changes in ecosystems, communities, communities, or other ecological component of the landscape. Examples include the effects of invasive species, land-use change or land conversion, pollution, dams and water diversions, and climate change and variability.

ecologically significant: designation by TPWD and NPS for rivers and stream segments having unique ecological values based on biological function, hydrological function, riparian conservation areas, water quality, aquatic life, aesthetic value, and unique communities.

ephemeral stream: ephemeral stream is one that carries water only during and immediately after rain and is above the water table at all times.

ejido: in Mexico, village lands that combine communal ownership with individual use. The ejido consists of cultivated land, pastureland, other uncultivated lands, and the *fundo legal* (townsite). In most cases the cultivated land is divided into separate family holdings, which cannot be sold although they can be handed down to heirs.

ejidatario: holder of a share or member in a common land.

endemic: native to or confined to a certain region.

exotic plant/animal species: an introduced, neozoon, alien, exotic, non-indigenous, or non-native species, or simply an introduction, is a species living outside its native distributional range, which has arrived there by human activity, either deliberate or accidental.

fire regime: a 'fire regime' is the term given to the general pattern in which fires naturally occur in a particular ecosystem over an extended period of time. Scientists classify fire regimes using a combination of factors including frequency, intensity, size, pattern, season, and severity.

forb/forbs: a broad-leaved herb other than a grass, especially one growing in a field, prairie, or meadow.

fescue: any of about 100 species of grasses constituting the genus *Festuca* (family Poaceae), native to temperate and cold regions of the Northern Hemisphere. Several species are important pasture and fodder grasses, and a few are used in lawn mixtures.

gabion/*gavión*: a stream embankment stabilization device consisting of connected wire baskets filled with rock, usually placed in a terraced formation. They can also be made by using two rows of heavy fencing with rock fill between them (two fence gabion).

grama grassland: grama grass**,** (genus *Bouteloua*), any of about 50 species of annual or perennial forage grasses constituting a group within the family Poaceae, and native mostly to North America, with a few species in Central and South America. Grama grasses may grow in tufts or clumps or spread by creeping horizontal stems above or below ground.

herpetological inventory: inventory of amphibian and reptile species.

hydrograph: a hydrograph is a plot of the variation of discharge with respect to time (it can also be the variation of stage or other water property with respect to time).

hydrologic regime: the distribution over time of water in a watershed, among precipitation, evaporation, soil moisture, groundwater storage, surface storage, and runoff.

hydrogeochemical: hydrogeochemistry is the study of the chemical characteristics of ground and surface waters as related to areal and regional geology.

hydrogeologic investigation: hydrogeology is a branch of geology concerned with the occurrence, use, and functions of surface water and groundwater.

intact: a community or ecosystem that is maintaining proper function and has not lost significant species (for communities) or significant communities (for ecosystems). Typically there will also not be a significant amount of invasive weeds.

ecological integrity refers to the health of an ecosystem. If a system has integrity, it is fully functional with intact key biotic and abiotic patterns, processes, and structural attributes responsible for that biological diversity and for ecosystem resilience.

intermittent stream: an intermittent stream is one that flows only at certain times of the year and may cease to flow during dry years or seasons or may be reduced to a series of separate pools or short areas of flow.

karst: terrain usually characterized by barren, rocky ground, caves, sinkholes, underground rivers, and the absence of surface streams and lakes. It results from the excavating effects of underground water on massive soluble limestone.

manantial: water source.

mesic habitat: type of habitat with a moderate or well-balanced supply of moisture, i.e. a mesic forest, a temperate hardwood forest, or dry-mesic prairie. Mesic is one of a triad of terms to describe the amount of water in a habitat.

mesquite (*Prosopis glandulosa*): woody shrub plant of the genus *Prosopis,* leguminous spiny trees or shrubs of the family Leguminosae, native to tropical and subtropical regions.

microphyll(ous) (shrubs): a leaf with only one vascular bundle and no complex network of veins.

midgrass: any of various grasses of moderate height which covered the undisturbed prairie in the United States; includes species of porcupine grass, grama grass, wheatgrass, and buffalo grass.

norias: water wheels used for livestock

phytogeography: also called geobotany, is the branch of biogeography that is concerned with the geographic distribution of plant species, or more generally, plants.

phytosanitary: pertaining to the health of plants.

piñon (or **pinyon**) **pine:** a number of very slow-growing, short-needled pine species that grow in the Intermountain regions of western North America. These pines produce edible nuts that are widely eaten by people and are a staple of birds and other animals.

priority conservation areas (PCAs): are areas of importance due to their ecological significance, threatened nature and opportunities for conservation, that are in urgent need of protection and restoration actions. These areas were defined based on the analysis of threats, opportunities and habitat in the Big Bend-Río Bravo region.

pristine: in its original condition; unspoilt, primitive or original.

sound ecological environment: defined by the State of Texas as an environment that sustains the full complement of the current suite of native species in perpetuity, or at least supports the reintroduction of extirpated species, sustains key habitat features required by these species, retains key features of the natural flow regime required by these species to complete their life cycles, and sustains key ecosystem processes and services, such as elemental cycling and the productivity of important plant and animal populations.

special interest areas: areas considered important because of their biophysical characteristics; these areas support one or more conservation targets. These were identified based on conservation targets as well as the analysis of ecological drivers.

substrates: soils derived from limestone origin in the mountains, relative to soil depth and topography, and barren exposed rock outcrops, cliffs and bluffs.

supercell: is a thunderstorm that is characterized by the presence of a mesocyclone: a deep, persistently rotating updraft.

tobosa grass: *Pleuraphis* (formerly *Hilaria mutica)* is a rhizomatous perennial grass that has the ability to become completely dormant during periods of drought stress.

vega: fertile, often wooded, flood plain.

xeromorphic: having special features which protect the plant from desiccation allowing them to survive with a small amount of water in a dry habitats.

zeolite: any of a large group of minerals consisting of hydrated aluminosilicates of sodium, potassium, calcium, and barium. They can be readily dehydrated and rehydrated, and are used as cation exchangers and molecular sieves.

Appendix: Participants in the Experts' Meeting

Listed by working group

Aquatic species

Alejandra Carrera Máynez, *Secretaría de Medio Ambiente del Estado de Coahuila*

Margarita Caso Chávez, *Instituto Nacional de Ecología*

Gary P. Garrett, Texas Parks and Wildlife Department

César Alberto González-Zuarth, *Instituto EPOMEX, Universidad Autonoma de Campeche*

Catherine Hallmich, Commission for Environmental Cooperation

David Larson, Big Bend National Park, National Park Service

Oscar Manuel Ramírez Flores, *Comisión Nacional de Áreas Naturales Protegidas*

Gabino Adrián Rodríguez Almaraz, *Universidad Autónoma de Nuevo León, Facultad de Ciencias Biológicas*

Raymond Skiles, Big Bend National Park, National Park Service

Terrestrial species

Michael Boruff, Texas Parks and Wildlife Department

Hernando Cabral Perdomo, World Wildlife Fund - *Conservación Desierto Chihuahuense*

Rogelio Carrera, *Universidad Autónoma de Nuevo León*

Alejandro Espinosa Treviño, Cemex

Jesús Guadalupe Franco-Pizana, Rio Grande Joint Venture

Feliciano Javier Heredia Pineda, *Pronatura Noreste A.C.*

Louis Harveson, Borderlands Research Institute, Sul Ross State University

Erick Felipe Jiménez Quiroz, Commission for Environmental Cooperation

John Karges, The Nature Conservancy

Alberto Lafón Terrazas, *Protección de la Fauna Mexicana A.C.*

Pablo Antonio Lavín Murcio, *Universidad Autónoma de Ciudad Juárez*

Alfonso Leal, US Department of Agriculture, Natural Resources Conservation Service

Aimee Michelle Roberson, Desert Landscape Conservation Cooperative, US Fish and Wildlfie Service

José Roberto Rodríguez Salazar, *Especialista en aves de pastizal*

Carlos Alberto Sifuentes Lugo, *Comisión Nacional de Áreas Naturales Protegidas – Área de Protección de Flora y Fauna Maderas del Carmen*

Hydrologic features

Jeffery Bennett, Big Bend National Park, National Park Service

Karen Chapman, Environment Defence Fund

Robert Joseph, US Geological Survey, Texas Water Science Center

Ramiro Luján G., *Comisión Internacional de Límites y Aguas entre México y Estados Unidos*

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Sergio Alberto Naranjo Macias, *Comisión Nacional del Agua*

Helen M. Poulos, College of the Environment, Wesleyan University

María Rebeca Quiñonez-Piñón, ECORed

Samuel Sandoval Solis, University of California, Davis

John Christian (Jack) **Schmidt III**, US Geological Survey, Grand Canyon Monitoring and Research Center

Raymond Skiles, Big Bend National Park, National Park Service

Kevin Urbanczyk, Rio Grande Research Center, Sul Ross State University

Elizabeth Verdecchia, International Boundary and Water Commission

María Dolores Wesson, Commission for Environmental Cooperation

Vegetation

Mark Briggs, World Wildlife Fund

Juan Antonio Encina Domínguez, *Universidad Autónoma Agraria Antonio Narro*

Juan Manuel Frausto Leyva, *Fondo Mexicano para la Conservación de la Naturaleza*

Ángel Frías García, *Comisión Nacional de Áreas Naturales Protegidas - Área de Protección de Flora y Fauna Cañón de Santa Elena*

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Ignacio José March Mifsut, The Nature Conservancy Mexico and Northern Central America

Albert Walter Miller, Miller Ranches

Andrés Nájera Díaz, *Universidad Autónoma Agraria Antonio Narro*

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