A Proposal for Developing Desired Future Conditions **for the Big Bend Reach of the Rio Grande**

Commission for Environmental Cooperation

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This report was prepared by **Mark Briggs** (Conservation Scientist, World Wildlife Fund), **Stacy Sirotnak** (Environmental Consultant, Panther Junction, Texas), and **Daniel Bunting** (Environmental Consultant, Tucson, Arizona) for the Secretariat of the Commission for Environmental Cooperation. The information contained herein is the responsibility of the authors and does not necessarily reflect the views of the CEC, or the governments of Canada, Mexico or the United States of America.

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For more information:

Commission for Environmental Cooperation
393, rue St-Jacques Ouest, Bureau 200
Montréal (Québec) Canada H2Y 1N9
t (514) 350-4300 f (514) 350-4314
info@cec.org / www.cec.org

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San Carlos Creek, Chihuahua Photo: Catherine Hallmich

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Acronyms and Abbreviations

BBCC	Big Bend Conservation Cooperative
BBNP	Big Bend National Park
BBRBI	Big Bend-Río Bravo Initiative
BBRSP	Big Bend Ranch State Park
CEC	Commission for Environmental Cooperation
DFC	desired future conditions
CHDN	Chihuahuan Desert Network
Conagua	*Comisión Nacional del Agua* (Mexico's National Water Commission)
Conanp	*Comisión Nacional de Áreas Naturales Protegidas* (Mexico's National Commission on Protected Natural Areas)
CRP	Texas Clean Rivers Program
ETPA	Edwards-Trinity Plateau Aquifer
IBWC	International Boundary and Water Commission/*Comisión Internacional de Límites y Aguas*
LCR-MSCP	Lower Colorado River Multi-Species Conservation Program
NGO	nongovernmental organization
NPS	National Park Service
RIGR	Rio Grande Wild and Scenic River Protected Area
Semarnat	*Secretaría del Medio Ambiente y Recursos Naturales* (Mexico's Ministry of Environment and Natural Resources)
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TPWD	Texas Parks and Wildlife Department
USBR	US Bureau of Reclamation
USDA	US Department of Agriculture
USDOI	US Department of the Interior
USFS	US Forest Service
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
WWF	World Wildlife Fund

Abstract

The aim of this report is to provide background information and a proposed operating framework that US and Mexican state and federal land and natural resource management agencies can use in making collaborative decisions relating to that portion of the Rio Grande that extends from its confluence with the Río Conchos, at Presidio, Texas, to the Amistad Reservoir, on such topics as: engaging additional stakeholders to develop and refine the shared vision for the river; developing operational guidelines and a set of desired future conditions for this reach of the river; and identifying rehabilitation, monitoring, and research priorities. The Big Bend-Río Bravo Steering Committee associated with this project reviewed this document.

Executive Summary

The Big Bend reach of the Rio Grande extends from the confluence of the Rio Grande and Río Conchos at Presidio, Texas, and Ojinaga, Chihuahua, to the Amistad Reservoir, located 500 km downstream near Del Rio, Texas, and Ciudad Acuña, Coahuila. This reach of the Rio Grande flows through the Chihuahuan desert landscape and several US and Mexican protected areas managed by the National Park Service (NPS), *Comisión Nacional de Áreas Naturales Protegidas* (Conanp), and Texas Parks and Wildlife Department (TPWD). Together, these agencies have been collaborating on joint conservation work for years. In 2008, these agencies met with a coalition of federal and state agencies, conservation organizations, universities, and citizens from both sides of the border to discuss opportunities related to collaborative conservation of the Rio Grande ecosystem, with the objective of advancing the scientific basis for management actions and monitoring their effects (WWF 2008). There, the participants worked together to create a shared vision for the Rio Grande ecosystem. This report proposes a path forward for developing desired future conditions (DFCs) for the Rio Grande ecosystem as a step toward achieving that vision and advancing conservation objectives.

The aim of this report is to provide background information and a proposed operating framework that US and Mexican state and federal land and natural resource management agencies can use to make collaborative decisions on such topics as: (1) engaging additional stakeholders to further develop and refine the shared vision for the river, (2) determining operational guidelines for developing desired future conditions, (3) developing a set of DFCs, and (4) identifying rehabilitation, monitoring, and research priorities. The fundamental objective is to provide valuable and thoughtful information that will promote collaborative binational comment and involvement. This report in no way overrides the regulations, priorities, activities, or work plans of any of the agencies or organizations mentioned. Its goal is to assist conservation partners and stakeholders in identifying opportunities, strengthening existing partnerships, and reaching out to build new cooperative initiatives.

This report includes the following elements:

- A brief description of the recent history of collaborative conservation in the Big Bend-Río Bravo region, with an emphasis on projects and partners sited and working there;
- A draft vision for the Big Bend reach of the Rio Grande;
- Proposed operational guidelines for developing DFCs for the Big Bend reach;
- A framework that regional conservation partners can use to reach consensus on DFCs for the Big Bend reach; and
- A summary of science, rehabilitation, and monitoring activities conducted by diverse academic and other researchers and agencies along the Big Bend reach.

Llano las Amapolas, Chihuahua
Photo: Raymond Skiles

Collaborative Conservation in the Big Bend-Río Bravo Region

The transboundary Big Bend-Río Bravo region of the northern Chihuahuan Desert has been a focus of biodiversity and landscape conservation for many decades. In the past few years, conservation partners in the US and Mexico have been focused on developing relationships and transboundary networks for identifying shared goals and informing and improving management and conservation of natural and cultural resources. These collaborative initiatives build on historic and ongoing cooperative conservation, science and monitoring efforts that have positioned partners in the US and Mexico to strengthen and broaden science-based resource management practices and provide a watershed context for the development and implementation of shared conservation priorities in the Big Bend-Río Bravo region (including federal, state, and private protected/conservation areas). The Big Bend Conservation Cooperative (BBCC) and the Big Bend-Río Bravo Initiative (BBRBI) engage in a variety of collaborative conservation activities in the Big Bend-Río Bravo region. One goal of these partnerships is to implement, assess, and refine management actions to benefit the Rio Grande ecosystem (see Figure 1), as well as the people, communities, and native fish and wildlife it supports. Activities range from pure and applied research on environmental flows, and climate change, to on-the-ground conservation and rehabilitation efforts, including endangered species conservation and invasive species management.

Big Bend Conservation Cooperative

Building on successful cooperative conservation projects in the Big Bend Region of the Chihuahuan Desert, three agencies within the Department of the Interior (DOI)—the US Fish and Wildlife Service (FWS), the National Park Service (NPS), and the US Geological Survey (USGS)—along with the Texas Parks and Wildlife Department (TPWD) signed a Memorandum of Understanding (MOU) in the Fall of 2010 establishing the Big Bend Conservation Cooperative (BBCC). Although the MOU was initially signed by only these four parties, it was created with the intention of providing a platform for the growth of a much larger emerging binational conservation partnership that was catalyzed by the 2008 WWF workshop that focused on lessons learned from a decade of conservation work along the Big Bend reach of the Rio Grande. Conservation partners working with the BBCC include a variety of other agencies, organizations, universities and citizens that are actively involved in conservation in the region.

The purpose of the BBCC is to continue working with a larger group of conservation partners, including private landowners, to leverage resources for accomplishing shared goals. The BBCC builds on and advances successful collaborative projects in the region, including control of saltcedar and other exotic species, studies of springs and aquifers that contribute to flows in the river, grassland management and restoration, and recovery of the endangered Rio Grande silvery minnow. Together, these collaborative efforts have allowed conservation partners in the region to successfully design and implement multi-jurisdictional, inter-disciplinary projects and to leverage resources and attract funding from external sources.

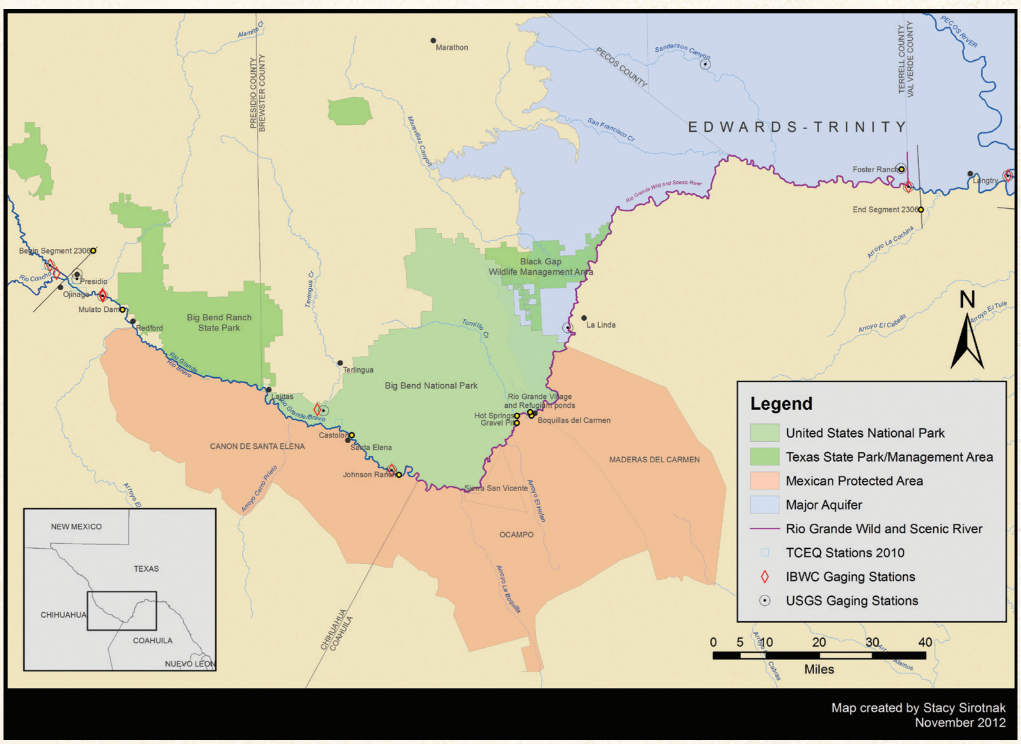
Sierra de Santa Rosa, Coahuila. Photo: Rodolfo Lopez

Big Bend-Río Bravo Initiative

In the interest of furthering conservation on protected lands approaching three and a half million acres on both sides of the US-Mexico border, the DOI and the *Secretaría del Medio Ambiente y Recursos Naturales* (Semarnat) are leading the Big Bend-Río Bravo Initiative (using the Spanish name of the river in preference to "Rio Grande" to emphasize the binational character of the intiative), which seeks to increase capacity for binational conservation amongst government, nongovernmental, and private conservation partners. In December 2010, DOI Secretary Ken Salazar met with Mexican Minister of Environment Juan Rafael Elvira Quesada to discuss a plan for the area of binational conservation interest that would encompass Big Bend National Park in Texas and several adjacent protected areas in Mexico. Inspired by that meeting, NPS and Conanp led efforts to create the "Action Plan for the Creation of the Binational Interest Conservation Area Big Bend-Río Bravo." Integral to the process were other DOI (FWS, USGS), US Department of Agriculture (Natural Resources Conservation Service), *Secretaría de Medio Ambiente y Recursos Naturales* [Semarnat; *Instituto Nacional de Ecología y Cambio Climático*[1] (INECC)] agencies, as well as Customs and Border Patrol and the Department of State. The Action Plan identifies priorities for short- and medium-term action, including opening a local border crossing to facilitate binational conservation efforts, ecosystem rehabilitation of the Rio Grande, management of rare and endangered species, detection of and response to animal diseases, wildfire management, law enforcement, data sharing, and ongoing coordination.

The members and partners of the BBCC and the BBRBI, all of whom have had considerable experience with rivers in the western US and northern Mexico, are summarized in Table 1 (page 4). The summary includes just those entities that have been significantly involved in management, scientific, rehabilitation, and other conservation-related activities along the Big Bend reach of the Rio Grande.

Figure 1: Map of Big Bend Region of South Texas and Northern Chihuahua and Coahuila, Delineating Major Political Boundaries and Major Tributaries of the Rio Grande



1 See <http://www.inecc.gob.mx/descargas/dgipea/decoupling_the_subsidy_for_water_pumping.pdf>.

Rio Grande
Photo: Catherine Hallmich

Table 1: Summary of Members and Partners of the BBCC and BBRBI Engaged in Collaborative Conservation of the Big Bend Reach of the Rio Grande

Name of Agency, Organization, Institution or Citizen	Stated Mission	Role in Rio Grande Conservation
Big Bend National Park	Preserve unimpaired the natural and cultural resources and values of Big Bend National Park	Instrumental in BBCC and BBRBI development, organization, identification of priorities, and binational coordination
Comisión Nacional de Áreas Naturales Protegidas	Manage 173 natural areas in Mexico for purpose of long-term natural resource protection	Instrumental in BBRBI development, organization, identification of priorities, and binational coordination
Comisión Nacional de Agua	Manage and preserve national waters and their inherent goods in order to achieve sustainable use	Management of Río Conchos flow, review of science, monitoring, and rehabilitation plans
Texas Parks and Wildlife Department	Manage and conserve the natural and cultural resources of Big Bend Ranch State Park in a manner that provides hunting, fishing and outdoor recreation opportunities	Instrumental in BBCC development, organization, identification of priorities, and binational coordination; personnel have provided considerable technical assistance on a variety biophysical applications
CLIMAS, University of Arizona	Improve the region's ability to react to climatic events and climate changes	Climate assessment, climate adaptation, and coordination with other climate service organizations
***El Carmen Project*, CEMEX**	Management of the Maderas del Carmen-Sierra del Carmen, ecosystem on a landscape level	Hosts for technical assistance to landowners and Mexican agencies, and cooperating partners on transboundary wildlife conservation, research on high priority species, support of students, and protection of cultural resources
El Carmen Land and Conservation Co. LLC (Adams Ranch) (CEMEX USA and Cuenca los Ojos, Owners)	Management and restoration of lands along the Rio Grande corridor	Cooperating partner with Texas Parks and Wildlife Department, Texas Bighorn Sheep Society, and partner with USFWS on the Rio Grande Silvery Minnow Reintroduction Project and Private Lands Agreement Program cooperator
Environmental Defense Fund	Preserve the natural systems on which all life depends	Legal counsel on binational river management, BBCC maturation and development
International Boundary and Water Commission/ *Comisión Internacional de Límites y Aguas*	Apply the boundary and water treaties of the United States and Mexico and settle differences that may arise in their application	Technical coordination on a host of binational issues and activities, including flow management, permit applications, hosting workshops and meetings, and technical assistance and review
Office of the State Climatologist of Texas	Provide the State of Texas with accurate climate information and critical expertise in the field of climatology	Climate assessment, climate adaptation, and coordination with other climate service organizations
La Junta Heritage Center	Maintain and support the vitality of the local culture and the underlying and supporting ecology through conservation, agriculture, and cultural preservation	Restoration and civic and cultural engagement

Name of Agency, Organization, Institution or Citizen	Stated Mission	Role in Rio Grande Conservation
Profauna, A.C.	Work to conserve flora and fauna in priority ecoregions of Mexico	Design and implementation of river rehabilitation and monitoring strategies
Sul Ross State University	Create a basin-wide perspective for the sustainable use of water resources within the binational Rio Grande watershed	Technical assistance on a range of biophysical monitoring and research activities
Texas Commission on Environmental Quality	Strive to protect Texas' public health and natural resources in a manner consistent with sustainable economic development	Technical assistance on a range of monitoring and research activities, particularly water quality
Texas State University at San Marcos	Enrich learning through the study of the Greater Southwest	Technical assistance on a range of biophysical monitoring and research activities
The Nature Conservancy	Protect Earth's natural resources and beauty	Technical assistance on a range of biophysical monitoring and research activities
Town of Boquillas, Coahuila		As a community near the mouth of Boquillas Canyon, Boquillas residents and other riverside citizens are the ultimate stakeholders of the river and have been involved directly in river conservation activities
Trans-Pecos Water and Land Trust	Nonprofit organization working to improve the flows of the Rio Grande in far west Texas and the Big Bend and dedicated to ensuring the Rio Grande and its tributaries have sufficient flowing water to benefit riverside landowners, fish, wildlife and recreation	Technical and Public oversight and assistant on a variety of conservation issues, including invasive species management and water rights management
Universidad Autónoma de Chihuahua	A public, autonomous institution of higher education dedicated to instilling citizens with universal values, and who are capable of giving pertinent and creative responses to a world in constant change	Technical assistance on a range of biophysical monitoring and research activities
US Fish and Wildlife Service	Conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people	Instrumental in BBCC and BBRBI development, organization, identification of priorities, binational coordination; River biophysical research and monitoring; focus on establishment and propagation of Rio Grande silvery minnow
US Geological Survey (Biological Resources Division, Central Region and Texas Water Science Center, Central Region and Grand Canyon Monitoring and Research Center)	Provide reliable scientific information to describe and understand the Earth	Scientific support on river biophysical conditions, trends, and response to biophysical decline

Name of Agency, Organization, Institution or Citizen	Stated Mission	Role in Rio Grande Conservation
Utah State University	Cultivate the diversity of thought and culture, and serves the public through learning, discovery, and engagement	Research on river biophysical conditions, trends, and response to biophysical decline, as well as remote sensing applications
University of Texas at El Paso	Provide quality higher education to a diverse student population	Research on river biophysical and chemical conditions, trends, and response to biophysical decline
World Wildlife Fund (Mexico)	Work for the conservation of natural spaces and the diversity of species	Technical coordination on a host of binational issues and activities, including hosting workshops and meetings, fundraising, and technical assistance and review

Proposed Vision for Collaborative Conservation of the Big Bend Reach of the Rio Grande

This vision has been modified from that developed at the 2008 WWF workshop (WWF 2008) and is provided as a starting point for engaging additional partners and stakeholders in the process of identifying desired future conditions for the Big Bend reach of the Rio Grande.

> *Agencies, institutes, organizations, and citizens from Mexico and the United States work together to conserve, enhance, and restore the riverine ecosystem and freshwater biodiversity of the Rio Grande, from the Río Conchos to Lake Amistad, for the benefit of humans and nature, including:*

- A wandering, laterally unstable river channel, including multi-threaded segments, where there is regular conversion between channel and floodplain habitats. The width of the belt within which the channel is laterally unstable should not threaten communities or historic structures;
- The river's cross-sectional form is relatively wide and shallow;
- A diverse, patchy and discontinuous riparian plant community, where no specific non-native species is dominant;
- An aquatic habitat that will sustain and enhance the distribution and extent of native river biota, including assemblages of native fish such as the silvery minnow, aquatic macro-invertebrates, and other key components that are indicative of the system's health and function;
- A river with flows that maintain channel capacity, thereby reducing the threat of flooding to communities along the river;
- A river that enhances the well-being of riverside citizens;
- A river whose natural aspects enhance recreational experiences and support low-impact human activities such as fishing and boating;
- A river whose water quality characteristics meet or surpass existing state and federal standards on both sides of the border;
- A border river that unites people rather than dividing them.

Proposed Operational Guidelines for Developing Desired Future Conditions

Operational guidelines are a set of principles or values agreed upon by conservation partners to help guide the decision-making process, and guide the mission, the vision, and the DFCs. The following guidelines were inspired by the operational guidelines put forward in the Crown Managers Partnership Strategic Plan 2011–2015 (CMP 2011), and are intended as a starting point for further discussion among BBCC/BBRBI members, partners, and stakeholders.

The proposed operational guidelines are as follows:

- Given that some environmental, resource and land management issues can only be addressed at the watershed scale, the process should begin with broad perspective and consider cascading effects;
- River management and rehabilitation activities are centered on the belief that their design needs not only affect the hydroecological condition of the river, but the social and economic well-being of riverside citizens as well;
- This conservation partnership is binational in nature and strives to have a balance of agencies, institutions, organizations, and citizens from both Mexico and the US;
- This partnership draws together diverse opinions and approaches to river management and rehabilitation. To enhance the development of collaborative and effective solutions, we interact in a manner respectful of that diversity;
- Focus on the development of management tools, data management, science, rehabilitation, education and outreach at the watershed scale;
- Operate on the principles of synergy and leverage, recognizing that in river management, data collection, rehabilitation, and problem-solving, numerous small contributions by a diversity of players will lead to something greater; and
- Be committed to science-based decision-making with science and monitoring activities conducted by river management agencies as well as the academic and research community.

Guidelines for Developing DFCs for the Rio Grande in Big Bend

What are 'Desired Future Conditions'?

Generally, "desired future conditions" (DFCs) are accepted as the social, economic, and ecological attributes that management strives to attain (IEMTF 1995). The DFC concept was pioneered by the US Forest Service (USFS) in the 1970s and 1980s as part of the agency's forest management planning process. As a result of criticisms and different applications, the concepts and definition of DFCs have evolved over time (Leslie et al. 1996). Desired future conditions can be relevant to many disciplines and the process can be implemented in a variety of ways.

Scientists, managers and the public, among many others, have different viewpoints on how resources should be managed. The objective of the process is to develop DFCs that account for the interests of multiple stakeholders, including the public. DFCs, in this context, are created through compromise and prioritization, often resulting from an intensive, iterative process that includes meeting, discussing ideas, and drafting and revising goals. Regardless of application, the intent of the DFC process is to outline a set of realistic and achievable goals that will direct management toward the desired improvement of resources over time. In other words, a DFC framework provides guidance and direction for management aiming to protect, conserve, or restore natural resources for future generations.

For this review, DFCs will be placed into the context of river restoration. The term 'restoration' is used in a broad sense in this report to mean any act of management intended to mitigate, rehabilitate, improve, or fully restore hydroecological processes of a river. While some concepts, such as 'natural variability,' have been used to isolate ecological disturbance and direct management toward desirable ecological conditions (Wright et al. 1995, Landres et al. 1999), the DFC process, as described here, emphasizes public input alongside political and environmental needs. Thus, social, economic, and cultural values play a large role in how DFCs are developed and defined.

Review of Existing DFCs

A comprehensive literature review was first conducted to understand how the DFC process has been used in the past and how it has evolved over time. Three sample case studies were selected that were river-oriented, had involved a variety of agencies and organizations, and that were located in the western United States. When possible, representatives from different agencies and projects involved in these efforts were interviewed to discuss and summarize the lessons they had learned in the DFC process and those are summarized here. Table 2 summarizes the key elements that make a successful DFC process development. A full description of each example can be found in Appendix I.

Depending on the participating agencies, affiliations, overall mission and goals, the DFC process is necessarily altered to fit individual situations. Collectively, the lessons learned from these case studies, along with a review of the scientific literature, provide guidance for developing broad DFC criteria that will improve future efforts to restore the Rio Grande and its resources along the Big Bend reach.

Table 2: Suggested Elements for Successfully Defining DFCs

Case study	Elements for successfully defining DFC
National Park Service (Glen Canyon Dam operations/Grand Canyon National Park)	• Focus initial DFC process first on "low-hanging fruit" • Develop clearly defined parameters and sidebars to focus the discussion • Foster an environment that allows all parties to remove their partisan hats and work together • Build a working relationship from the beginning
US Bureau of Reclamation (Lower Colorado River Multi-species Conservation Program)	• Develop a diverse team that allows different interest groups to articulate desired future conditions • Employ a third-party consulting firm to mediate and facilitate meetings • Understand historical biophysical conditions • Quantify DFCs • Compromise
US Department of Agriculture/US Forest Service (forest management plan)	• Describe goals at multiple, nested scales that include physical, biological, and social/economic resources

Guidelines for Developing DFCs for the Big Bend reach of the Rio Grande

Six lessons learned from the DFC case studies above were identified as potentially important in advancing the DFC development process in the Big Bend region:

❶ **Create a diverse committee or team**
❷ **Describe the history of biophysical conditions**
❸ **Develop a flexible and adaptable DFC process**
❹ **Determine spatial scale and quantify objectives**
❺ **Decide what constitutes realistic DFCs**
❻ **Encourage public participation**

❶ Create a diverse committee or team

The interdisciplinary steering committee or team that is formed to guide the DFC process is responsible for framing the questions to be answered, and will ultimately determine the overall objectives and goals. To ensure that input is broad and relayed in a fair and transparent manner, the team needs to be diverse with representation of all main stakeholders, potentially including representatives from city, county/*municipio*, state, and federal agencies; nongovernmental organizations (NGOs), nonprofits, and other smaller affiliations; and academic institutions as well as native tribes and the public. A series of closed and open-public meetings will set a middle ground, promote compromise, and tease out a list of priorities including what can be restored, why and who will benefit.

In the Big Bend region, close relationships between Big Bend National Park and Conanp in the BBCC provide a strong foundation for establishing a diverse team for guiding a DFC process. One particular important priority for the BBCC is to strengthen public (i.e., citizens of the Big Bend region) participation in the BBCC in a manner that encourages direct involvement and long-term support of the DFCs that are ultimately developed.

❷ Describe the history of biophysical conditions

Understanding past biophysical conditions is an important element for evaluating the extent of change that has occurred, the reasons for those changes, and what potentially can be accomplished in the future. By understanding how and why an ecosystem has changed over time, managers can begin outlining plans and strategies to develop DFCs, which ultimately become the goals or end-points for restoration and ecosystem management.

For example, the lower Colorado River Multi-species Program (MSCP) found that building historical descriptions for multiple river reaches along the Colorado River was the best strategy for identifying opportunities for protecting existing or creating southwestern willow flycatcher habitat. The Rio Grande has many similarities to the lower Colorado River and, like many southwestern rivers, has undergone degradation over the last century. Although the restoration of hydroecological conditions along the Big Bend reach of the Rio Grande to pre-dam conditions is not feasible or even desirable, understanding the river's historical conditions is critical to a thoughtful and realistic restoration program that is based on the extent of change that has occurred, the main drivers of change, and current trends.

Fortunately for our work along the Big Bend reach of the Rio Grande, sound understandings of past conditions, the extent of change, and the main drivers of change have been realized via research efforts conducted by the Utah State University (Dean and Schmidt 2011), US Geological Survey (Moring 2002), and others. Certainly, more biophysical research can and should be conducted. Indeed, lists of priority research needs were developed by the BBCC as part of recent binational workshops in 2008 (WWF 2008) and 2012 in Mexico City (CEC 2014). Nonetheless, the current understanding of the river processes and conditions of the river through Big Bend provides a strong foundation for moving forward to develop and finalize DFCs.

❸ Develop a flexible and adaptable DFC process

Establishing DFCs for geographically large areas should differ both spatially and temporally. DFCs for montane ecosystems will differ from those established for bottomland ecosystems even though the differing ecosystems might be managed by the same entity (e.g., a National Forest). From a temporal perspective, changes in the political landscape (e.g., land ownership and jurisdiction), socio-economic considerations, land use, climate, such natural stochastic events as large floods and fires, and a variety of other considerations will affect both DFCs that are formulated as well as the effectiveness of the strategies and management actions put in place to realize them.

To account for unanticipated change, the DFC process needs to be inherently adaptive and flexible. DFC teams should not consider established DFCs as set in stone. As such, DFCs need to be developed with the best information of today's environmental, natural resource, socio-economic, political situation with the understanding that they will be reviewed at a set time in the future (e.g., every five years) and/or following the occurrence of a dramatic event (e.g., realization of an important political agreement that has a significant bearing on management, or drought, fire, etc.). For example, USFS reviews forest management plans for each national forest or grassland every 15 years. Such a review approach could be used in the Big Bend region, allowing new information to be incorporated and assessed in the context of the DFCs that have been put forward.

❹ Determine spatial scale and quantify objectives

As part of the DFC process, there will be an evitable debate concerning qualitative versus quantitative parameters. As noted in several of the case studies, quantifying DFCs is critical, providing the data and, therefore, the foundation for assessing progress toward achieving DFCs, monitoring, and adaptive management; none of which is possible without quantification. That said, the first step in the DFC process will, by necessity, be descriptive, beginning broadly before focusing in on specific ecosystem types and processes.

For the Rio Grande through Big Bend, the process might begin with a broad descriptive DFC, such as *improved river biophysical conditions for native wildlife species and riverside citizens*, moving toward greater specificity, such as *wide and shallow channel morphology in place of current channel morphologic conditions that are narrow and deep*.

It is important to note that the BBCC has already put forward such qualitative detail from results of the WWF workshop (WWF 2008):

A wandering, laterally unstable, river channel, including multi-threaded segments, where there is regular conversion between channel and floodplain habitats. The width of the belt within which the channel is laterally unstable should not threaten communities or historic structures.

This is a sound beginning and needs to be taken advantage of by the BBCC as a foundation for the next, often more challenging step, of quantifying DFCs that will ultimately be put forward. For example, moving forward in the Big Bend region will require quantifying channel morphology, as meant by "the width of the belt." Part of the challenge in determining DFCs is to identify and address the science gaps required for quantification. What science is needed before DFCs for channel morphology can be quantified? That is an important question to answer, using strict criteria that allow the BBCC to identify priority science needs without developing an endless laundry list of research that will never be completed.

The other significant challenge to quantifying DFCs is the spatial scale that is being considered. For example, developing a channel morphologic DFC for the entire reach of the Rio Grande through Big Bend may not be scientifically possible. The river in Big Bend passes through subreaches dominated by bedrock as well as less geologically constrained subreaches dominated by alluvium. Channel-morphologic DFCs will inherently differ between the two. Reducing spatial considerations to a scale more appropriate for quantifying specific DFCs is part of the answer. For the river in Big Bend, developing channel morphologic DFCs for reaches of like geomorphologic characteristics may make the most sense. For example, developing channel-morphologic DFCs that center on the reach through Hot Springs Canyon (an 11-km subreach where hydrologic modeling and significant monitoring is being conducted) is both a reasonable and realistic way to begin. The DFC process can start small and move forward. The same can be done for biologically focused DFCs. Continuing with the above example, a DFC for the population of the Rio Grande silvery minnow could also be developed for Hot Springs Canyon, with DFCs for the minnow differing as the population is considered in other parts of the river.

❺ Decide what constitutes realistic DFCs

While it is easy to argue semantics, deciding what constitutes realistic DFCs will play a big role in finalizing the DFC process as well as defending why specific DFCs were ultimately selected. Answering what constitutes realistic is often challenging, particularly when considered in the context of diverse members of a DFC *ad hoc* committee. On one extreme, members coming from a natural resources conservation perspective may advocate for a DFC that describes an intact, fully functional ecosystem that reflects pre-impact conditions (Bennetts and Bingham 2007).
On the other hand, some may advocate for DFCs that reflect little if any improvement in hydroecological conditions.

It should be recognized that one or the other of the above extremes may be perfectly appropriate, depending on the situation. However, putting forward a DFC that describes either full restoration or a do-nothing scenario should be as carefully considered as other DFC scenarios that occupy a middle ground. Full restoration may not be possible, given the extent and diversity of impacts. And a do-nothing scenario may err by putting forward only what is achievable. This, for example, might arise when managers are accountable for an outcome, especially if future funding is dependent on an evaluation of achievement (Bennetts and Bingham 2007). In such a scenario, the DFC 'bar' might be set low to insure that the DFC is realized and future funding is secured.

Answering the question of 'what is realistic?'—the 'gray area' between those two extremes—is one of the inherent responsibilities of the DFC *ad hoc* committee and certainly underscores the importance of augmenting the diversity of DFC committee members. Regardless of how the 'what is realistic debate?' is answered, DFCs will need to account for sidebars (e.g., irreversible constraints imposed by a regulated river) or laws and regulations related to the area of interest. Policies, for instance, may be in place to protect natural resources, but, in some cases, may hinder an ideal DFC from being selected due to outlying factors (e.g., upholding energy production requirements, protecting sports-fishing). If a DFC is downgraded in order to compromise or take into account practicality, explanations should be included with the DFC to explain why such compromises were made.

Given the focus of DFCs on channel morphology, developing quantifiable realistic DFCs for the Rio Grande through Big Bend will depend on several factors, with the following three being toward the top of the list:

- The effectiveness of giant cane and saltcedar eradication along channel margins as a means for promoting processes of sediment evacuation and channel widening;
- The impacts of climate change (e.g., potential changes in the frequency, severity, and duration of extreme precipitation events that could significantly alter sedimentary input from local tributaries and, therefore, the river's sediment budget) on both the effectiveness of ongoing restoration tactics as well as our ability to realize restoration goals (i.e., DFCs); and
- The ability to work collaboratively with Conagua on river management issues to address biophysical and socio-economic conditions along both the lower Río Conchos as well as the Rio Grande through Big Bend.

❻ Encourage public participation

Public input is essential for developing DFCs. As exemplified by the case studies considered as part of this report, the levels of public input, as well as the methods for obtaining it, vary considerably from one project to the next. Public input was gained via letters, surveys/questionnaires, and public meetings. As the DFC public process moves forward, frequent questions arise concerning the role of the public in developing DFCs and when the level of public participation is sufficient. Certainly, all stakeholder groups need to be invited, giving all interested parties an opportunity to determine for themselves their level of involvement.

Of the various forms of public participation, direct discussions with local citizens about the DFC process, potential avenues for collaboration and involvement may be the most effective way to engage and invite direct participation. Certainly, disparate voices will be heard as the diversity and depth of public involvement moves forward. For example, public meetings associated with the DFC process in Glenn Canyon brought anglers opposed to the Glen Canyon Dam releases together with those who wanted to bring back the native humpback chub population. Indeed, incorporating such disparate views into the DFC process and coming to a compromise is one of the hallmarks of the DFC process and challenge. Janet Balsom (Deputy Chief, Science and Resource Management, Grand Canyon National Park) noted that the most effective way to engage multiple visions is to clearly articulate the legal frameworks that are required to be met as part of meeting desired future conditions. This provides clear expectations to be set from the very beginning with regard to the mandates that might have to take precedent. Developing clearly defined parameters and sidebars to focus the discussion can be helpful in creating the context for formulating DFCs around set guidelines.

Chinati Mountains, Texas
Photo: Charlie Llewellin

One of the priorities for the BBCC is to augment public participation such that 'the binational public' of the Big Bend region becomes an integral part of our meetings and decision-making processes. Over the last few years, progress has been made in this regard. Small groups of citizens from the town of Boquillas, Coahuila, work directly and regularly on implementing river restoration actions, which has opened lines of communication and trust, setting the stage for deeper involvement of the community in river efforts. In addition, the fact that members of the boating community in Terlingua, Texas, are also involved directly in river restoration efforts opens similar lines of communication with that important community.

However, much more needs to be done as our binational team moves forward with both river management, river restoration and the DFC process. Priorities for augmenting public participation might include:

- Conducting several meetings in the border towns of Ojinaga, Presidio, El Mulato, Terlingua, and Boquillas to review river efforts and invite involvement;
- Pursue the establishment of a river community-based NGO that could help to foster and organize participation of riverside citizens; and
- Initiate studies to better understand the connection between the river work and potential socio-economic benefits of river restoration (i.e., DFCs) to riverside citizens. By themselves, such studies will do nothing to augment public involvement. However, information that connects biophysical benefits of the river work to socio-economic benefits to riverside citizens will be extremely valuable in promoting and encouraging citizen involvement in our efforts.

Proposed Next Steps in the DFC Process for the Rio Grande in Big Bend

In light of the guidelines provided above, the following steps are suggested to carry out the DFC process, under the authority of the International Boundary and Water Commission (IBWC):

1. **Assemble a DFC team (e.g., Steering Committee)**
    a) Develop an overall strategy for the process
        i) Share lessons learned among agencies
        ii) Discuss any existing DFCs frameworks and existing agency mandates and authorities that may guide the DFC process
    b) Establish leadership, involvement, and roles
        i) City, state, county/*municipio* and federal agencies
        ii) NGOs, conservation organizations, nonprofit affiliations
        iii) Indigenous cultures
        iv) Public officials, public
2. **Facilitate discussions**
    a) Conduct several open meetings, closed meetings, field visits, etc.
        i) What is/are the main question(s)/objective(s)/goal(s)
            1. What is being restored?
            2. Why is it being restored?
            3. Can it be restored, rehabilitated, or maintained?
            4. Who will benefit?
    b) Present (at meetings) historical description of the Rio Grande
        i) Life history (Chronology of events)
            1. Human disturbances (social/cultural influences)
            2. Developments (social/economic influences)
            3. Policies (social/political influences)
        ii) Natural history (hydroecological factors)
            1. Physical changes (hydrology, geomorphology)
            2. Biological changes (ecology, flora, fauna)
    c) Outline future considerations
        i) Policy changes
            1. Land ownership/jurisdiction
            2. River management

ii) Climate Change uncertainty
   1. Pressure on water supplies
   2. Species range shifts
   3. Stochastic events (floods/fires)

d) Compromise among stakeholders and prioritize needs and opportunities
   a) What is practical/realistic?
   b) What is attainable/achievable?
   c) Cost/benefit analysis, action versus no-action alternatives

3. **Finalize DFCs for specific scope of work**
   a) Define and state concise DFCs
   b) Establish a scale (quantitative/qualitative?)
   c) State assumptions and potential errors in the process

Summary of Science, Rehabilitation, and Monitoring Activities Conducted along the Big Bend Reach of the Rio Grande

To inform the DFC development process, information and literature on science, rehabilitation, and monitoring activities conducted to date along the Big Bend reach of the Rio Grande was synthesized and summarized in Appendix II. Given the vast amount of science, rehabilitation, and monitoring activities conducted binationally in the Rio Grande basin, criteria were developed for selecting research material pertinent and most appropriate for this particular exercise, allowing a filter for identifying the most pertinent activities for inclusion in this report.

The criteria used were as follows:

1) Investigations, rehabilitation, monitoring and other activities had to be river- or bottomland-focused, which includes tributaries of the Rio Grande (i.e., efforts that were predominately upland-focused were not included).
2) Investigations, rehabilitation, monitoring and other activities needed to be geographically focused on the Big Bend reach of the Rio Grande (defined for the purposes of this report as the reach that extends from the confluence of the Rio Grande and Río Conchos to Amistad Dam).
3) The results of the investigations, rehabilitation, monitoring and other activities considered were documented in one form or another, i.e., in order to be included in this summary, a paper (or electronic) trail had to exist that summarized objectives, methods and results of the activity being considered.
4) Exceptionally, "on-the-ground" rehabilitation and other activities (e.g., efforts to eradicate giant cane) that typically are not well-documented were included, to the extent possible.
5) The summary results here of existing science, rehabilitation, and monitoring activities are intended to be updated as this document is reviewed and more research becomes available.

In general, information was collected and organized in the following broad categories:

1) Literature review – A literature review of all relevant published and available articles, reports, technical papers, and dissertations was conducted. Where possible, all documents were submitted to the World Wildlife Fund.
2) Rehabilitation activities – These include "on-the-ground" efforts that are primarily rehabilitation efforts and do not have final reports or summaries available. These are primarily verbal summaries.
3) Hydrology research and mapping projects "in-progress" – These include "in-progress" research that will likely result in a peer-reviewed article or dissertation.
4) Rio Grande Basin-wide projects – These include large, basin-wide projects that may contain relevant studies. Delving into these now was considered too time-consuming but information there might ultimately prove valuable.
5) Other literature citations – Several documents were discovered of potential relevance to this work but were not included for the following reasons: 1) the report/article was not available as a digital file, 2) time constraints did not allow the gathering of the information, and 3) there was no way to obtain it. A list of these works is included.

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

Appendix I: Examples of Desired Future Conditions

Example 1: National Park Service (Glen Canyon Dam operations/Grand Canyon National Park)

Overview

The Glen Canyon Dam Adaptive Management Program (AMP) is responsible for providing guidance to meet the goals of the Grand Canyon Protection Act, which includes protecting, mitigating adverse impacts to the Glen Canyon Dam, and improving the resources downstream from it. The operations at the dam affect hydropower generation but also impact sediment retention and distribution, aquatic and terrestrial plants and wildlife, and social values such as recreation and visitor experience. A DFC *ad hoc* committee was assembled by the Adaptive Management Working Group (AMWG) to revise and update past DFCs provided by the US Department of the Interior (USDOI). Phase One DFCs were intended to be statements of qualitative goals and objectives for the AMP, realistic and achievable through the operation of Glen Canyon Dam and related activities, subject to the Law of the River and other laws and authorities, and consistent with the Grand Canyon Protection Act (USDOI 2011). Phase Two DFCs, a revision initiated in 2009 and which is ongoing, will be quantitative, with intent to add measureable, objective, and implementable criteria to the Phase One DFCs.

Lessons Learned

Anne Castle (Assistant Secretary for Water and Science, USDOI) stated in a memorandum that many involved with Glen Canyon Dam issues and management felt that the fundamental flaw of the (DFC) process was the lack of agreed-upon goals, following the completion of Phase One. The Phase One effort did attempt to streamline the process, providing direct, concise summaries of results that allowed the effort to move forward. The DFCs that were formulated were summarized as short, narrative descriptions to guide future management, including the Long-Term Experimental and Management Plan (LTEMP) that is co-led by the US Bureau of Reclamation (USBR) and NPS, with scientific monitoring and research conducted by the USGS through the Grand Canyon Monitoring and Research Center (GCMRC).

Mark Wondzell (Hydrologist, NPS-Water Resources Division) also stressed the need for DFCs to have some form of metrics, or measureable attributes. This is extremely important to enable understanding of how well management applications are meeting DFC goals and is a theme shared by many of the case studies.

Janet Balsom (Deputy Chief, NPS–Science and Resource Management, Grand Canyon National Park) agreed that the biggest challenge continues to be a lack of shared vision and mission. She noted that future efforts could be improved by:

1) Focus initial DFC process first on "low-hanging fruit"—issues on which the majority of participants agree (e.g., protection of endangered species and natural processes)—before tackling more contentious issues is a good strategy for developing a sense of shared purpose and team work.
2) Develop clearly defined parameters and sidebars to focus the discussion. It was noted that the NPS goals and mission are very clear and articulated in law and policy, thus DFCs should be formulated around these guidelines.
3) Foster an environment that allows all parties to remove their partisan hats and work together. Interviews with our case study participants, including Janet Balsom, revealed that politics often played a negative role and impeded progress for finalizing DFCs.
4) Build a working relationship from the beginning. Understanding multiple viewpoints, bonding from the get-go, and preserving continuity within the team ensures that everyone plays a role and provides direction and focus toward what is trying to be accomplished.

Example 2: US Bureau of Reclamation (Lower Colorado River Multi-species Conservation Program)

Overview

The 1997 Biological and Conference Opinion issued by the USFWS tasked the US Bureau of Reclamation (USBR) to "protect, enhance, restore, and acquire southwestern willow flycatcher habitat from Hoover Dam to the US/Mexico border" (USFWS 1997). This responsibility, along with the conservation and protection of 25 other species covered by the 1997 Opinion, is being carried out through the 50-year, $626 million Lower Colorado River Multi-species Conservation Program (LCR-MSCP). While the DFC process was not specifically defined and implemented for this program, the process developed by the USBR and steering committee paralleled what a sound DFC framework might look like today. Lessons gained from these efforts may help guide the DFC framework and strengthen future restoration efforts along the Big Bend reach of the Rio Grande.

Lessons Learned

Theresa Olson (Wildlife Group Manager, LCR-MSCP, USBR) offered many lessons learned during their process, including:

1) Develop a diverse team that allows different interest groups to articulate desired future conditions. The steering committee formed to guide the MSCP process was composed of 57 entities, including landowners (e.g., farmers, ranchers), water rights holders, and conservation groups, along with federal, state, and local agencies (expanded list of participation can be found at: <http://www.lcrmscp.gov/steer_committee/governance.html>).
2) Employ a third-party consulting firm to mediate and facilitate meetings. The main challenge was to promote an environment of cooperation that encouraged all parties to cooperate early on and find middle ground. Employing a unbiased consulting firm was critical, allowing practical resolutions to be put forward and evaluated using models and the best available science.
3) Importance of understanding historical biophysical conditions. Although restoration back to pre-European settlement conditions is often not realistic, it is nonetheless important to understand pre-impact conditions, the extent of change that has occurred, and the main drivers of change to the fullest extent possible. This step might be an arduous task in some cases, but the steps outlined in a 1998 USBR report (USBR 1998) defining historical, current, and potential southwestern willow flycatcher habitat is a useful template. Understanding that managing the entire river as one entity would not be possible, the MSCP divided the lower Colorado River into reaches based on historical description. The MSCP management area was defined as the 100-year floodplain and full-pool elevations of all reservoirs from Lake Mead to the Southerly International Boundary. A chronology of exploration as well as development was depicted and documented along the Colorado River. Documents used to understand the natural history included journals from explorers dating back to the 16th-19th centuries, old survey plats, historical maps, and archived aerial photography. It was also noted that the USBR and US Army Corps of Engineers are good sources for finding archived information because these agencies have been in charge of developing river resources over the last century. Collectively, these documents, along with scientific (e.g., peer-reviewed journals) and gray (e.g., technical reports) literature, resulted in a depiction of historical southwestern willow flycatcher habitat that could subsequently be compared to today's river and used to outline potential, future opportunities for restoration and enhancement of the species' habitat.
4) Importance of quantifying DFCs. The conservation measures set forth as part of the MSCP are quantifiable, allowing monitoring to accurately gauge progress toward specified objectives and for employing effective adaptive management if progress made is deemed unacceptable.
5) Need for compromise. Because the USBR's management must accommodate current water diversions and power production, the DFCs put forward needed to recognize the presence of dams and levees, which are subjected to the current realities of the Law of the River. Setting DFCs in this context necessitated compromise between true restoration and what is practical and feasible, given the current biophysical constraints of the river.

Example 3: **US Department of Agriculture/US Forest Service (forest management plan)**

Overview

As with any federal agency, the US Forest Service (USFS) has a specific mission, but its motto, "Caring for the Land and Serving People," and its "sustainable, multiple-use management concept" perhaps makes this agency the most open to public input and guidance. Every national forest or grassland uses the DFC process as a tool for updating its Land and Resource Management plan, which is revised every 15 years to incorporate new information, account for changes in national policy and direction, and address new issues and opportunities. While the Southwestern Region (Region 3) manages 12 forests and one grassland in Arizona and New Mexico, this review focuses on the Prescott National Forest.

Prescott National Forest

The Prescott National Forest uses the DFC process to guide revisions and to depict DFCs in a timeless, descriptive manner. Given the multiple objectives and goals inherent in Prescott National Forest's mission to conserve natural resources and develop provisions that benefit the economy and public experience, among other responsibilities, DFCs and land management goals are described at multiple, nested scales that include physical, biological, and social/economic resources. DFCs are given for the following physical aspects of Prescott National Forest: climate, airsheds, and watersheds. For its biological resources, DFCs are described for vegetation, aquatic wildlife, and terrestrial wildlife. For social and economic resources, DFCs are presented for recreation, transportation, and cultural values.

In many cases, a DFC matches the current condition; so the goal is to retain existing characteristics. This approach ensures that any proposed action or management practice that does not meet a specified DFC must be amended in such a way that it trends toward the DFC. As put forward in Prescott National Forest's Land and Resource Management Plan, DFCs are timeless, having no specific date by which they are considered "completed." As such, they are defined as "ecological and socioeconomic attributes toward which management of the land and resources of the plan area are directed" (USDA 2012). They are not intended to finalize decisions or approve activities, but more to guide the development of forest projects and activities.

Appendix II: Summary of Science, Rehabilitation, and Monitoring Activities Conducted along the Big Bend Reach of the Rio Grande

PHYSICAL AND CHEMICAL INVESTIGATIONS

REMOTE SENSING

Study/date	**Watershed Assessment along a Segment of the Río Conchos in Northern Mexico using Satellite Images**; 2004
Study area	lower Río Conchos (~100 km long)
Purpose	Determine if and how satellite images could be used to evaluate the ecological impacts of precipitation and land use onto the riparian area and water quality of a segment of the lower Río Conchos.
Findings	Variations in water levels and surface changes of reservoirs along the Río Conchos, their water quality, riparian vegetation abundance, soil salinity and land use were determined from analysis of four Landsat Thematic Mapper (TM) images taken over a period of 10 years. A variety of image enhancement techniques and collected ground data were used. A proliferation of "abandoned' irrigation plots were detected as drought conditions intensified.
Next steps	Obtain additional imagery and ground data (including ground truthing) to conduct a detailed supervised classification of the entire agricultural region so that a more complete estimation of the extent of the drought conditions could be determined for the lower Río Conchos basin.
Principal investigator and affiliation: Melida Gutierrez, Missouri State University	

SEDIMENT

Study/date	**Stratigraphic, Sedimentologic, and Dendrogeomorphic Analyses of Rapid Floodplain Formation along the Rio Grande in Big Bend National Park, Texas**; 2011
Study area	Two excavated trenches near Castolon and Rio Grande Village along the Rio Grande in Big Bend National Park
Purpose	Conduct stratigraphic, sedimentologic, and dendrogeomorphic analyses within two long floodplain trenches to precisely reconstruct the timing and processes of recent floodplain formation.
Findings	This study shows that the channel of the Rio Grande narrowed through the oblique and vertical accretion of inset floodplains following channel-widening floods in 1978 and 1990–1991.
Principal investigator and affiliation: David J. Dean, Utah State University	

WATER QUALITY

Study/date	**Rio Grande/Río Bravo Toxic Substance Study: Phase 1** (1992-1993); 1994
Study area	Sample sites include mainstem and tributary stations along the Big Bend reach of the Rio Grande
Purpose	The main objective was to screen the system for the occurrence and impact of toxic chemicals. The goals were to clarify concerns about present conditions in the river, and to determine if existing water quality controls are adequate
Findings	The study identified 30 toxic chemicals that exceeded screening levels and are considered to be of potential concern in the Rio Grande system.
Next steps	Follow-up binational studies were recommended for the purpose of better defining the degree of impact, assessing temporal variation, and further identifying sources of toxic chemicals.
Principal investigator and affiliation: International Boundary and Water Commission (US and Mexico sections)	

Study/date **Rio Grande/Río Bravo Toxic Substance Study: Phase 2** (1995); 1998

Study area Sample sites include mainstem and tributary stations along the Big Bend reach of the Rio Grande

Purpose Continue to assess and characterize the extent of toxic contamination of the Rio Grande and its tributaries along the international reach.

Findings Identified 28 toxic chemicals that exceeded criteria/screening levels. The Phase 2 report consists of 2 volumes. Volume 1 consolidates findings reported by both countries. Volume II contains technical assessment reports and the complete Phase 2 data set. Sediment and fish tissue data should be regarded as the most meaningful basis for comparing conditions during the respective phases of the study because they are better indicators of existing conditions.

Next steps Create a binational workgroup for the routine monitoring of the Rio Grande. Exact sources of a particular contaminant are difficult to pinpoint; this study should be considered a starting point, and not an answer to all water quality issues facing the Rio Grande. Concerns identified in this study help focus resources on sites and contaminants most likely to impair water quality.

Principal investigator and affiliation: International Boundary and Water Commission (US and Mexico sections)

WATER/STREAM FLOW STUDIES

Study/date **Channel Responses to Declining Flow on the Rio Grande between Ft. Quitman and Presidio, Texas**; 1993

Study area Ft. Quitman to Presidio, TX

Purpose Describe changes in channel geometry (Ft. Quitman – Presidio, TX, reach) where flow has been depleted by upstream water control and diversion systems.

Findings Channel morphologic response was described by reaction time and categorized as one of three stages of channel evolution: channel shrinkage, stabilization with aggradation, and re-aggrading as a result of bed load deposition at tributary mouths. The river approached a balanced sediment budget by increasing its capacity (via reduced sinuosity and increased gradient), and decreasing sediment input by migrating away from tributaries. The river approached a balanced sediment budget both by increasing its capacity by shortening and steepening, and by decreasing sediment input by migrating away from tributaries.

Principal investigator and affiliation: Benjamin L. Everitt (Retired)**, Utah Rock Art Research Association**

Study/date **Hydrogeologic Framework of the Edwards-Trinity Aquifer System, West-Central Texas**; 1996

Study area Edwards-Trinity aquifer; multi-county

Purpose Describe the hydrogeologic framework of the Edwards-Trinity aquifer system.

Findings Report includes: 1) depositional, tectonic, diagenetic, and stratigraphic conditions of the rocks that compose the aquifer system, 2) hydraulic characteristics, aquifers, and confining units, and 3) correlation chart and seven hydrogeologic sections illustrate the relations between chronostratigraphic and lithostratigraphic units and the aquifers and confining units in study area.

Principal investigator and affiliation: Rene A. Barker, Texas State University-San Marcos

Study/date **Hydrology and Geomorphology of the Rio Grande and Implications for River Rehabilitation**; 2003

Study area Rio Grande basin

Purpose Describe hydrologic and geomorphic conditions of the Rio Grande during the past century and summarize changes in the water and sediment flux.

Findings A comprehensive restoration of the Rio Grande is impossible. Dams and diversions have altered the natural hydrologic regime and sediment flux, thereby producing significant geomorphic changes in the channel. No single environmental management goal is appropriate for all of the Rio Grande. Priorities and associated rehabilitation goals must be established for different segments of the river to improve ecological processes.

Principal investigator and affiliation: John C. Schmidt, US Geological Survey

Study/date	**An Evaluation of the Effects of Hot Spring Discharge on the Rio Grande in Big Bend National Park, Brewster County, Texas**; 2004
Study area	Thermal springs along the Rio Grande between Santa Elena Canyon and Rio Grande Village in Big Bend National Park
Purpose	Assess the discharge and chemical contributions of thermal springs on the river system.
Findings	Findings include: a detailed review of hydrology and hydrogeology of the Rio Grande basin, thermal spring contribution "improves" the water quality (lowers the TDS) only in the winter months, the ability to interpret volumes of water (mass balance approach) was hampered by the fact that the downstream (of the thermal spring) sample does not represent a complete mix. Gain/loss study conducted during the seasonal low flow/high TDS condition shows a general decrease in specific conductivity with distance downstream, and discharge for the downstream sample site was higher than the upstream discharge (average value for this study was 12.50 cfs).
Next steps	Future studies should attempt to collect downstream samples at a location more representative of the mixed system, conduct gain/loss study in summer high flow/low TDS condition, and calculate discharge for other springs.
Principal investigator and affiliation: Laurie Trevizo, Sul Ross State University	

Study/date	**Streamflow Gains and Losses and Selected Water-Quality Observations in Five Subreaches of the Rio Grande/ Río Bravo del Norte from near Presidio to Langtry, Texas, Big Bend Area, United States and Mexico**; 2006
Study area	Five subreaches of the Rio Grande extending from near Presidio, TX, to near Langtry, TX.
Purpose	Provide an initial characterization of streamflow gain and loss and water quality in five subreaches of the Rio Grande extending from near Presidio to near Langtry, Texas.
Findings	Streamflow gain and loss and water-quality constituent concentration were compared for each subreach. Subreach A was determined to be a losing reach; subreaches B, C, D, and E were determined to be gaining reaches. Subreaches A and B had measured total dissolved solids, chloride, and sulfate exceeding the general use protection criteria established by the Texas Commission on Environmental Quality. Subreaches C, D, and E did not exceed the protection criteria for any constituent concentration, but dissolved oxygen concentrations did not meet the general use criteria in these subreaches.
Principal investigator and affiliation: Timothy H. Raines, US Geological Survey	

Study/date	**Texas Instream Flow Studies: Technical Overview**; 2008
Study area	Texas river reaches and segments
Purpose	In 2001, Senate Bill 2 was enacted by the 77th Texas Legislature, which established the Texas Instream Flow Program. The purpose of the program is to perform scientific and engineering studies to determine flow conditions necessary for supporting a sound ecological environment in the river basins of Texas.
Findings	This document describes the general process and scientific studies that agencies will use to determine flow conditions necessary for supporting a sound ecological environment within the rivers and streams of Texas.
Principal investigator and affiliation: Texas Commission on Environmental Quality	

Study/date	**A River Transformed: Historic Geomorphic Changes of the Lower Rio Grande in the Big Bend Region of Texas, Chihuahua, and Coahuila**; 2009
Study area	Three alluvial study reaches: Castolon reach (14.5 km between the mouth of Terlingua Creek and Castolon, TX); Johnson Ranch reach (12.5 km in the vicinity of the Johnson Ranch gauge); and Boquillas reach (12.1 km near Boquillas, Coahuila).
Purpose	Conducted a comprehensive analysis of historical channel change through hydrologic analysis of historic stream gauge data, analysis of discharge measurement notes, historic oblique and aerial photograph analysis, field mapping of geomorphic surfaces, and stratigraphic and dendrogeomorphic analysis of inset floodplain deposits.
Findings	Reductions in mean and peak stream flow to the lower Rio Grande in the Big Bend region resulted in channel narrowing, vertical floodplain accretion, and non-native vegetation establishment. The channel of the lower Rio Grande has narrowed by more than 50% since 1941. The most significant periods of channel narrowing occurred during drought and increased stream-flow management. The establishment of non-native riparian species promoted sedimentation, bank stabilization, and additional channel narrowing. Management options include non-native vegetation removal and managed dam releases.
Principal investigator and affiliation: David J. Dean, Utah State University	

Study/date	**Historical Perspective of Surface Water and Groundwater Resources in the Chihuahuan Desert Network (CHDN), National Park Service**; 2009
Study area	Parks within the CHDN include Big Bend National Park and Rio Grande Wild and Scenic River. Surface water quality monitoring sites include locations within the Big Bend reach of the Rio Grande mainstem.
Purpose	Improve understanding of surface and ground-water hydrology, water-quality conditions and trends, and the condition of macroinvertebrate communities in major water resources of the CHDN park units.
Findings	Provides results from trend analyses of available data that address four of CHDN's vital signs: surface-water quantity/hydrology, surface-water quality, invertebrates in aquatic systems, and ground-water quantity/hydrology.
Principal investigator and affiliation: Stephen D. Porter, Texas State University-San Marcos	

Study/date	**The Role of Feedback Mechanisms in Historic Channel Changes of the Lower Rio Grande in the Big Bend region**; 2011
Study area	The Big Bend region extends from the confluence of the Rio Grande and Río Conchos 490 km downstream to Amistad Reservoir
Purpose	Describe the characteristics of negative and positive geomorphic feedbacks in historic channel changes of the lower Rio Grande. (Builds upon David Dean's thesis, 2009)
Findings	Analyses indicated that three historic floods have acted as negative feedbacks by resetting the narrowed channel to a previous, wider state; however, channel narrowing resumed. Channel narrowing by vertical accretion occurred simultaneously with the rapid establishment of non-native riparian vegetation, which created a positive feedback and exacerbated the processes of channel narrowing and vertical accretion. The persistence of positive feedbacks have led to unusually high rates of sediment accumulation. These changes reflect a shift in the geomorphic nature of the Rio Grande from a wide, laterally unstable, multi-thread river, to a laterally stable, single-thread channel with cohesive, vertical banks, and few active in-channel bars.
Principal investigator and affiliation: David J. Dean, Utah State University	

Study/date	**Hydrogeologic Study of Springs in the Lower Canyons of the Rio Grande, Rio Grande Wild and Scenic River**, **Texas**; 2012
Study area	Lower Canyons reach of the Rio Grande Wild and Scenic River (the section of the Rio Grande from Maravillas Creek to Dryden Crossing)
Purpose	Conduct structural and geochemical studies of the springs to determine recharge areas, ground-water flow paths, the effects of regional structure, and the influence that the springs have on water quality and quantity in the Rio Grande.
Findings	Data collected include: spring data, spring chemistry, chemical data, and well data. Data was used to create a potentiometric map to assist in groundwater flow analysis and a GIS atlas. This work provides information that reveals the nature of the Edwards-Trinity Plateau Aquifer (ETPA). The springs dilute the Rio Grande and comprise approximately 60–70% of base flow in the Rio Grande, providing fresh water to users downstream.
Next steps	Future studies should include the reach below the Lower Canyons. A detailed structural analysis of the study area is warranted to provide insight into major folds, faults, and joint sets and how they influence the ETPA via mixing, flow paths, and groundwater barriers. A study of well data would improve this project, including the groundwater data for the adjacent aquifers in Mexico (Cerro Colorado-La Partida and Serranía del Burro).
Principal investigator and affiliation: Billie A. Brauch, Sul Ross State University	

Study/date	**Water Mass Balances for the Rio Grande/Bravo from Fort Quitman, Texas to Foster Ranch Near Langtry, Texas: An Assessment of Factors**; 2012
Study area	The section of the Rio Grande between Fort Quitman and Langtry, Texas
Purpose	Assess the spatial and temporal variability of elements intervening in the water mass balance for the section of the Rio Grande between Fort Quitman and Langtry, Texas during the time period extending from January 1990 through December 2005.
Findings	Results from this study indicate that surface runoff and groundwater inflows constitute an important source of water to the lower river reaches. Groundwater extractions within the river's basin and out of basin water transfers for Rio Grande water users create a significant impact on the river's water resources. Groundwater extractions from the Upper Rio Grande reach should be limited and regulated in order to avoid a drastic reduction of water availability on this region.
Principal investigator and affiliation: Ramiro Lujan, University of Texas at El Paso	

BIOLOGICAL INVESTIGATIONS

Study/date	**Baseline Assessment of Instream and Riparian-Zone Biological Resources on the Rio Grande in and Near Big Bend National Park, Texas**; 2002
Study area	Assessment sites at Colorado Canyon, Santa Elena, Johnson's Ranch, Boquillas, and Black Gap Wildlife Management Area along the Rio Grande
Purpose	Provide baseline data and supporting interpretations on the occurrence and distribution of instream and riparian-zone biological resources of the Rio Grande in five reaches in and near BBNP. The report describes the field methods of assessment of stream habitat, fish communities, and benthic macro invertebrates.
Findings	Differences in stream-habitat conditions and riparian vegetation reflect differences in surface geology among the five sampling reaches. Eighteen species of fish and a total of 474 individuals were collected among the five reaches. Fish trophic structure reflected fish-community structure among the five reaches. Eighty percent of the benthic macroinvertebrate taxa collected were aquatic insects. The EPT index, named for three of these macroinvertebrate orders (*Ephemeroptera, Plecoptera* and *Trichoptera*) and taken as an indicator of the ecological health of streams, was largest for the Colorado Canyon reach and smallest for the Johnson Ranch reach.
Next steps	The three sites in BBNP are benchmark sites, marked with identifying monuments, for proposed long-term monitoring.
Principal investigator and affiliation: J. Bruce Moring, US Geological Survey	

Study/date	**Biological Resources Survey: Rio Grande and Tijuana River Flood Control Projects; New Mexico, Texas and California**; 2005
Study area	Includes: Presidio-Ojinaga Flood Control Project reach (extends 15.2 miles along the Rio Grande and includes spur levees between the sister cities of Presidio, Texas, and Ojinaga, Chihuahua, Mexico)
Purpose	This is a literature review of biological resources such as habitats, communities, and species in the Rio Grande and Tijuana River watersheds, focusing on those resources within the five flood control project areas and includes the results of a new field survey in the Presidio project area.
Findings	General descriptions of vegetation and wildlife are provided based on recent and historical information obtained from the literature and supplemented by the new field survey. Survey identifies general threats to vegetative and wildlife communities and reveals the species of concern for the project area. Observations include: 1) aquatic environment appears to be most impacted by sedimentation, channelization/bank disturbance, and likely to include human and/or animal waste from untreated or marginally treated wastewater/industrial waste, 2) riparian habitats consist of a mixture of native and non-native species with non-native species dominant in some areas, 3) unvegetated areas are regularly disturbed by US Border Patrol activities, and 4) several types of terrestrial organisms that are expected to be common in this area, are notably absent.
Principal investigator and affiliation: International Boundary and Water Commission (US Section)	

AMPHIBIANS

Study/date	**Evaluation of Canoe Surveys for Anurans along the Rio Grande in Big Bend National Park, Texas**; 2002
Study area	Four river stretches along the Rio Grande mainstem in Big Bend National Park
Purpose	Explore temporal and spatial variation in amphibian counts from audio and visual surveys from canoes and test associations between amphibian counts and environmental variables and document amphibian-habitat associations along the banks of the Rio Grande.
Findings	Seven anuran species were documented (including four rare species), but Rio Grande leopard frogs *(Rana berlandieri)* accounted for 96% of the visual counts. Observed populations of *R. berlandieri* were influenced by river gauge levels and air and water temperatures, suggesting that surveys should be conducted under certain environmental conditions to maximize counts and maintain consistency. Spotlight surveys from canoes were useful for visual counts of anurans; however chorus surveys were not as useful probably because river trips were not scheduled to coincide with rain events.
Next steps	Future work should determine the extent of annual variation in anuran counts using this method (spotlight survey), address the bias associated with the method (use observation or capture-based methods for estimating detection rates and population sizes), and collect environmental/habitat data among the sampling areas.
Principal investigator and affiliation: Robin Jung, USGS Patuxent Wildlife Research Center	

Study/date	**Community Assembly of Xeric-adapted Anurans at Multiple Spatial Scales**; 2005
Study area	Baseline surveys of amphibians were taken at sites along the Rio Grande in Big Bend National Park, and at the Cañon de Santa Elena and Maderas del Carmen Protected Areas, Mexico.
Purpose	Determine the distribution of anurans in the Big Bend region of the Chihuahuan Desert and to examine how abiotic and biotic factors shape the composition and structure of anuran communities at multiple spatial scales.
Findings	At the landscape level anuran distributions seem to be influenced by environmental factors that influence the survival of the adult stage. At the level of the breeding site, microhabitat and abiotic components of the aquatic environment do not seem to play an important role in influencing breeding site use by different species. Rather, it seems likely that predation on tadpoles by predators is important in limiting the distribution of some species and that the fast-developing *Scaphiopus couchii* may exclude other species from using sites via oophagy and predation on small tadpoles.

Principal investigator and affiliation: Gage Hart Dayton, Texas A&M University

BIRD

Study/date	**Environmental Contaminants in Prey and Tissues of the Peregrine Falcon in the Big Bend Region, Texas, USA**; 2002
Study area	Santa Elena Canyon, Mariscal Canyon, and Boquillas Canyon in Big Bend National Park; Black Gap Wildlife Management Area along the Rio Grande
Purpose	Determine levels of selected inorganic and organic contaminants in salvaged carcasses and tissues of the peregrine falcon, and in potential prey of the peregrine falcon and to evaluate potential impacts of environmental contaminants on reproduction of peregrine falcons in Big Bend National Park.
Findings	Analyses of potential prey indicate that peregrine falcons nesting in the park may be affected by contaminants such as selenium (Se), mercury (Hg), and possibly DDE.
Next steps	A more concerted effort needs to take place so that a wider range of peregrine falcon prey and samples from nestlings and addled eggs are analyzed.

Principal investigator and affiliation: Miguel A. Mora, US Geological Survey, Columbia Environmental Research Center, c/o Wildlife and Fisheries Sciences, Texas A&M University

Study/date	**Further Assessment of Environmental Contaminants in Avian Prey of the Peregrine Falcon in Big Bend National Park, Texas**; 2007
Study area	Mariscal Canyon along the Rio Grande, Big Bend National Park
Purpose	Continue assessment and provide additional support to the hypothesis that some contaminants, particularly Se and Hg, might be implicated in reproductive failures of the peregrine falcon in Big Bend National Park. Determine differences in concentrations of contaminants among three locally abundant prey species to ascertain the contribution by each species, particularly mourning doves, to the peregrine falcon diet.
Findings	Concentrations of Se and Hg were present at high levels (up to 11 and 2.2 mg/g dry weight, respectively) in some avian prey and could be implicated in reproductive failures of the peregrine falcon in Big Bend National Park. All other inorganic elements were below concentrations known to affect reproduction or to be associated with other deleterious effects in birds. Of all the organochlorines analyzed, only DDE and total PCBs were present above detection limits in all species, although at low concentrations.
Next steps	A more thorough assessment that considers the potential contribution of contaminants from each potential prey species in the diet is warranted. Additionally, further monitoring of sites adjacent to and throughout the park might help identify the potential sources of Hg and Se.

Principal investigator and affiliation: Miguel A. Mora, US Geological Survey, Columbia Environmental Research Center, c/o Wildlife and Fisheries Sciences, Texas A&M University

Study/date **Mitochondrial Mutation: A Possible Change in the Genetic Code of Endangered *Gambusia gaigei (Poeciliidae)***; 1999

Study area Rio Grande Village refugium pond, Big Bend National Park

Purpose Assess individual genetic variation as well as to observe general molecular evolution.

Findings Due to the presence of compensatory mutations, it is hypothesized that mutant tRNA suppressors and/or tRNA wobbling may contribute to the viability of the cytochrome b gene in the rare Big Bend gambusia *(Gambusia gaigei)*.

Principal investigator and affiliation: Christopher M. Seabury, Sul Ross State University

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Study/date **Conservation and Status of the Fish Communities Inhabiting the Río Conchos Basin and Middle Rio Grande, Mexico and United States**; 2002

Study area Various sampling sites: on Río Conchos and on Rio Grande from above the confluence to the Dryden area, Texas (includes tributaries and creeks).

Purpose Sampled the Río Conchos basin and adjoining aquatic habitats in the Rio Grande to assess the status of the fish of this region. Compared data to a series of historic collections to better indicate the magnitude and direction of changes in the aquatic communities that either have occurred or are presently occurring.

Findings Most sites showed some degree of human-induced impacts. A number of potentially threatened fish were either abundant at only a few sites or rare or absent throughout the localities sampled. Without concerted binational efforts to conserve the fish of the region, further deletions to the native fish fauna will likely occur.

Principal investigator and affiliation: Robert J. Edwards, The University of Texas-Pan American

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Study/date **Biomonitoring of Environmental Status and Trends (BEST) Program: Environmental Contaminants and Their Effects on Fish in the Rio Grande Basin**; 2004

Study area Big Bend region collection stations were at Foster Ranch, Langtry, TX, and below Amistad Reservoir, TX, along the Rio Grande.

Purpose Document the occurrence and distribution of contaminants and their effects on fish in the largest rivers of the Rio Grande basin and evaluate the potential risk represented by these contaminants to other biota.

Findings Elemental contaminants were most evident in fish from sites in the central Rio Grande basin. Selenium (Se) concentrations were high enough to represent a threat to fish and wildlife. Amistad site: fish with slightly elevated concentrations of Se were also characterized by comparatively high organosomatic indices, proportions of fish with external lesions, and health assessment index (HAI) scores; elevated concentrations of total Hg in bass. Langtry site: arsenic (As) concentrations were comparatively high and a comparatively large percentage of carp had high HAI scores caused primarily by the presence of parasite-induced external lesions. Data are available via a national database: <http://www.cerc.usgs.gov/data/best/search/index.htm>.

Principal investigator and affiliation: Christopher J. Schmitt, US Geological Survey

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Study/date **Status of Fish Communities in the Rio Grande, Big Bend National Park, Texas - Comparison Before and After Spring 2003 Period of Low Flow**; 2005

Study area Assessment sites at Santa Elena, Johnson's Ranch, and Boquillas along the Rio Grande in BBNP

Purpose Re-evaluate the status of fish communities in three reaches of the Rio Grande in Big Bend National Park (previous established in 1999; Moring, 2002 included here) and determine any measurable differences between the fish community status of 1999 and that of 2003–04 that likely are attributable to the spring 2003 period of low flow (less than 1 cubic meter per second for 58 consecutive days).

Findings The findings of this study provide some evidence that the spring 2003 period of low flow affected fish communities and include: decrease in number of fish species collected for all three sites, less similarity in fish communities at Johnson's Ranch and Boquillas sites than Santa Elena, and a shift in fish communities from small minnow-dominated in 1999 to a population largely of gar and catfish at Johnson Ranch and Boquillas sites in 2004. Differences in flow conditions between the two downstream sites and the Santa Elena site might account for the dissimilar findings (gauge records indicate flows were greater and more sustained at the Santa Elena site in spring 2003 compared to the Boquillas and Johnson Ranch sites).

Principal investigator and affiliation: J. Bruce Moring, US Geological Survey

Study/date	**Freshwater Fishes and Water Status in Mexico: A Country-wide Appraisal**; 2008
Study area	Mexico
Purpose	Address the interest on the global status of freshwater fishes as basic bio-indicators of the availability of freshwaters by quantity and quality. To gain such a global perspective requires a country-by-country review.
Findings	Provide a summary of the state of knowledge and understanding of freshwater fish and hydrological basins, as inclusively as possible, for Mexico.
Next steps	Provide recommendations to manage freshwater fishery resources.

Principal investigator and affiliation: S. Contreras-Balderas, Comité de Especies Prioritarias–Subcomite Peces de Agua Dulce, Semarnat. Mexico, 2003–2006; Comité de Especies en Riesgo, Sociedad Ictiológica Mexicana, A.C., Mexico

Study/date	**Mercury Contamination of the Fish Community of a Semi-arid and Arid River System: Spatial Variation and the Influence of Environmental Gradients**; 2010
Study area	Big Bend area/Rio Grande mainstem sites (Contrabando, Santa Elena Canyon, and Hot Springs) and tributary (Terlingua and Tornillo Creeks)
Purpose	Examine Hg concentrations in fish of the Lower Rio Grande/Río Bravo del Norte drainage, Texas and in several of its major tributaries in order to assess whether variation of spatial Hg concentrations occurs in fish in the drainage and if patterns of Hg contamination in fish relate to gradients in environmental variables.
Findings	Study shows spatial variation in fish Hg across the lower Rio Grande drainage, with highest concentrations found in the Big Bend region and that fish Hg concentrations are related to specific environmental variables. Results from the present study indicate that Hg contamination of the Rio Grande/Río Bravo del Norte has substantial implications for management and protection of native, small-bodied obligate riverine fish, many of which are imperiled.
Next steps	Future studies of Hg dynamics in the Rio Grande drainage should focus efforts on sampling larger piscivorous fish, assessment of temporal patterns of Hg concentrations in sediments and the biota, and the identification of locations within sites where methylmercury production occurs.

Principal investigator and affiliation: Alexandra Smith, Texas State University, San Marcos

Study/date	**Cross System Transfer of Organic Matter and Contaminants in Arid and Semi-arid Riverine Systems**; 2011
Study area	Rio Grande mainstem sites at Santa Elena Canyon and Hot Springs. Four low-order, spring-fed perennially flowing sites tributary systems at Terlingua Creek, Tornillo Creek, Independence Creek, and Dolan Creek.
Purpose	Examine the relative contribution of sources of autochthonous and allochthonous organic matter to fish communities in the Rio Grande drainage and assess patterns in the potential movement of Hg from streams to riparian consumers. Research focused on three main areas: (1) the cycling of organic matter and contaminants within and across aquatic-terrestrial interfaces, (2) landscape- and regional-level parameters that influence macroinvertebrate assemblages at local and landscape spatial scales, and (3) the effect of environmental processes on aquatic communities (studied via stable isotope-derived ecometrics).
Findings	Results provide a greater understanding of the movements of organic matter and contaminants across local and landscape-level environmental gradients.

Principal investigator and affiliation: Alisa A. Abuzeineh, Texas State University, San Marcos

Study/date	**Intra-annual Variation in fish Communities and Habitat Associations in a Chihuahua Desert Reach of the Rio Grande/Río Bravo del Norte**; 2012
Study area	Rio Grande mainstem sites: Contrabando Creek (BBRSP); Santa Elena Canyon, USGS gaging station/Castolon, Johnson Ranch, Tornillo Creek, and Boquillas Canyon (BBNP); Maravillas Creek (Black Gap Wildlife Management Area)
Purpose	Quantify occurrence, abundance, and habitat associations among local communities, assess local community and habitat change with respect to intra-annual variation in streamflow, and describe relationships among abundant small-bodied taxa in terms of current velocity suitability and associated implications for community dominance.
Findings	Fish community composition indicated spatial and temporal variations, but habitat characteristics showed more variation between sampling sites than between months. Results suggest that large flood pulses and maintenance of habitat heterogeneity are necessary for the persistence of both declining and intact local fish communities in the Rio Grande/*Río Bravo del Norte*.

Principal investigator and affiliation: Thomas C. Heard, Texas State University–San Marcos

INVERTEBRATES AND MICROORGANISMS

Study area	**Characterizing Wetlands using Adult Insect Communities**; 1993-1995 (Study period)
Study area	Four geographic regions of Texas, including Rio Grande Village wetlands
Purpose	Investigate whether adult insect communities could serve as useful indicators of wetland structure and function
Findings	Results suggest that *Trichoptera* families may provide a useful tool for characterizing wetland ecosystems.
Principal investigator and affiliation: Eric N. Wold/Ralph J. Garono, Earth Design Consultants, Inc.,	

Study/date	**Insects Associated with Salt cedar, Baccharis and Willow in West Texas and Their Value As Food for Insectivorous Birds: Preliminary Results**; 2003
Study area	Sample sites include along the Rio Grande mainstem; specific locations unknown.
Purpose	Compare species and populations of both adult and immature insects that were collected from saltcedars compared with native willows *(Salix* spp.) and *Baccharis salicifolia* (baccharis, also called "mule fat" or "seepwillow").
Findings	Total numbers of insects was greatest on saltcedar but 86 to 94% were of one species, the small, exotic leafhopper, *Opsius stactogalus*. Species diversity was much greater in native willows and baccharis. While some birds feed readily on leafhoppers, many insectivorous birds do not and instead prefer the native insect types present on the willows and baccharis.
Principal investigator and affiliation: Allen Knutson, Texas A&M AgriLife Extension Service	

Study/date	**Life on the Edge: Rotifers from Springs and Ephemeral Waters in the Chihuahuan Desert, Big Bend National Park, Texas, USA**; 2005
Study area	Sample sites include Hot Springs along the Rio Grande, Rio Grande Village ponds, and the river itself.
Purpose	Describe the rotifers that inhabit the springs (seeps), streams, tanks (diked ephemeral streams), and huecos and tinajas (small and large rock pools) of Big Bend National Park
Findings	Redundancy analysis revealed significant associations between environmental parameters and species distributions among water sources. Highest species richness was found in more permanent habitats, such as ponds and springs, while species associated with rock pools were associated with high conductivity and temperature.
Next steps	Continuation of a more comprehensive study of desert aquatic systems is warranted. It is likely to increase the number of rotifers known to science, provide a better understanding of their biogeography, and elucidate the fundamental structure of these communities.
Principal investigator and affiliation: Robert L. Wallace/Elizabeth J. Walsh, University of Texas – El Paso	

Study/date	**First Record of *Bothriocephalus acheilognathi* in the Rio Grande with Comparative Analysis of ITS2 and V4-18S rRNA Gene Sequences**; 2007
Study area	From the Rio Grande mainstem at Santa Elena Canyon near the confluence with Terlingua Creek in Big Bend National Park
Purpose	Report the first record of *Bothriocephalus acheilognathi* in the Big Bend region of the Rio Grande in Texas
Findings	Identification of *B. acheilognathi* confirmed by morphologic and genetic techniques. Its prevalence was 27% and was found in the red shiner, C*yprinella lutrensis*, and Tamaulipas shiner, *Notropis braytoni*, a Rio Grande endemic and a new host record. The occurrence of *B. acheilognathi* might have negative ecological impacts on endemic fishes in the Rio Grande, several of which are fishes that could serve as definitive hosts and are of conservation concern.
Principal investigator and affiliation: Megan Bean, Texas State University–San Marcos	

Study/date	**How Well Do Single Samples Reflect Rotifer Species Diversity? A Test Based on Inter-annual Variation of Rotifer Communities in Big Bend National Park, Texas, USA**; 2007
Study area	Artificial ponds at Rio Grande Village; upper pond, water pumped from the Río Bravo and lower pond, receives water from the upper pond.
Purpose	To determine how well species' richness is reflected in these studies, we examined variation of rotifer species' richness and monogonont community structure from one year to the next in 10 aquatic systems, comprising four habitat types—springs, rock pools (tinajas), former cattle tanks, and artificial ponds.
Findings	Both species' richness and species' turnover indices (STI) varied considerably across habitat type. Species' richness varied by 2–10 between consecutive years and STI ranged from 64 to 89% over the entire study. Results indicate that rotifer community composition fluctuates greatly over time, and that rotifer community structure may be more labile than is generally believed. Species' richness, and thus biodiversity, may be dramatically underestimated in single sampling or the short-term strategies that are often employed in studies of zooplankton community structure.
Principal investigator and affiliation: Elizabeth J. Walsh, University of Texas – El Paso	

Study/date	**Occurrence and Impact of the Asian Fish Tapeworm *Bothriocephalus acheilognathi* in the Rio Grande (Río Bravo del Norte)**; 2008
Study area	Big Bend reach Rio Grande sites were located at Presidio, Texas, and Santa Elena Canyon, Terlingua Creek, and Boquillas Canyon within Big Bend National Park.
Purpose	Examine the presence and mean intensity of *Bothriocephalus acheilognathi* in *Cyprinella lutrensis* to determine spatial and temporal patterns in several reaches of the Rio Grande and examine seasonal trends in tapeworm maturation and intraspecific competition. Assess impacts of *B. acheilognathi* infection on condition and reproduction in *C. lutrensis* to make inferences about potential impacts on other endemic cyprinid species.
Findings	Higher prevalence of spatial differences were found to occur in the Big Bend reach than in the lower Rio Grande and upper Pecos River. Highest prevalence (27%) of *C. lutrensis* was observed in BBNP in the winter. Within BBNP, prevalence was higher at mainstem sites across months ($P < 0.01$) than the tributary site (Terlingua Creek). Mean intensities across BBNP sites ranged from 1.4 to 1.7 tapeworms per fish. Information from this study provides information on potential impacts of *B. acheilognathi* infections of imperiled Rio Grande fish species.
Principal investigator and affiliation: Megan Bean, Texas State University–San Marcos	

Study/date	**Macroinvertebrate Relations with Ecoregions and Aquifers as Influenced by the Hydrology and Water Quality of Western Texas Spring Ecosystems**; 2009
Study area	Rio Grande mainstem sites include springs in the lower canyons (Wild and Scenic River)
Purpose	Test 4 hypotheses to gain understanding of the factors that determine the distribution of aquatic invertebrate species in western Texas and to provide documentation of organisms collected. Results provide new (baseline) macroinvertebrate data for 41 springs.
Findings	This research supported the hypothesis that local taxonomic composition in springs is influenced by regional differences in aquifer properties and elevation. Each factor was found to explain some variance in species-environmental relations.
Next steps	This study might have benefited from considering habitat diversity (e.g., substrate composition) and a larger sample size. Further analyses and sampling of more systems will benefit the understanding of these relationships.
Principal investigator and affiliation: Jaimie E. Maher, Texas State University–San Marcos	

Study/date	**State-wide Assessment of Unionid Diversity in Texas, including Big Bend National Park**; 2010
Study area	Rio Grande Wild and Scenic River (RIGR) in Texas; sampling began at John's Marina (Dryden Crossing), Terrell County
Purpose	Determine presence and conservation status of freshwater unionids (mussels and clams) in Big Bend National Park.
Findings	Two very rare Rio Grande unionid species are found in very small numbers at John's Marina at Dryden Pass, *Potamilus metnecktayi* and *Popenaias popeii* (live specimens). In 2010, Texas conservation status for both species was listed as threatened/critically imperiled, and *P. popeii* is also listed as a candidate for federal protection under the ESA.
Next steps	These rare Rio Grande species still persist in the river, but in very restricted areas and at low densities. Special care should be given to protect the few remaining stretches of the river that support these populations. The stretch downstream from Big Bend National Park and west of Dryden down to the confluence with the Pecos River is probably the only area on the river where live *P. metnecktayi* can still be found.
Principal investigator and affiliation: **Lyubov E. Burlakova, Great Lakes Center, Buffalo State College**	

Study/date	**Spatial and Temporal Distribution of the Asian Fish Tapeworm *Bothriocephalus acheilognathi* (Cestoda: *Bothriocephalidea*) in the Rio Grande (*Río Bravo del Norte*)**; 2010
Study area	Rio Grande mainstem sites within Big Bend National Park include Santa Elena Canyon, Terlingua Creek, and Boquillas Canyon
Purpose	Determine distribution and definitive hosts of the Asian fish tapeworm within the Rio Grande drainage and to quantify occurrences and abundances.
Findings	The parasite was collected from red shiners *(Cyprinella lutrensis)*, Tamaulipas shiners *(Notropis braytoni)*, sand shiners *(N. stramineus)*, river carpsuckers *(Carpiodes carpio)*, plains killifish *(Fundulus zebrinus)*, western mosquitofish *(Gambusia affinis)*, blue suckers *(Cycleptus elongates)*, blacktail shiners *(Cyprinella venusta)*, proserpine shiners *(Cyprinella proserpina)*, and Manantial roundnose minnow *(Dionda argentosa)*, with the last four species being new host records. With over 50 percent of Rio Grande icthyofauna in Texas considered imperiled, the occurrence and pathological effects of the Asian fish tapeworm, in combination with reduced water quantity and quality and increased habitat fragmentation, are of concern for these taxa.
Principal investigator and affiliation: Megan G. Bean, Texas State University–San Marcos	

Study/date	**Influence of Ground and Surface Water Relations on Algal Communities in the Rio Grande Wild and Scenic River**; 2011
Study area	Sampling sites include IBWC and TCEQ-USGS river gauges below the Río Conchos confluence near Presidio, Texas, to the gauge at Foster Ranch near Langtry, Texas.
Purpose	Describe algal relations with trophic and salinity conditions in the Rio Grande and the natural and human factors that influence those conditions.
Findings	The Rio Grande exhibits a gradient of salinity, nutrient, and organic enrichment extending from the Río Conchos confluence down river to Foster Ranch. Findings during low-flow conditions include: 1) algal communities in the upper segment of the river were dominated by brackish-water species indicative of eutrophic to hypereutrophic conditions, 2) algal communities in the middle segment were dominated by planktonic green, blue-green, and diatom taxa indicative of mesotrophic or eutrophic conditions, and halophilic, freshwater benthic diatoms, 3) lower segment was a zone of improving water quality, resulting from considerable discharges of relatively higher-quality ground water, and algal communities were dominated by filamentous red algae, benthic diatoms, and nitrogen-fixing algae indicative of mesotrophic conditions and relatively low concentrations of dissolved nitrogen.
Next steps	Suggested future monitoring efforts include 1) assessments of algal communities in conjunction with water-quality and biological monitoring, 2) calculating and monitoring rates of river metabolism [e.g., algal productivity (Pmax) and community respiration (Rmax)] as an indicator of organic enrichment and microbial processes from existing continuous-monitoring data, and 3) results from recent hydrologic investigations could be used to estimate the percentages of flow gains attributable to groundwater inflow from spring complexes so that site selection for biological, water quality, and habitat assessments could be based on a gradient of groundwater contributions to river flow rather than a series of fixed-interval sampling locations.
Principal investigator and affiliation: Stephen D. Porter, Texas State University-San Marcos	

MAMMALS AND REPTILES

Study/date **Recent Records of Bats from the Lower Canyons of the Rio Grande River of West Texas**; 2002

Study area Lower Canyons reach of the Rio Grande Wild and Scenic River (Maravillas Creek to Dryden Crossing)

Purpose Record occurrence of bat species

Findings The report notes the occurrence of 13 bat species in the Lower Canyons, including 2 new records from Terrell County.

Principal investigator and affiliation: Loren Ammerman, Angelo State University

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Study/date **Chiropteran Community Structure and Seasonal Dynamics in Big Bend National Park**; 2002

Study area Sample sites included Cross Canyon on the Rio Grande, Terlingua Creek at Rio Grande, and Rio Grande Village Gambusia pools.

Purpose This work summarizes the efforts of year-round sampling, allowing: (1) the investigation of the seasonal activity and seasonal abundance of all bat species in the lowland regions; (2) the construction of hypotheses concerning the migration or hibernation of species that were found in low abundance, or altogether absent in winter; and (3) the study of the reproductive habits and seasonal differences in the observed sex ratios of *Chiroptera*.

Findings Collection of baseline data within chiropteran ecology to increase understanding of many species of bats.

Principal investigator and affiliation: Jana Higginbotham, Angelo State University

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Study/date **Demography and Population Structure of a Rio Grande Endemic Emydid, the Big Bend Slider**; 2010

Study area Rio Grande mainstem locations in Big Bend Ranch State Park, Big Bend National Park, and Black Gap Wildlife Management Area

Purpose Evaluate the genetic differentiation between populations of *Trachemys gaigeae gaigeae* [Big Bend slider] in Texas and New Mexico. Assess the prevalence of hybridization in extant *T. g. gaigeae* populations and determine whether hybridization is a result of introduction of red-eared sliders from distant populations or from westward range expansion of native *T. scripta elegans* [red-eared slider]. Evaluate the current status of extant *T. g. gaigeae* populations, using multiple polymorphic microsatellite markers. Characterize the long-term demography of the population of *T. g. gaigeae* in the Big Bend region, using capture-recapture techniques and survival analysis.

Findings Microsatellite data support occurrence of hybridization, viability of hybrids, and introduced origin of *T. s. elegans* in Big Bend National Park but also revealed potential range expansion of southern Rio Grande native *Trachemys scripta elegans*. *T. g. gaigeae* has a greater than anticipated ability for dispersal yet shows a high degree of site fidelity even after large floods. Abundance estimates from mark-recapture data show that the Big Bend population is small and this is corroborated by genetic estimates of effective population size. *T. g. gaigeae* in the Big Bend region warrant continued concern, given moderate adult survivorship and low abundance.

Next steps The occurrence of hybridization, as observed in this study, is a real threat to the genetic integrity of the Rio Grande endemic *T. g. gaigeae*. This alone justifies extensive *T. s. elegans* removal efforts within the historical range of *T. g. gaigeae*. Given the population structure, low genetic diversity, low effective population size and directly estimated population size determined in this study, the conservation status of *T. g. gaigeae* should be elevated to endangered or even critically endangered.

Principal investigator and affiliation: Jacob T. Jackson, Texas State University–San Marcos

Study/date	**Nutria *(Myocastor coypus)* in Big Bend National Park; A Non-native Species in Desert Wetlands**; 2010
Study area	Conducted along a 16 km stretch of the Rio Grande River from a gravel pit located 7.6 km upstream of Rio Grande Village (RGV) to the mouth of Boquillas Canyon (including hot springs, RGV, and beaver pond).
Purpose	Objectives include: 1) determine distribution of nutria along the Rio Grande River from the gravel pit to the mouth of Boquillas Canyon; 2) describe and quantify centers of nutria activity in the research area; 3) quantify the food consumption habits of nutria; 4) estimate nutria population size in the study area; and 5) use radio telemetry to estimate home range size and movements of nutria living in the limited wetland habitat of the Chihuahuan Desert.
Findings	During 2004 and 2005, more than 30 locations of nutria activity were documented. Seventeen nutria were captured, marked, and released; between 38 and 74 nutria were estimated to inhabit the RGV area. Stomach contents (n = 14) contained common reed *(Phragmites australis)*, water pennywort *(Hydroctyle umbellata)*, giant cane *(Arundo donax)*, spikerush *(Eleocharis caribaea)*, bermudagrass *(Cynodon dactylon)*, water hyssop *(Bacopa monnieri)*, foxtail (*Alopecurus* spp.), and flatsedge *(Cyperus* spp.). Mean home-range size was estimated to be 10.0 ha and the mean maximum daily distance traveled was estimated to be 637.4 m.
Next steps	Further research is needed on Mexican beaver populations and their response to nutria. Management of this invasive species is necessary due to its potential impact to native species; specifically, the Mexican beaver, Big Bend gambusia, and the limited remaining stands of *Phragmites* within the RGV area.
Principal investigator and affiliation: Matthew T. Milholland, Texas State University-San Marcos	

Study/date	**Assemblages of Rodents in Riparian Forests along the Rio Grande in Big Bend National Park, Texas: Current and Historic Insights on the Effects of Invasion by Salt Cedars**; 2012
Study area	Sample sites were along the Rio Grande, between Castolon and Santa Elena Canyon in Big Bend National Park.
Purpose	Comparisons of assemblages of rodents along the Rio Grande in Big Bend National Park were made using recent (2009–2010) and historic (1977) data to evaluate the effects of invasion by saltcedars *(Tamarix* spp.).
Findings	Comparisons of abundances and species of rodents between sites with mesquites *(Prosopis* spp.), cottonwoods *(Populus* spp.), or saltcedars revealed no significant difference between habitats. Comparisons of recent and historic assemblages of rodents suggested low turnover of species, but structure of assemblages differed between studies. Differences in assemblages may be caused by shifts in riparian plants toward a more closed canopy or by recolonization following flooding.
Principal investigator and affiliation: Daniel J. Leavitt, Texas A&M University	

OVERVIEW INVESTIGATIONS

Study/date	**The Río Conchos: A Preliminary Overview,** 2001
Study area	Conchos basin
Purpose	Examines what type of information is available about the Conchos and identifies information gaps. Explores the relevant legal and institutional framework for water resources management.
Findings	Provides a preliminary picture of water resources management in the Conchos basin.
Principal investigator and affiliation: Mary E. Kelly, Texas Center for Policy Studies	

Study/date	**Legal and Institutional Framework for Restoring Instream Flows in the Rio Grande: Fort Quitman to Amistad (Texas)**, 2001
Study area	Section from Fort Quitman to Amistad
Purpose	Overview of existing framework for this stretch of river, including water availability and use, water quality, planning efforts, rights and permitting, and strategies to provide additional water.
Findings	Three suggested strategies that additional water might be provided through this stretch: via El Paso, saltcedar removal, and Río Conchos releases.
Next steps	Issue a water rights permit specifically for instream use and determine/develop the level of instream flow necessary to sustain healthy aquatic ecosystems.
Principal investigator and affiliation: Laura Brock, Texas Center for Policy Studies	

Study/date	**An Analysis and Proposal to Improve Water Rights Transfers on the Mexican Conchos Basin**, 2009
Study area	Río Conchos basin
Purpose	We evaluate water policy in Mexico as it relates to transfers and propose alternatives to current policy under proposed guidelines for water markets that comply with efficiency and equity.
Findings	We suggest that: 1) the institutions and infrastructure found in the Conchos basin provide the basis for a flexible, market-based means of allocating water among users; 2) for water transfers to be successful, an adequate network of monitoring devices is required to ensure trust in the quantities of water to be traded; and 3) water users and society in general must be educated about the benefits and costs of transfer of water across irrigation districts, and even about types of use.
Principal investigator and affiliation: Jesús R. Gastélum, University of Arizona	

REHABILITATION ACTIVITIES

MONITORING

Project and period	**Chihuahuan Desert Network Vital Signs Monitoring Plan,** 2005-current
Location	Big Bend National Park, Rio Grande Wild and Scenic River (RIGR)
Planned/proposed work	The plan identifies a suite of vital signs (a subset of valued resources and indicators of overall ecosystem condition) for monitoring. The network will prepare and implement 10 protocols to monitor the vital signs in member parks. Vital Signs include: air quality, climate, landbirds, heteromyid rodents, invasive plants, landscape condition, soils and vegetation, and water quality and quantity. Website: <http://science.nature.nps.gov/im/units/chdn/Purpose.cfm>
Results	Twelve natural resource inventories are being conducted in park units. Vertebrate and vascular plant inventory: Big Bend National Park (BBNP)—vascular plants, amphibians and reptiles, fish, birds—winter grasslands are complete and vegetation mapping is planned; RIGR—fish and mammals complete. Physical sciences and paleontology: complete for all parks. Special projects have been conducted in BBNP and RIGR. Inventories website: <http://science.nature.nps.gov/im/units/chdn/reportpubs.cfm>
Participants	**Chihuahuan Desert Inventory and Monitoring Network, National Park Service**

MONITORING - HYDROLOGY

Project and period	**Texas Clean Rivers Program (CRP)**; 1998-current
Location	Rio Grande basin
Planned/proposed work	The CRP is a state fee-funded program specifically for water quality monitoring, assessment, and public outreach, and aims to improve the quality of water within each river basin in Texas through partnerships with the TCEQ and participating entities.
Results	Program maintains a basin-wide routine water quality monitoring program and water quality database; provides quality-assured data to TCEQ for use in water quality decision-making; identifies and evaluates water quality issues and summarize in reports; promotes cooperative watershed planning; informs and engages stakeholders; produces the annual Basin Highlights Report. Website: <http://www.ibwc.gov/CRP/index.htm>
Participants	**International Boundary and Water Commission** (US Section)

Project and period	**Geomorphology of Sandbars in Boquillas Canyon, Big Bend National Park**; 2004–2011
Location	Boquillas Canyon
Planned/proposed work	Monitor the changing geomorphologic condition of the river in Boquillas Canyon.
Participants	**Sul Ross State University, Big Bend National Park**

Project and period	**Continuous Water Quality Monitoring Network (Rio Grande Network)**; 2004–current
Location	Rio Grande basin
Planned/proposed work	TCEQ continuous water quality monitoring stations, data, locations, and photos of monitoring sites.
Results	http://www.tceq.texas.gov/waterquality/monitoring/swqm_realtime.html
Participants	**Texas Commission on Environmental Equality**

Project and period	**Geomorphic Monitoring Trip**; 2012 October
Location	Boquillas Canyon
Planned/proposed work	Conducted a geomorphic monitoring trip
Participants	**Sul Ross State University, Commission for Environmental Cooperation (funding)**

Project and period	**Metals in Water**; 2012–current
Location	Big Bend Area
Planned/proposed work	Clean Rivers Program will sample Mercury at about a dozen stations. Metals data will be posted regularly on website.
Participants	**International Boundary and Water Commission** (US Section)

Project and period	**IBWC Gaging Stations—US and Mexico**; current
Location	Rio Grande basin
Planned/proposed work	The US and Mexican sections operate and maintain numerous gaging stations on the main channel of the Rio Grande and gaging stations located on measured tributaries of each country as well as gaging stations on diversion and return flow channels.
Results	Data available: near real-time stream gauge data and historical mean daily discharge data. Website: <http://www.ibwc.state.gov/Water_Data/Rio_grande_WF.html>
Participants	**International Boundary and Water Commission** (US Section)

MONITORING – SPECIES OF CONCERN

Project and period	**Big Bend Gambusia *(Gambusia gaigei)* Broodstock Acquisition and Maintenance**; 1991–1993
Location	Refuge ponds near Rio Grande Village
Planned/proposed work	Maintain diverse refugium stock of the endangered Big Bend Gambusia for recovery and research purposes. 1984 Recovery Plan for Big Bend *Gambusia gaigei*
Results	A captive population of Big Bend gambusia has been maintained at USFWS Dexter National Fish Hatchery in New Mexico since 1974. Record flooding in 2008 prompted an additional collection of wild fish. Post-quarantine and genetic analysis, these fish were added to the captive stock as a supplement.
Participants	**USFWS, Southwestern Native Aquatic Resources & Recovery Center** (formerly Dexter National Fish Hatchery and Technology Center) (Buddy Jensen)

Project and period	**Status of the Endangered American Peregrine Falcon *(Falco peregrinus anatum)***; 1991–1997
Location	Big Bend National Park and Rio Grande Wild and Scenic River
Planned/proposed work	Document falcon presence, nesting chronology, and breeding success at each location.
Results	1991: record year of 15 fledglings, new territory identified; 1992: ten pairs exhibited courtship behavior and of those, five pair successfully raised fledgling young; 1993: six offspring fledged from ten active territories; 1994: five offspring fledged from 14 active territories, at several locations, offspring hatched but did not survive; 1995: three offspring fledged from what began as 14 active (paired falcons exhibiting breeding behavior) territories; 1996: six young fledged from 14 nesting pair of adults; and 1997: 17 offspring fledged from 11 active territories (eight aeries).
Participants	**Big Bend National Park-National Park Service, US Fish and Wildlife Service**

Project and period	**American Peregrine Falcon *(Falco peregrinus anatum)* Post-delisting Monitoring**; 2003–2015
Location	Four USFWS post-delisting sites (historic aeries) within Big Bend National Park
Planned/proposed work	The American peregrine falcon was removed from the list of endangered and threatened species in 1999. Post-delisting monitoring began in 2003, and is being carried out every three years over a 15-year period (2006, 2009, 2012, and 2015).
Results	Results from 2003 show the population continuing to climb, and was estimated at about 3,000 breeding pairs in the US, Canada, and Mexico. Territory occupancy, nest success, and productivity were all at levels considered normal for healthy peregrine falcon populations. Big Bend National Park results include 2004: All four historic sites were occupied by mating pairs; three young were produced from these four locations. 2006: Two pairs and one breeding pair produced one fledgling.
Participants	**US Fish and Wildlife Service, Big Bend National Park-National Park Service**

Project and period	**Big Bend Gambusia *(Gambusia gaigei)* Monitoring**; 2007-2011
Location	Refuge ponds near Rio Grande Village, Big Bend National Park
Planned/proposed work	Semi-annual monitoring of Big Bend gambusia populations
Results	Data used for USFWS 2008 five-year review of an endangered species. Recommendation in 2012 of “No change needed” for current classification.
Participants	**University of Texas Pan-American, US Fish and Wildlife Service**

Project and period	**Rio Grande silvery minnow reintroduction;** 2008 December – 2012 (ongoing)
Location	Mulato Dam to Foster's Weir, east of the Terrell/Val Verde county line
Planned/proposed work	Establish a nonessential experimental population of Rio Grande silvery minnow *(Hybognathus amarus)*, a federally listed endangered fish, into its historic habitat in the Big Bend reach of the Rio Grande in Presidio, Brewster, and Terrell counties, Texas. (*Federal Register*, December 2008, USFWS 73 FR 74357–74372).
Results	The initial reintroduction of Rio Grande silvery minnow occurred on 17 December 2008, with the release of 431,196 adults and juveniles at four sites in the Rio Grande within and near Big Bend National Park. Fish were equally distributed across all 4 sites (National Park Service, Research Permit and Reporting System, Permit # BIBE-2009-SCI-0004). Annual releases have been conducted 2008–2012.
Participants	**US Fish and Wildlife Service, the National Park Service, Texas Parks and Wildlife Department, University of Texas – Pan American**

Project and period	**Rio Grande Silvery Minnow Monitoring**; 2008–2013 (ongoing)
Location	Sites within Big Bend Ranch State Park, Big Bend National Park, and Rio Grande Wild and Scenic River
Planned/proposed work	A monitoring program was established to collect fish assemblage information, check persistence of the species in the region, evaluate fish health, and monitor for signs of recruitment. Subsequent releases were planned; a target number to be released was 200,000 fish per year for five years (2008–2012).
Results	Fish releases: 2008 (initial) = 431,000 adults/juveniles; 2009 = 509,000 juveniles; 2010 = 500,000 individuals; 2011 = 267,000 juveniles; 2012 = 120,000 individuals. Fish were equally distributed across all four sites. Approximate total number of fish released to date = 1,827,000 individuals. 2009: silvery minnows present; natural reproduction not documented. 2010: silvery minnows present; no young of year. 2011: Evidence of natural reproduction, survival, and movement (silvery minnows were found downstream a considerable distance; National Park Service, Research Permit and Reporting System, Permit # BIBE-2011-SCI-0024) documented; fins were clipped for genetic analysis. 2012: silvery minnow, including young of year present.(National Park Service, Research Permit and Reporting System, Permit #s BIBE-2008-SCI-0048, BIBE-2009-SCI-0004, and BIBE-2009-SCI-0028)
Participants	**US Fish and Wildlife Service, Texas Parks and Wildlife, University of Texas-Pan American, and USFWS-Southwestern Native Aquatic Resources and Recovery Center** (formerly Dexter National Fish Hatchery and Technology Center)

MONITORING - VEGETATION

Project and period	**Riparian Vegetation Monitoring – BBNP**; 2005–current
Location	Total of eight sites in Boquillas Canyon and sites in Hot Springs Canyon
Planned/proposed work	Collect data from eight established riparian vegetation monitoring sites and photo points to assess effectiveness of invasive plant control and ecological effects of riparian restoration efforts.
Results	Sampling to be conducted annually, post growing season
Participants	Big Bend National Park, World Wildlife Fund

Project and period	**Riparian Vegetation Monitoring Site Establishment – BBNP**; 2012 July
Location	Three new sites established in Boquillas Canyon
Planned/proposed work	Established three new riparian vegetation monitoring sites and photo points to assess effectiveness of invasive plant control and ecological effects of riparian restoration efforts.
Results	Baseline monitoring completed, including taking new and existing photo points. Total of eight sample sites within Boquillas Canyon.
Participants	**Big Bend National Park, World Wildlife Fund**

RESTORATION PROJECTS

Project and period	**La Junta Project**; 2009–current
Location	La Junta Heritage Center, Presidio, Texas; La Junta is located at the confluence of the Rio Grande and Río Conchos
Planned/proposed work	Restore La Junta Heritage Center agriculture/grassland/wetland complex; 80 acres (job creation, recreation & tourism). <http://lajuntaheritage.org/>
Participants	**Trans-Pecos Water and Land Trust**, volunteers

Project and period	**Riparian Habitat Restoration**; 2010–current
Location	Private land in the Terlingua Creek watershed
Planned/proposed work	Multi-year landscape scale riparian restoration using mechanical brush removal and revegetation of buffer and riparian zones (307 acres, 3 miles).
Participants	**Texas Parks and Wildlife Department, US Fish and Wildlife Service**

Project and period	**Riparian Revegetation Site Visit**; 2012 October
Location	Boquillas Canyon
Planned/proposed work	Conducted a site visit with Pronatura and Fred Phillips Consulting, to develop a riparian re-vegetation plan for restoration sites within Boquillas Canyon
Results	Three sites identified.
Participants	**Big Bend National Park, Pronatura, Fred Phillips Consulting, Commission for Environmental Cooperation** (funding)

Project and period	**Wetland/Riparian Habitat Restoration**; 2012–current
Location	Private land near Presidio, Texas; ~ 0.4 mi north of the Rio Grande
Planned/proposed work	Establish 24.5 acres of wetlands and associated riparian habitat.
Participants	**Trans-Pecos Water and Land Trust, Environmental Defense Fund**

Project and period	**Alamito Creek Restoration**; 2012-current
Location	South of Marfa, Texas and north of Big Bend Ranch State Park in Presidio County, Texas
Planned/proposed work	Remove invasive vegetation to begin restoration of the floodplain at the Alamito Creek Preserve.
Participants	**Trans-Pecos Water and Land Trust** (in cooperation with Dixon Water Foundation), **Texas Parks and Wildlife Department, US Fish and Wildlife Service**

VEGETATION MANAGEMENT

Project and period	**Propagation of Native Species – BBNP**; 2009–current
Location	Boquillas Canyon, Terlingua Creek, Tornillo Creek
Planned/proposed work	Propagate cottonwood and willow trees for use in landscaping and restoration projects.
Participants	**Big Bend National Park**

Town of Boquillas, Coahuila.
Photo: Catherine Hallmich

VEGETATION MANAGEMENT – BIOLOGICAL CONTROL AGENTS

Project and period	**Impact of the Tamarisk Leaf Beetle on Salt Cedar and Athel along the Rio Grande River in Presidio and Brewster Counties, Texas**; 2006-current
Location	Three locations along the Rio Grande (Candelaria, TX, to the western edge of Big Bend National Park, Texas).
Planned/proposed work	Establish and monitor the tamarisk leaf beetle *(Diorhabda* spp.) in an attempt to control the spread of saltcedar and restore the riparian corridor, which has become populated by a monoculture of saltcedar.
Results	Twelve release sites along the Rio Grande are being monitored at varying levels of establishment. Researchers have had the most success with and are currently monitoring the Subtropical Tamarisk beetle *(Diorhabda sublineata)*, as well as the limited establishment of Mediterranean Tamarisk beetle *(Diorhabda elongata)*. A comparison of the establishment and efficiency of the *D. sublineata* on saltcedar and athel trees in the vicinity of Presidio, TX, is being conducted. Current results show *D. sublineata* initially prefers saltcedar, but will defoliate athel secondarily within a region. Impacts on regrowth and continued defoliation by the beetles on both plants are under examination.
Participants	**Sul Ross State University** (Christopher Ritzi), **Texas AgriLife Extension, US Department of Agriculture-Agricultural Research Service** (Jack DeLoach, retired**)**

Project and period	**Texas AgriLife Extension Salt Cedar Biological Control Implementation Program**; 2008–2010
Location	Campgrounds between Santa Elena Canyon and Castolon Visitor Center and at Gravel Pit, Big Bend National Park
Planned/proposed work	Provide technical expertise, assistance and material support (cages and beetles) to establish leaf beetle populations in Big Bend National Park for the biological control of saltcedar.
Results	Fall 2011: Summary reports established populations of Crete (now Mediterranean) beetles *(Diorhabda elongata)* at Santa Elena and Tunisia (now Subtropical) beetles *(Diorhabda sublineata)* at Gravel Pit. Also reported, in September 2010, this population (unclear which species) had defoliated saltcedar along an estimated 17 river miles from Boquillas Canyon up river to Mariscal Canyon, Big Bend National Park.
Participants	**Texas AgriLife Extension-Texas A&M University System** (Allen Knutson and Mark Muegge)

Project and period	**Monitoring and Sampling of Athel *(Tamarix aphylla)* and Giant Reed *(Arundo donax)* for Biological Control Impacts inside Big Bend National Park**; 2008-2011
Location	Beetle sites: Santa Elena Canyon, Gravel Pit; later extended to Rio Grande Village. Wasp sites: 3 in Santa Elena Canyon, 3 in Rio Grande Village/Boquillas Canyon
Planned/proposed work	Assess the impact of introduced tamarisk leaf beetles *(Diorhabda elongata* and *D. sublineata)*, released to control invasive saltcedars *(Tamarix* spp.), on athel *(Tamarix aphylla)* trees inside BBNP. Determine if the Arundo wasp *(Tetramesa romana)* has dispersed along the Rio Grande into BBNP
Results	2008: Santa Elena site - athels present at one site only, larvae observed on saltcedar. 2009: Santa Elena - beetles had not yet dispersed from the saltcedar release site to the area of mixed-saltcedar athel. Gravel Pit - population not established yet. 2010: Mature athel trees were defoliated at all sites, including Rio Grande Village. Immature saltcedar was colonized earlier and to a greater extent with resulting lower damage levels on athel at the Gravel Pit site. By December 2010, athel trees at all sites had recovered 80% or more of lost foliage. 2011: Mature athel trees that were completely defoliated in 2010 by tamarisk beetles and again by the February 2011 freeze showed partial regrowth/recovery in 2011 (15 to 30% of their 2010 canopy). Recovery of mature athel at Gravel Pit and Rio Grande Village was reduced 20 to 30% by tamarisk beetle damage in the late summer or early fall of 2011; trees regained all foliage lost to beetles by November 2011. Immature athel trees at Santa Elena and the Gravel Pit regained only 5 to 15% of their 2010 canopy in 2011. Immature athel trees were not damaged by tamarisk beetles in 2011; immature saltcedar trees were completely defoliated by mid-summer. Saltcedar trees are more heavily colonized and hence damaged more than athel. The Arundo wasp *(Tetramesa romana)* is not present inside Big Bend National Park. (National Park Service, Research Permit and Reporting System, Permit #s BIBE-2008-SCI-0029, BIBE-2010-SCI-0025, BIBE-2011-SCI-0013)
Participants	**US Department of Agriculture, Agricultural Research Service (Patrick Moran)**

VEGETATION MANAGEMENT – INVASIVE PLANTS

Project and period	**Salt cedar removal;** 2008-2010
Location	Madera Canyon, Fresno Canyon, and Contrabando Canyon in Big Bend Ranch State Park
Planned/proposed work	Multi-year project to remove saltcedar from 290 miles of canyons and creeks in Big Bend Ranch State Park
Results	Completed removal of saltcedar in Madera Canyon down to the River Road bridge and began work in Fresno Creek near the old mine. Cleared 7 miles of the upper Fresno Canyon, and 4 miles of the lower Contrabando Canyon.
Participants	**Trans-Pecos Water and Land Trust**, volunteers

Project and period	**Giant cane *(Arundo donax)* control (with herbicide) – BBNP**; 2012
Location	20 miles in Boquillas Canyon
Planned/proposed work	Completed application of herbicide on giant cane in Boquillas Canyon
Participants	**Big Bend National Park, World Wildlife Fund, and Coca Cola** (funding)

Project and period	**Giant cane control (fire) – Mexico**; 2012-2013
Location	Above and within Boquillas Canyon
Planned/proposed work	Completed experimental cane control program using prescribed fire on several miles of river on the Mexican side.
Participants	**Conanp, Profauna, and Commission for Environmental Cooperation** (funding)

Project and period	**Giant cane control (herbicide/fire) – BBNP**; 2012 September-October
Location	Hot Springs Canyon, Rio Grande Village, and Boquillas Canyon along the Rio Grande
Planned/proposed work	Control giant cane in three project areas: a maintenance treatment (herbicide) of 80 acres in Hot Springs canyon; initial treatment of 12 acres using prescribed fire at Rio Grande Village; and initial treatment using prescribed fire on 80 acres in Boquillas Canyon
Participants	**Big Bend National Park** (funding from **World Wildlife Fund** and **Coca Cola** for Boquillas Canyon)

Project and period	**Working for the Rio Grande;** Funding needed
Location	River stretch from Rio Grande/Río Conchos confluence to Lajitas, Texas.
Planned/proposed work	Eradicating non-native vegetation and replanting native species
Participants	**Trans-Pecos Water and Land Trust, Big Bend Ranch State Park**

HYDROLOGY RESEARCH AND MAPPING PROJECTS IN-PROGRESS

PROJECT	LOCATION	PLANNED/PROPOSED WORK	PARTICIPANTS
Acquisition of LIDAR and Multispectral Imagery Data for the Rio Grande through Big Bend National Park	Rio Grande through Big Bend National Park	Use aerial-based Light Detecting and Ranging (LIDAR) to generate baseline topographic and riparian vegetation data (maps) and terrain models for the 100-mile reach of the Rio Grande that flows through Big Bend National Park	Big Bend National Park, World Wildlife Fund, Utah State University, Desert Landscape Conservation Cooperative (funding)
Vegetation mapping of Big Bend National Park	Lower Canyons within the Rio Grande Wild and Scenic River	Collect field data for completion of riparian vegetation mapping.	Big Bend National Park, Chihuahuan Desert Network-Inventory and Monitoring
Relation of stream flow to available habitat for Rio Grande silvery minnow in the Big Bend reach of the Rio Grande, Texas	Big Bend reach of the Rio Grande	Provide information to refine the process of release site selection, assist in the development of a more focused species monitoring assessment strategy, and provide detailed physical habitat information for the species over a range of flow conditions.	US Geological Survey (Bruce Moring), US Fish and Wildlife
Near-continuous suspended sediment monitoring of the Rio Grande using multi-frequency acoustic instrumentation in Big Bend National Park	Upstream gauge near Castolon and downstream gauge near Boquillas, Big Bend National Park	Use suspended-sediment gauges to assess sediment transport dynamics to inform river management planning.	Utah State University (David Dean), US Geological Survey
Hydrologic, geomorphologic, and GIS analysis and development of an interfaced sediment/ discharge sampling station as a means to quantifying a sediment budget for the upper Terlingua Creek watershed	Upper Terlingua Creek watershed, Brewster County, Texas	Evaluate and monitor the hydrology, sediment load characteristics and general watershed condition of the watershed and to create a baseline data set to assess sediment mobility and the effects of the restoration projects.	Sul Ross State University
A study of hyporheic waters from Big Bend National Park sandbars	Sandbars near Castolon and Rio Grande Village	Assess the hyporheic conditions and hydrologic parameters of two sandbars through the use of piezometers and pressure transducers.	Sul Ross State University

RIO GRANDE BASIN-WIDE PROJECTS

PERIOD	PROJECT	ENTITY
1997	**Biology of the Rio Grande Border Region: A Bibliography, Information and Technology Report.** USGS/BRD/ITR-1997-0001 <http://www.cerc.usgs.gov/Assets/UploadedFiles/ExternalDocs/91113.pdf>	US Geological Survey, US Department of the Interior
2007	**The US-Mexican Border Environment: Transboundary Ecosystem Management**	Southwest Consortium for Environmental Research and Policy (SCERP)
2012	**Environmental Flows Recommendations Report: Final Submission to the Environmental Flows Advisory Group, Rio Grande Basin and Bay Area Stakeholders Committee, and Texas Commission on Environmental Quality**	Upper Rio Grande Basin and Bay Expert Science Team (BBEST)
2001; 2005-2006;	**A Physical Assessment of the Opportunities for Improved Management of the Water Resources of the Binational Rio Grande/Río Bravo Basin**	Center for Research in Water Resources, University of Texas at Austin and The Natural Heritage Institute
2002-current	**Efficient Irrigation for Water Conservation in the Rio Grande Basin/ Rio Grande Basin Initiative**	Texas Water Resources Institute
2004-2006; 2008-2010	**Sustainable Agricultural (Fresh) Water Conservation in the Rio Grande Basin (SAWC)**	Texas State University System

Morelos Grasslands, Coahuila. Photo: Google Earth

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Commission for Environmental Cooperation
393, rue St-Jacques Ouest, bureau 200
Montréal (Québec) Canada H2Y 1N9
t 514 350-4300 f 514 350-4314
info@cec.org / www.cec.org