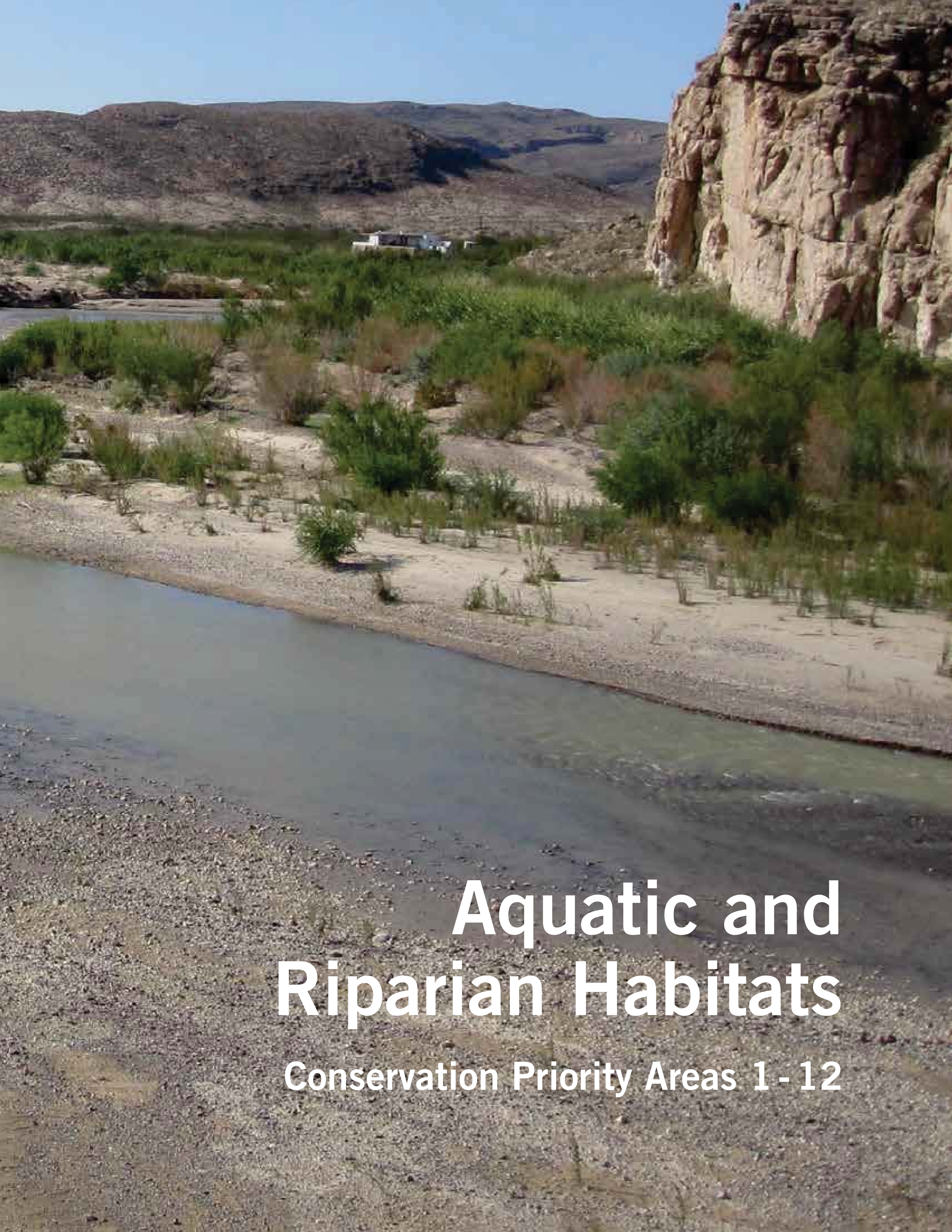


Aquatic and Riparian Habitats

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

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

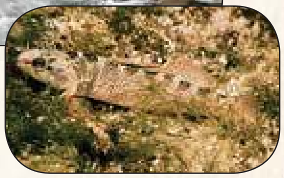
Pecos River

Author: John Karges

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*).

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



Rio Grande darter.
Photo: Garold Sneegas

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.

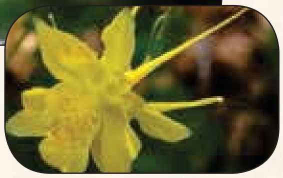
Priority Conservation Area

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*), Gooding willow (*Salix goodingii*), 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

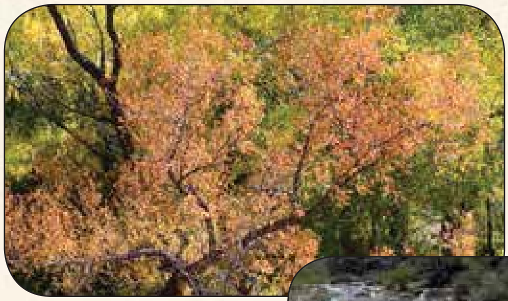
- Work with partners to manage exotic plant and animal species.
- Obtain funding to complete the research and monitoring needs described above.

Priority Conservation Area

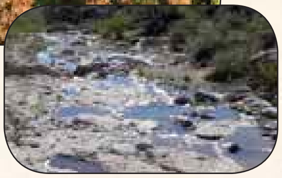
10

San Carlos Springs

Authors: Claudia N. Castillo Jiménez and Ángel Frías García



Cottonwoods at Rancheria Springs, Chihuahua. Photo: Gary Nored



San Carlos Springs, Chihuahua. Photo: Catherine Hallmich

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'.

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.

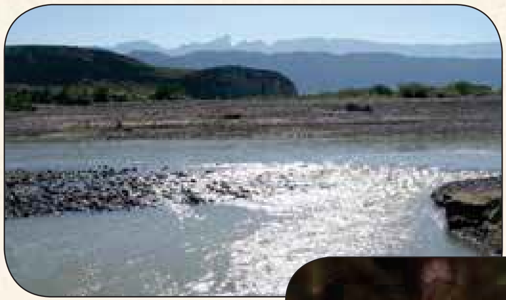
San Carlos Springs, Chihuahua.
Photo: Catherine Hallmich

Priority Conservation Area

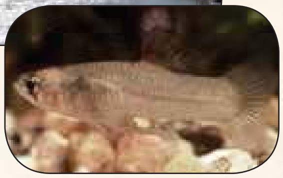
11

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

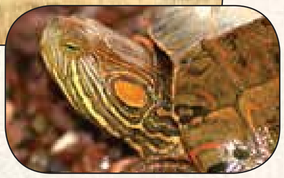
12

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 habitats 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