PROCEEDINGS OF THE FIFTH

Natural History of the Gila Symposium

February 27–March 1, 2014

Western New Mexico University

Silver City, New Mexico

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Introduction

The Fifth Natural History of the Gila Symposium took place during a time of great flux in the Gila Region. The main issues creating this flux and uncertainty were two catastrophic fires, the Whitewater/Baldy Fire Complex and the Silver Fire, in the Gila and Aldo Leopold Wilderness Areas of the Gila National Forest, as well as multiple smaller fires the past few years; continuing drought; and the ongoing Arizona Water Settlements Act (AWSA) process, with possible Gila River diversion. Though the majority of talks focused on aspects of these issues, there were also talks about education, Gila trout and wildlife conservation, wetland monitoring and conservation, botany and ornithology, anthropology, archaeology, and paleontology; and a session for local authors to showcase their works inspired by the Gila Region. And there were three recipients of Lifetime Achievement Awards: Kelly W. Allred, Charles W. Painter, and David L. Prost.

The keynote address by Dr. Julio Betancourt, "Reflections on the Relevance of Environmental History in a Changing World," questioned whether our long-standing ecological models following ecological disturbances are still valid, given the climate changes that are occurring. The post-fire and flood-recovery studies presented at this symposium will be critical in helping to answer the questions posed by Dr. Betancourt.

Ayesha Burdett's introduction of a new exhibit at the New Mexico Museum of Natural History and Science, *Gila: Biodiversity and Conservation*, highlighted why the Gila Region is so important and is ideal for a variety of studies. The exhibit will highlight the region's importance for both its aesthetic value and its largely still-functioning ecosystem.

The catastrophic fires that occurred in the Gila National Forest provided multiple opportunities for a variety of studies. Some studies endeavored to determine if the Forest Service post-fire treatments were beneficial, detrimental, or made no difference to erosion control and plant recovery. Other studies undertook to rescue aquatic vertebrates from certain extinction in several watershed areas that were going to flood and become too silted for these animals to survive.

There were two anthropological presentations. One compared the healthfulness of historical diets of local Apache tribes with today's diets. The other talk focused on the irrigation techniques of aboriginal people 3,600 to 4,000 years ago.

One of the more controversial programs is the ongoing AWSA process, which allows for the annual diversion of up to 14,000 acre-feet of Gila River water. Scientists working for the Interstate Stream Commission presented the current state of the process and results from studies being done.

The education session highlighted the promising future for conservation. Silver City's Children's Water Festival introduced young kids to the Gila River, some for the first time. Their response was very positive. Eastern Arizona College's use of Science, Technology, Engineering, and Math (STEM) curricula for college, high school, and middle school students to work on tasks agreed upon with the local federal agencies proved to be empowering to the students and made them feel they could make a real difference.

The most poignant moment of the symposium was the bestowing of the Lifetime Achievement Award on Charlie Painter. Charlie's contribution to the field of herpetology is second to none and everyone in the room recognized his contributions. The 1997 book *Amphibians and Reptiles of New Mexico* that he coauthored with Degenhardt and Price is considered the bible by both hobbyist and scientist alike. All symposium attendees wished him success in his battle with cancer, which, sadly, he ultimately lost. His passing on May 12, 2015, is a great loss to his many friends and colleagues and to the scientific community.

Two others shared the award, Dave Propst and Kelly Allred. Dave's work on fish genetics, habitat restoration, and studies on the effects of river flow rates on native and non-native fish has proven critical for maintaining genetic diversity and health of threatened fish species in New Mexico. Kelly's knowledge of plants in the Southwest is unparalleled. The collection he has maintained at NMSU will be a lasting legacy for generations of botanists to come.

Special thanks to the US Forest Service, Gila District, for its generous support of the symposium; to Western New Mexico University for use of its facilities; and to Dr. Joe Shepard for refreshments during the breaks.

Thank you also to the NHGS planning committee for the long hours it spent making sure the symposium would be a success.

We are indebted to Dr. Kelly Allred (Emeritus Professor, New Mexico State University), editor of the *New Mexico Botanist*, for facilitating publication of these proceedings as a special edition of this journal. We are grateful for the editorial assistance and reviews provided by almost two dozen people, several of whom devoted hours of their expertise to help bring manuscripts to life. We owe a special debt to Sarah Johnson, who spent many hours copyediting and formatting this publication.

—Karen Beckenbach, on behalf of fellow steering committee members Joneen (Jony) Cockman, Richard Felger, William (Bill) Norris, Ted Presler, Art Telles, and Kathy Whiteman

Dr. David L. Propst: A Biography

James Brooks

The Beginning

The first time I met David L. Propst was in 1983. Fittingly, we were both in a meeting in Silver City, New Mexico, to discuss a proposed water-development project on the upper Gila River. Dave, a recent PhD recipient, was working under contract with the New Mexico Department of Game and Fish, studying warm-water native fishes of the Gila River to address potential impacts of the seemingly ever-present threat of water development. Little did either of us know at the time that we would become the friends and colleagues that we have been over the course of more than 30 years of working and traveling together.

The Gila Region of southwestern New Mexico remains Dave's highest priority when it comes to knowledge about native fishes and efforts toward their conservation. But he has significantly affected the science and protection of native fishes in other river basins. The Upper Colorado River, including the San Juan River in northwestern New Mexico, received his considerable focus. The Pecos River, the Middle Rio Grande in central New Mexico, the Canadian River Basin, the Zuni River, the Tularosa Basin, and Mexico all benefited from Dave's scientific curiosity. There are many details, including a variety of species and conservation issues, that can be recounted regarding Dave's contributions. But why repeat what has already been said about Dave? The Desert Fishes Council, nominating him for the 2010 W. L. Minckley Conservation Award, recognized his importance to native fishes conservation and to the acquisition of exceptional scientific data.

To that end, I provide here the nomination letter prepared by several of us who have been so positively influenced in our careers by Dave. All coauthors of the report are listed at the end of the letter, but two close friends of Dave's, Stephen Platania and Kevin Bestgen, deserve most of the credit for pulling together his story.

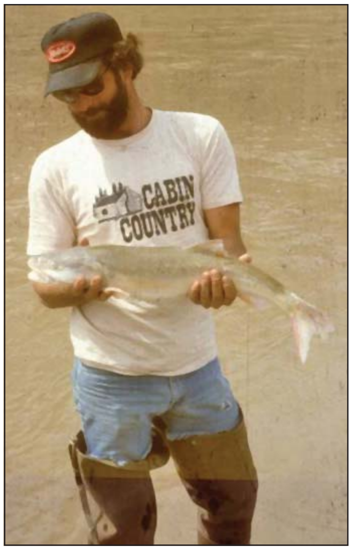
Nomination Letter for the 2010 W. L. Minckley Conservation Award, Desert Fishes Council

We are proud and honored to nominate Dr. David L. Propst for the Desert Fishes Council's 2010 W. L. Minckley Conservation Award. Dr. Propst's contributions over the past 30 years to the preservation and sustainable ecosystem management of desert aquatic ecosystems and their native biota are evident in his extensive research and publications; public outreach efforts; mentoring of students, employees, and colleagues; development of public policy; and unique team-building abilities. There can be no doubt that the tireless efforts of Dr. Propst will perpetuate, into the indefinite future, healthy and naturally functioning desert aquatic ecosystems in the American Southwest. In the narrative that follows, we detail

David L. Propst (center) after receiving the 2010 W. L. Minckley Conservation Award by the Desert Fishes Council. Pictured with him are several of his colleagues from Mexico and the US.

Endangered loach minnow (top) and spikedace, two species that benefited from the conservation efforts of David L. Propst.

how David L. Propst epitomizes the ideals championed by W. L. Minckley and how this award is a fitting acknowledgment of David's contributions to desert aquatic ecosystem conservation.



PhD candidate David L. Propst, 1978, on the Colorado River.

An abbreviated chronology, with selected highlights, from the career of David L. Propst follows. He graduated with a BA from Hampden-Sydney College, Virginia, in 1970 and served in the US Army from 1970–1972 as an Artillery Meteorologist. After his honorable discharge from military service, he attended graduate school at New Mexico State University and, in 1973, earned an MA in History. David's career path diverted in the mid-1970s, when he entered graduate school at Colorado State University (CSU), where (in 1978) he earned a second master's degree, this one in Biology, with a thesis entitled *The Use of Aquatic Insects to Assess Cattle Impact on Montane Streams.* He continued his post-baccalaureate education and in 1982 he earned his PhD from the Department of Fishery and Wildlife Biology at CSU, based in part on his dissertation, *Warmwater Fishes of the Platte River Basin, Colorado: Distribution, Ecology, and Community Dynamics.*

Soon after completing his PhD, David moved to Silver City, New Mexico, and began surveying the fishes of the Gila River Basin. Under this New Mexico Department of Game and Fish (NMGF)–funded contract, David undertook the first extensive survey of the fishes in the Gila River, made initial contacts with ichthyologists and fishery biologists in the American Southwest, and started a Gila River fish-sampling regime that continues to this day. After two years of research in the Gila River Basin, David was hired by the NMGF as their first Endangered Species Ichthyologist (1984), a position he has held for over 25 years. In that time, he has seen six NMGF directors come and go, and witnessed (precipitated?) the turnover of at least that many immediate supervisors. His dedicated advocacy for conservation made him a lightning rod for volatile issues related to surface water and endangered species and he has been the target of more than one New Mexico politician who believed that life would be easier if Dr. Propst was not involved.

Besides his early studies in the Gila River, he worked in the San Juan River in the mid-1980s, where he was part of a team that rediscovered a relict population of Colorado pikeminnow *Ptychocheilus lucius* heretofore thought extirpated. His work in the Pecos River included taking part in the discovery of the introduction of a non-native cyprinid, working in collaboration with state and federal agencies to establish a research program on threatened Pecos bluntnose shiner *Notropis simus pecosensis*, and helping to develop a working relationship between water users and conservation groups to facilitate compromises in the allocation of limited water. In the Rio Grande, David worked on the redescription of the Rio Grande silvery minnow *Hybognathus amarus* and provided critical systematic and taxonomic information vital to its federal listing as an Endangered Species. Most recently, David is involved in a basin-wide survey of the fishes of the Canadian River in northeastern New Mexico. Overall, he has undertaken and helped establish some of the longest-running research programs on fishes in New Mexico, including 22 years of autumn data on Gila River fishes from multiple locations. He also helped establish the survey protocols on Rio Grande and Pecos River fishes that have been used annually for 19 years and 22 years, respectively, and has been personally involved in the 24 consecutive years of fish surveys in the San Juan River.

In addition to his personal involvement in research, David's efforts to provide non-NMGF parties with research opportunities on native fishes extended his influence across a broad geographic scale. Over his career with the NMGF, we estimate that David was responsible for bringing at least $10,000,000 to New Mexico for fish research. Whether acquiring $1,000 to help defer the costs for a fish illustration or $250,000 for a basin-wide fishery survey, David viewed the work with the same passion and value while enduring the seemingly endless problems associated with agency accounting, compliance, and logistics. His goal was to provide resources necessary to ensure that needed work was accomplished and that it was done with unquestionable scientific integrity. The vast majority of funding that David acquired was distributed to researchers outside of the New Mexico Department of Game and Fish. He counts among his colleagues individuals at University of New Mexico, New Mexico State University, Western New Mexico University, Highlands University, Colorado State University, Arizona State University, Kansas State University, Texas Tech University, University of Texas, Oklahoma State University, North Dakota State University, and Cornell University. There are few state or federal resource agencies with which David has not worked closely. Among those with which he has spent the most time collaborating are the US Fish and Wildlife Service, New Mexico Fish and Wildlife Conservation Service Office, Arizona Fish and Wildlife Conservation Service Office, US Bureau of Reclamation, US Forest Service, and US Bureau of Land Management. Through those diverse collaborations, David was also able to provide graduate student funding and mentoring to young scientists. His impact in those areas will persist long into the future, as many of those scientists are now placed in important resource conservation jobs in agencies and universities.

Another vital role that David filled was to bridge the gap that often exists between agency biologists, academicians, and field biologists. Few people spent more time in the field than David, and, given the amount of time he was in the field, it is difficult to understand how he was able to accomplish what he did in development of conservation policy and scientific programs. Probably one of the best measures of his impact on the conservation of native fishes was the consternation that he caused water-resource managers. He has always relied on scientific principle over hyperbole and has never hesitated to tell a colleague or opponent if he thinks their science is wanting or poorly supported by the evidence. His ability to bring together disparate groups of individuals is surpassed only by his ability to cut through the verbal gymnastics that often occur at meetings and deliver a short, concise, and memorable rebuke of the fallacious thinking that accompanies what he terms "mental diarrhea." His witticisms are legendary and his friends and colleagues often feel compelled to imitate some of his more infamous epigrams. If imitation is the sincerest form of flattery, then David Propst should feel flattered indeed.

During his tenure at the NMGF, David published over 50 peer-reviewed papers and authored countless other technical agency reports. Many of these papers provide critical benchmarks for the conservation of regional fisheries and have guided and will continue to guide management and research of desert fishes. The breadth of topics on which he published is great and includes works on distribution, life history, habitat use, population dynamics, genetics, spatial variation in stable isotopes and feeding ecology, native–non-native species interactions, and species replacements in fishes. The fishes that he studies span the gamut of life-history strategies, from small-bodied, short-lived forms that occupy small home ranges to large-bodied, long-lived taxa that require hundreds of kilometers of lotic habitat to complete their life cycles. The list of fish species that David has studied clearly indicates a similar breadth of interest and includes representatives from almost all major taxonomic categories, from topminnow to trout. Despite working for a state agency, David's research on fishes and their associated aquatic habitats has not been limited to New Mexico but also includes Utah, Arizona, Colorado, Texas, and Mexico.

Throughout David's career he has been able to maintain a strong presence in professional societies that advocate conservation of desert fishes. He served as president of the Arizona/New Mexico Chapter of the American Fisheries Society (1989–1990), president of the Desert Fishes Council (1999–2001), and subject editor for *The Southwestern Naturalist* (2001–2003). He remains an active member in those and several other scientific organizations. During his career, David received a number of professional and academic awards in recognition of his efforts to further the causes of conservation biology. These include the Nature Conservancy Aldo Leopold Conservation Award, the George Miksch Sutton Award in Conservation Research (given by the Southwestern Association of Naturalists), the US Forest Service Rise to the Future Award, and the Western Association of Fish and Wildlife Agencies Professional of the Year.

In summary, Dr. David L. Propst has dedicated more than 30 years to conservation of imperiled aquatic animals and habitat in the American Southwest. In addition to overseeing the NMGF endangered fish program, David has conducted and contributed to significant ecological, life history, and taxonomic research throughout the American Southwest. His research and management initiatives have addressed threats to fishes and aquatic ecosystems in the Rio Grande, Canadian, Pecos, Mimbres, Gila, Zuni, and San Juan Rivers and the Tularosa Basin, every major system in New Mexico, and greatly contributed to their protection. Dr. Propst's tireless dedication as a leader of the Gila trout restoration project helped achieve a historic downlisting of the species from endangered to threatened. He continues to serve in instrumental roles on endangered fish recovery teams, interagency collaboration, and conservation planning task forces. His individual and team research is widely known and well reputed for being the stimulus and foundation for many fish and aquatic habitat conservation strategies. He has been a member of the Desert Fishes Council for over 20 years, and many if not all members can attest to his leadership as a conservationist for desert fish.

David L. Propst, right, with Johnny Zapata (left) and Nick Smith on Mogollon Creek during a Gila Trout rescue attempt caused by the LL Complex Wildfire.

Finally, this letter of nomination would not be complete without reflecting on David's professional and personal relationship with W. L. Minckley. Propst and Minckley first met in November 1982, when David sought advice on sampling the upper Gila River, New Mexico, a project initiated in conjunction with a proposal for dam construction in one of the last free-flowing streams of the Lower Colorado River Basin. During that first meeting, Minck gruffly remarked that he had no time for such a discussion. Three hours later the two of them had not only spoken of nuances of sampling but had laid a foundation for a productive relationship in fish conservation in the American Southwest and a decades-long mutual friendship based in respect and admiration. David looked upon Minck as a mentor, one from whom he could learn not only about issues of biology but also about matters related to the politics of conservation. It is at least partially a product of their relationship that Hooker Dam has still not been built in the upper Gila River, that the full natural complement of native warmwater fishes still thrives in that area nearly 30 years later, and that, in general, native fishes in the American Southwest have benefited. Thus, it seems fitting that the special relationship and mutual respect between these two men that began nearly 30 years ago would come full circle with Dr. David L. Propst's being the first recipient of the W. L. Minckley Conservation Award.

Respectfully submitted for your consideration by (alphabetic order):

Kevin R. Bestgen, PhD, Colorado State University, Fort Collins
James E. Brooks, US Fish and Wildlife Service
Stephanie Carman, Bureau of Land Management
Steven P. Platania, American Southwest Ichthyological Researchers, LLC
Thomas F. Turner, PhD, University of New Mexico
Amy Unthank, US Forest Service

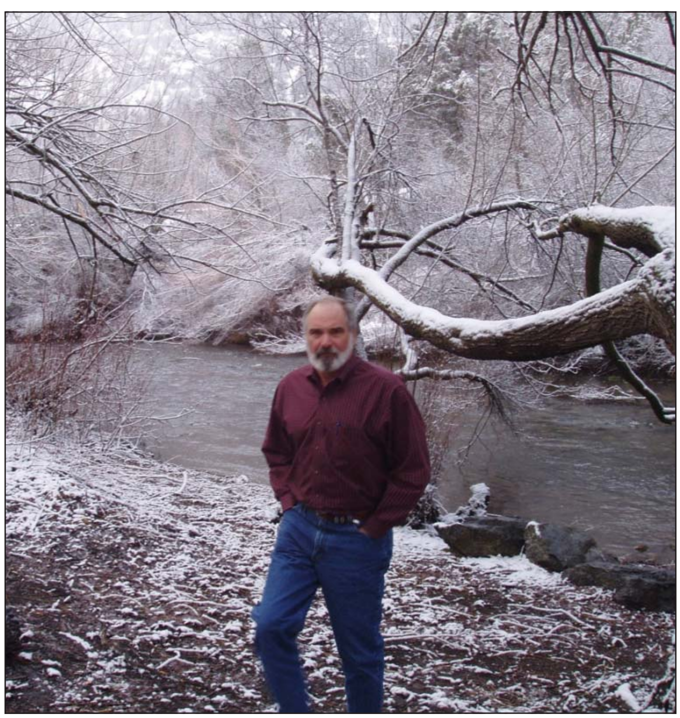
Epilogue or Prologue?

Dave retired from the New Mexico Department of Game and Fish in December 2010, after 26 years as the Native Fish Section Supervisor in the Conservation Services Division. After his retirement not one of us thought he would do anything else but continue on, "unencumbered" by the politics that agency biologists face. Dave would tell us all of the work he had left to do and data he still needed to publish. And we were right. Dave has continued on, with annual October monitoring of upper Gila River Basin fishes, a long-term data set now 30 years in the making. This monitoring effort and the data it has provided are a unique resource, one that is difficult to find these days, and this effort represents one of the most long-standing monitoring efforts for native fishes of the Southwest and anywhere else in North America.

Since 2010 he has authored or coauthored eight publications in peer-reviewed journals on Gila River fishes and their ecology. Currently he's an adjunct professor and senior researcher at the Museum of Southwestern Biology, University of New Mexico. Dave serves as a committee member for graduate students. He has served as the inaugural president of the new Trout Unlimited (TU) Bosque Chapter in Albuquerque and has also provided TU a considerable scientific resource on native trout. And Dave continues to teach a course on the use of piscicides in native fishes conservation for the National Conservation Training Center of Shepardstown, West Virginia.

Dave, in spite of his long-term tenure as an agency biologist, has always been the "academic in the agency crowd." His drive and intelligence improved the agency and ensured that it implemented recovery programs for native fish. Dave has taught all of us the importance of detailed field notes, an art that is not always present these days. Perhaps most importantly, Dave has always been there to support his colleagues, to stand up for the science when faced with the politics, to fight the good fight.

There are and will be other great native fish biologists in the American Southwest. But there will never be another Dr. David L. Propst.



Dr. David L. Propst in Utah, there to teach a class on piscicide use for the National Conservation Training Center.

Gone Herpin': Charles Wilson Painter

Randy D. Jennings and Lee A. Fitzgerald

Charles Wilson Painter was born in Butler, Pennsylvania, on 23 February 1949, the second of two sons born to Leah and Donald Painter. The family soon relocated to rural Arkansas, where they worked a family farm. Arkansas is where Charlie was introduced to the out-of-doors and where the seeds of his fascination with amphibians and reptiles were planted. Unfortunately, when Charlie was still young, his father died a violent death, and the family was not in a position to maintain the farm. Although there must have been many factors weighing on the family during this time, the family story is that Leah decided to move the boys to Louisiana after she had a conference with one of Charlie's teachers, who used improper grammar.

From all indications, Charlie loved growing up in Louisiana. He and his brother, Robert, joined the Boy Scouts and enjoyed the outdoors and many campouts. Throughout his life, Charlie remembered the many knots he learned, and their proper applications. Later in life he always had a well-organized camp, and his camp food was excellent. The early years were formative for his becoming a great field biologist. Robert went on to become an Eagle Scout, but not Charlie. He always joked about being kicked out of the Boy Scouts, and it is likely that many of you have heard the reason he often gave for his expulsion.

Charlie graduated from Robert E. Lee High School in Baton Rouge in 1966. The United States was at war in Vietnam, and he was drafted into the US Army, where he was stationed in South Korea to serve as a dental assistant. His love of herpetofauna continued to manifest during this tour of duty. During his service in South Korea, Charlie amassed a collection of over 1,500 specimens of amphibians and reptiles.

Upon his discharge from the US Army, Charlie returned to Louisiana and attended Northeast Louisiana University (NLU, now University of Louisiana at Monroe), where he pursued a Bachelor of Science in Biology (which he completed in 1974), then a Master of Science in Biology (completed in 1976). His undergraduate mentor and master's advisor was ichthyologist Neil Douglas. Charlie was a work-study student during his undergraduate years, working as a curatorial assistant in the zoological collections at NLU. His master's thesis was an inventory of amphibians and reptiles of Colima, Mexico. During graduate school, he was a teaching assistant for botany, zoology, vertebrate zoology, herpetology, and ichthyology classes. Charlie clearly took advantage of the opportunity for a broad natural history education at NLU, resulting in his becoming a truly accomplished naturalist, with a breadth that is seldom encountered in today's graduates. While at NLU, Charlie met and married his first wife, Sherry.

After Charlie received his MS, he and Sherry moved west, where he began his pursuit of a PhD at the University of New Mexico, in Albuquerque. During the early days of his doc-

Boy Scouts Robert and Charles Painter in Louisiana in 1962.

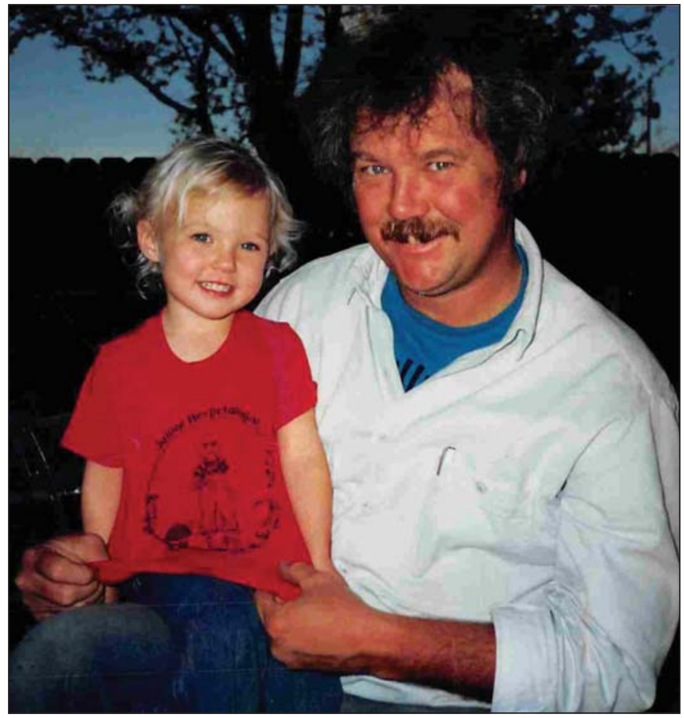
toral studies, he worked on several interesting projects with Norman J. Scott, Jr., through the National Fish and Wildlife Labs (a cooperative with the US Fish and Wildlife Service) at UNM. Projects included monitoring seed production and use in arid lands; effects of livestock grazing on the Kofa Game Range, Arizona; surveys of Mexican Ducks in northern Mexico; vertebrate surveys on Sierra Laguna in Baja California Sur, Mexico; vertebrate surveys of the Sierra Ladrones, New Mexico; and toxicology and fishes of the Rio Grande of central New Mexico. Charlie met and worked with many biologists who would, as became a pattern, remain good friends with him throughout his life.

In 1979, Charlie and Sherry divorced. Charlie put his PhD on hold and moved to Eugene, Oregon, where his brother Robert was living. He worked for a year as a fisheries biologist with the US Army Corps of Engineers. There, he got his head back on his shoulders and returned to UNM, only to find his position as a PhD student had disappeared. He supported himself over the next couple of years working short-term contracts as a biologist and as a carpenter and construction laborer. But when Charlie wasn't working on herps, he was thinking about them.

Charlie spent the early 1980s trying to develop a relationship with the New Mexico Department of Game and Fish (NMGF). He volunteered on several projects. He accompanied a herpetology class from UNM to the San Francisco River in 1983. This would be his first experience with the Gila Country of New Mexico. In 1984 he got a contract with NMGF working on the status and distribution of fishes in the Gila and San Francisco Rivers, with Kevin Bestgen and directed by David Probst. Charlie experienced much of the Gila during this work, and of course learned not only the fishes he was paid to survey, but all the vertebrates of the region. In 1984 he won a contract with NMGF to document the herpetofauna of the Gila and San Francisco River drainages. He set pitfall arrays, surveyed with road cruising, and conducted searches on foot. This work added much information to our knowledge of the Gila herps.

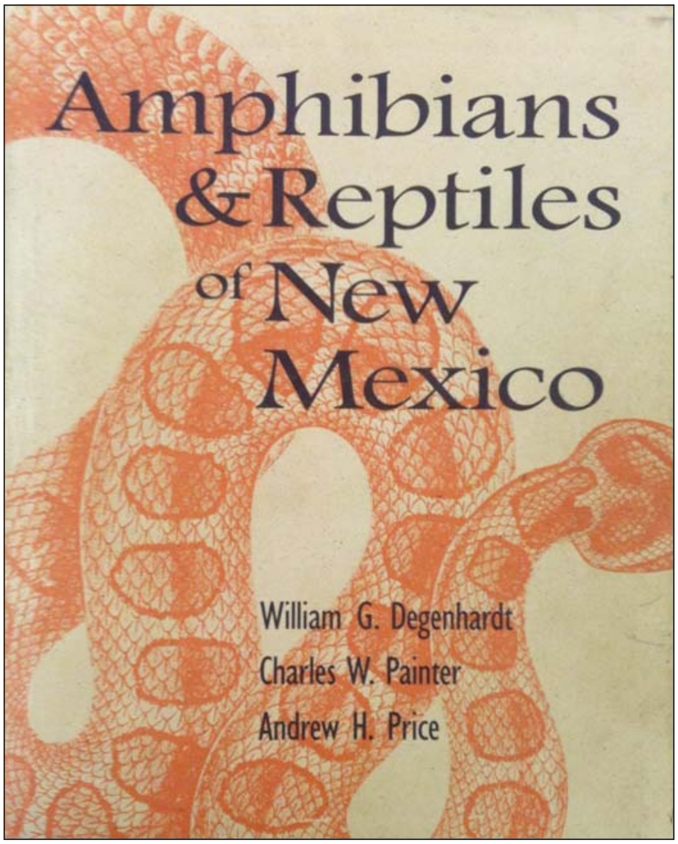
Although Charlie never finished his PhD, he landed the job of his dreams in September 1985, when he became the first herpetologist for New Mexico Department of Game and Fish. His job title was Endangered Species Biologist, in the Endangered Species Program, Conservation Services Division. That same year he and his second wife, Brenda Williams, had a daughter, Ashley Painter. Charlie likened his position to a show he and his brother watched as kids, and said he never imagined he would "be so lucky to ride through the desert like the Lone Ranger, having one adventure after another." Charlie was in the field from about April through October every year, studying herps across the entire state. He went on many pack trips deep in the Gila Wilderness with New Mexico Game and Fish, US Fish and Wildlife Service, and US Forest Service personnel, studying fish and herps. He had a reputation for well-equipped field camps with chuck-wagon style cooking, and usually went big. It was always a treat to be in camp, if for no other reason than the fried potatoes ("taties"), early morning birding, and conversation. Beginning in the mid-1990s Charlie hired seasonal field assistants, and from that point on became a mentor to many budding herpetologists.

Charlie was the state's herpetologist for more than 28 years, until he retired in December 2013. Tireless energy, inclusive collaboration, and staunch defense of New Mexico's amphibians and reptiles were the hallmarks of his career. Among his greatest achievements were his leadership in



Charlie and Ashley Painter in Albuquerque, NM.

Charlie with his NM Game and Fish truck. He worked those trucks hard.



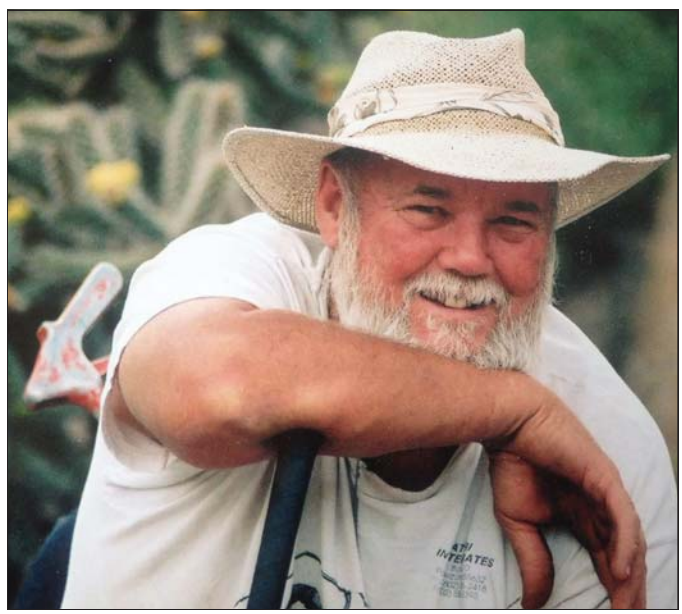
Degenhardt, W. G., C. W. Painter, and A. H. Price. 1996. Amphibians and Reptiles of New Mexico. University of New Mexico Press, Albuquerque. 431 pp.

producing *Amphibians and Reptiles of New Mexico*, which he coauthored with William Degenhardt and Andrew Price (1996); ushering in legislation on Regulation of Commercial Trade of Amphibians and Reptiles [19.35.10.2 NMAC-N, 31 October 2001]; and publishing more than 80 articles, reports, and other scholarly works on many species.

Charlie was recognized as Wildlife Professional of the Year several times while at NMGF. In 2013, he received the prestigious Alison Haskell Award in Herpetofaunal Conservation by Partners in Amphibian and Reptile Conservation, PARC. In 2014 he received a Lifetime Achievement Award at the Fifth Natural History of the Gila Symposium.

Charlie met his third wife, and the love of his life, in 2002 at an International Herpetological Society meeting in Chicago. Charlie and Lori talked daily, regardless of his field schedule. Lori became his herpetology partner and his greatest advocate. They were married in June 2009. Together they conducted herpetological studies, made art, and shared endless conversations.

Sadly, Charlie lost a very hard-fought battle with cancer on 12 May 2015. Since the mid-1980s, Charlie had been the hub of herpetology in New Mexico. His accomplishments remain critical to the conservation of the amphibians and reptiles not only of the Gila Region, but throughout New Mexico. All of us who worked with him are direct beneficiaries of his great energy. He cared about his relationships even more than he cared about herps. He encouraged many young students of herpetology to follow their dreams, and a good number have built their own careers in herpetology and environmental science. Charlie connected people professionally, as well as personally, and was a central figure among herpetologists within New Mexico and across the country. He truly was the nexus for New Mexico herpetology. Charles W. Painter is survived by his loving wife and partner in herpetology, Lori King Painter; his daughter, Ashley Painter; stepdaughter Kelly Senyé; brother, Robert Painter; and all his friends. We will profoundly miss him.



Charlie and Lori K. Painter in 2009.

Patterns, Patience, and Purpose: Kelly W. Allred

Gene Jercinovic

In the spring of 1846 a large group of Mormon pioneers under the leadership of Brigham Young were encamped on the east side of the Missouri River in what is now southwestern Iowa. They harbored plans to move en masse to the west to seek a permanent homeland and wished to have federal assistance. An emissary was sent to Washington, DC, to meet with high-level government officials and, eventually, President James K. Polk. An agreement was reached by which the US government gave permission for the Mormon community to occupy Indian land along the Missouri River for the winter, with the proviso that the Mormons supply a contingent of troops in support of the US efforts in the newly declared Mexican War. By mid-July more than 500 volunteers were mustered into service for the period of one year and by August had arrived at Fort Leavenworth in Kansas as part of the Army of the West commanded by Colonel Stephen W. Kearny. The Mormon Battalion had been formed. In mid-October, the new battalion commander, Captain Philip St. George Cooke, reported that 486 volunteers had reached Santa Fe, New Mexico.

According to Cooke's report to the US Senate in 1849, about 60 men were unfit for service due to illness. In addition, "twenty-five women and many children" accompanied the battalion. Cooke felt that the women and children would be quite out of place on the difficult journey that was to be the mission of the battalion, and ordered them to be sent with the sick back to winter quarters at Pueblo, Colorado, but "reluctantly consented to take five women, the wives of officers and serjeants [*sic*]." On October 19 the remaining group headed south from Santa Fe to travel through central New Mexico to the south end of the Black Range and then west and south through New Mexico and Arizona to San Diego. Although not involved with actual combat, the battalion made a remarkable and historic march across uncharted territory, arriving at the California coast on January 29, 1847. From Cooke's report:

> **The Lieutenant-colonel commanding congratulates the battalion on their safe arrival on the shore of the Pacific ocean, and the conclusion of the march of over two thousand miles. History may be searched in vain for an equal march of infantry. Nine-tenths of it has been through a wilderness where nothing but savages and wild beasts are found, or deserts where, from want of water, there is no living creature. . . . [T]hus, marching half-naked and half-fed, and living upon wild animals, we have discovered and made a road of great value to our country.**

Cooke's record of this incredible journey by the Mormon Battalion provides one of the earliest glimpses of plants, animals, and landscapes of New Mexico.

The men completed their term of service by training and performing other military duties in southern California and were discharged there on July 16, 1847, but there was more history to be made. A group of about 150 of these "veterans" headed north to the Sacramento area seeking work. About 100 decided to stay through the winter. They heard that a man named Sutter was looking for workers to build a sawmill. The men offered their services and in January of 1848 the facility began operating. On January 24, a small group of the ex-soldiers were working on some refinements when James Marshall, Sutter's partner, walked up from the millrace, which had been freshly scoured by water the night before. He showed the men a handful of shiny nuggets. The history of California was forever changed.

One last contribution to New Mexico from this nontraditional battalion has come from one of the descendants of this group, who has had quite an impact on the botany of the state. In his own words: "I had seven ancestors in that battalion or maybe even more. So I have been in New Mexico for a long time. I've been here since before I was born."

His name is Kelly Wayne Allred.

Kelly

Kelly was born on August 23, 1949, in Sutter Hospital in Sacramento, California. His father was Wendell Union Allred, who acquired his middle name as a result of his birth in 1918 at the end of World War I. Early in 1942 Wendell was among the first to be drafted for service in World War II. He had met Kelly's mother, Norma Hall, in Portland, Oregon, during the war. They subsequently married. Both were Mormons. Their first child, Kelly's brother Cory, was born in November of 1946. But all was not gold in the marriage, and when Kelly was just two years old, Norma abandoned the family. "My first mother was less devout than she should have been." A divorce was inevitable. A year later Wendell married Virginia Boothe from Provo, Utah. "I was adopted by my stepmother and raised by my stepmother and my father." He was "raised in a household of faith" in Sacramento.

In the early fifties Wendell moved the family to Provo in order to finish his college education at Brigham Young University under the GI Bill. He completed his degree in engineering and the Allreds returned to Sacramento, where he took a job with the US Geological Survey. He had spent the war making topographic maps for the army. Kelly's half sister, Beverly, was born there on May 1, 1958. Kelly spent kindergarten

Kelly 1951

and his first four grades at Dyer-Kelly Elementary School in Sacramento.

In 1958 Wendell accepted a position in Menlo Park at the headquarters of the USGS and the family took up residence in Palo Alto, southeast of San Francisco. Kelly entered fifth grade at Greendell Elementary with Miss Juckland. "I couldn't do long division and I was always staying after class to finish my long division." He mastered the math. Schoolwork was not really a problem. In sixth grade he had Mr. Small. That year he had a very unnerving incident with a girl and a surprising response from Mr. Small.

> **I was very good on the monkey bars and Jennifer Leghorn, a redhead, would chase me around the monkey bars. Finally, I was swinging around and I landed, I sort of jumped off and she jumped on top of me and kissed me on the lips. So I smacked her in the face and then she went crying to Mr. Small and we told what happened and he said, "Well, I guess you got what you deserved."**

It would be a long time before he experienced another kiss.

Even before entering his junior high school years, he had developed an interest in the natural world around him. His father had gotten him a microscope. "I had little nature books." He went out into the backyard and marked out a square one foot on each side, set four pegs, and surrounded it with string. "I tried to nose around and find every living organism in this little square." He even kept notebooks of his activities and explorations. His grandmother sent him a book of the birds of eastern North America. "I got interested in birds and I tried to identify birds with this book." He was interested in things biological but without any specific goal.

In 1961 Kelly began attending Wilbur Junior High School. There he had his first official science class. "I had for science, at Wilbur Junior High, Mrs. Acevado, and we did some very interesting things. I remember being enthralled with the word *environment* because it had an m and an n next to each other." Hardly a ringing endorsement for studying science! In fact, Kelly was not really that interested in his classes. He made reasonably good grades, but his real passion was much more down to earth, namely basketball. "My life was basketball."

He carried his love for the sport into Cubberly High School. He was a devoted fan of the Boston Celtics in the National Basketball Association and had a special place in his heart for their star center, Bill Russell. Another idol was Bill Bradley. "Bill Bradley graduated college in 1965 from Princeton. He went to be a Rhodes Scholar, came back to the NBA and played on the New York Knicks. Then he became a senator and ran in the primaries for president. I'd have voted for him in a drop, a heartbeat." Kelly was a starting guard for the Cubberley Cougars basketball team as a junior and senior, averaging about 10 points and 10 assists per game. "I thought of myself as a star but I was not." In a curious twist, his coach was Bud Presley, who was quite a sports star at the New Mexico Military Institute in Roswell, where he roomed with Ty Cobb's son.

High school basketball

His success in athletics did nothing to create more scholarly behavior. "I guess I was a B student. I just didn't pay a bit of attention to academics." His athletic success did, however, affect his social status. Cubberly High held an annual "Hukilau" dance with a Hawaiian theme. Girls had the privilege of inviting the boys. Each girl would make a muumuu dress for herself and, out of the same material, a shirt for her date. Everyone wore a lei. "And so they had a contest for Hukilau King and I was somehow chosen. I have no idea how that happened." Yet there was still time for his own private interaction with the world of biology. "My dad had two old tree-identification books. He took a trees and shrubs class in college, I think. So I got those and started identifying the trees around the house. I'd walk into the hills of Palo Alto and start to identify the trees a little bit if I could."

In the fall of 1967 Kelly began his college education at BYU. "Somehow I ended up at BYU. I don't remember applying, but I guess I did." He continued the long history of his family at BYU. He entered his freshman year with dreams of becoming a writer. In high school he had been a devoted fan of John Steinbeck. That dream never caught fire. For a time he considered becoming a forest ranger, but there was a certain aimlessness in his early career at BYU. As a freshman he enrolled in a general botany course, but his dedication to athletics got him

Hukilau King
(Kelly second from left)

into trouble. The class involved a lab that met at four o'clock in the afternoon. The gymnasium opened at three thirty. His priorities were clear. As a result of not attending the labs, he failed the botany course.

Because of his success in high school, he very much wanted to play on the freshman basketball team at BYU. He had played ball all through the previous summer and knew several guys who ended up on the team. He decided to talk with the coach about trying out for the team. He went to the coach's office.

> **There was a guy in his office talking to him who was on the varsity team and I'd played with him. He kind of said some nice things . . . We talked and the coach said "great" and shook my hand. I walked out and got halfway down the hall and realized he didn't tell me when the practice was, nor did he invite me there. So, they weren't the least bit interested. I could have been the greatest player in the world.**

Kelly's future on the hardwood faded to black.

There were, of course, warmer dimensions as well to those early days of college. One August day, not long after Kelly had arrived on campus, he and some friends gathered in a dorm room. One of his friends made a phone call to a girls' dorm to talk to a girl he had been seeing. After a few minutes, he passed the phone to Kelly, who found himself talking to a girl named Lynda.

Both the boys and the girls continued to pass the phone around. The next day the guys "went up to meet these girls we'd been talking with" and Kelly met Lynda face to face. As the semester continued they would see each other and say hello or even talk a bit, but things didn't seem to progress much. Kelly dated a few other girls, but "there wasn't any chemistry there." Then in November the girls' dorm held a "Buddy Party." A girl could select a young man to be her date, but could not invite him. A roommate had to do the actual inviting. Lynda chose Kelly and her roommate invited him. At the party they got to know one another much better and discovered that they enjoyed each other's company. They began dating regularly.

At BYU every young man of faith was expected to go on a mission for the Church of Jesus Christ of Latter-day Saints. This generally occurred after the freshman year. Kelly did not feel ready to go at the end of his first year and continued his studies for another year. He retook Botany 105, this time earning an A. He also took a trees and shrubs class with a professor by the name of Stan Welsh, who would later have a strong influence on Kelly. Kelly continued to pursue his relationship with Lynda. By the end of his sophomore year he decided that he was ready to undertake his mission.

Kelly passport 1969

> **So my decision to go came with a sort of a spiritual experience that I had, that kind of whispered to me that you need to do this, it's time to do this. That's all part of my foundation of things that I say. I'd had enough experiences in my life that I no longer wondered about the existence of God or these kinds of things. So it was a matter of growing up, maturing, having experiences and developing my own faith that now it's time to go.**

In the summer of 1969 he began preparation for his mission at a missionary training center. By autumn he was in northern France, where he would spend the next two years in service to his church. There he was paired up with a companion to spread the word of the church. "I had about six or eight companions in the two-year period that I was in about six different cities." Life in Provo went on without him.

Lynda

Lynda Street was born on March 5, 1949, in Pittsburg, a steel town, but not in Pennsylvania, rather in California, somewhat inland on the east side of San Francisco Bay, not far from the mouth of the Sacramento River. Her father was Carl Wilson Street from Provo, where he was a steel worker. He was a Mormon. In Provo he met and married Zella Peterson. She was a Mormon. There were Mormon pioneers in her lineage. The steel mill in Provo transferred Carl to Pittsburg.

Lynda was the youngest of four daughters. Judy was the oldest, followed by Kathy and then Sherry, all born in Provo. "I was always the baby, that's the way my mother introduced me." Lynda was actually raised in West Pittsburg (now Bay Point). In 1954 she entered first grade at Ambrose Elementary. Schooling was simple and easy to fit into, but not a focus. "I was a tomboy. I liked to play outdoors." When she was about 11, she took roller-skating lessons at a rink, on

Lynda age 4

old-fashioned skates with two wheels on the front and two wheels on the back. She got rather good at it. She could even skate backward. In competition she won a trophy. “Then they paired me up with a guy and we competed. I don’t remember winning anything, but we went to meets and we skated together.” She had fun.

By the time she entered seventh grade, life at home wasn’t the best. Her sisters had completed high school and she was the only daughter left at home. It had become apparent that her father was an alcoholic. The void between her mother’s and her father’s commitment to faith had reached crisis proportions. When Lynda was 13, her parents formalized their divorce. Zella and Lynda left California and settled in Provo. Lynda completed ninth grade at Farr Jr. High School there, but she and her mother were not getting along. “I really didn’t like Utah or the relationship my mother was in, so I went back and lived with my sister.”

Back in West Pittsburg, Lynda moved into a spare room offered by Sherry and her husband. She enrolled at Pacifica High and began her high school career in earnest. As always, schoolwork was not a problem for her. “I was a B+ student or A-.” She was no fan of math or science, but she worked her way through them. Her real interest was in the area of language. She very much enjoyed English and Spanish, but it was in extracurricular areas that she displayed the most energy. She was quite involved with student government, even becoming the vice president of the student council. She went to conferences for leadership for high school girls. She was in a play. She was a pom-pom girl.

> **I was in the chorus in high school. I had my fingers in many different things. Clubs, student council, honor society, Spanish club. I was very involved. I liked to be involved.**

She was moving forward with her life. Sherry and her husband were members of the church. This provided Lynda with a degree of comfort with her faith. “There were only three or four of us in the high school in California. It helped me live my religion.” In the summer of 1966, Sherry and her husband moved. Lynda lived with Judy for the remainder of the year. Then in January of her senior year, she was invited to live with the family of Mr. McQueen, a math and science teacher at Pacifica and a church member, for her final semester. While back in California, she visited her mother every year.

Lynda and Sherry

She graduated in the spring of 1967. In high school she wanted to have good grades and to be active outside the classroom so that she could go to college. Her father had told all of her sisters that girls shouldn’t go to college. Judy had to fight to go to college. She did and got a degree. Lynda yearned to go on to a university.

> **I decided to go back to Utah because I’d always heard about BYU. Neither of my parents graduated from college. Growing up in the church, BYU was the mecca and I thought I wanted to go there.**

She applied there. It was her only application. She was accepted and offered a scholarship of $100 per semester for her freshman year. In the summer of 1967, Lynda and a girlfriend got jobs as maids in a Lake Tahoe resort and Lynda saved every penny she could for college. In August she was back in Provo living in a dorm, determined to get a college education.

Lynda paid her own way through college. “My father was no support. There was no support from my mother.” With the scholarship and the money she had saved, she was able to meet all of her expenses in her freshman year. Tuition was only $200 per semester for members of the church. But for most of the rest of her career at BYU, she had to work to pay all the bills. She didn’t want to borrow money. After her freshman year she lived in an apartment with friends. It was less expensive than staying in the dorm. “All I remember is that I was a waitress. I was a maid. I worked in the laundry at BYU.” Meanwhile, she took her academics seriously. Not surprisingly, she concentrated on language, English and Spanish. At the end of her junior year she crystallized her study of Spanish by spending a summer in Mexico City. The church had a high school there to try to provide a good education for local students. BYU professors accompanied their students on the trip. “We got the culture and flavor of it all.” The trip was her only exception to her policy of not borrowing money.

Of course, her life at BYU was not just work and study. She also had a social life, even from the beginning. In her first few weeks at BYU, she was already part of the dating scene. Her sister Sherry had an acquaintance in California who was going to BYU. She had given him Lynda’s phone number. Lynda had gone on a couple of dates with him. One day that August he called her at her dorm.

> **I was in my dorm and I was dating this guy in their dorm and the guy passed the phone around and I talked to a guy named Kelly. I never knew a guy named Kelly. So we talked. He was dating this girl and I was dating this guy.**

She and Kelly saw each other now and then during the fall. Then in November she decided to “invite” Kelly to her dorm’s Buddy Party. A relationship began that night. They continued dating steadily for the next year and a half, until Kelly started off on his mission.

The Couple


Kelly & Lynda, Spring 1968

Kelly returned from France in August of 1971 a bit more focused and ready to take his education seriously. It was good to be back in Provo. Commonly, young men would come back from their missions and find their girlfriends in serious relationships or married. He had missed Lynda and was very glad that she was still unattached. That summer she was taking her last class toward the completion of her studies. She was a semester behind, since earlier she had taken a semester off to help Judy, who was pregnant with a third child. That month she graduated with a degree in secondary education. Mitt Romney gave the valedictory address.

Fall began for Kelly with a new attitude toward academics. He enrolled in a plant taxonomy class taught by Welsh.

> **Somehow he and I hit it off, his personality, my personality, and I said that's what I want to be. I remember the day when I went to Lynda and said I know what I want to be. I want to be a botanist, do floristic studies and have a little herbarium, specialize in some little group of plants.**

Welsh was a major figure in the study of the botany of Utah and the intermountain region and was the lead author of *A Utah Flora*. "He gave me a B and I'm still kind of perturbed about that." Despite the perturbation, Welsh would later be his major professor. His lab instructor in the taxonomy course was another famous Utah botanist, Duane Atwood. Kelly became a botany major.

During the fall of 1971 Lynda did her student teaching. She lived with her mother. She also held down a job as a secretary in an insurance office. Kelly also landed a job. Despite being an undergraduate, he became a teaching assistant. His first assignment was in the general biology class, a course he had not taken. Kelly and Lynda spent a lot of time together. Their relationship had acquired an aura of permanence. Although not quite on bended knee, Kelly sought her hand in marriage in January of 1972. Lynda recalls the event. "All I remember is him saying, 'I'll take care of you.' And I said, 'Are you asking me to marry you?' And he said yes." So did she. They decided to wait until the following summer.

As his studies progressed, Kelly solidified his mastery of the scientific content of his courses, but also began to develop a field dimension. He took a course from a professor who had been raised in Palo Alto. Kelly's mother had known this professor as a youngster and remembered him as "a little hellion in church." A field project was required in the course. Kelly decided to study the diatom population in a small creek that ran through the campus. "I was very much intrigued by the patterns of the diatoms. Taxonomy is pattern recognition to a great extent." A plant morphology course from Professor Tidwell had a powerful effect. In order to encourage students to be thoroughly prepared in class, Tidwell would have a student stand in front of the class. He would then show slides of tissues and cells and ask detailed questions. *What kind of section is this? Tangential? Cross-section? Longitudinal section? What tissue are we in?* Kelly was an early victim.

> **As soon as he discovered that you hadn't prepared well, he would keep you up there and humiliate you, which he did. And I sat down after the first humiliation because I hadn't known what to prepare for. I'm going to show that #@*%! So I really studied hard. I got an A in the class and took three more classes from him. It motivated me because I was humiliated in front of the whole class, but I wasn't the only one. It only took two or three of us up there making fools of ourselves and suddenly everyone was studying.**

Coupled with his clear vision of where he wanted to head, this adjustment of his intensity and dedication was a perfect complement. Tidwell's courses also did much to broaden Kelly's experience base with fieldwork.

The summer came. Arrangements for the wedding were gradually finalized. Lynda's sister Kathy provided a special surprise. Kathy was living in Hawaii. She went out and gathered local orchids, packed them carefully in a box, and shipped them to Lynda. "I took them down and had them

made into bouquets at the florist." The ceremony took place in the Salt Lake Temple of the Church of Jesus Christ of Latter-day Saints on August 9, 1972. Kelly's parents, Wendell and Virginia, were there, as were Cory and Beverly, Cory as best man. Judy and Kathy came, as did the McQueens. Lynda's maid of honor was her dearest friend from junior high, Paula Bailey. Lynda became an Allred.

That fall they set up housekeeping together and began the pursuit of Kelly's vision of his future. Lynda continued her employment. Kelly remained a teaching assistant but concentrated his energies on his studies, broadening his base in botany, but also taking a few lower-division courses required for graduation. Even though he had been involved in teaching the general biology class, he also had to take the course. At the end of the spring semester of 1974 he was awarded his Bachelor of Science degree in botany. 1974 also saw the birth of the newest Allred, a son, Nathan.

There was never a question about the next step. He would pursue a master's degree. During his final undergraduate semester he had applied and been accepted into the graduate program at BYU. He was granted an assistantship and Lynda was able to leave her job and take care of the baby. Immediately after graduation he began work on his thesis research on the flora of Mount Timpanogos, a mountain in central Utah. Mount Timpanogos, Sleeping Maiden, is the second highest peak in the Wasatch Range, at 11,752 feet. "The flora was 600-and-something species. I went from about 6,000 feet to 12,000 feet." He completed his research and wrote his thesis in a single year and received his Master of Science in botany in 1975.

With the master's in hand, a PhD program became an imperative. Kelly's closest adviser, Stan Welsh, had come to BYU from Iowa State University and had sent other graduate students there. It seemed natural for Kelly to apply there. He received a letter in return from ISU professor Duane Isely, indicating that Kelly was certainly qualified and would be welcome but that no assistantship was available. Isely also mentioned that the ISU grass expert, Richard Pohl, had heard that Frank Gould, agrostologist at Texas A&M University, had an assistantship available. Kelly wrote Gould. Gould responded, inviting Kelly to go to College Station. "So that's how I got into grasses. I wasn't planning to study grasses. I had one grass course at BYU using Gould's book as a text. So I went down to Texas A&M in the fall of 1975."

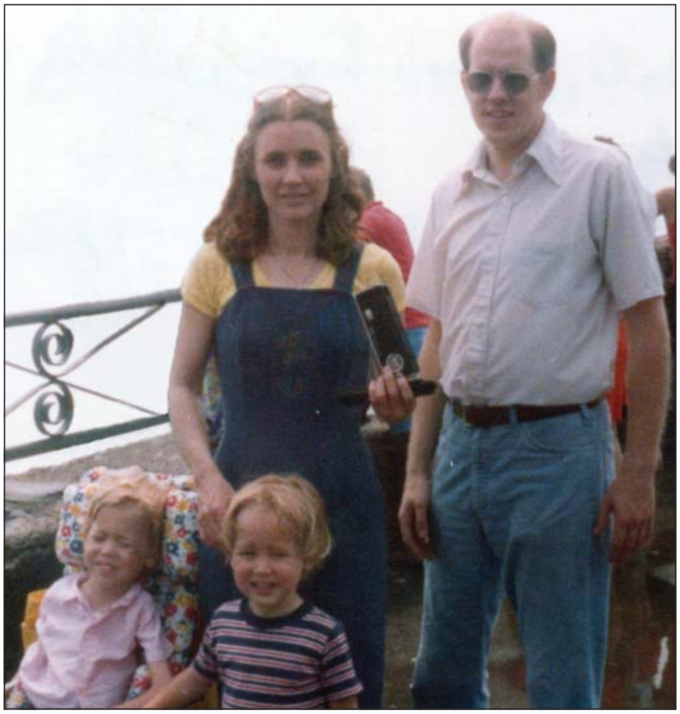
The young family traveled deep into the heart of Texas in late summer. Summer in south-central Texas is not the same as summer in north-central Utah. Lynda was shocked. "Texas was too hot and humid. How do people live in this place?" The situation was compounded by the fact that she was pregnant. Their married-student housing was in an old recycled army barrack, the last in a group being replaced by more modern units. The barrack had a roach infestation. Kelly and Lynda were quite distressed. "We would come home at night and they were on the walls. That was a little hard on us." As the birth drew near, in 1976, Lynda returned to Utah to have the baby, a second son, Jesse. Back in Texas, she tried to make the best of the situation. "I didn't work so we were very poor. We lived on $600 a month, the four of us, and we just did it. After a year, we moved out of the barracks into married-student housing that was brick and more modern."

Despite the difficulties, Kelly energetically went to work on the final phase of his education. In 1976, the *Great Basin Naturalist* published his first major paper, a result of his researches at BYU, concerning the gentian family in Utah. Then it was time to begin new research at Texas A&M. Gould suggested a direction for his dissertation research, the systematics and patterns of evolution in the grass genus *Bothriochloa.* Kelly began an in-depth study of the group. He and Gould started to suspect that some species might be the products of hybridization of others. "In the greenhouse I hybridized them, planted the seeds, up they came and there they were." By the spring of 1978, most of his research was complete and things seemed to be moving along. But he was in for an unfortunate surprise. Dr. Gould came to see him. He said, "I'm sorry, my assistantship money has run out. The grant is gone and I don't have any money for you." The year Kelly had counted on for the final crafting of his dissertation vanished. The young family was in dire straits.

The proximity of the long-sought goal and this sudden roadblock brought sadness and disappointment, but eventually determination and perseverance as well. There had to be a way, and there was. Kelly found and accepted a position at the State University of New York at Geneseo, about 60 miles east of Buffalo. It was a one-year position teaching courses in biology. The situation was far from ideal. The biology department occupied a two-story building and there was a schism in the department, with the lower floor at war with the upper floor. The Xerox machine was not on Kelly's floor. He did not have copy privileges and had to pay for every copy out of his own pocket. But the pay was steady, his teaching responsibilities were manageable, and the snowy winter conducive to progress with his dissertation. In fact, on February 26, 1979, Geneseo had its largest single-day snowfall in its history, 23 inches.

> **My research was basically done. So I did much of the analysis, all the writing, all the photography development in Geneseo. I taught at the college, teaching from eight to five. Home, dinner. Seven o'clock I'd go back, one mile back. I'd walk or maybe drive. Be there until midnight or so. I had all these pictures of chromosomes and things for my dissertation.**

After he had drafted the dissertation, he would have liked some suggestions from his advisor, but Gould had gone to Mexico. He turned to another member of his PhD committee, Paul Fryxell, who was "very, very helpful." In the summer of 1979, as he was putting the finishing touches on the dissertation, he began applying to a number of universities for employment for the next academic year. "I applied everywhere." He scheduled his dissertation defense back in College Station for early August. As the summer progressed, he had no success with his applications. Finally, after he had



Niagara Falls, 1979

made plane reservations for the trip back to Texas, New Mexico State University contacted him for an interview. "They said, 'Why don't you change your tickets?' So I went to my thesis defense, flew over to Las Cruces, did my presentation there and flew back to Geneseo." Two days later he received a call from the range science department head saying that NMSU would like to offer him the job. Kelly accepted on the spot.

Kelly's dissertation defense had gone well and he was officially Dr. Allred. And he had a job. The only problem was that classes would be starting in a week and a half at a university nearly 2,000 miles away.

> **It took us three or four days from Geneseo. We had two kids in the back of our Dodge Dart. We were pulling a double-axle trailer. We had to replace the transmission before we got there. We came from White Sands up the big hill. Back then there was nothing. The valley where it goes into the Jornada was just bare, and it was dry and brown. And Lynda asked, "Is this where we are living?" and I said this is it.**

Lynda had never seen New Mexico before (nor had Kelly before his interview). As a child she had traveled in summer with her family across the desert west of the Great Salt Lake in order to visit her grandparents. Her memories of desert were "just brutal." Those US-70 miles in New Mexico decades later were certainly less than comfortable. "But when we got into town, it was fine." From Geneseo they had contacted church members in Las Cruces. "They got us an apartment, and the day we drove in they had a crew of people there to unload the trailer." It was an important beginning.

Since Kelly had done his PhD at Texas A&M in the range science department, he had a PhD in range science. In actual fact, he had never taken a single class in range science. In the fall semester of 1979 he taught courses in range science, range plants, range grasses, and plant identification. Undaunted, he approached his assistant professorship with intensity and enthusiasm. The family settled in at their apartment on Missouri Avenue, within walking distance of the NMSU campus. And his salary was twice what he had received in Geneseo. There was, however, to be a dimming to their bright new life in Las Cruces. Even before they had arrived there, it had become clear that young Nathan had serious health problems. Soon after the end of that first semester, their first son lost his battle with spinal muscular atrophy. 1980 began darkly.

Such loss eludes acceptance, but eventually time, indomitable optimism, and the very essence of faith softened the sorrow for Kelly, Lynda, and Jesse. Future, so silenced by past and present, found its usual place again. Kelly wanted very much to have a successful career at NMSU, as part of his collegiate vision of a life in botany, and for his family. He continued his commitment to teaching and guiding his students. He had inherited a graduate student from his predecessor, Dr. Stephen Hatch, who had, amazingly, just accepted a position at Texas A&M. Kelly helped that student, Robert Soreng (now a botanist at the Smithsonian), through his studies in the grass genus *Poa* and to the completion of his master's degree in 1980. Kelly also published a paper in 1981 and another in 1982. By 1981 the family had moved out of their apartment and into a house on Jordan Road, also near campus, which is still home to this very day. By 1982 Kelly had moved into quarters in Room 321 in the recently completed Knox Hall, the brand new home of the Department of Animal and Range Sciences. In that same year Jesse entered school and his new brother, Brady, entered the world. Two years later, another Allred son, Corby, arrived in the household to complete the family.

In 1983, Kelly reached two milestones. He formally published the results of his earlier researches in *Bothriochloa* and, more importantly, became an associate professor and gained tenure. It was then time to seek a new direction in research. He recalled that he had always had difficulty identifying grasses in the genus *Aristida*. "I'll just start collecting all the *Aristida* that I can and see what I can do, and that gradually worked into a major focus." As the eighties progressed he not only collected in the field but also began visiting other herbaria. "I visited all the ones in New Mexico and the two big ones in Arizona. I visited in California, mostly Berkeley, Rancho Santa Ana Botanic Garden, and Chico." He visited the Smithsonian. He even made four excursions into Mexico for "a week or two" to study the species there with Jesús Valdés-Reyna, a Mexican agrostologist he had met while both were graduate students at College Station. "So I spent a lot of time looking at plants, looking, looking, looking. Finally, I started to understand the variation patterns." Ultimately he came to realize that previous workers had named a large number of species without understanding these subtle patterns and that the taxonomy of the group could be greatly simplified. He continued to publish papers on *Aristida* for another 20 years.

Kelly's academic world was by no means limited to *Aristida*. In his first semester at NMSU he had taught plant identification. In the range science department this meant that the instructor was the coach of the "plant team." The plant team was a group of students chosen from the identification class to participate in a very difficult plant identification competition against teams from around the United States and even Canada and Mexico, at the annual meeting of the Society for Range Management. The 1980 team from NMSU won first place. "Then we won four or five times in a row, with the team from Saltillo, Mexico, where Jesús Valdés-Reyna was, finishing second." Kelly continued with plant teams for most of his career, but the Saltillo team gained the upper hand and dominated the competitions for many years.

Kelly also taught the course on range grasses every semester of his career. In the early years he began writing identification keys for the grasses of New Mexico. He and his students continually tested and improved them as more were developed. He began to envision writing a book on New Mexico grasses. "The way I work in research is I'll get interested in a project and the first thing I think of is the title." In this case it was *A Field Guide to the Grasses of New Mexico.* In 1993 the first edition was published, through the Department of Agricultural Communications at NMSU. A new and improved second edition appeared in 1997 and then a third in 2005.

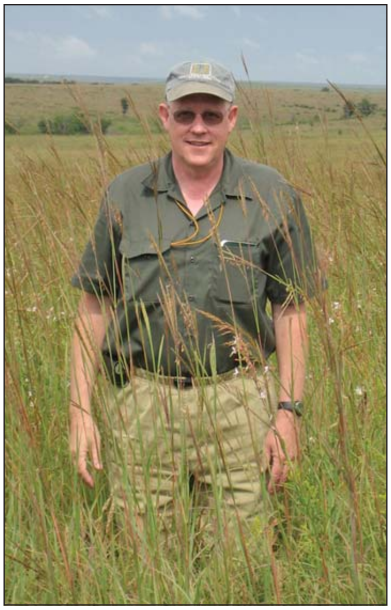
In the eighties Kelly made a point of going to meetings "with all the grass people." He had been in contact with botanists all over the country for his researches in *Aristida.* Through his published papers in the decade, he had become well known in the grass world. In the early nineties he was selected to author treatments of *Aristida*, *Bothriochloa,* and 13 other grass genera for the 1993 edition of *The Jepson Manual: Higher Plants of California* for the University of California Press. Nine years later he authored treatments of 10 grass genera for *The Jepson Desert Manual*. Then in 2003 he was selected by the *Flora of North America* editorial committee to prepare treatments of *Aristida, Bothriochloa,* and 5 other grass genera for Volume 25 of the *Flora of North America* project for Oxford University Press.

Throughout his three decades at NMSU he worked steadily to improve the small collection of three or four thousand dried plant specimens that the range science department used for teaching. He collected plants extensively. He arranged with other herbaria around the country to receive duplicate specimens or to have an exchange of specimens. He also had a number of graduate students in his charge over the years doing research for their master's degrees who did field studies and contributed many specimens. Several of these students went on to tremendous careers in botany. "Travis Columbus [now a grass systematist at the Rancho Santa Ana Botanic Garden in California] has been our most famous one. He has now become the world authority in [the grass genus] *Bouteloua*." Columbus contributed more than 2,000 specimens. Thanks to the efforts of Kelly and his graduate students, the Range Science Herbarium at NMSU, now with almost 30,000 specimens, is recognized as a significant research herbarium and is officially listed as NMCR in the *Index Herbariorum*, the directory of the world's herbaria by the New York Botanical Garden.

In the mid-nineties Kelly began to develop some new interests. He and a different graduate student, Eric Roalson (now a highly respected plant molecular systematist at Washington State University), hatched the idea of establishing a master checklist of the plants of the state. "The idea was to get all the names, get the documentation and where it was reported from New Mexico." Eric did a tremendous amount of work on the project and was the main author of the first *Working Index of New Mexico Vascular Plant Names.* Kelly continued expanding and improving it for years. The nineties also spawned another long-term project. Kelly decided that it might be beneficial to put together a newsletter to help keep the state's botanists abreast of new developments. In September of 1995, he began publishing *The New Mexico Botanist* through the Cooperative Extension Service. It presented articles of interest, announcements of new plant records, and references to pertinent literature. By the end of the decade 13 editions had appeared. Also during this era, he initiated his study of a whole new vista in botany, the mosses. In 1998 he published his first papers on the moss flora of the state. In 2001 he published, with Carl Darigo of the Missouri Botanical Garden, *Mosses of New Mexico County Checklist*. His studies in muscology became a lifelong passion.

Not far into the first decade of the new century Kelly began to think that the Working Index might be developed into something more. As was his wont, the title came first, *Flora Neomexicana.* In early 2007 he produced what would be the last interim draft edition of the Working Index. By the end of the year the plan for the *Flora Neomexicana* project had crystallized. It would consist of three volumes. The first would be an expanded and improved version of the Working Index. The second would be a detailed survey of the origins and meanings of the Latin and Greek words used to generate the scientific names of the plants. The third would be an identification manual down to species, subspecies, and variety levels, with range and habitat data. By 2008 the project was off and running. *Flora Neomexicana I: The Vascular Plants of New Mexico* came out. Kelly was also hard at work on the second volume. In odd moments he concentrated on developing identification keys. And he started thinking of how nice it would be to have illustrations in the third volume. He contacted the state's foremost plant illustrator, Robert DeWitt Ivey, about the possibility of collaboration, and the third volume gained a wonderful new dimension.

In 2009 the second volume in the series, *Flora Neomexicana II: Glossarium Nominem,* was complete. Kelly also produced the 132-page guide *Identification Keys to the Vascular Plants of New Mexico: Families and Genera*. Yet much more work was necessary to bring the keys to the species level and below. Although accomplishing much of the task himself,



Kelly, 2008

Kelly elicited assistance from several other botanists in the state. It took another three years to complete the text, perfect the formatting, and integrate more than 1,600 illustrations. The 8½-×-11 inch, 715-page *Flora Neomexicana III: An Illustrated Identification Manual* reached publication in 2012. Later that year Kelly created an 8-×-9 inch, 482-page *Flora Neomexicana IIIa: Field Keys,* without illustrations.

Also during the same period, he had a remarkable visit from his old friend *Aristida*. His extensive studies of the genus had made him into a highly regarded authority, but a new day had dawned with the advent of DNA analysis. Things came full circle when a graduate student at the Rancho Santa Ana Botanic Garden undertook a molecular study of *Aristida*. Her advisor was none other than Travis Columbus. Kelly was asked to be on her committee in order to verify identifications of specimens used in the research. After some six years, in 2011, her analysis was published.

> **She went through and ran the molecular analyses on all these species that I had studied and said these are all related and those are all related. I had all the relationships exactly correct. So I was very gratified that all the relationships that I had divined and figured out just based on a lot of experience, how it grows, structure of the hairs, what the leaves look like, some curl, some don't. So all this stuff I had figured out just matched up with her DNA analysis.**

This level of parallelism between morphological analysis and molecular methods is unusual in botany. In his patient and intensive study, Kelly had produced unquestionable science by combining an extreme thoroughness in observing minute details, an uncommon capacity to perceive patterns, and a strength of intellect to correlate and organize data.

The relationship between religion and science has forever been contentious, if not vitriolic. Numerous in the world of science are those for whom rational inquiry and religious faith would appear to be in direct conflict. Kelly Allred maintains a strong presence in both his church and his biology. Clearly his pursuit of scientific understanding is not impeded by his beliefs.

> **The revealed religion that we have in our faith, in Mormonism, really doesn't speak about biological origins at all, and the Church, by the way, has no stand on evolution. I think that true science and true religion are one and the same. One of the tenets of Mormonism is that truth, no matter where you find it, is part of this religion.**

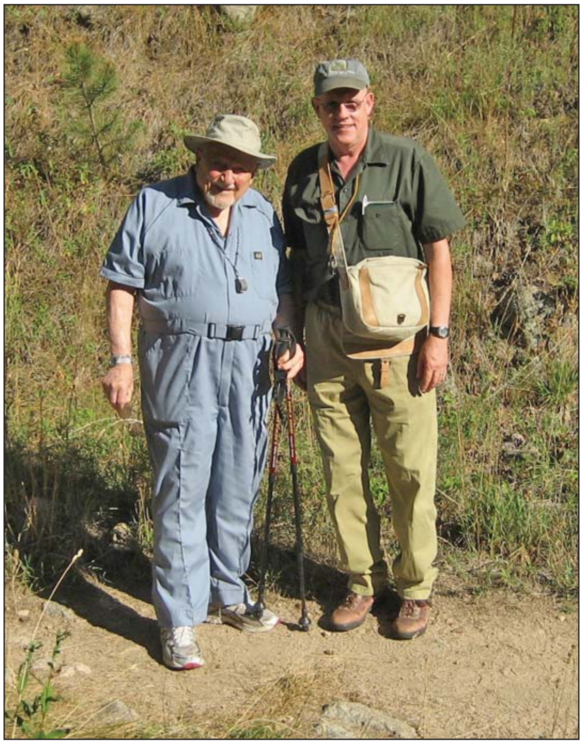
Religion can inculcate, in some, a personal devotion obscuring rational processes, becoming obsession. Kelly maintains a calm and contemplative faith far distant from obsession. In his view, God "oversaw the creation" of the universe in which we play a part.

> **A lot of Protestants have the idea of creation *ex nihilo*, there was nothing, and God went phoom and there was something, creation from nothing. I think that is totally wrong. I am perfectly content that He is using all the natural processes that we see in action now.**

From that perspective, the study of natural processes does not in the least conflict with faith.

Science operates in a domain of observable and measurable things, gathering data, seeking patterns and generalizations. Religion occupies a domain of intangibles, relying on well-established and time-honored resources for insight. Both religion and science are bastions for their devotees. Yet, for many, such domains are not so clearly definable, and, as Kelly has expressed, they may, in some way, be aspects of the same thing, some perpetual quest for understanding. Science itself is not empty of faith. Any graduate student embarking on an advanced degree confronts some hypothesis to explore. Such exploration carries a dimension of faith, if only in an incalculable certainty that something unknown can become known. Therein is a blending of the essential components of inquiry, both spiritual and scientific. Faith need not be inimical to science. Kelly is at home in both domains, and each has its special space. His faith and his church have much more to do with generosity, sincerity, and hope than with *Aristida*.

For Kelly, 2012 was quite a year. The University of California Press published a second edition of *The Jepson Manual: Vascular Plants of California,* with Kelly's treatments of six genera of grasses. At the end of NMSU's fiscal year, he became professor emeritus of the Department of Animal and Range Sciences. Of course, 2012 was a most important year for the *Flora Neomexicana* project and the year would be busy, but there was time for a bit of traveling, trips to the Sangre de Cristo Mountains and Maine in June and a visit to Alaska in August. Kelly spent July tidying up details, and *Flora Neomexicana III* was fully launched by the middle of August. The production of *Flora Neomexicana IIIa* required reformatting and editing of the August volume and became available by the middle of November. Even before the year ended, he began to think of integrating material from *FNM I* into *FNM III* and adding more complete descriptions of genera to produce a new, revised edition.



Mossing with Bill Weber

And he had not abandoned his investigation of the moss flora of New Mexico. Throughout the 2000s he traveled all over the state hunting mosses and refining the skills necessary for their study. He also became associated with other moss aficionados in the western United States in a program called SO BE FREE, which is an acronym for Spring Outing, Botanical Excursion, Foray, Retreat, and Escape to the Environment. Organized in California in 1996, the annual program brings together bryologists and other interested people for a long weekend in March to study the moss flora of some selected area. In 2010, Kelly arranged for the meeting to be held in the Sacramento Mountains of New Mexico. Kelly has worked quietly on the state's mosses for almost two decades, mostly without assistance until the past few years. The result is a documented moss flora encompassing 42 families, 139 genera, and over 350 species, destined to become a part of the *Flora Neomexicana* project.

Kelly has had a rich and rewarding career. He has worked tirelessly to enrich the worlds of his dedication, his botany, his classroom, his church, and his family. Since 1976 Kelly has produced nearly 200 publications in dozens of scientific journals, government reports and circulars, books, and other venues. He has given countless talks, presentations, and workshops. His wry sense of humor and irrepressible ebullience have put him in demand. His contributions to the botany of New Mexico and the entire world of grasses are legion. The *Flora Neomexicana* project is the first new view of the state's flora in over a third of a century, during which time the science of botany has undergone profound change. For Kelly the uncovering of truth and generality in his science and in his faith has been a simple privilege of sentience and a vital duty of intellect.

He has never been one to quail before a task, however daunting. His quarter century of waltzing with *Aristida* is a testimonial. In the second decade of the new millennium work continues on the revision and expansion of *Flora Neomexicana III*. The moss flora has been mostly defined, and an identification manual is under development. In February of 2010 *The New Mexico Botanist* Number 50 appeared and was the last hard copy distributed by mail. In the following June, Number 51 was the first electronic issue. The newsletter continues and in March of 2015 reached Number 63. Kelly's days remain full.

For his many pursuits, awards have never been necessary. Kelly is not one to seek adulation. Yet sometimes recognition from peers carries special meaning and value. In 2011, a species of flax new to science from southeastern New Mexico, *Linum allredii,* was named for him, a permanent preservation of all that he has accomplished for the state's botany.

Gila: Biodiversity and Conservation—An Exhibit in Development at the New Mexico Museum of Natural History and Science

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Abstract

The New Mexico Museum of Natural History and Science provides educational experiences and promotes scientific inquiry to inspire a greater appreciation, understanding, and stewardship of science and our natural world. We are currently developing an exhibit about the Gila ecosystem in southwestern New Mexico, to engage visitors and highlight why the region is so valuable and important. The exhibit will focus on three questions: (1) What makes the Gila unique? (2) What is the human influence on the ecosystem? and (3) What can the Gila teach us? Visitor surveys taken at the museum provided information that most visitors have some knowledge about the Gila Region and that nearly all visitors value wilderness areas. More generally, the Gila exhibit can be used as a case study for discussing broader issues of biodiversity and conservation. Exhibits that highlight important regions in New Mexico are not only of aesthetic interest but should also encourage an appreciation and respect for our natural heritage.

Index Descriptors: natural history museum, exhibit, informal learning, biodiversity

Introduction

Museums in urban centers can be important tools for creating a greater appreciation and understanding of the natural world. For example, museums can provide informal educational events, promote scientific inquiry, and—very importantly—bring nature to an audience that may not seek outdoor experiences or be able to visit natural areas (Novacek 2008). While learning inside a museum is not the same as a real-life experience, museum exhibits can inspire or excite individuals and communities (Black 2010) and can be a useful way to raise awareness of natural systems through informal learning (Falk 2002; Ferreira 2012). An exhibit can teach about the underlying geology or intricate biology of a region. Visitors can learn about the dynamics of ecological functions and processes and can be encouraged to continue their inquiry after leaving the museum. For example, the *Becoming Los Angeles* exhibit at the Natural History Museum of Los Angeles County incorporates ecological elements in an urban landscape, while engaging a diverse audience (Ferguson 2013). Learning in a relatively "safe" environment like a museum could be a gateway to exploring—figuratively and literally—the natural world; this understanding can develop a personal appreciation of nature and subsequently encourage stewardship.

The New Mexico Museum of Natural History and Science is located in Albuquerque, the largest urban center in New Mexico, and therefore presents an opportunity to introduce nature (and ecological concepts) to a largely urban audience. Part of the mission of the museum is to provide educational experiences and promote scientific inquiry to inspire a greater appreciation, understanding, and stewardship of science and our natural world. Museum staff members are currently developing an exhibit about the Gila ecosystem, a region in southwestern New Mexico with diverse topography and high levels of biological diversity. The exhibit will engage visitors and highlight why the region is so valuable and important. In order to develop ideas for the exhibit content, we held workshops and conducted a survey of museum visitors to assess their knowledge of the Gila Region.

Methods

Two workshops were held to discuss potential topics to include in an exhibit about the Gila. The first workshop was held in Albuquerque (November 2012) and the second was held in Silver City, New Mexico (April 2013). A list of potential participants was developed by museum staff to represent different areas of expertise for the Albuquerque workshop, and these participants suggested additional experts for the Silver City workshop. Participants were chosen to represent a diversity of local knowledge at the workshop (Table 1).

In each workshop, we spent the majority of the time brainstorming key concepts that could be included in the exhibit. After each workshop, the key ideas were summarized, and then concepts from the two workshops were synthesized for exhibit development.

With the information from these workshops, a visitor survey was developed for distribution at the museum. The survey was designed to assess general knowledge about the Gila from museum visitors.

Experienced museum volunteers distributed the survey to visitors in the museum in February and March 2014. Visitors were asked to complete the survey themselves, with no input from the volunteers. Data from the surveys were entered into a spreadsheet as either binary data (for answers to multiple-choice or yes/no questions) or string text (for open-ended questions).

Table 1. Participants in the Albuquerque and Silver City brainstorming workshops. Participants were affiliated with the University of New Mexico (UNM), United States Fish and Wildlife Service (USFWS), National Park Service (NPS), New Mexico Museum of Natural History and Science (NMMNHS), New Mexico Department of Game and Fish (NMDGF), Western New Mexico University (WNMU), The Nature Conservancy (TNC), and Northern Arizona University (NAU).

Albuquerque	Silver City
Meghan A. Balk (UNM)	Michael Berman (photographer)
Michelle R. Christman (USFWS)	Cynthia A. Bettison (WNMU)
Joseph A. Cook (UNM)	Martha S. Cooper (TNC)
William W. Dunmire (NPS/UNM)	Randy D. Jennings (WNMU)
James Lane (NMDGF)	William R. Norris (WNMU)
Gary S. Morgan (NMMNHS)	Ellen S. Soles (NAU)
Thomas F. Turner (UNM)	Kathy E.Whiteman (WNMU)

Results

Workshops

Seven expert participants attended each of the workshops (Table 1). Museum staff members also attended the meetings to introduce the exhibit, focus discussion, and record outcomes for the day.

At the Albuquerque workshop, the group discussed concepts of conservation and management. The geology and ecology of the Gila were recognized as being interrelated and unique to the region. Workshop participants talked about the high levels of endemism in the region (partly influenced by topography) and some of the current flora and fauna in the region. Other topics discussed included conservationist Aldo Leopold, who proposed that part of the Gila National Forest become the first designated wilderness area in the United States; traditional land uses; and future management challenges such as climate change and wildfire. There were also indications that the exhibit should highlight conservation success stories as well as conservation challenges.

At the Silver City workshop, the group spent some time defining *Gila*. The word could define a watershed (including the Gila, Mimbres, and San Francisco watersheds), a river that extends into Arizona, or a wilderness area. As in the Albuquerque workshop, there was also a discussion of the long history of the region and future challenges such as flood, fire, and drought. There was a lengthy discussion about the important ecological value of the Gila River and the high levels of biodiversity in the region. The group created a list of organisms that may be interesting to include in an exhibit (including Mexican gray wolf, *Canis lupus baileyi*; Gila trout, *Oncorhynchus gilae*; Chiricahua leopard frog, *Rana chiricahuensis*; and beaver, *Castor canadensis*).

The Silver City workshop also identified ecosystem services as an essential feature of the Gila Region that should be included in the exhibit. Part of what makes the Gila unique is that it is unregulated; it is the last free-flowing river in New Mexico. One workshop participant described it as "the marvel of a riparian ecosystem in the desert." While the Gila represents a unique ecosystem, there are ways to make "global" comparisons with other regions and other systems. For example, it could be placed in the context of the Colorado Basin. Workshop participants identified that it is important to make the region "tangible" for museum visitors, who may not visit the Gila.

From these two workshops, the discussion points were synthesized and reviewed by the exhibit committee at the museum (Fig. 1). Three focus questions were developed for the exhibit and were used to develop the visitor survey:

(1) What makes the Gila unique?
  a. Understand the links among biology, geology, and climate.
  b. Learn about biodiversity, highlighting unique organisms.

(2) What is the human influence on the ecosystem?
  a. Natural resources are influenced by the history of human colonization and use.
  b. Highlight management of wilderness areas, na-

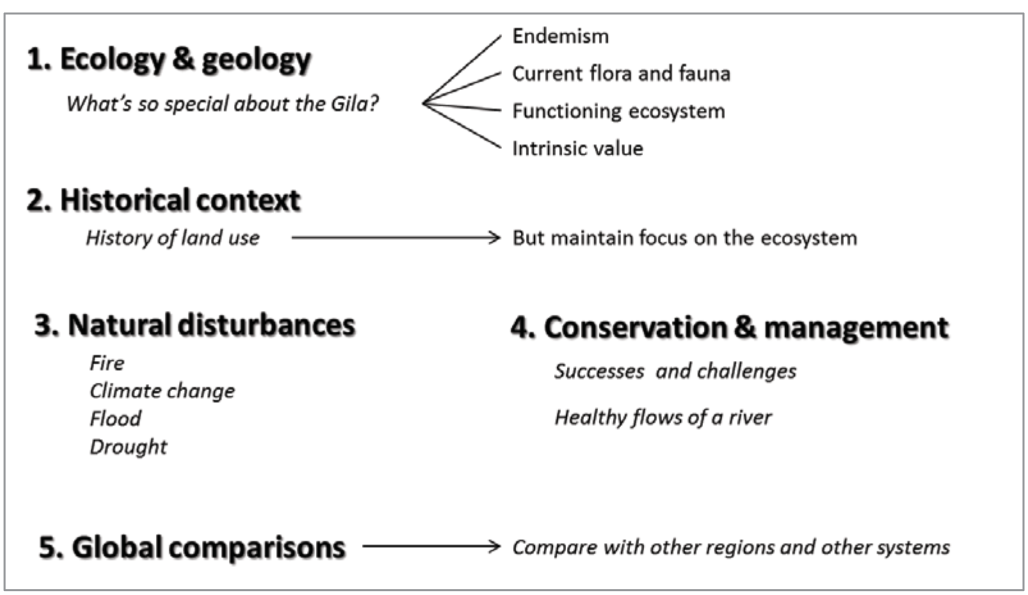

Fig. 1. Major concepts for Gila exhibit ideas from the brainstorming workshops in Albuquerque and Silver City.

Table 2. Questions included in the visitor surveys used to determine knowledge about the Gila Region.

	Topic-Driven Questions	Answer Format
1	What do you think of when you hear the word *Gila*?	multiple choice
2	Have you been to the Gila?	yes/no
	If you answered yes, which of these areas have you visited?	multiple choice
3	Do you think the Gila Region is important to New Mexico?	yes/no
	If you answered yes, in what ways is this area important?	multiple choice
4	Check which topics you have heard about in the news.	multiple choice
5	Can you mark the Gila on the map?	blank map of NM
6	Do you plan to visit the Gila Region within the next year?	yes/no
7	Have you visited another wilderness area in the past 10 years?	yes/no
8	Do you think wilderness areas are important?	yes/no
	If you answered yes, why are wilderness areas important to you?	multiple choice
	Demographic Questions	
1	Age	multiple choice
2	ZIP code	blank
3	Ethnicity	multiple choice
4	Education	multiple choice

tional forests, and national monuments—managing for ecological, recreational, and aesthetic goals.

(3) What can the Gila teach us?
   a. Although unique, the Gila is tied to other places.
   b. The Gila can be used as a model to understand ecosystems.

Visitor Surveys

The survey included eight topic-driven questions and four demographic questions (Table 2). The survey was deliberately kept brief, as visitors would be completing it while standing near current museum exhibits.

Museum visitors completed 135 surveys. The demographics reflect the typical visitors to the museum (Table 3): younger adults (21–40 years of age) or older adults (> 50 years of age) usually accompany young children or school groups. Most respondents identified as "White" and many had completed higher education.

Many of the respondents had heard of "Gila Monster" (45.9%) or the "Gila Wilderness" (43.0%), and about one-third had heard of either "Gila River" (32.6%) or "Gila National Forest" (31.1%). Few of the respondents identified "Gila Trout" (8.9%).

Approximately half of respondents had visited the Gila (51.1%). The respondents had visited the Gila National Forest (36.3%), Gila Cliff Dwellings (30.4%), Gila Wilderness (30.4%), or Gila River (27.4%). Only a few of the respondents (7.4%) could identify having visited the Aldo Leopold Wilderness.

Table 3. Demographic data of survey respondents. Museum visitors completed 135 surveys.

		Visitors (%)
Age Group	Under 12	1.5
	12–20	13.3
	21–30	17.0
	31–40	18.5
	41–50	7.4
	51–60	11.1
	61–70	19.3
	Over 70	11.9
Ethnicity	Native American/American Indian	3.7
	Hispanic or Latino	11.9
	Black/African American	0.7
	Asian/Pacific Islander	1.5
	White	74.1
Education	Current student	13.3
	High school	17.8
	College degree	28.9
	Higher degree	34.8

Nearly all respondents thought that the Gila Region is important to New Mexico (90.4%) and only four respondents (3.0%) did not think it was important. Of those that did think it was important, "Wilderness" was clearly identified as the most important reason (71.9%), and other environmental assets were also identified as important: "Ecosystems" (58.5%), "Water Cycles/Watershed" (52.6%), "Biodiversity" (48.9%), and "Forestry" (43.0%). "Mining" was identified as important by a smaller percentage of respondents (14.1%).

Most respondents had heard about the Gila in the news (91.9%). Of those who had not heard about the Gila, most were from the Albuquerque/Santa Fe region (8.1% of total), two were from out of state, and one was an international visitor. The topic that most frequently had been heard about in the news was "Fires" (79.3%). "Endangered Species" was identified by nearly half of the respondents (45.9%), and "Wolves" and "Gila Trout" were both mentioned twice in the extra comments. "Drought" and "Lack of Water" were also noted in the comments; many respondents also identified "Floods" (39.3%), "Water Diversions" (36.3%), and "Arizona Water Settlements Act" (12.6%) as topics that they had heard about in the news. Finally, "Copper Mines" was identified by 28.9% of respondents as a topic in the media.

When asked to mark the Gila on the blank map of New Mexico, nearly half of the respondents (44.5%) either left the map blank (30.4%) or marked the wrong quadrant (14.1%). However, more than half of the respondents (55.5%) were able either to place it in the right quadrant of the map (51.1%) or marked the map with a very accurate representation (4.4%).

Only about one-third of respondents planned to visit the Gila Region within the next year (34.1%). However, most respondents had visited another wilderness area in the past ten years (86.7%) and nearly all respondents thought that wilderness areas are important (97.8%). As a follow-up to question 8, respondents were asked, "Why are wilderness areas important to you?" Respondents had several reasons for valuing wilderness areas (Fig. 2). Most respondents identified preservation of natural assets, and many identified recreational activities as being important. This question received the most written comments, with reasons listed for why wilderness areas are important to individual respondents. Several respondents commented about wildlife (e.g., "birding," and "keep wildlife safe") or ecological functioning (e.g., "water preservation" and "healthy ecosystems"). Other respondents added comments that were more cultural ("history and significance"), economic ("tourism to the state"), or non-material ("dark skies," "living with earth," "future generations' pleasure," "just existing").

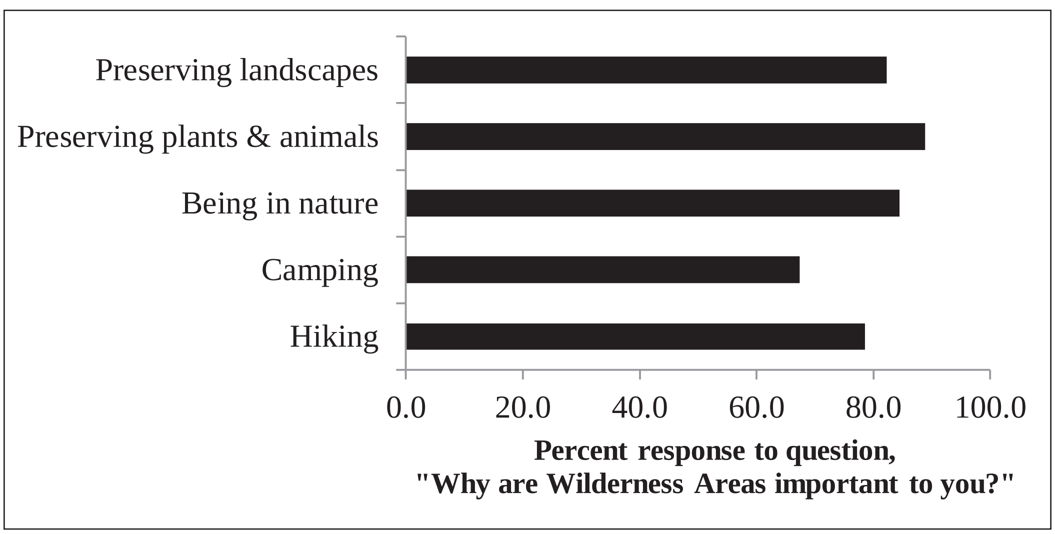

Fig. 2. Responses to question 8 of the museum visitor survey. Visitors were first asked, "Do you think wilderness areas are important?" For those respondents who answered yes, they were then asked to identify, "Why are wilderness areas important to you?" The responses to the second part of the question are represented here.

Discussion

Through the two workshops with local experts, three focus questions were developed for the exhibit: (1) What makes the Gila unique? (2) What is the human influence on the ecosystem? and (3) What can the Gila teach us? The Gila can be used as a valuable case study of natural resource management, particularly because it includes the first designated wilderness area in the United States and is recognized for geologic features and biological diversity. Furthermore, many of the conservation issues discussed in the workshops and included in the visitor survey are not specific to the Gila and can be used to provide a more "global" context for the exhibit by creating comparisons with other regions.

The visitor survey indicated that visitors had a basic knowledge of the Gila, but that there were some knowledge gaps for the public. Only half of the survey respondents had visited the Gila Region or could accurately place it on a map of New Mexico. Respondents were also asked about the value of the region, and of wilderness areas in general; respondents valued wilderness areas for a number of reasons, ranging from economic and historical to biological and spiritual. The results of these surveys will be used to guide the design process for the exhibit, so that some established knowledge can be reinforced while new concepts are introduced to the museum audience.

Information included in the exhibit could be an effective way to educate museum visitors more generally about the natural environment (Orams 1997). Also, a well-designed exhibit can promote learning and could stimulate further questioning about, or participation in, nature (cf. Beaumont

2001). For example, the exhibit will also be used to teach some general principles of ecosystem science. Workshop participants emphasized that the Gila River is largely intact and that the natural flow regime contributes to the maintenance of the system's biodiversity. The Gila can be used as a good example of an ecosystem in a relatively natural state (i.e., "a functioning ecosystem"); systems that can be considered a reference state are extremely valuable for the field of restoration ecology (Hobbs and Norton 1996; Ehrenfeld and Toth 1997; Giller 2005).

Visitors to the museum usually have an interest in natural history, particularly adult audiences who choose to come to the museum. It could be argued that creating an exhibit for audiences like this is effectively "preaching to the choir" rather than recruiting new audiences that do not already have an interest in wilderness or natural history (Beaumont 2001). However, reinforcing concepts that are already familiar to an audience can still be effective and can make it more likely that visitors will continue their learning from the exhibit once they are at home (Storksdieck et al. 2005).

A museum exhibit cannot replace the experience of visiting a natural area such as the Gila. Visitors to wilderness often describe their experience as awe-inspiring, spiritual, or soul-fulfilling (Ashley 2012). Nearly all of the respondents to the visitor survey at the museum agreed that there is an intrinsic value to wilderness, whether or not they visited regularly. A visit to the museum can also be inspirational and offer the opportunity to learn from experience (Falk and Dierking 2010).

Acknowledgments

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Gila River Flow Needs Assessment

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Abstract

The substantially natural hydrograph of the upper Gila River supports the largest complement of native fishes and some of the best remaining riparian habitat in the lower Colorado River Basin. Changes to the river's flows may significantly degrade the aquatic and riparian ecosystem. The Arizona Water Settlements Act (AWSA) authorizes federal funds to build a New Mexico Unit that could divert up to 14,000 acre-feet annually. The goal of Flow Needs Assessmentwas to define the ecosystem water needs of the upper Gila River in New Mexico and to evaluate the impact of the proposed diversion and climate change. To achieve this goal, a team of academic partners synthesized scientific literature on hydrology, geomorphology, riparian vegetation, wildlife, and flow-ecology relationships and conducted new analyses. Diversion allowed under the AWSA and climate change would reduce the number and magnitude of mid-size flows in the 150–4,000 cubic feet per second (cfs) range. If the frequency of these flows is reduced, the floodplain would be inundated less often, with decreases in alluvial aquifer recharge. The most pronounced seasonal impact from the proposed diversion would occur during the snowmelt runoff period. Reduced flows and abrupt changes in flow as snowmelt recedes would reduce the cleaning of fine sediments from gravel and cobbles, and limit the re-sorting of these substrates to create suitable spawning habitat for native fish. This would reduce spawning success and diminish aquatic invertebrate production. Invertebrates are an important food source for fish, birds, amphibians, reptiles, and mammals. The Gila River Flow Needs Assessment offers a comprehensive overview of projected impacts of climate change and water diversion on the ecosystem in the Cliff-Gila Valley; this paper provides a summary of this report.

Index Descriptors: Gila River, hydrology, ecology, diversion, Arizona Water Settlements Act.

Introduction

The Gila River is widely recognized for the habitat it provides for people and wildlife in southwest New Mexico. Flow variability is the defining feature of the Gila River in New Mexico—creating a multi-aged riparian forest and floodplain wetlands that support rich bird diversity (Hubbard 1971; Baltosser 1986; USFS 2002) and provide habitat for numerous mammals (Simpson 1964; Frey 2010). An array of aquatic habitats supports native fishes (Propst et al. 2008). Numerous federally protected species are found in the Cliff-Gila Valley: Southwestern Willow Flycatcher (*Empidonax traillii extimus*) (USFWS 1995), spikedace (*Meda fulgida*) (USFWS 1986b), Western Yellow-billed Cuckoo (*Coccyzus americanus*) (USFWS 2014a), loach minnow (*Tiaroga cobitis*) (USFWS 1986a), northern Mexican gartersnake (*Thamnophis eques megalops*) (USFWS 2014b), and narrow-headed gartersnake (*Thamnophis rufipunctatus*) (USFWS 2014b). The Gila is a rare example of a southwestern river with a natural flow pattern that sustains its high biodiversity.

The Arizona Water Settlements Act of 2004 (AWSA) provides an opportunity to augment water supply in southwest New Mexico, authorizing diversion of an additional 14,000 acre-feet annually from the upper Gila River in exchange for Central Arizona Project water (US Congress 2004). Terms of diversion are described in the Consumptive Use and Forebearance Agreement (CUFA) in the AWSA. AWSA was accompanied by an appropriation to New Mexico that may be used for either "other water utilization alternatives to meet the water supply demands" of the region or a permanent river diversion and other associated facilities (US Congress 2004). The Gila River Flow Needs Assessment (the "Assessment") is intended to help water and natural resource managers effectively weigh the ecological impacts of a permanent diversion and adapt to climate change.

Description of Study

The Nature Conservancy and a team of academic partners received funding for the Assessment from Bureau of Reclamation's WaterSMART Program and the Desert Landscape Conservation Cooperative. The Assessment describes the existing condition of the Gila River in the Cliff-Gila Valley, New Mexico, and examines the potential impacts of additional diversion and climate change on the riparian and aquatic ecosystem of the 35 km (22 mi) Cliff-Gila Valley (Fig. 1). The project team completed a draft report summarizing river flows and ecological attributes. A workshop brought together 35 scientists from 24 agencies, universities, and organizations with expertise in some aspect of the Gila River's hydrology and ecology (Table 1). Workshop participants reviewed and contributed to the report. The report includes a summary of workshop findings, focusing on how flows shape the ecosystem and how these interactions may be affected by flow alterations due to CUFA diversion and climate change.

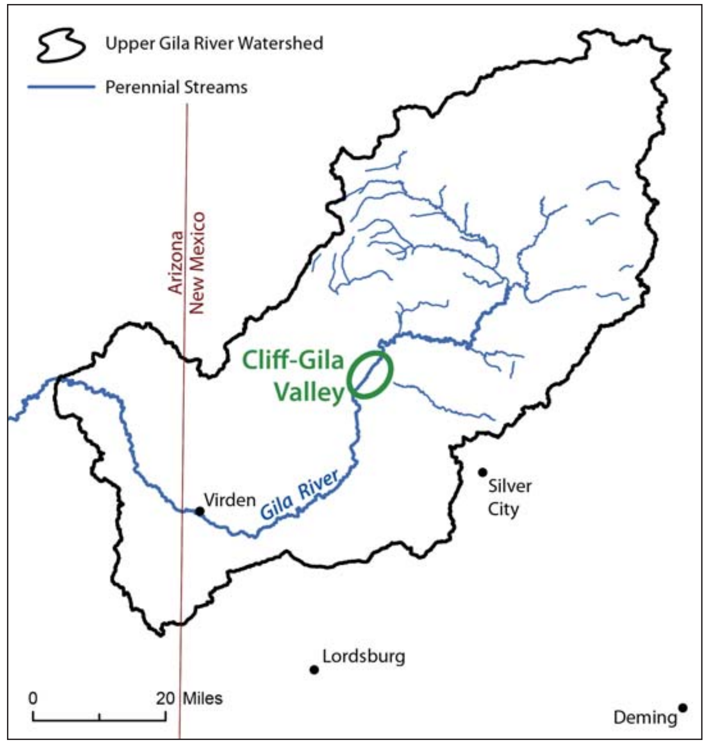

Fig. 1. Upper Gila River watershed, showing extent of perennial flow and the Cliff-Gila Valley.

River Flows and Floodplain Processes

The Gila River in New Mexico fluctuates between extraordinarily high and low flows within years and over the course of years (Propst et al. 2008). Native flora and fauna have evolved life history strategies and life cycles in direct response to the natural flow regime (Poff et al. 1997; Bunn and Arthington 2002). Flows during each season play distinct ecological roles that support the diversity of the aquatic and riparian ecosystem (Yarnell et al. 2010). The annual hydrograph was delineated into four seasonal blocks: snowmelt runoff, late spring and early summer low flow, monsoon, and fall and winter (Fig. 2) (Kelly et al. 2005). Flow patterns within each seasonal block and their ecological functions were then characterized for important riparian and aquatic species.

Flows of different magnitudes have different functions in creating and maintaining topographic and vegetative complexity (Poff et al. 1997; Bunn and Arthington 2002; Tockner and Stanford 2002). Infrequent large floods rework the floodplain (Soles 2003), support nutrient cycling (Poff et al. 1997; Tockner et al. 2000), scour out secondary channels, and create off-channel pools and wetlands (Fig. 3) (Makaske 2001). Frequent mid-size flows inundate these secondary channels (Makaske 2001), transport nutrients across the floodplain (Tockner et al. 2000), rehydrate wetlands, and raise groundwater levels that support floodplain forests and dense thickets of vegetation (Junk et al. 1989; Stromberg et al. 1992; Hupp and Osterkamp 1996; Poff et al. 1997; Tockner et al. 2000; Stella et al. 2006; Wilcox and Shafroth 2013).

Changes to Flows

The New Mexico Consumptive Use and Forbearance Agreement (CUFA), ratified by the AWSA (US Congress 2004), sets forth specific Terms of Diversion under which New Mexico may divert surface water from the Gila River, referred to as the "CUFA diversion." This Assessment evaluates the potential impact of diverting an average of 14,000 acre-feet annually, with an additional constraint that 150 cubic feet per second (cfs) of water be allowed to bypass the diversion to meet downstream obligations. The most significant effect of CUFA diversion is to reduce the number and magnitude of mid-size flows and flood pulses (400–4,000 cfs range), particularly during snowmelt runoff and monsoon (Fig. 4) (SSPA 2013). The number of days that flows in this range occur in the historic gage data (1937–2012) is 2,049; with diversion, the number is reduced to 1,364, a 33% decrease. In addition, a high proportion of flow can be diverted within this range: 350 cfs removed from a 500 cfs flow results in 70% reduction in flow.

Results from climate models project reduced snowpack, earlier snowmelt, and lower overall annual streamflow due to increases in temperature (evapotranspiration) and slight decreases in precipitation, aligned with trends reported in other recent climate change modeling studies for the Southwest (Seager et al. 2007; Barnett et al. 2008; Cayan et al. 2008; Barnett and Pierce 2009; Gershunov et al. 2013). These changes will result in smaller peak flows in the spring, a more rapid decrease in flows during snowmelt runoff, lower flows during the summer, and higher-magnitude monsoon flood events. The summer low-flow period is projected to begin earlier and last considerably longer, a time of significant stress for both aquatic and terrestrial organisms.

CUFA diversion and climate change will reduce flows in the mid-size range (400–4,000 cfs), with direct negative effects on many ecological processes: the floodplain will be

Table 1. Workshop Participants. Participants of the Silver City Workshop (January 8–9, 2014) and Albuquerque Workshop (April 14, 2014).

Name	Affiliation
Leslie Bach	The Nature Conservancy
Dr. Mike Bogan	University of California, Berkeley
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Dr. Carol Campbell	New Mexico State University
Rob Clarkson	US Bureau of Reclamation
Martha Cooper	The Nature Conservancy
Dr. Cliff Dahm	University of New Mexico
Matt Ely	US Geological Survey, New Mexico Water Science Center
Carol Evans	US Bureau of Reclamation
Dr. Deb Finch	US Forest Service, Rocky Mountain Research Station
Dr. Jennifer Frey	New Mexico State University
Mike Fugagli	Private consultant (Ornithology)
Dr. Gregg Garfin	University of Arizona
Dr. Keith Geluso	University of Nebraska
Dr. Keith Gido	Kansas State University
Dr. Dave Gori	The Nature Conservancy
Dr. Dave Gutzler	University of New Mexico
Jeanmarie Haney	The Nature Conservancy
Dr. Mary Harner	Crane Trust
Deb Hathaway	S.S. Papadopulos and Associates
Jennifer Holmes	Northern Arizona Univ./ Colorado Plateau Research Center
Dr. Mark Horner	University of New Mexico
Dr. Jerry Jacobi	Highlands University
Dr. Randy Jennings	Western New Mexico University
Matt Johnson	Northern Arizona Univ./ Colorado Plateau Research Center
Dr. Kelly Kindscher	University of Kansas
Dale Lyons	The Nature Conservancy
Steve MacDonald	University of New Mexico
Dr. Paul Marsh	Marsh & Associates
Melissa Mata	US Fish & Wildlife Service
Laura McCarthy	The Nature Conservancy
Jerry Monzingo	Gila National Forest
Dr. Ryan Morrison	University of New Mexico
Dr.Esteban Muldavin	NM Natural Heritage Program
Nathan Myers	US Geological Survey, New Mexico Water Science Center
Nessa Natharius	Gila National Forest
Dr. Dave Propst	University of New Mexico
Mary Richardson	US Fish and Wildlife Service
Craig Roepke	NM Interstate Stream Commission
Dr. Phil Rosen	University of Arizona
Jeffrey Samson	University of New Mexico
Dr. Roland Shook	Western New Mexico University
Ellen Soles	Northern Arizona University
Dr. Mark Stone	University of New Mexico
Dale Turner	The Nature Conservancy
Dr. Tom Turner	University of New Mexico
Hanna Varani	New Mexico Natural Heritage Program
Dr. Hira Walker	Colibri Consulting
Andy Warner	The Nature Conservancy
Dr. Meg White	The Nature Conservancy
Dr. Kathy Whiteman	Western New Mexico University
Jill Wick	New Mexico Department of Game and Fish

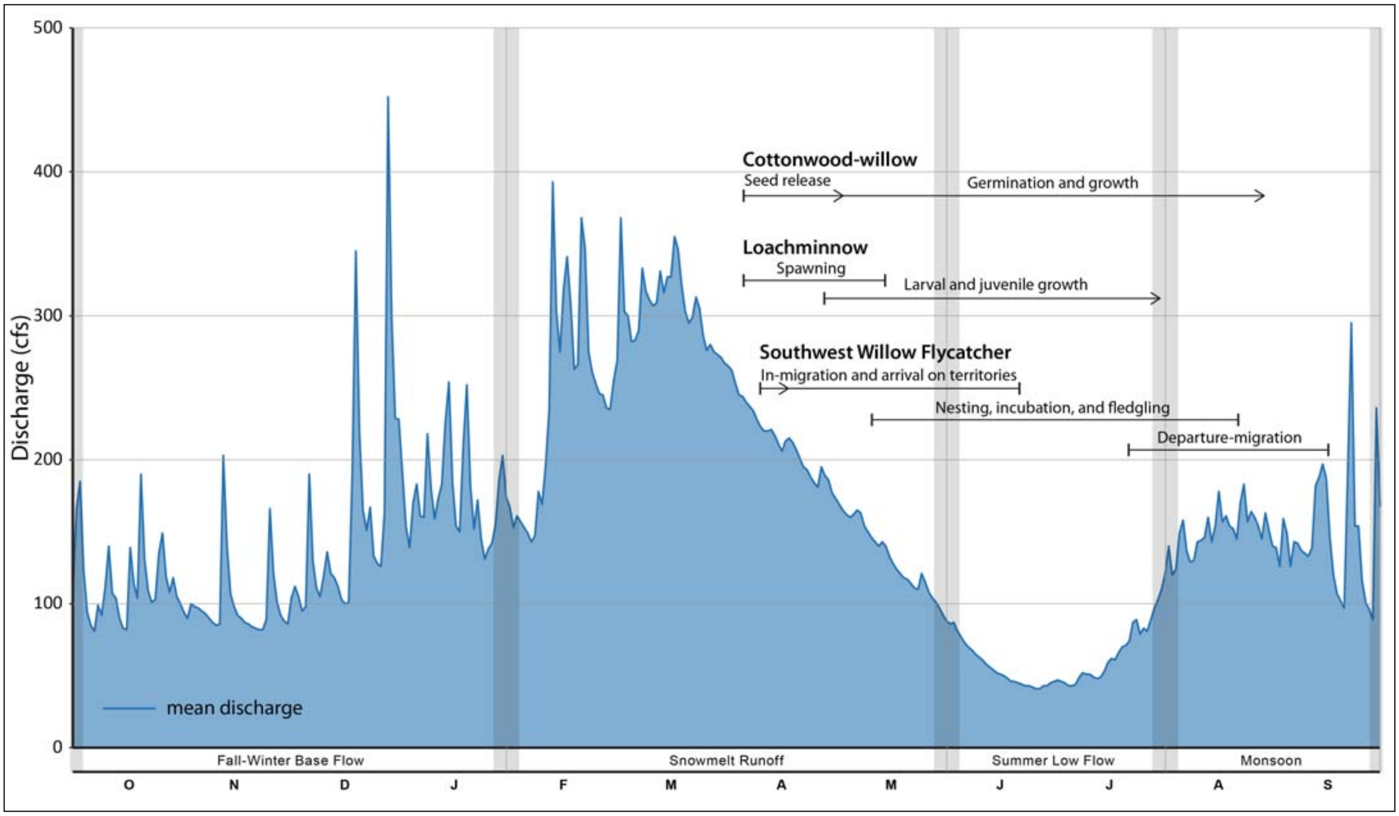

Fig. 2. Conceptual ecological model for the upper Gila River. The mean daily flow for the period of record (1929–2013) at the Gila near Gila gage is divided into four seasonal blocks. The black lines and arrows show the approximate timing of life history events and life stages of important riparian and aquatic species (Mahoney and Rood 1998; Propst et al. 2008; Sogge et al. 2010). These events and stages are tied to flows in the river that created and maintain habitat, provide food, and promote environmental conditions necessary for survival and reproduction. River-dependent species have evolved life history strategies in direct response to the natural flow regime.

inundated less often, reducing alluvial aquifer recharge; surface water and groundwater levels will decline faster, surface water temperatures will increase, and nutrient cycling will be decreased, resulting in a less productive ecosystem (Hughes 1980; Junk et al. 1989; Ward and Stanford 1995; Naiman and Decamps 1997; Tockner et al. 2000; van der Nat et al. 2003; Heffernan and Sponseller 2004; Ficklin et al. 2013).

Results

Existing conditions, flow-ecology relationships, and the associated impacts of CUFA diversion and climate change on each community type are described below.

Riparian and Wetland Plant Communities

Flow is a major determinant of physical habitat in rivers and on the floodplain (Poff et al. 1997). Infrequent high-magnitude flows (> 11,000 cfs) are needed to reconfigure the floodplain periodically and remove woody riparian vegetation, maintaining the compositional and structural diversity of riparian vegetation in the floodplain. Mid-size flows (400–4,000 cfs) in the snowmelt runoff and summer monsoon periods that periodically inundate the floodplain through secondary channels (Fig. 3) and recharge groundwater are necessary for growth and survival of woody and herbaceous riparian vegetation.

Groundwater levels in the floodplain rise and fall with fluctuating river flows. Floods recharge groundwater; the amount of recharge depends on the size and duration of flows. Extended dry periods drop groundwater levels; mortality of riparian trees occurs when groundwater levels remain too low (Stromberg et al. 1992; Leenhouts et al. 2006).

Vegetation in the Cliff-Gila Valley is characterized by multi-aged stands of numerous native tree and shrub species, dominated by Fremont cottonwood (*Populus deltoides* var. *fremontii*) and willow (*Salix gooddingii*, *S. exigua*, *S. irrorata*, etc.) (Fig. 5). Regeneration of cottonwood and willow occurs episodically, requiring the alignment of a particular set of circumstances: a large flood to prepare a seedbed of fine sediment and slow recession of flows during the snowmelt runoff period to keep soil moist as seeds germinate, take root, and grow (Mahoney and Rood 1998; Rood et al. 2003).

Reduced floodplain inundation and abrupt changes in flow from CUFA diversion would lead to rapid declines in groundwater that will decrease the survivorship and vigor of seedlings, saplings, and mature riparian trees (Mahoney and Rood 1998). A decrease in the number of cottonwood recruitment events, together with impacts to survivorship and vigor,

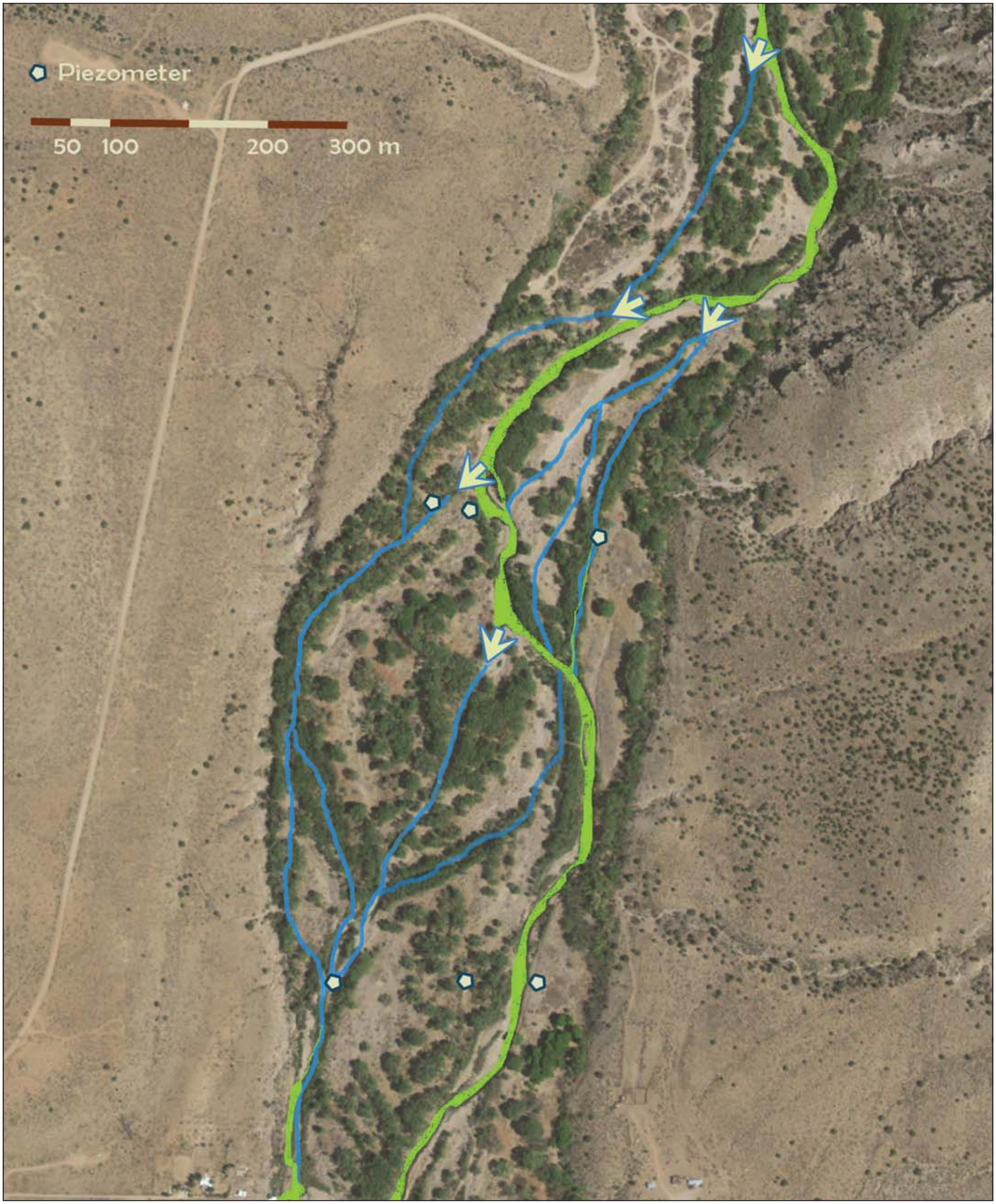

Fig. 3. The position of the main Gila River channel in 2011 is shown in green. The location of this photo is just downstream of the Gila National Forest Box Canyon recreation area. Blue lines indicate some of the secondary channels present on the floodplain. Arrows mark points where flow diverges from the main channel into secondary channels when flows in the river rise. The majority of riparian vegetation (80%) is located along secondary channels away from the main channel.

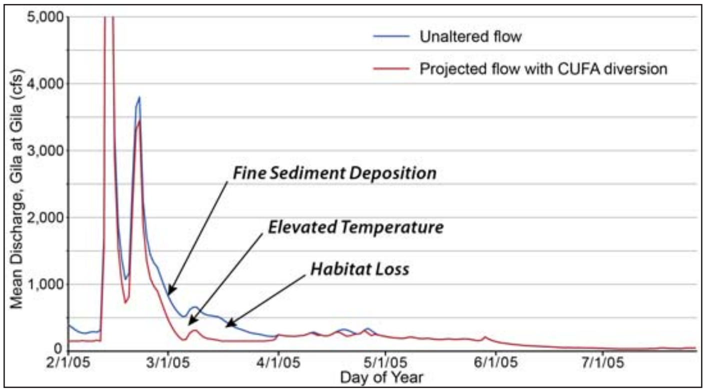

Fig. 4. The snowmelt runoff period is the seasonal block most affected by diversion. Reduced flows would lead to increased silt deposition on gravel and cobble substrates, elevated water temperatures, and habitat loss for aquatic species (Yarnell et al. 2010).

will lead to an overall reduction in the areal extent, structural diversity, and canopy cover of the riparian forest.

Floodplain wetlands are depressions that hold water for all or part of the year. Mid-size river flows inundate and rehydrate wetlands, transport nutrients that maintain their productivity, and maintain groundwater and surface water conditions that wetland herbaceous plants need for growth and survival (Ward and Stanford 1995; Naiman and Decamps 1997; Tockner et al. 2000; van der Nat et al. 2003). Reduced floodplain inundation and nutrient transport would reduce the size and productivity of wetlands.

Climate change will also lead to reduced floodplain inundation and alluvial aquifer recharge, increased evapotranspiration, and more rapid declines in groundwater. Like diversion, this will likely reduce the extent, structural diversity, and vigor of the riparian forest. Wetlands are also likely to decrease as the floodplain dries, while the abundance of plants that thrive in drier habitats is expected to increase. Groundwater decline, drought, and higher temperatures create conditions favorable for the establishment and spread of nonnative salt cedar (*Tamarix*) (Leenhouts et al. 2006), which is currently largely absent in the Cliff-Gila Valley.

Aquatic Invertebrates

The upper Gila River supports diverse aquatic invertebrate communities. Aquatic invertebrates are the base of the aquatic and riparian food chain, supporting amphibians, fish, birds, and mammals (Cummins et al. 2008). Aquatic invertebrates live in the interstitial spaces among gravel and cobbles. Receding flows in the spring after peak snowmelt remove silt and fine sediments and help maintain this habitat (Yarnell et al. 2010).

Abrupt flow changes during snowmelt runoff from CUFA diversion could reduce cleansing of gravel and cobbles and blanket these substrates in silt, reducing the abundance of aquatic invertebrates (Dewson et al. 2007). A truncated snowmelt recession limb could also contribute to a more rapid increase in water temperatures, leading to reduced and earlier emergence of aquatic invertebrates (Durance and Ormerod 2007). In addition, reduced floodplain inundation and connectivity diminishes exchange of organic and inorganic material between the river and floodplain (Hughes 1980; Tockner et al. 2000; Ficklin et al. 2013). Altering nutrient cycles reduces productivity, leading to a decrease in abundance and size of aquatic invertebrates (Ward and Stanford 1995). Wildlife that depends on aquatic invertebrates for food would be negatively impacted.

Native Wildlife

Mid-size flows sustain a multi-aged mosaic of riparian forest patches that provides habitat for hundreds of birds, including Southwestern Willow Flycatcher and Western Yellow-billed Cuckoo (Shook 2013). The Southwestern Willow Flycatcher

Fig. 5. Multi-aged riparian forests of cottonwood, willow, and other native trees and shrubs provide habitat for numerous wildlife species in the Cliff-Gila Valley. This photo was taken in 2013 downstream of the Hwy. 180 bridge on the Iron Bridge Conservation Area.

nests in stands of mature riparian forest and needs moist or saturated soils during the summer months to sustain conditions necessary for successful reproduction—specifically, thermoregulation of eggs and nestlings (USFWS 2002). Mid-size and larger flows also stimulate germination and growth of herbaceous plants in wetlands that provide habitat and food for reptiles, amphibians, and mammals (Bunn and Arthington 2002; Poff et al. 1997). CUFA diversion and climate change would negatively impact numerous species dependent on riparian forests and wetlands.

Changes in the structure and vigor of the riparian forest, coupled with increased air temperature and evapotranspiration from diversion and climate change, would increase stress on many riparian-obligate birds while they are breeding and raising young (McKechnie and Wolf 2010). Higher temperatures can stress nesting birds and lower humidity can reduce the abundance of insects that birds eat (Durance and Ormerod 2007). Earlier emergence of aquatic insects due to increased water temperatures may cause a temporal asynchrony between peak invertebrate abundances and the time when riparian birds are feeding their young (Anders and Post 2006). These factors would likely result in increased mortality and reduced reproductive success for riparian-obligate birds, particularly Western Yellow-billed Cuckoo and Southwestern Willow Flycatcher (Stoleson and Finch 2000; Shook 2013).

Fish

The Gila River in New Mexico supports one of the two most intact native fish communities in the lower Colorado River Basin (Fig. 6), including important populations of spikedace (Fig. 7) and loach minnow (Fig. 8) (Propst et al. 2008; Whitney et al. 2014).

Flow variability over the course of the year supports the persistence of native fishes (Propst et al. 2008). Mid-size

Fig. 6. Annual fish surveys have occurred for 24 years at permanent monitoring sites in the Cliff-Gila Valley. This data set is particularly useful for understanding how seasonal flows affect the reproduction success and population sizes of loach minnow and spikedace (Propst et al. 2008).

Fig. 7. Spikedace. (W.H. Brandenburg for New Mexico Department of Game and Fish)

flows in the winter and snowmelt runoff period sort gravel and cobble, restructuring aquatic habitat in the main channel that native fish use for spawning and as larvae, juveniles, and adults (Poff et al. 1997; Yarnell 2010). When daily discharge is greater in the spring, reproductive success for spikedace, loach minnow, and desert sucker (*Catostomos clarki*) is greater (Stefferud et al. 2011). The lowest flows occur in June and July. During this time, loach minnow and spikedace are especially threatened by nonnative fish, which compete for food and prey on natives as both become concentrated in the dwindling river. Monsoon rains restore flows to the river and fish benefit from increased habitat and food sources.

A change in the magnitude and frequency of seasonal flows from CUFA diversion will degrade fish habitat and reduce reproductive success. Reduced flows and abrupt changes in flow (by up to 350 cfs) as snowmelt recedes will diminish the cleaning of silt and fine sediments from gravel and cobbles, and limit the re-sorting of these substrates to provide suitable spawning habitat for native fish (Yarnell et al. 2010).

Reduced flows in spring due to diversion would also convert exceptionally good years for spikedace and loach minnow recruitment into bad years. These fish live 2–3 years, and 2 years without good reproductive success could decimate the population. A diversion structure will prevent or inhibit movement of native fish upstream and reduce population connectivity. Dispersal and gene flow from core populations in the Cliff-Gila Valley are necessary to sustain the genetic diversity of spikedace and loach minnow populations in the Gila Forks Area and to augment the population following disturbances such as wildfires and debris flows. A diversion structure would impede movement and increase the likeli-

Fig. 8. Loach minnow. (W.H. Brandenburg for New Mexico Department of Game and Fish)

hood of extinction of these upstream populations, in addition to compromising Cliff-Gila Valley populations of these two species.

Smaller peak flows and a greater rate of flow decline during spring runoff due to climate change will likely result in increased stranding of aquatic invertebrates, larval native fish, and amphibians as main-channel and floodplain aquatic habitats dry up. Truncation of the snowmelt recession period and lower flows overall will extend and exacerbate the summer low-flow period, leading to increased water temperatures, reduction in the extent of some aquatic habitats, and reduced water depth and velocity in remaining wet areas (Yarnell et al. 2010). Aquatic habitats would likely shrink down to pools interspersed and connected by shallow-water habitats. Nonnative species would be concentrated in the pools with native fish and narrow-headed gartersnakes, increasing competition and predation on native species (Pool and Olden 2014). Altered flows and thermal regimes will favor nonnative species like northern crayfish (*Orconectes virilis*) (Whitney et al. 2014).

Conclusion

The high biodiversity of the Gila River in the Cliff-Gila Valley is a function of the natural flow regime in the upper watershed. This Assessment concludes that CUFA diversion and climate change create risk of significant ecological impact. The snowmelt runoff period is predicted to be the most strongly affected, a critical period of time in the life cycle of multiple species and communities in the Cliff-Gila Valley. Mid-size flows that would be diverted most frequently are critical for recharging groundwater, supporting riparian plants, and maintaining the quality and diversity of aquatic habitats. Reducing these frequent elevated flows could have a cascading negative effect on the aquatic and riparian ecosystem.

Riparian and aquatic species in the Cliff-Gila Valley face numerous challenges, including nonnative aquatic species, drought, and the downstream effects from large, high-severity wildfires in the upper watershed. Climate change will impose additional severe stresses. Diversion will significantly exacerbate these challenges. Numerous species, particularly fishes, will be at increased risk of extirpation and ultimately extinction.

For More Information:

The 500-page Gila River Flow Needs Assessment is available at http://nmconservation.org/Gila/GilaFlowNeedsAssessment.pdf.

Acknowledgments

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Southwestern Willow Flycatcher (*Empidonax traillii extimus*) Survey and Territory Monitoring in the Gila Lower Box Canyon, New Mexico, 2013

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Abstract

The Gila Lower Box Canyon (GLBC) is a 14 km stretch of the lower Gila River, located in western New Mexico and administered by the Bureau of Land Management. Restoration efforts in the GLBC initiated in the 1990s have resulted in the regeneration of native riparian vegetation, increasing habitat for the Southwestern Willow Flycatcher (*Empidonax traillii extimus*). Southwestern Willow Flycatcher surveys in the GLBC were first performed in 1993 and continued in most years through 2008. Numbers of Southwestern Willow Flycatchers remained limited through the early years, but large increases began to occur in 1999. By 2007, the GLBC population occupied 20% of the known territories in New Mexico and 31% of the territories in the Upper Gila Management Unit of the Gila Recovery Unit, which is designated critical habitat. In 2013, surveys resulted in detections of 131 resident Southwestern Willow Flycatchers, including 54 pairs that occupied 75 territories. We monitored 71 nesting attempts by 49 pairs. Minimum totals of 68 eggs and 40 young were found in nests. Of 54 pairs, 16 (29.6%) were successful in fledging at least one young. We conservatively estimated that 23 young fledged (57.5%). Of 61 nests with known outcomes, 45 failed (73.7%), which was the highest nest failure rate recorded for the GLBC. Southwestern Willow Flycatcher abundance, proportion of territories occupied by pairs, and nest success were all lower in 2013 than in 2008. Successional changes to riparian forest may account for some of the declines, but recent drought conditions have negatively impacted the GLBC and habitat for the Southwestern Willow Flycatcher.

Index Descriptors: endangered species, Gila River, nest monitoring, Southwestern Willow Flycatcher, New Mexico, riparian habitat, riparian restoration

Introduction

The Southwestern Willow Flycatcher (*Empidonax traillii extimus*) occupies riparian habitats in six southwestern states, including New Mexico. It was listed as federally endangered in 1995 (US Fish and Wildlife Service [USFWS] 1995) and as endangered in the state of New Mexico in 1996 (New Mexico Department of Game and Fish [NMDGF] 1996). Threats to the species include habitat loss and alteration on the breeding and wintering grounds, Brown-headed Cowbird (*Molothrus ater*) brood parasitism, and depredation (Phillips 1948; Phillips et al. 1964; Hunter et al. 1987; Unitt 1987; Whitfield 1990; Harris 1991; Rosenberg et al. 1991). The USFWS (2005) designated 1,186 km of critical habitat for the Southwestern Willow Flycatcher in 2005, and expanded this to 1,975 km in 2013 (USFWS 2013).

Estimates of the total Southwestern Willow Flycatcher population and number of breeding sites have greatly increased since initial surveys in 1993, due to increases in effort and sites surveyed. However, overall population trends are unknown, due to differences in annual surveyed area and methodologies used by participants (Durst et al. 2007). The most recent range-wide estimate of the Southwestern Willow Flycatcher population was 1,299 breeding territories at 288 sites in 2007 (Durst et al. 2007). About 40% of Southwestern Willow Flycatcher territories were located in New Mexico. A large proportion of these occur along the Gila River, in particularly large clusters near Gila and Cliff and further downstream in the Gila Lower Box Canyon (GLBC).

The GLBC is a riparian segment of the Gila River in western New Mexico administered by the Bureau of Land Management (BLM) Las Cruces District Office (LCDO) and is included in the Gila Recovery Unit–Upper Gila Management Unit of designated critical habitat for the Southwestern Willow Flycatcher. To investigate the response of the Southwestern Willow Flycatcher to riparian restoration efforts in the GLBC, surveys and nest monitoring were conducted during the years 1993, 1996–2003, 2005, 2007, and 2008 (Campbell 2002, 2009; Meyer 2005, 2008a, 2008b). In the 2013 breeding season, we continued the effort to quantify the population of Southwestern Willow Flycatchers in the GLBC and measure productivity by conducting surveys and territory monitoring using established protocols. Results from the study provide a perspective on riparian restoration and the responses of the Southwestern Willow Flycatcher to habitat enhancement.

Project Area

The GLBC is a 14 km stretch of the lower Gila River located in Grant and Hidalgo Counties in western New Mexico (Fig. 1). The GLBC is included in the Gila Lower Box Wilderness Study Area (WSA) and the Gila Lower Box Area of Critical

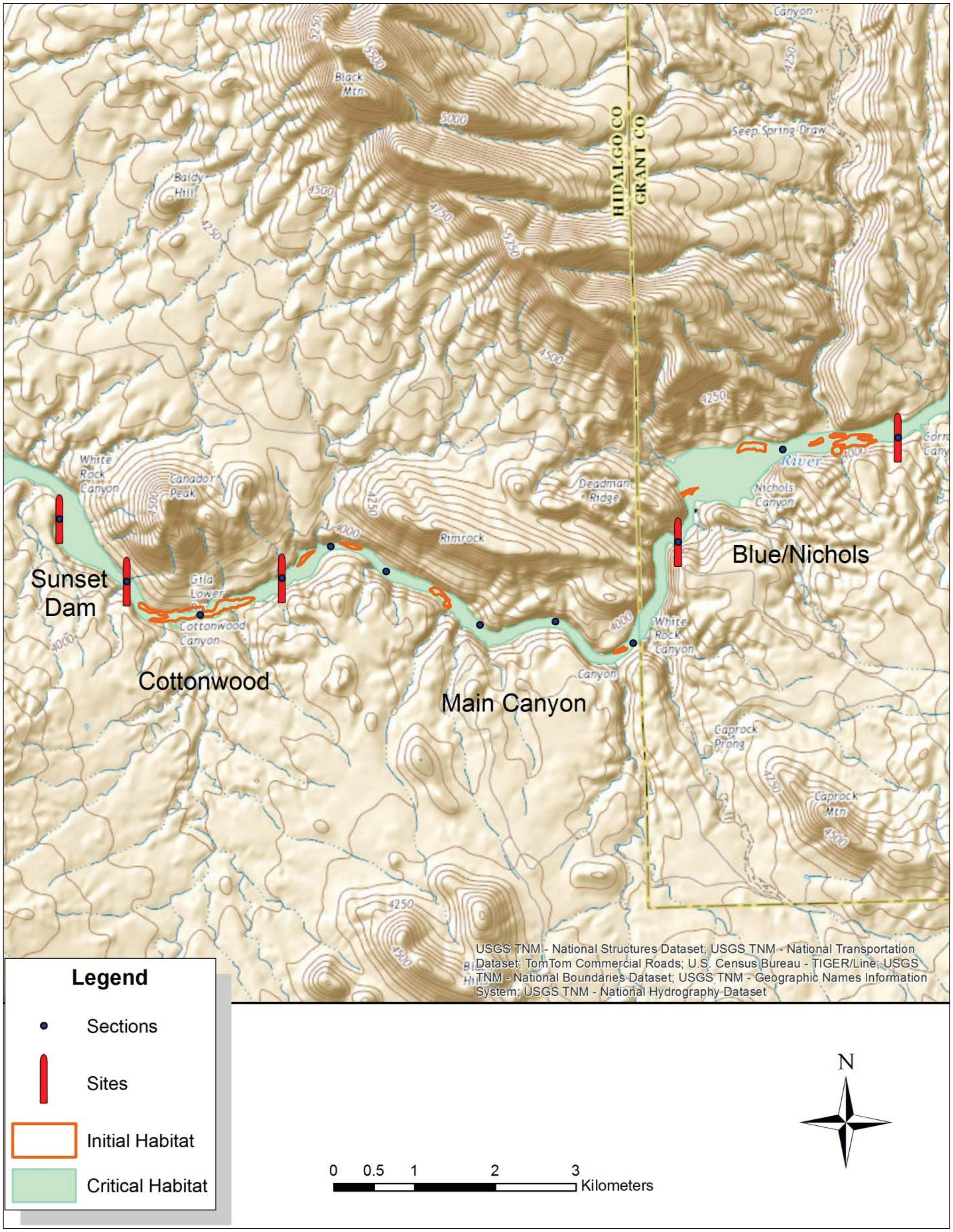

Fig. 1. Study area location of the Southwestern Willow Flycatcher survey in the Gila Lower Box Canyon, Grant and Hidalgo Counties, New Mexico, 2013.

Environmental Concern (ACEC). WSAs are protected lands to be studied for their resource values and for evaluation as potential wilderness areas. The ACEC designation was applied to the area to protect its value as a riparian system (BLM 1993). The GLBC is a low-gradient segment of the river ranging in elevation from about 1,190 m at the uppermost (eastern) boundary to 1,150 m at Sunset Dam near the western mouth of the canyon. Within much of the GLBC, the river flows through a narrow, steep-sided canyon where the floodplain is generally less than 300 m wide. Wider areas occur at the confluence of tributaries such as Nichols Creek, where the floodplain is about 600 m wide. Large floods involving streamflows above 425m^3/s occur periodically, with recent events occurring in 1997, 2005, and 2008. Irrigated agricultural fields and livestock pastures constitute much of the Gila River Valley beyond the mouth of the canyon, about 1 km west of the study area.

Up until the 1990s, the area was heavily grazed, with only isolated riparian woodlands and sparse understory vegetation, providing limited habitat for avian species. Vegetation consisted of sparse stands of mature Fremont cottonwood (*Populus deltoides* var. *fremonti*), with lesser amounts of Goodding's willow (*Salix gooddingii*), Arizona sycamore (*Platanus wrightii*), and velvet ash (*Fraxinus velutina*). Linear patches of seep willow (*Baccharis salicifolia* and *B. salicina*) lined channel margins. Stands of netleaf hackberry (*Celtis reticulata*), honey mesquite (*Prosopis glandulosa*), and to a lesser extent Arizona walnut (*Juglans major*), Emory oak (*Quercus emoryi*), and Gray oak (*Q. grisea*) existed on elevated portions of the floodplain (Campbell 2002).

In the early 1990s, steps were taken to reduce and eventually eliminate livestock presence in most of the GLBC. Fences along the north and south uplands were completed in 1993, but cattle still accessed the GLBC through the river floodplain. It wasn't until 1995, when electric fencing was installed at Sunset Dam and the north end of Nichols Canyon, that livestock were completely excluded from all but the upper and lower extremes of the GLBC. Subsequently, the ungrazed area underwent rapid vegetation community succession, resulting in tremendous increases in habitat for wildlife that utilize riparian habitats (BLM LCDO, unpubl. data; J. Barnitz, BLM LCDO, pers. comm.).

At the time of the study, riparian woodlands bordered most of the river and alternate channels within the GLBC, occurring as various-sized linear patches composed of a variety of community mosaics and structural age classes. Woodland patches typically were 50–200 m in width and consisted of cottonwood-willow riparian and mixed broadleaf forest (Minckley and Brown 1994; Muldavin et al. 2000). Dominant tree species included Fremont cottonwood, coyote willow (*Salix exigua*), Goodding's willow, netleaf hackberry, velvet ash, Arizona walnut, Emory oak, Gray oak, and Arizona sycamore. Subtree and shrub species included desert willow (*Chilopsis linearis*), salt cedar (*Tamarix ramosissima*), seep willow, false indigo (*Amorpha fruticosa*), burrobrush (*Ambrosia monogyra*), brickelbush (*Brickellia* sp.), tarbush (*Flourensia cernua*), honey mesquite (*Prosopis glandulosa*), and creosote (*Larrea tridentata*). On open floodplains and old river channels vegetation was composed of shrubs such as four-wing saltbush (*Atriplex canescens*) and rabbitbrush (*Ericameria nauseosa*), and herbaceous forbs and grasses such as Wright's beebrush (*Aloysia wrightii*) and dropseeds (*Sporobolus* spp.).

Mature cottonwood-willow gallery forest, with canopy tree heights ranging from 10–25 m, was a dominant community type in the river corridor. Stands of coyote willow were common, particularly on the river banks, bordering other woodlands, and in alternate channels where trees were able to access the water table. Individual young salt cedar were widely scattered throughout the study area, and Russian olive (*Elaeagnus angustifolia*) was rare. In wider sections of the canyon one or more alternate river channels existed in the floodplain with associated stringers of riparian vegetation. Periodic flood events altered vegetation and reset the progression of vegetation succession along sections of the river. Coyote willow and early successional communities were heavily influenced by the periodic flooding events and variable hydrological conditions.

Limited grazing continued in the uppermost 1.5 km stretch of the project area, including the confluence of Blue Creek with the Gila River, which was isolated from the rest of the GLBC by an electric fence. Utilization by cattle in past assessments was categorized as slight to none and the riparian area was rated as properly functioning (BLM LCDO, unpubl. data). The allotment ran approximately 35 head of cattle that usually remained on private land near Redrock and adjacent uplands. Contiguous riparian vegetation extended upstream of the project area boundary on state trust land.

In 2002, livestock was excluded from the remaining 1.1 km stretch of the project area downstream of the Sunset Dam at the western terminus of the GLBC. Following the removal of livestock, riparian vegetation developed quickly in the area.

Methods

Establishment of Study Sites

Previous Southwestern Willow Flycatcher surveys in the GLBC were performed in 1993, 1996–2003, 2005, 2007, and 2008 (BLM LCDO, unpubl. data; Meyer 2005, 2008a, 2008b). In 1993 and 1996, all potential habitat in the GLBC was mapped and surveyed by BLM personnel. Suitable habitat was limited to isolated patches mainly occurring in the upper and lower reaches of the project area (Fig. 1).

In coordination with the USFWS and the NMDGF, the riparian corridor was divided into three segments that were designated as Southwestern Willow Flycatcher survey sites: Cottonwood, Main Canyon, and Blue/Nichols (Fig. 1). The Cottonwood site extended from Sunset Dam 2 km upstream. The Main Canyon site was the middle 7.4 km segment of the GLBC and included the narrowest section of the canyon. The Blue/Nichols site extended 3.5 km from Main Canyon upstream to the GLBC upper boundary.

From 1997 to 2005 only partial surveys of the GLBC were performed. Portions of the middle segment of the study area, in particular, the narrow middle section of the Main Canyon survey site, were not surveyed (Meyer 2005). In addition, the downstream end of the Blue/Nichols site with limited habitat was not surveyed.

As riparian vegetation continued to develop, the amount of survey area increased, particularly in the lower and upper segments of the GLBC. In both 2007 and 2008 the entire length of the GLBC was surveyed (Meyer 2008a, 2008b). Due to the increase in potential flycatcher habitat throughout the GLBC the three previously established survey sites were divided into subsections that could be covered by observers in one morning survey (Table 1, Fig. 1). The length of the subsections depended on the amount of habitat and potential territories based on previous year surveys. By 2008, marginally suitable habitat had developed immediately below Sunset Dam, and a Southwestern Willow Flycatcher survey was performed in June of that year, with no detections made. In 2013, the 1.1 km from the dam to the western boundary of BLM land was surveyed as a fourth survey site, identified as Sunset Dam (Fig. 1).

Table 1. Southwestern Willow Flycatcher survey sites and subsections in the Gila Lower Box Canyon, New Mexico, 2013.

Site	Subsection	Length (km)
Sunset Dam	**Total**	1.1
Cottonwood	C-1	1.1
	C-2	1.2
	Total	2.3
Main Canyon	M-1	0.7
	M-2	0.8
	M-3	1.4
	M-4	1.1
	M-5	1.3
	M-6	1.7
	Total	7.0
Blue/Nichols	B/N-1	2.0
	B/N-2	1.5
	Total	3.5

Bird Survey Protocol

Survey methods followed those described in the standard protocol in Sogge and others (2010) and the conditions included in the Native Endangered and Threatened Species Recovery permit issued by the USFWS. Survey efforts were divided into three survey periods: 15–31 May, 1–24 June, and 25 June–17 July. At least one complete survey was performed for all survey sites within each of the three survey periods. Surveys began as soon as there was enough light to safely walk (about one hour before sunrise) and ended by about 1030 hours, depending on the temperature, wind, rain, background noise, and other environmental factors. Surveys at each site included listening and observing for one to two minutes or longer, followed by broadcasting the Willow Flycatcher song recording for 10–15 seconds; then listening for approximately one minute for a response. This procedure was repeated every 20–30 m throughout each survey site. Additional surveys were performed in areas of high habitat potential and in areas adjacent to occupied habitats. Because birds commonly failed to respond to vocalization playback, active searching of potential habitat was necessary to detect flycatchers.

For each pair detected we attempted to ascertain their breeding status, monitor nesting attempts, and determine reproductive fates. Procedures for finding nests and nest monitoring followed the guidelines of Rourke and colleagues (1999) and those stipulations included in the USFWS endangered species permit. Nest visits were kept to a minimum, with at least five-day intervals in between. We attempted to visit nests only during incubation and brooding. We used mirror poles and a small camera fixed to a telescoping pole to inspect nest contents. When a nesting attempt failed, we continued monitoring the territory and searching for replacement nests for up to three attempts. Monitoring at territories ceased following successful nesting attempts.

Nest site characteristics were measured after flycatcher activity in the area ceased. The heights of lower nests were measured using a telescoping pole for nests located in the understory, or a rangefinder for nests located in tree canopies. Nest heights in the upper cottonwood canopy were estimated to the nearest meter.

We used the same definitions and methods for estimating Southwestern Willow Flycatcher numbers and productivity that we had used in previous years (Meyer 2008b). We defined resident Southwestern Willow Flycatchers as all members of pairs and any additional Willow Flycatchers present after 14 June. Other subspecies of Willow Flycatchers that potentially migrate through the area were unlikely to be present in mid-June. A territory was defined as a fixed area occupied by one or more resident Southwestern Willow Flycatchers seen during two or more visits. Nest success was categorized as confirmed (adult and at least one fledgling seen in the territory), probable (estimated age of young in nest > 9 d old, or empty intact nest and adults agitated, giving the characteristic alarm call, but fledglings not seen), or unknown (active but inaccessible nests with no evidence of failure or fledging, and nests with young ≤ 9 d old at last nest check). We included those nests with probable fledging in our estimates of successful nests. Because of several factors we were unable to determine the actual number of fledged birds at all nests and we thus used conservative estimates of Southwestern Willow Flycatcher productivity. For conservative estimates of productivity, we assumed one fledgling for each nest with "probable" success. A nesting attempt was considered failed in cases where the nest was damaged or dismantled; the nest previously contained eggs or young but was found empty prior to possible fledging; the nest contained eggs or young but was not attended by adults; the nest was incubated by the female but was later inactive.

To investigate effects of livestock on flycatcher breeding activities, nesting data from the three most recent surveys (2007, 2008, and 2013) were pooled. We employed chi-square testing to compare proportions of nest substrates in grazed and ungrazed portions of the GLBC (Zar 1984). The Mann-Whitney U-test was used to detect differences in nest heights in grazed and ungrazed subsections of the project area. In analyses $P < 0.05$ was considered statistically significant.

Results

Detections, Residents, and Territories

A total of 140 Willow Flycatchers, including 131 resident Southwestern Willow Flycatchers, were detected during the 2013 survey effort (Table 2). The resident population comprised 54 pairs and 23 individual residents occupying 75 territories (Table 2). Pairs occupied 72.0% of territories and the remaining territories were held by single males. Two additional residents were not associated with a territory. One of the two was a female that nested adjacent to a pair and the other was considered a male floater.

The highest numbers of Southwestern Willow Flycatcher territories and pairs were found in the Main Canyon site, followed by Blue/Nichols (Table 2). A total of six Willow Flycatchers, including two Southwestern Willow Flycatcher pairs in adjacent territories, were detected in the newly established Sunset Dam survey site.

Southwestern Willow Flycatchers were not distributed evenly throughout the GLBC but were clustered in contiguous habitat patches. Areas with high densities of Southwestern Willow Flycatcher territories included M-2 in Main Canyon and B/N-2 in Blue/Nichols (Table 2). Other, smaller clusters occurred in the upper end of C-2 at the Cottonwood site, in the M-6 subsection of Main Canyon, and in the lower end of B-1 at Blue/Nichols.

Nesting and Productivity

Southwestern Willow Flycatcher breeding activity, including nest building, was underway during initial surveys on 18 May and continued through 05 August, when surveys were terminated. A relatively small proportion of territories was occupied by breeding pairs (65.3%). We monitored 69 nesting attempts by 49 pairs and 2 additional nesting attempts by an unpaired female (Table 2). The nesting attempt by the unpaired female with a neighboring breeding male is the first documented instance of polygyny in the GLBC, although it was suspected in previous seasons. No evidence of breeding was observed for 5 pairs. Of 71 monitored nests, 61 had known outcomes (including nests with probable success). Number of nesting attempts per territory ranged from 0 to 3, with all replacement nests following failed previous attempts.

A minimum total of 68 eggs and 40 young were found in nests (Table 2). Clutch size in accessible nests ranged from 1–3 eggs, with a mean of 1.7 (SD = 0.82). Of the 68 confirmed eggs, 40 (58.9%) hatched. Some nests were too high to check, and in other cases egg/young counts were minimums because of difficulty in viewing contents. Of 54 pairs, 16 (29.6%) were successful in fledging at least 1 young (includ-

Table 2. Willow Flycatchers, resident Southwestern Willow Flycatchers, and territories detected in survey sites of the Gila Lower Box Canyon, New Mexico, 2013.

Site	Sub-section	Resident SWWFs	No. Terr.	No. Pairs	Pairs/ km	Breeding Pairs	Nests	Eggs	Young	Fledglings	Successful Nests
CW	C-1	3	3	0	0	0	0	0	0	0	0
	C-2	18	10	7	5.8	7	7	12	3	3	2
	Subtotal	21	13	7	3.0	7	7	12	3	3	2
MC	M-1	3	2	1	1.4	0	0	0	0	0	0
	M-2	20	10	9	11.3	9	16[a]	7	5	6	4
	M-3	2	2	0	0	0	0	0	0	0	0
	M-4	10	6	4	3.6	4	5	5	4	0	0
	M-5	9	6	3	2.3	3	5	2	0	0	0
	M-6	20	12	8	4.7	7	9	17	12	5	3
	Subtotal	64	38	25	3.6	23	35	31	21	11	7
B/N	B/N-1	18	9	9	4.5	6	5	7	5	2	2
	B/N-2	24	13	11	7.3	11	22	16	9	5	4
	Subtotal	42	22	20	5.7	17	27	23	14	7	6
SD		**4**	**2**	2	1.8	2	2	2	2	2	1
Total		131	75	**54**	**3.9**	**49**	71	**68**	**40**	**23**	16

CW—Cottonwood, MC—Main Canyon, B/N—Blue/Nichols, SD—Sunset Dam

[a] Includes 2 nests of unpaired female

ing 2 pairs with probable success). We did not determine the number of fledglings at every nest due to the timing of nest visits but we estimated that at least 23 young fledged (57.5%) (Table 2). Twenty-eight pairs failed in all of their nesting attempts and the reproductive outcome of 1 additional pair was unknown. Of 61 nests with known outcomes, 45 (73.8%) failed.

Table 3. Southwestern Willow Flycatcher pairs and nest success in the Gila Lower Box Canyon, New Mexico, 2005–2013.

	No. Terr.	No. Pairs	Mean clutch size	Proportion (%) of Successful Pairs	Mean No. Fledglings/Pr.
2005	55	37	n/a	56.8	n/a
2007	102	65	2.8	60.0	1.17
2008	111	92	2.2	39.1	0.59
2013[a]	75	54	1.7	29.6	0.42

[a] Includes additional site Sunset Dam

Mean clutch size was lower in 2013 than in the two previous survey seasons (Table 3). Nests in 2013 experienced a high failure rate of 73.8% and the proportion of successful pairs (29.6%) was the lowest recorded by us in the GLBC and less than half of that in 2007 (Table 3). A slightly greater proportion of Southwestern Willow Flycatcher nests were successful in the ungrazed subsection (23.2%) than in the grazed subsection (19.0%) of the GLBC in 2013, but the difference was not statistically significant for the limited sample size.

Brown-headed Cowbirds were ubiquitous in the GLBC. Only two Southwestern Willow Flycatcher nests were found parasitized by Brown-headed Cowbirds in 2013 and both were abandoned. However, during the survey, Brown-headed Cowbirds were observed parasitizing the nests of several other species, including Yellow Warbler (*Dendroica petechia*), Bell's Vireo (*Vireo bellii*), Abert's Towhee (*Pipilo aberti*), and Song Sparrow (*Melospiza melodia*). Brown-headed Cowbird eggs also were found in abandoned Blue Grosbeak (*Guiraca caerulea*) and Yellow-breasted Chat (*Icteria virens*) nests.

Nest Site Characteristics

Southwestern Willow Flycatchers nested in coyote willow stands, cottonwood gallery forest with little mid- and understory vegetation, and mixed woodlands. Coyote willow was most frequently used as a nest substrate in 2013, but proportional use was less than in 2008 (Fig. 2). Similarly, there was a reduction in frequency and proportional use of Goodding's willow. Conversely, there was an increase in use of Fremont cottonwood from 2008 to 2013. For the first time during our study of Southwestern Willow Flycatchers in GLBC, flycatchers were observed utilizing Arizona sycamore (n = 1) as a nesting substrate. Another nest was constructed in salt cedar. The use of salt cedar as a nest substrate in the GLBC had not been observed since 1998 (BLM LCDO, unpubl. data).

Southwestern Willow Flycatcher nest heights in trees ranged widely, from 2 to 21 m, but most were located at heights of less than 6 m (n = 54), with the majority at 3 to 6 m (n = 32) (Fig. 3). Nests in coyote willow averaged 3.7 m in height and those in cottonwoods averaged about 11 m in height. The Goodding's willow, sycamore, and tamarisk nest substrates were young trees and nest heights were similar to those in coyote willow.

Significant differences in proportions of nest substrates and nest heights occurred between the grazed and ungrazed portions of the GLBC in data pooled from the three most recent survey years (Table 4). In the grazed subsection of the GLBC, greater proportions of nests were located in cottonwood than in the ungrazed subsection of the Blue/Nichols site and the rest of the GLBC. Average nest height in

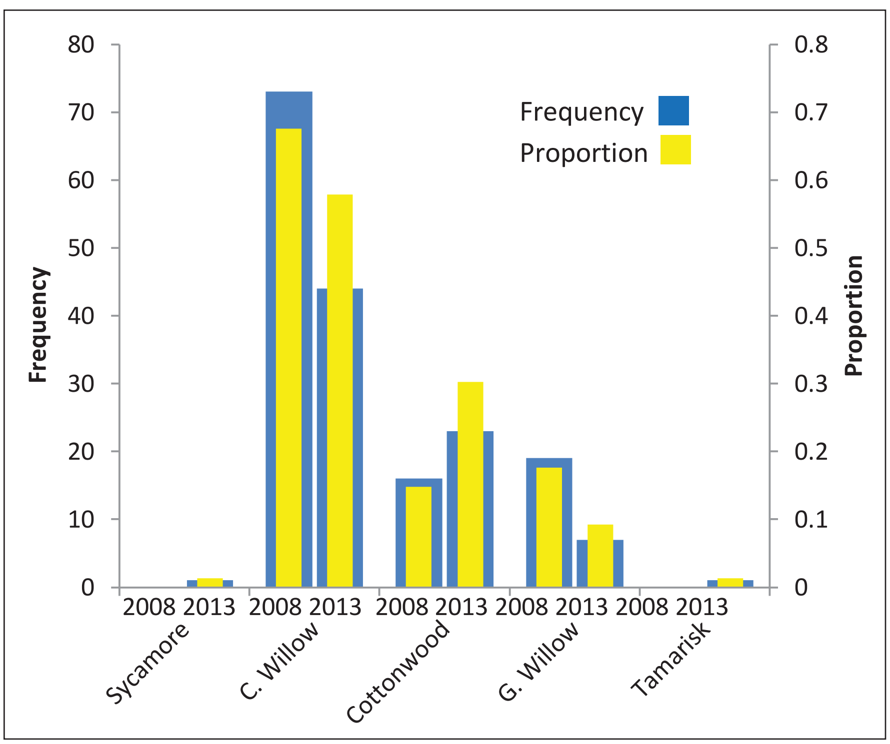

Fig. 2. Frequency and proportion of nest substrates used by Southwestern Willow Flycatchers in the Gila Lower Box Canyon, New Mexico, 2008–13. Sycamore = AZ sycamore, C. Willow = coyote willow, Cottonwood = Fremont cottonwood, G. Willow = Goodding's willow.

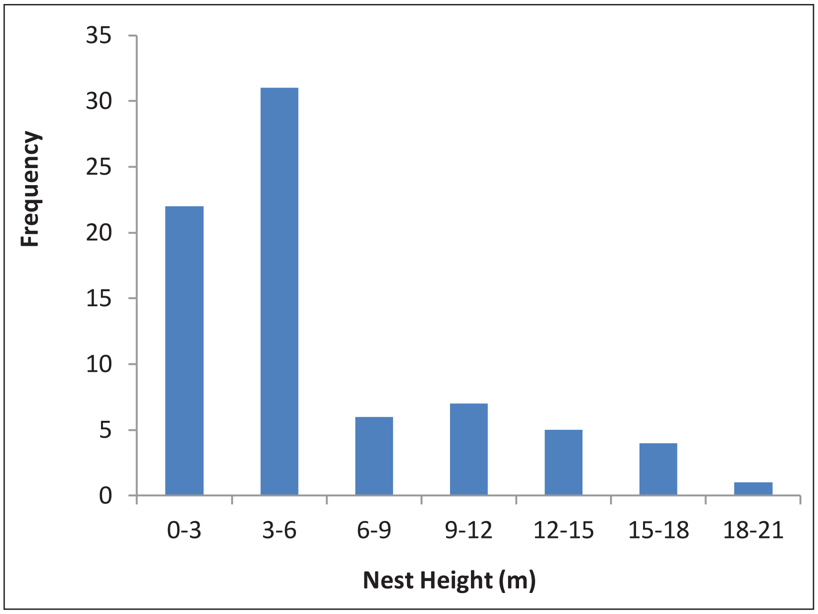

Fig. 3. Distribution of Southwestern Willow Flycatcher nests (n = 69) in height classes at the Gila Lower Box Canyon, New Mexico, 2013.

the grazed subsection was 7.7 m; in the rest of the GLBC it was 4.8 m (U-statistic = 6545.5, $z = 4.15$, $P < 0.001$).

Discussion

Colonization

Widely scattered stands of primarily mature cottonwood trees existed in the GLBC prior to restoration efforts. Most of these were unsuitable as Southwestern Willow Flycatcher habitat because they lacked sufficient canopy and understory vegetation (Marshall and Stoleson 2000; USFWS 2002). However, Southwestern Willow Flycatchers were detected in woodlands in the uppermost reaches of the GLBC during the first survey in 1993, prior to livestock exclusion. The initial presence of flycatchers in the upper section probably was related to an earlier change in stocking rates of cattle and the remoteness of that particular stretch of the river, which minimized the presence of cattle and allowed vegetation regeneration to begin prior to the erection of fences in the floodplain (J. Barnitz, BLM LCDO, pers. comm.).

Regeneration of vegetation in riparian zones can occur quickly when livestock effects are reduced or eliminated (Fleischner 1994; Ohmart 1996). Rapid vegetation succession in the GLBC following the removal of livestock was documented in photo-point monitoring (BLM LCDO, unpubl. data). Expansion of riparian vegetation continued, eventually resulting in woodlands extending throughout most of the corridor segment. There was an estimated 258% increase in river-edge habitat in the GLBC during the period of 2000–2008 (Table 5).

Southwestern Willow Flycatcher territories were restricted to the uppermost section of the Blue/Nichols site through 1996 (Table 6). Initial colonization of the Cottonwood site at the downstream end of the project area occurred in 1997 and at the Main Canyon site in 1999. Early flycatcher colonization of the GLBC occurred in the existing woodlands, where habitat suitability increased rapidly in the absence of livestock. The Southwestern Willow Flycatcher population in the GLBC remained limited through the early survey years, but large gains occurred during the period of 1999–2008, with annual increases as high as 144% (Table 6). By 2000, Southwestern Willow Flycatchers occupied seven disjunct habitat patches throughout the GLBC. Pairs initially nested almost exclusively in Gooding's willow and Fremont cottonwood. Suitable conditions in stands of coyote willow developed more slowly, delaying flycatchers' use for nesting until 2000. In 2007, the GLBC population occupied 20% of the known territories in New Mexico, 15.5% of the territories in the Gila Recovery Unit, and 31.0% in the Upper Gila Management Unit (Durst et al. 2007). The Gila Recovery Unit accounted for 50.7% of the known Southwestern Willow Flycatcher territories in North America.

Rapid development of riparian vegetation also occurred below Sunset Dam following the exclusion of livestock in 2002, but absence of existing woodland delayed flycatcher colonization relative to the upper sites. In 2008, riparian habitat within the Sunset Dam site was considered unsuitable as Southwestern Willow Flycatcher habitat due to narrow patch width and canopy heights generally less than 5 m (Meyer 2008b), but by 2013 territories were occupied by breeding pairs.

Similar positive responses to riparian restoration have been observed in other locations. Willow Flycatchers colonized riparian areas in southeastern Oregon after livestock grazing intensities were reduced (Taylor and Littlefield 1986). A 61% population increase within a five-year period was documented in the Sierra Nevadas following reductions in livestock numbers (Harris et al.

Table 4. Cumulative proportions of nests in the most commonly used substrates during the three survey seasons of 2007, 2008, and 2013 in Gila Lower Box Canyon, New Mexico. Chi-square tests are between the grazed subsection and the ungrazed areas.

	Blue/Nichols Site		
	Ungrazed Subsection (B/N-1)	Grazed Subsection (B/N-2)	Total Ungrazed Portion of the GLBC
C. willow	59.5	29.0	87.1
F. cottonwood	13.5	39.5	4.8
G. willow	24.3	31.6	8.1
	$X^2 = 11.9$, P = 0.003		$X^2 = 14.4$, P = 0.001

Table 5. Estimated length (m) of potential Southwestern Willow Flycatcher habitat in the three Southwestern Willow Flycatcher survey sites at the Gila Lower Box Canyon, New Mexico.

	Cottonwood	Main Canyon	Blue/Nichols	Overall
2000	1,045	648	1,337	3,030
2003	1,860	1,168	1,865	4,893
2008	1,865	6,152	2,839	10,856
2000–2008 difference	820	5,504	1,502	7,826
2000–2008 % change	78	849	112	258

1987). Increases in other avian species at the GLBC during the restoration effort were not documented, but, considering the tremendous growth of riparian vegetation, corresponding population increases in a large array of other avian species undoubtedly occurred (Krueper et al. 1993).

Temporal trends in Southwestern Willow Flycatcher abundances varied within portions of the GLBC. Possibly because of the relatively large amount of contiguous woodland present initially, Cottonwood experienced the greatest numerical increases in the early years and in 2003 supported 71% of the GLBC flycatcher population (Table 6). Numbers quickly decreased from a peak of 66 individuals in 2003 to a low of 8 birds in 2007, followed by small gains in subsequent years. A different pattern occurred in Southwestern Willow Flycatcher abundances at the upper sites. Numbers generally increased at Main Canyon and Blue/Nichols through 2008 (Table 6). The rate of increase in the Blue/Nichols site was rapid during the later years from 2005 to 2008. The pattern of increase was less clear for the Main Canyon because of incomplete surveys prior to 2007. From 2008 to 2013, both upper sites experienced sharp reductions in numbers, with the largest decline at the Blue/Nichols site.

Growth of suitable habitat was slowest in Main Canyon, where Southwestern Willow Flycatchers were not observed until 1999. Although the Main Canyon site was longer than the combined two other sites, only small, isolated patches of potential habitat existed for several years following the removal of livestock. Because of the narrow floodplain in the Main Canyon, effects of flood events were more severe, hindering plant colonization and succession. Southwestern Willow Flycatchers occurred in a few isolated habitat patches in Main Canyon through 2003; however, the site was not thoroughly surveyed from the late 1990s through 2005. Previously unsurveyed mature habitat was occupied during the complete survey in 2007, suggesting that Southwestern Willow Flycatchers were present in earlier years. Due to the small amount of woodlands at the outset of the restoration effort, the greatest increases in potential habitat occurred in Main Canyon. In 2007 and 2008, more than 50% of resident Southwestern Willow Flycatchers in the GLBC were located in Main Canyon (Table 6).

Table 6. Southwestern Willow Flycatchers detected annually since surveys were initiated at the three sites in the Gila Lower Box Canyon, New Mexico.

Year	Cottonwood	Main Canyon	Blue/Nichols	TOTAL
1993	—	—	5	5
1996	—	—	7	7
1997	3	—*	2*	5
1998	0	—*	9*	9
1999	5	2*	15*	22
2000	8	4*	10*	22
2001	22	6*	15*	43
2002	46	12*	14*	72
2003	66	12*	15*	93
2005	47	16*	24*	87
2007	8	101	58	167
2008	13	110	80	203
2013	21	64	42	131

*Partial survey, portions of site not surveyed

Population Change

The rapid decline in Southwestern Willow Flycatchers in the Cottonwood site from 2003–2007 and continued low numbers thereafter are not easily explained by obvious changes in habitat or extreme contrasts with the upper sites. Cottonwood contained woodlands similar in age and structure with those in the Blue/Nichols site. Independent processes may be responsible for population decline at Cottonwood and population increases at the upper sites; however, because of site fidelity and the tendency of birds to move locally (Kenwood and Paxton 2001), it is likely that the population changes were, to some degree, interrelated. The availability of more-preferred habitat, i.e., coyote willow and stands of younger trees, farther upstream may have drawn birds from the Cottonwood site. Negative effects of Brown-headed Cowbirds originating from nearby agricultural lands and pastures on flycatcher nesting may have prompted birds to seek alternative sites in subsequent breeding seasons. Forsman and Martin (2009) observed cowbird avoidance in host species under simulated high-cowbird densities. They suggested that potential hosts assessed parasitism risk and avoided high-risk areas. In the case of Southwestern Willow Flycatchers in the GLBC, lower cowbird densities likely would occur upstream, farther from the main cowbird foraging areas (Morrison et al 1999; Goguen and Mathews 2001; Brodhead et al. 2007).

Brown-headed Cowbird surveys conducted by BLM in 1997 and 1998 did not detect large numbers of cowbirds on adjacent uplands, and agency biologists concluded that more cowbirds resided within the river valley and originated from adjacent private and state lands bordering the study area (BLM LCDO, unpubl. data). We also observed cowbirds traveling through the river corridor but not flying to or from adjacent uplands.

The lower end of the canyon experienced more extreme conditions than farther upstream. A moderate flooding event prior to the 2005 breeding season had a greater impact on the lower portion of the GLBC, but habitat alteration was temporary. Deterioration of habitat as a result of reduced foliage in summer was common within the GLBC but more evident at Cottonwood. Changes in water availability related to streamflow, water table fluctuation, and hydrogeomorphic processes can result in leaf loss and tree mortality (Scott et al. 2000; Merritt and Bateman 2012).

Southwestern Willow Flycatcher abundance and pair occupancy of territories in the upper two sites were much lower in 2013 than in 2007 and 2008 (Table 6). Flycatcher numbers at the Main Canyon and Blue/Nichols sites were 42% and 48% lower, respectively, in 2013 than in 2008. There were no indications of catastrophic events such as flooding at the GLBC to account for the large-scale reduction in Southwestern Willow Flycatcher abundances, suggesting that multiple interacting processes probably were involved.

Succession

Habitat quantities and quality in the GLBC vary because of the dynamic nature of the riverine system. It is expected that Southwestern Willow Flycatcher numbers and distribution would show corresponding variation over time as changes in riparian woodlands occurred (Ellis et al. 2008; Sogge et al. 2010). Periodic flooding altered Southwestern Willow Flycatcher habitat. In 2005 and 2008 heavy flooding prior to the breeding seasons reduced the amount of Southwestern Willow Flycatcher habitat. While having negative immediate effects, flooding events also promoted vegetation establishment in new areas.

Maturation of woodlands decreases habitat suitability for Southwestern Willow Flycatchers, as canopy height increases and foliage density in lower strata is reduced. In Arizona, Southwestern Willow Flycatcher emigration from breeding patches increased with the relative age of trees, which indicated preferences for younger riparian vegetation structure (Paxton et al. 2007). Woodlands in the GLBC, particularly those existing prior to livestock removal that were initially colonized by flycatchers, experienced loss of mid- and understory growth; however, territories persisted in mature cottonwood gallery forest in the GLBC, with birds nesting in very sparse understory vegetation and in the upper canopy.

Habitat Condition and Resource Availability

Reduced habitat quality in the GLBC is suspected as a major factor in the lower numbers of Southwestern Willow Flycatchers and lower proportion of paired birds. Maturation of woodlands accounted for some decrease in mid- and understory vegetation in portions of the GLBC, but much more apparent were effects caused by persistent drought conditions, low streamflows, and receding water table in the past few years. The region experienced annual precipitation well below the long-term average in three of the last four years, and streamflows on the Gila River were less than half of the long-term average (Table 7). In 2013, the streamflow was initially low in spring and decreased as summer progressed. By the end of June the river bed was dry as far as 3.5 km above Sunset Dam. Streamflow was sufficiently low to allow dam construction by beavers (*Castor canadensis*) in Main Canyon, an event we had not observed previously above Sunset Dam. Effects of water levels were evident in the condition of the riparian vegetation. Vegetation density was noticeably less than in previous years and decreased through the summer. Significant mortality of trees, particularly coyote willow, occurred in woodlands throughout the GLBC. Less precipitation and flooding also limited plant colonization in new areas and undergrowth. Reduced soil moisture and sparse herbaceous vegetation negatively affected prey availability (Brown and Li 1996).

Changes in habitat condition affect territory occupancy and proportion of paired birds (Paxton et al. 2007). Poor habitat conditions likely caused flycatcher emigration to other locations in 2013 and declining quality in prior drought years, reducing the likelihood of residents returning to the GLBC (Sedgwick 2004; Paxton et al. 2007; McLeod and Pellegrini 2013). The breeding population sizes in years between 2008 and 2013 are not known, but in light of the drought conditions and river levels, a declining trend would be expected.

Livestock

In previous years, small numbers of cows (< 10) were observed in the upper subsection of Blue/Nichols; however, at least 20 head were present in 2013. Some Southwestern Willow Flycatcher nests constructed in small trees at low heights in the area were susceptible to disturbance, but no direct effects from livestock were observed at the nests.

Indirect effects of recent increases in livestock occurring within the uppermost subsection of the GLBC may have contributed to declining Southwestern Willow Flycatcher numbers and higher proportions of nests in mature cottonwood trees.

Table 7. 2008–2013 and long-term average (1932–2013) daily-mean discharge measured at a USGS gauge station downstream of Nichols Canyon in the Gila Lower Box Canyon, New Mexico. Data courtesy of USGS.

Year	Daily-Mean Discharge (cubic ft/sec.)
2009	83.9
2010	328.2
2011	67.3
2012	90.7
2013	215.3
Long-term Average	**156.0**

The greatest decline in flycatcher numbers in the GLBC from 2008 to 2013 occurred in the Blue/Nichols site. Within the site, there was an 18% decrease in the number of pairs in the ungrazed subsection, compared to a 57.7% decrease in pairs in the grazed subsection. Livestock grazing and trampling alter the composition and structure of vegetation and hinder development of vegetation in riparian areas (Kauffman and Krueger 1984; Ohmart 1996). Greater impacts from livestock were evident, particularly in stands of coyote willow and tree saplings in 2013. Extensive soil disturbance and damage to the river banks had occurred in the upper end of the GLBC.

Effects of grazing could not be isolated, however, because of variation in floodplain structure and vegetation along the river corridor. For instance, unique conditions in portions of the Blue/Nichols site, including steeper gradient and infrequent overbank flooding, may have contributed to a lower presence of coyote willow and limited vegetation colonization of new areas. Differences in the areal extent of vegetation types and successional stages along segments of the river also affected flycatcher distribution. Continued monitoring of the flycatcher population within the GLBC and the adjacent upstream habitat could provide more information necessary for appropriate management.

Breeding and Productivity

Southwestern Willow Flycatcher nest success and productivity vary from year to year and among locations (Paxton et al. 2007). The overall nest success rate of 34.2% in recent years at the GLBC was low relative to most other areas. Flycatchers' nesting success in native vegetation ranged from 36% in Arizona to 47% in California and was 42% elsewhere in New Mexico (USFWS 2002). Higher rates were found in other studies. A nest success rate of about 56% was observed in long-term studies of sites across Arizona and on the Middle Rio Grande in New Mexico (Moore and Ahlers 2006; Ellis et al. 2008).

Low nest success rates in Southwestern Willow Flycatchers have been observed at particular sites and under extreme conditions. Upstream of the GLBC, in the Cliff-Gila Valley, a low nest success rate of 33% in 1999 was attributed to drought conditions and extreme weather conditions that disrupted nesting (Stoleson and Finch 2000). Previously, under more favorable conditions, nest success was much higher. In Arizona, only two nests of 150 breeding pairs were successful at a site during a drought year (Smith et al. 2003; Ellis et al. 2008). Heavy cowbird parasitism resulted in low reproductive success on the Kern River, California, and in the Grand Canyon in Arizona (Harris 1991; Sogge et al. 1997).

In 2013, fewer pairs occupied territories, fewer nested, and fewer were successful than in previous surveys. Due to brief, infrequent nest visits and inaccessibility of some nests, causes of most failures were not determined in the GLBC. Most accessible failed nests were either found empty or had been removed. A small number of nests with eggs were abandoned. Low flycatcher nest success at the GLBC in certain years may be related to the site's physical characteristics and conditions. The site is a highly dynamic riverine system that experiences rapid fluctuations involving large changes in flow rates. River and water table levels decrease sufficiently within a season to cause leaf loss and mortality in trees. Poor habitat condition in the GLBC was considered an important cause of lower Southwestern Willow Flycatcher productivity in 2013. Clutch size, pair success, and fecundity were lower in 2013 than in previous years. A number of proximate causes arising from lower moisture levels in the riparian system can be involved in higher nest failure rates and decreased productivity. Potential prey levels can vary greatly from season to season (Durst 2004). Brown and Li (1996) found evidence that monsoonal precipitation of the previous year affected insect populations, which in turn influenced female physiological condition and reproductive efforts. Females lacking sufficient food resources lay fewer eggs, desert nests more readily, and make fewer renesting attempts (Smith et al. 2003).

Poor habitat conditions also increased the likelihood of nest predation and brood parasitism for nests constructed at lower heights in the GLBC. Lower nests often were exposed with little concealment and were more vulnerable to predation and parasitism (Uyehara and Whitfield 2000). Yet another possible consequence of reduced habitat quality was increased interspecific competition for suitable nesting areas. Southwestern Willow Flycatchers tend to nest in areas with high densities of other nesting passerines. Although not considered to be of significance in conservation of the species (USFWS 2002), instances of interspecific aggression involving flycatchers with Yellow-breasted Chat, Yellow Warbler, Northern Cardinal, and Blue Grosbeak were observed by us in the GLBC in 2013.

Other Factors

There was no predation observed at Southwestern Willow Flycatcher nests, but it was possible in cases where we found intact but empty nests as well as the few damaged nests. However, empty nests also were a result of abandonment prior to egg laying (Stoleson and Finch 2000). Predation is a major cause of nest failure in Southwestern Willow Flycatchers (Sogge 2000; Graber et al. 2012; McLeod and Pellegrini 2013). Farther downstream, on the Gila River below Coolidge Dam in Arizona, 55% of all failed nests were depredated (Graber et al. 2012). The predominant cause of nest failure also was predation in the Cliff-Gila Valley, upstream of the GLBC (Stoleson and Finch 2000).

The GLBC hosts high densities of potential predators of flycatchers, including birds, snakes, rodents, and medium-sized mammals (e.g., raccoons, foxes, and skunks) (Sogge 2000; Sedgwick 2000; McLeod and Pellegrini 2013). In Arizona, Cooper's Hawk (*Accipiter cooperii*) and California kingsnake (*Lampropeltis getula californiae*) were the two most common predators at nests monitored by cameras (Ellis et al. 2008). At least one pair of Cooper's Hawk had nested previously in the GLBC, but only single birds were observed in 2013. Several other raptor species present in the GLBC were potential predators. Passerines known to depredate flycatcher nests—including Bewick's Wren (*Thryomanes bewickii*), Yellow-breasted Chat, and Brown-headed Cowbird (Paradzick et al. 1999; Hoover and Robinson 2007; Ellis et al. 2008; Benson et al. 2010; Stumpf et al. 2011; McLeod and Pellegrini 2013)—were present in the GLBC, with the latter two being common.

Potential impacts to breeding Southwestern Willow Flycatchers from livestock include direct disturbance to nest sites and decreases in canopy and ground cover, resulting in microclimate changes and increased risk for cowbird parasitism (USFWS 1995, 2002). The difference in apparent success between flycatcher nests in ungrazed (31.2%) areas of the GLBC and in the grazed subsection of the GLBC (28%) was not significant; however, a smaller sample size in the grazed portion limits the validity of definite conclusions. A similar insignificant difference in nest success between grazed and ungrazed habitats was observed farther upstream, in the Cliff-Gila portion of the Gila River, where Southwestern Willow Flycatchers nested mostly in box elders (*Acer negundo*) (Stoleson and Finch 2000). Stoleson and Finch also found no significant evidence of grazing impacts on Southwestern Willow Flycatcher density and Brown-headed Cowbird parasitism.

The presence of livestock in the upper Blue/Nichols subsection of the GLBC did not have a noticeable influence on Brown-headed Cowbird distribution. Open foraging areas for cowbirds were limited and cows mostly remained in dense vegetation. Cowbirds were seen only once associating with cattle, at a small grassy area on the river's edge. According to the USFWS (2002), Brown-headed Cowbird brood parasitism is no longer considered a major threat to the overall Southwestern Willow Flycatcher population; however, cumulative effects of parasitism, nest predation, and harassment by cowbirds can significantly impact Southwestern Willow Flycatcher productivity at particular sites (Harris 1991; Whitfield and Sogge 1999; Uyehara et al. 2000). Parasitized nests also suffer greater predation rates, further decreasing productivity (Stumpf et al. 2011). In a long-term study upstream of the GLBC, 20.2 % of nests were parasitized (Brodhead et al. 2007). Below Coolidge Dam on the Gila River in Arizona, parasitism occurred in 10% of nests, but this study included a large population without Brown-headed Cowbirds (Graber et al. 2012). A multi-year study found an overall parasitism level of 23% at several nesting areas along the Lower Colorado River and tributaries in Arizona, Nevada, and California (McLeod and Pellegrini 2013).

Although Brown-headed Cowbirds were common throughout the GLBC and agonistic interactions with flycatchers were observed at several territories, parasitism rates of Southwestern Willow Flycatcher nests appeared low, based on direct evidence observed during nest monitoring. Cowbird parasitism of flycatcher nests was first documented at the GLBC in 2005, although other species were impacted prior to this (BLM unpubl. data; Meyer 2005). Only two cases of parasitism were confirmed in GLBC in 2013, but greater proportions of parasitized nests, as high as 10.9% in 2007, were observed in this area during previous years (Meyer 2008a, 2008b). The occurrence of abandoned and dismantled nests suggests that brood parasitism is more common than direct evidence suggests. The low frequency of nest checks, a sizable proportion of inaccessible nests, and other potential impacts (e.g., harassment causing abandonment and nest predation) leave additional uncertainty of the actual effects of cowbirds on flycatchers in the GLBC (Sedgwick and Knopf 1988; Whitfield 1990).

Host nesting habitat and distance to foraging areas are two important factors influencing Brown-headed Cowbird presence in a given area (Knopf et al. 1988; Tewksbury et al. 1999; Brodhead et al. 2007). Habitat conditions in the GLBC were conducive to parasitism, i.e., narrow, linear woodlands with high edge-to-area ratio. Southwestern Willow Flycatchers tended to nest near the river in habitat with high densities of other nesting passerines, both of which increased the likelihood of Brown-headed Cowbird parasitism (Robinson et al. 1995; Tewksbury et al. 1998; Tewksbury et al. 1999; Broadhead et al. 2007; Stumpf et al. 2011). Brown-headed Cowbirds forage and roost in the agricultural lands and livestock pastures at the mouth of the river canyon, approximately 1 km downstream from the western boundary of the GLBC. A similar but more limited source of cowbirds existed several kilometers upstream of the GLBC. Greater rates of nest parasitism might be expected at the upper and lower extremities of the GLBC, but an effect could not be seen in the small number of observed cases. However, qualitative observations over multiple years suggested that cowbirds were more numerous in the lower segment of the GLBC.

Adverse weather, particularly high winds, can have a significant impact on Southwestern Willow Flycatcher nesting. Stoleson and Finch (2000) observed a negative effect on flycatcher nesting farther upstream from the GLBC in one particular year with strong storms. In the GLBC, high winds associated with convective storms in midsummer (Adams and Comrie 1997) caused damage to vegetation, particularly in the middle segment of the Main Canyon. Greater water stress in trees due to the recent drought conditions probably increased susceptibility to damage. In two territories, downed trees damaged either a nest tree or adjacent trees. Some nests were constructed in very slim coyote willow trees near the edge of habitat patches and were vulnerable to strong winds. There were no indications of direct impacts on nests by flooding in 2013, but high water levels and debris later in the summer may have disrupted some flycatcher nesting activities.

Nest Site Characteristics

Southwestern Willow Flycatchers nested in a variety of situations, where patch size, patch shape, and vegetation structure and composition differed. However, larger aggregations of territories usually occurred in large stands of mature coyote willow and in cottonwood-willow gallery forest bordered by coyote willow along the river. The occurrence of flycatcher nests across a wide range of heights and age classes of trees was possibly another indication of the generally poor habitat condition that forced birds to seek alternative nest sites. Birds in southeast Oregon attempted to maintain territories at sites where changes in habitat conditions included loss of understory vegetation and widespread mortality of coyote willow (Sedgwick 2004). In areas with reduced canopy, pairs may have selected cottonwood because cover for nest concealment and microclimate conditions elsewhere were less suitable. There were potential benefits to nesting in the upper canopy. Nests located at higher levels can be less susceptible to Brown-headed Cowbird parasitism (Brodhead et al. 2007). Nests in large trees also face reduced risk of damage by adverse weather. Lastly, vulnerability to some potential predators such as snakes and other passerines might be decreased.

Historically, 75–80% of Southwestern Willow Flycatcher nests were built in willows; however, populations may be adapting their nesting behavior in otherwise suitable habitat (Phillips et al. 1964; Hubbard 1987; Unitt 1987). In riparian areas lacking historical natural habitat, Southwestern Willow Flycatchers have used alternative species for nesting, even preferentially selecting them over willow (Stoleson and Finch 2003; Moore and Ahlers 2006). Despite varying nest height above ground, studies found that the relative location of nests within plants was quite uniform at about 0.60–0.62 m (McCabe 1991; Paradzick et al. 1999; Stoleson and Finch 2003). Plant structure and microclimate may be more important than species composition in Southwestern Willow Flycatcher nest site selection.

Management Implications

The lower Gila River in New Mexico has become an extremely important habitat for avian communities and a large breeding population of Southwestern Willow Flycatchers (Johnson et al. 1974; Hubbard 1977; Baltosser 1986). The recent decline in Southwestern Willow Flycatcher numbers and breeding success is cause for concern. Several interrelated factors likely are involved, including vegetation succession, drought, and possible early effects of climate change. Increasing effects of climate change in the southwestern United States are projected to include generally drier conditions, with greater variability and more extreme weather, potentially causing lower productivity, greater stress, and less food resources for some avian species (IPCC 2007; Parry et al. 2007; North American Bird Conservation Initiative 2010). Generally drying climatic conditions including less winter precipitation will result in lower river and water table levels in riparian systems, with detrimental effects on native vegetation and associated wildlife (Horton and Clark 2001; Lite and Stromberg 2005; Merritt and Bateman 2012).

Efforts to maintain healthy and productive ecological conditions on the Gila River should remain a high-priority objective for management agencies (BLM 1993). It will be increasingly important for land managers to improve watershed condition and maximize delivery of instream flows. Measures that control erosion and restore grasslands within the Gila River watershed will benefit the riparian system by improving hydrological processes and water quality. Negative effects of low water levels on the riparian system have been seen in the past few years. Further reductions in streamflow and water table levels would exacerbate the current situation and potentially threaten the Southwestern Willow Flycatcher population.

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Keynote

Reflections on the Relevance of Environmental History in a Changing World

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In the American West, looking back at history has been a serviceable way to estimate future conditions and courses of action in resource and risk management. Unlike in the East, ecological legacies still largely explain what we see now in the West and will determine what happens next. Climatic means and variances of critical variables are changing in directional ways, however, altering the frequency, intensity, magnitude, timing, and scale of droughts, floods, fires, and other ecological disturbances. Also, ecological forecasts based on past behaviors are now confounded by urbanization, novel grass invasions, and altered wildfire regimes. Societal adaptation to continuous and directional change will depend critically on the extent that future conditions will deviate from the present and the past. To what degree and exactly how will history stay relevant in a non-stationary, non-analog world? To address these questions, I will reflect on more than three decades of interdisciplinary research to synthesize climate and vegetation dynamics on scales from years to millennia. My presentation will scrounge far and wide for insights, from the Pleistocene to the Holocene, from the atmosphere to the oceans, and from large-scale plant migrations to regional population dynamics and disturbance regimes. I will conclude with speculation about different futures, both in the near and far term, and will discuss and prioritize some needed advances in environmental science and management.

Session Abstracts

Modeling Benthic Macroinvertebrate Responses to Proposed Diversions under the 2004 Arizona Water Settlements Act

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The 2004 Arizona Water Settlements Act (AWSA) permits additional New Mexican use of Gila River water. The New Mexico Interstate Stream Commission (ISC) is evaluating proposed diversion and storage projects and their potential consequences for the Gila River ecosystem. To those ends, the ISC commissioned one study with the objective of quantifying and evaluating flow-ecology relationships between the Gila River and benthic macroinvertebrates in the Cliff-Gila Valley and the consequences for those relationships under potential diversion scenarios.

The study uses instream flow and population models to examine the current effects of anthropogenic river drying and potential effects of AWSA diversions on aquatic insects. In addition, the modeling is used to estimate effects of flow augmentation on benthic macroinvertebrate distribution, diversity, and abundance. Study results will become part of the corpus of scientific information used by the ISC to determine which, if any, AWSA projects to fund and to identify any necessary environmental mitigation. This presentation provides an update on the study's progress, preliminary findings, and incorporation into ISC's decision-making process.

Prehistoric Trackways National Monument

McKinney Briske

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Located in the Robledo Mountains west of Las Cruces, New Mexico, Prehistoric Trackways National Monument is considered one of the most significant sites for Permian Period fossils in the world. The trace fossils preserved in Prehistoric Trackways National Monument provide a window into a single instant in time, hundreds of millions of years in the past. Hundreds of fossil sites in and around the monument preserve different parts of the ancient Early Permian Period ecosystem. These sites include trace fossils of tracks and imprints made by reptiles such as Dimetrodon, amphibians, fish, arachnids, and insects, and also include marine fossils, plant fossils, and petrified wood. Together, all of these fossils are considered a *Lagerstatte* ("mother lode"), a German word that is used in paleontology to describe a place that has a variety of fossils in exceptional preservation. Scientist can use Prehistoric Trackways to study an ancient world and answer questions about climate change, animal behavior, and adaptations of the Early Permian Period. It is a truly exceptional resource to solving mysteries of an extinct world.

Changes in Distribution and Abundance of Gila Trout in Response to the Whitewater-Baldy Wildfire

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The Whitewater-Baldy wildfire encompassed much of the occupied range of Gila trout, *Oncorhynchus gilae*. Immediate post-fire efforts in June 2012 were implemented to evacuate Gila trout from key streams to captive propagation facilities for holding and use in future conservation efforts. Summer rainstorm events in the region in July 2012 and July through September 2013 resulted in severe erosion to several watersheds. This resulted in the elimination of Gila trout from much of the upper West Fork Gila River, including four tributary streams. Status of two Gila trout populations in the upper San Francisco River is currently unknown, due to inability to access these remote locations in rugged terrain, but is a priority activity for 2014. Individuals from one relict population in the upper Middle Fork Gila River were evacuated during April 2013 and the stream was subsequently impacted by post-wildfire flood/scour events. Efforts to establish two new populations of Gila trout were initiated in 2012, with the transplant of fish from impacted to unimpacted and fishless streams. Efforts to broaden the distribution of Gila trout in post-fire streams formerly inhabited by non-native salmonids were initiated in November 2013. Development of revised conservation strategies for Gila trout are in progress.

Chihuahua Scurfpea Petitioned for Listing: Does It Have a Cultural Connection?

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Chihuahua scurfpea, aka Indian breadroot (*Pediomelum pentaphyllum* (L.) Rydberg)), is a rare leguminous forb in southwestern New Mexico and southeastern Arizona that was petitioned for listing under the Endangered Species Act in 2008. It is state listed as endangered in New Mexico and is Bureau of Land Management (BLM) sensitive. It is currently known from the New Mexico bootheel and at two locations in southeastern Arizona and occurs primarily on lands administered by the BLM. The Nature Conservancy was contracted in 2010 to examine soils. Point-location data and aerial imagery revealed a pattern that brought up the question of a possible cultural connection. Arizona BLM Safford Field Office has been researching the cultural question. This paper reviews cultural findings in the field, demographic data, and ethnobotanic considerations.

A Living Rivers Program for the Gila Box Riparian National Conservation Area

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The Gila Box Riparian National Conservation Area (RNCA) is managed by the Bureau of Land Management (BLM) Safford Field Office in southeastern Arizona. Twenty-three river miles are designated for preservation and conservation through the Arizona Desert Wilderness Act of 1990 H.R. 2570 Public Law 101-628. Since the removal of livestock grazing the river has gone through a healing process and continues to improve in ecological condition. A Living Rivers Program was initiated in 2011 through an Assistance Agreement between the BLM Safford Field Office and Eastern Arizona College. During summer 2013, students completed the first six miles of intensive inventory and assessment work to support BLM's proper functioning condition (PFC) assessment for lotic riparian areas. This paper discusses (1) the development and design of the inventory and monitoring work for the Living Rivers Program that is feasible for a two-year community college while supporting BLM with credible scientific data, and (2) outcome of the studies for the first six miles of the Gila Box RNCA, with recommendations for management.

Hinge-Felling in Forgotten Waters

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Ciénagas are the "forgotten waters" of the International Four Corners Region (Arizona, New Mexico, Sonora, Chihuahua, and surrounds) and are in need of recognition, restoration, and preservation. We think of ciénaga, terrace, drainage, and grassland repair as "habitat shallowing" (not trivial or superficial; rather, the opposite of incised). This paper details the core aspects of restoring a ciénaga, with an emphasis on the developing technique of "hinge-felling" of stream-side Gooding's willows, a restoration template that could have application to other tree-lined aridland waters.

Benefits of the Children's Water Festival

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Some of the greatest conservationists credit time spent in natural environments during their youth for inspiring their current stewardship ethic. This presentation provides examples from the annual Children's Water Festival conducted by staff and volunteers from the Gila Conservation Education Center and its partner organizations, including The Nature Conservancy. Findings from these local events reinforce more than a decade of research on the benefits derived from time spent in natural areas by children. This presentation focuses on the history of the event, school personnel response to it, expansion of the event beyond Silver Consolidated Schools in recent years, and possible reasons for the remarkable number of local children who have not been to the Gila River prior to the Children's Water Festival. Highlights include the positive impacts noted in these children as a result of spending just modest amounts of time in natural environments, an overview of research by environmental educators on the long-term benefits of spending time in natural environments, and plans for the future of the event.

Effects of Post-Wildfire Groundcover Treatments on Plant and Bird Communities in the Whitewater-Baldy Complex Area One Year after the Fire

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In 2012 the Whitewater-Baldy Fire became the largest wildfire in New Mexico history, burning over 297,000 acres, with approximately 38,000 acres classified as severely burned. Aerial-broadcast seeding and mulching are commonly used post-wildfire treatments and were prescribed for specific areas in the burned area. The effectiveness of these treatments at increasing vegetation cover and reducing noxious invasive plant species is highly variable, depending, in part, on geographic location, topography, precipitation patterns, soil characteristics, and life histories of plants. The effects of these treatments on bird communities is unknown, although fire-induced habitat changes alone have been shown to be beneficial for some avian species, while detrimental to others. Numerous post-fire treatment studies have been conducted in ponderosa pine (*Pinus ponderosa*) forests, but relatively few have focused on higher-elevation mixed-conifer forests and none on the Gila National Forest. The purpose of this study is to examine the effects of the groundcover treatments of seeding and combined seeding and mulching in severely burned mixed-conifer forests. We will present data collected during the first year after the fire on plant and bird communities, which provides a baseline for ongoing studies. Cooperation of the Gila National Forest office in Silver City, New Mexico, was essential, and greatly appreciated, in this study.

The Antiquity of Irrigation in Southern Arizona

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What do you do with all those frost-free days and limited precipitation in southern Arizona? Preliterate cultures in this region tackled this situation by developing the most extensive irrigation works in all of North America. Agriculture was introduced into southern Arizona more than 4,000 years ago, and irrigation systems were developed there by at least 3,600 years before present. This presentation provides an overview of ancient Native American irrigation systems identified by archaeologists in southern Arizona and discusses the implications for understanding social complexity.

Groundwater Levels in the Mimbres Basin: Stable or Declining?

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A 2013 USGS report on groundwater depletion in the United States shows water levels in the Mimbres Basin to be "generally stable" from 2000 to 2008. However, an examination of that study's data and additional data revealed that the report relied solely on water levels from 15 Silver City wells, which are located in the northwest corner of the Mimbres basin and the eastern portion of the Gila basin. Some stakeholders have attributed the lack of groundwater mining to savings from drip irrigation, despite the fact that multiple studies have indicated drip irrigation will actually increase depletions. To estimate the trend in groundwater levels in the basin, field measurement data were analyzed from the 67 wells that were spatially distributed throughout the basin and were sampled regularly since 1997 according to USGS protocols. The results indicated continued water-level declines in the Mimbres basin for the 2000–2008 period. There are several other studies that confirm the declining water levels in the Mimbres basin for the same period.

The Ecological Significance of Irrigation Canals to Avian Communities in the Upper Gila River Valley

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Agricultural production in the Cliff-Gila Valley of southwestern New Mexico has been facilitated by the establishment and maintenance of earthen-lined, gravity-fed irrigation canals whose waters are diverted directly from the Gila River. Despite the ecological costs associated with these water diversions on the river's mainstem riparian community, the historic earthen character of the canals has allowed their near-perennial flows to support extensive linear bands of riparian and semiriparian vegetation on the outer edges of the river's floodplain, providing supplementary habitat for a wide variety of riparian-associated species. In the valley's upper reaches, an approximately one-half-mile section of the upper Gila Ditch bisects The Nature Conservancy's Gila River Farm, where, in the absence of grazing pressure, the ditch's vegetative community is particularly well developed. Potential changes to the ecological character of this and other ditches in the valley, including increased tree removal and the possibility of cement lining or large-scale piping to reduce water losses through seepage, prompted the farm's homeowners' association to conduct seasonal avian surveys along their half-mile interest to better understand the ditches' ecological significance. Spring-migration, breeding-season, and fall-migration surveys have been completed. Winter and nighttime surveys are still ongoing.

Estimating Survival and Movements of Band-Tailed Pigeons in New Mexico

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We studied the demography, distribution, and movements of Band-tailed Pigeons (*Patagioenas fasciata*) from June 19 to September 28, 2013, near Silver City, New Mexico. Band-tailed Pigeons were captured and individually marked with leg bands and PIT tags. A PIT tag reader and data logger on-site recorded the presence of individuals. To examine movements of pigeons, we fitted birds with light-level geolocators and VHF transmitters. For all birds, we recorded age, sex, length of bill, tarsus and wing, body mass, and molt status, and we took oral swabs to test for presence of *Trichomonas gallinae*. We captured and marked 126 Band-tailed Pigeons; 14 were fitted with geolocators and 9 with VHF transmitters. Transmittered pigeons remained in the area until early August, when they dispersed following the onset of summer rain. One nest was found 15.2 km from the capture site; however, most pigeons moved > 20 km from the capture site and were not detected. During the study, 37 PIT-tagged pigeons were recorded at the site by the data logger. We did not detect *T. gallinae* in pigeons and most individuals departed the area prior to September 16. We plan to continue the study at this site in 2014.

An Overview of the College Perspective on Setting Up an Assistance Agreement with BLM and the Ability of the Community College Students to Perform Well on BLM Science Tasks

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It all started with a conversation on the sidewalk outside the EAC Math/Science Building. The college had many young, eager students with professional aspirations in the fields of riparian ecology, range management, and environmental restoration. The Safford BLM had projects awaiting attention from an understaffed field office. Brainstorming that day has led to a mutualistic-symbiotic relationship that can serve as a pilot for future Higher Education/Federal Agency agreements in this age of downsizing and professional career recruitment.

The Logistics of Managing 60 College, High School, and Middle School Students on a Complex Grassland Seeding Research Project

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While incorporating a STEM educational theme, a regional community college developed curriculum to complete several major tasks within a mutual agreement with a local federal agency. Nothing unusual, you might say. But try including local high school and middle school students, soliciting materials and resources so that project costs are minimal, transporting bodies and resources over 100 miles of desert, and having a successful outcome, in which all parties involved have been empowered to make a real difference.

Spatial and Temporal Variation among Root-Associated Fungal Communities Inhabiting Grass Roots

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We assessed spatial and temporal distribution of Fungal Dark Septate Endophytes (DSE) within the roots of *Bouteloua gracilis* (blue grama) and other semi-arid C4 grasses. Root samples were collected throughout several seasons from Sevilleta National Wildlife Refuge in New Mexico and once from several sites across North America. Visual assessment using digital imaging software indicated that DSE are abundant but not uniformly distributed within secondary roots. Our visual and molecular assessment also revealed that DSE colonize areas within the root cortex and not the vascular cylinder, with many hyphae growing on the external surfaces of the endodermis and most hyaline hyphae weaving through the external portions of the cortex and out beyond the root-soil interface. Additional work with *Sporobolus cryptandrus* growing within rainfall-manipulation plots in New Mexico also suggests that specific clades of DSE vary over time and with rainfall events. Based on this and previous work on semi-arid grasslands, we suggest that a few taxonomic clades of microfungi establish complex, and spatially and temporally variable, interactions with the roots of most, if not all, species of aridland grasses.

New Mexico Wetlands Rapid Assessment Method (NMRAM)—Lowland Riverine Metrics Selection and Analysis for the Gila and Mimbres Watersheds

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The New Mexico Environment Department Surface Water Quality Bureau Wetlands Program is developing a wetlands rapid assessment method (NMRAM) in order to classify and assess the condition of New Mexico's wetland resources. In 2012 and 2013, data were collected using draft NMRAM metrics for the Lowland Riverine subclass in the Gila and Mimbres watersheds. This presentation will provide information about that data-collection effort and the next steps for finalizing Gila Lowland Riverine wetlands rapid assessment metrics. Gila watershed riverine wetlands provide important ecological information about one of the few relatively intact watersheds in the arid Southwest. The challenge has been to select metrics that reflect "Big River" systems and still remain rapid. The New Mexico wetlands rapid assessment combines landscape assessment in a GIS platform and a set of observable field indicators to express the relative condition of a particular wetland site. Sites of the Gila Lowland Riverine subclass were selected to reflect a disturbance gradient and were scored based on their ecological condition. Without assessment information, wetlands resources will continue to decline from a variety of stressors. The NMRAM is designed to provide ecological condition information about wetland subclasses. This information is then used to determine the status of the wetland subclass as a whole and to determine actions that can minimize future loss and degradation. Preservation of wetland ecological processes that are linked to river health and maintaining wetland function results in both direct and indirect positive effects on environmental quality and human health and welfare.

Post-fire Responses by Several Rare and Sensitive Plant Species on the Gila National Forest

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The Whitewater-Baldy Complex Fire of 2012 and the Silver Fire of 2013 together burned more than 425,000 acres of the Gila National Forest in southwestern New Mexico. Much of the high-intensity burn occurred in higher-altitude mixed-conifer forests above 8,000 feet. Several rare and sensitive plant species endemic to the Gila occur in the same habitat. Known pre-fire locations of *Hieracium brevipilum*, *Scrophularia macrantha*, *Anticlea mogollonensis*, and *Allium gooddingii* were visited in 2013 and positive plant identifications were made in over 80% of the visited sites. Rare-plant locations occurred within BEAR treatment reseed areas and unseeded habitats, and initial vegetative surveys found comparable growth and diversity of native grasses and forbs in both areas, with some suppression of successional grasses in areas heavily mulched and seeded with annual barley. Few invasive species were noted. Most affected of the rare plants appeared to be several large populations of *Allium gooddingii*, which appear to have disappeared completely from known sites in the area of Bear Wallow Lookout—an area with large acreage of high-intensity and severely burned forest. Further study and continued site visits can assist in understanding rare-plant survivability in catastrophic-fire situations.

Post-fire Land Treatment Effectiveness Monitoring of the 2013 Silver Fire, Gila National Forest

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In 2013, the Silver Fire burned large, contiguous tracts of National Forest System lands in the southeastern portion of the Gila National Forest. The majority of the high-severity burn was limited to mixed-conifer and pine vegetation types in the extremely steep and rugged Black Range. Several communities, many private properties, and county, state, and Forest Service infrastructure were left at risk from post-fire flooding, sedimentation, and debris flows. A Burned Area Emergency Response (BAER) team conducted an assessment of the fire and made recommendations to minimize post-fire effects. The BAER team's recommendations included aerial application of certified-weed-free straw to 2,880 acres of high-severity burn and aerial application of certified-weed-free seed to 12,900 acres of high-severity burn. The recommended seed mix included a small percentage of native perennial grass species and a non-persistent annual barley (*Hordeum vulgare*). An effectiveness monitoring plan was developed to evaluate treatment effects on site productivity, site diversity, and long-term recovery. This monitoring plan also sought to determine whether invasive or noxious weeds were introduced with these treatments. Permanent plots were established in mixed-conifer and pine vegetation types in non-treated, seeded, and seeded and mulched treatment units. This presentation provides the first year's monitoring results of the ongoing three-year effort.

Kidney Wood: An Arizona/New Mexico Treasure Challenged by Drought

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Kidney wood (*Eysenhardtia orthocarpa* (A. Gray) S. Watson) is a leguminous shrub endemic to southern Arizona and southwestern New Mexico, extending south into Sonora. Often confused with mesquite and acacia, it stands taller and broader and provides more shade. It provides important vertical structure and canopy coverage in wildlife habitat of the lower Chihuahuan desert from Tucson to Lordsburg. We sought to procure plants for habitat restoration but discovered it was not in production. We began to investigate this species and learned that it is challenged by drought and the infestation of mistletoe, and it appears the pollinator may also be challenged. Our report discusses baseline conditions of the species from three locations in Arizona and New Mexico and ongoing work with seed collection and germination studies.

Conservation Genetics of Gila River Fishes

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The upper Gila River basin in southwestern New Mexico is one of the last unimpounded rivers in North America and a stronghold for a threatened and largely endemic fish fauna. Despite absence of impoundments, distributions of native fishes have declined over the last 20 years. We used microsatellite DNA markers to examine population genetic structure of seven native species, including two federally endangered and one state-listed species. Levels of genetic diversity, measured as heterozygosity and allelic richness, were similar across species, with headwater chub and speckled dace having the least. Sample sites in the Cliff-Gila Valley housed the greatest genetic diversity for longfin dace and endangered loach minnow and spikedace. Sonora sucker (N_e = 1,617) and longfin dace (N_e = 1,217) had the largest genetic effective sizes of native fishes, whereas headwater chub (N_e = 86), speckled dace (N_e = 143), and spikedace (N_e = 325) had the smallest effective sizes. Estimates of basin-wide genetic structure reveal population dynamics where most native fishes are capable of moving throughout the basin but some natural landscape features may obstruct gene flow. Conservation priorities for these native species should include protecting local populations in the Cliff-Gila Valley with high genetic diversity and maintaining population connectivity.

Nest'án: The Traditional Western Apache Diet Project

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This project is a multi-year, collaborative effort of the San Carlos Apache Tribe, the White Mountain Apache Tribe, the Tonto Apache Tribe, and the Yavapai-Apache Nation in response to epidemic rates of diet- and obesity-related diseases in Apache communities. Based primarily on interviews with elders, this project describes in detail the pre-Reservation Western Apache diet in both Apache and White nutritional terms. Initial findings show that this diet was extremely healthy (high in fiber, low in saturated fats, high in healthy fats, low in cholesterol, low in sodium and processed sugar, and rich in a wide variety of whole foods); this diet was highly seasonal in nature; food gathering and production was the basis of most daily activity and group movement, economy, political structure, and ceremony; and the traditional Apache relationship with food was deeply personal, respectful, and spiritual.

Captive Propagation of Gila Trout

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Mora National Fish Hatchery currently rears five wild lineages of Gila trout. Fish are reared in naturalistic rearing units that are designed to mimic natural conditions that the fish would normally inhabit, including shared habitat with native species that naturally co-occur with Gila trout in the wild (e.g., Sonoran and desert suckers). The system design contains riffles and pools with current flow, tank bottoms are lined with rocky substrate, tanks contain natural and artificial cover, and the diet is supplemented with live feed. To prevent genetic drift, captive stocks are supplemented with wild fish from lineage-specific populations. Prior to spawning, randomly selected and suitable brood-fish are genotyped using microsatellite markers. From these data, a matrix of relatedness measures (relationship coefficient, R_{XY}) is created and fish with a higher proportion of shared alleles are identified as unsuitable pairs. The brood-fish are then spawned using only individuals that are "unrelated" (share fewer alleles). Post-spawn, family lots are kept separate until they are large enough to tag and family lots are tracked. Hatchery survival rates have dramatically improved due to new infrastructure and culture techniques.

Efficacy of Mechanically Removing Non-native Predators from a Desert Stream

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Habitat alteration and alien species have caused the decline of native fishes throughout the American Southwest. We initiated a 6-year study to evaluate the efficacy of mechanical removal of predaceous non-native fishes from an open 4.6 km reach of the West Fork Gila River. Removal efforts involved intensive sampling with a 10- to 12-person crew using backpack electro-fishers and seines over a 4-to-5-day period each year. Two control sites were sampled with similar methods to compare temporal changes in species mass in the absence of a removal effort. Results were mixed. Mass of yellow bullhead, rainbow trout, and brown trout declined in the removal reach from 2007 through 2012, but there was no change in smallmouth bass mass. Concurrently, mass of rainbow trout, yellow bullhead, and smallmouth bass did not change at two control sites, but brown trout mass declined, indicating factors other than removal were driving abundance of brown trout. The only native species to indicate a positive response to predator removal was spikedace. Results of this study suggest that with moderate effort and resources applied systematically, mechanical removal can benefit some native fish species, but movement of problem species from surrounding areas into removal reaches limits benefits.

Update on Bureau of Reclamation Activities Related to the Arizona Water Settlements Act of 2004 in the Upper Gila River Basin

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The Arizona Water Settlements Act (AWSA) is a complex web of agreements affecting the laws and policies of federal, state, tribal, and local governmental agencies and water management entities in Arizona and New Mexico. The AWSA reduces uncertainty for non-Indian municipal, industrial, and agricultural water users, assures tribes of long-term water supply, and provides assistance to build water infrastructure. This presentation provides a brief background and overview of the AWSA and discusses current Reclamation activities associated with implementation of several AWSA provisions in the Gila River basin. Among other activities, Reclamation is providing technical assistance to the New Mexico Interstate Stream Commission (ISC) regarding New Mexico's decision on whether to construct a New Mexico Unit of the Central Arizona Project (CAP) in exchange for delivering CAP water from the mainstem Colorado River to downstream water users in Arizona. This includes conducting appraisal-level economic analyses of the remaining ISC Tier 2 Proposals and an engineering assessment of various diversion, storage, and conveyance options.

Fire on the Gila: Impacts on Rare and Endemic Plants of the Gila National Forest

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In 2012, the Whitewater-Baldy wildfire burned nearly 300,000 acres of forested lands in New Mexico, making it the largest wildfire in state history. The Gila NF (Catron County) is home to 20 federal- and state-listed Species of Concern plants, 9 of which have the potential to have a significant portion of their range impacted by the Whitewater-Baldy fire. For some of these species, it is estimated that as much as 95% of their entire range might have burned, putting them at risk of extinction. The response of these species to wildfire and potential associated habitat alterations has not been studied. The objective of this study is to collect baseline information on the initial response of rare-plant populations to wildfires, and ultimately shed light on the impacts of altered fire regimes (increased severity and frequency) to the habitats of rare and endemic plants and how their habitats will be altered by vegetation community changes brought on by the synergistic effects of wildfires, continued drought, and the potential invasion of non-native species. Preliminary results of this 2-year study will be presented.

An Investigation into the Ecohydrologic Processes of Two Riparian Wetlands along the Gila River, NM

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The dynamism of the Gila River in southwestern New Mexico has resulted in the creation of a topographically diverse floodplain that supports an array of riparian wetlands. The purpose of this paired wetland study is to investigate the ecohydrologic processes of two wetlands, in order to predict their potential responses to anthropogenic or natural changes in hydrology. One represents a natural wetland and the other a wetland that exists only as a result of an anthropogenic modification to the river valley system. A network of 28 wells and two weather stations were installed in early 2013 to provide a high resolution of data on surface water and groundwater hydrologic conditions. Phreatic surface contour maps were produced to aid in the visualization of sub-surface gradients. Based on these results, an electrical resistivity investigation was conducted to identify paleoflow channels as well as depth to bedrock and other potential areas of interest. These data will form the development of three-dimensional ModFlow models that will be used to investigate potential future stream-flow scenarios on wetland hydrology.

Quick-Response Experimental Post-wildfire Translocations in the Narrow-Headed Gartersnake (*Thamnophis rufipunctatus*)

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When catastrophic events affect habitats, management actions including salvage, translocation, or repatriation of threatened species may be necessary. In May of 2012, the largest wildfire in New Mexico occurred in the Gila National Forest. In the wake of the fire, wildlife professionals raised concerns regarding post-fire effects on extant populations of narrow-headed gartersnake, *Thamnophis rufipunctatus*. Post-fire threats to the snake include ash flows from monsoonal rains in burned areas, causing loss of foraging habitat and die-offs of native fish. The decision was made to salvage gartersnakes from two creeks that had robust populations and in which post-fire impacts were predicted to be severe. Narrow-headed gartersnakes were salvaged in June 2012 from Whitewater Creek and the Middle Fork of the Gila River. On 31 July–1 August 2012, 18 snakes (8 radioed and 10 under 440 SVL) from Whitewater Creek were relocated into Saliz Creek. Telemetry results were compared to those of previous studies on non-translocated narrow-headed gartersnakes, to determine differences in behavior and movements attributed to translocation efforts for this species. The results of the translocations will be presented during the talk.

Environmental Site Investigations in Grant County, New Mexico, under the Chino Administrative Order on Consent

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An environmental investigation is being conducted under the Chino Administrative Order on Consent (AOC) to study the possible effects of historical mining and mineral processing activities occurring before current environmental regulations, in the area surrounding Chino's operation, covering approximately 50 mi^2. The Chino AOC was formed in 1994 to protect public health and the environment and is a voluntary agreement between Chino Mines Company and the New Mexico Environment Department. The chemicals of potential concern are primarily metals. The Chino AOC is divided into the following investigation units (IU), each with its own contaminant sources, transport mechanisms, affected media, and exposure pathways: Hurley Soils, Hanover and Whitewater Creeks, Smelter and Tailing Soils, and Lampbright Draw. Following a "CERCLA"-type process, the environmental site investigation for each unit typically involves the summary of existing data, identification of additional data needs, remedial investigation of the nature and extent of contamination, probabilistic risk assessment of human and environmental health due to potential exposure pathways and the length and amount of exposure, feasibility study of remediation alternatives, record of decision, remediation if necessary, completion report, and site maintenance and effectiveness monitoring. An update on each investigation unit will be provided.

Status of Activities Related to Implementation of the New Mexico Arizona Water Settlements Act

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The New Mexico Interstate Stream Commission (ISC) has been addressing implementation of the New Mexico Arizona Water Settlements Act (AWSA) since 2004. The ISC has worked diligently to ensure that New Mexicans are kept informed about its activities, each stakeholder voice is heard, and no stone is left unturned in evaluating every aspect of stakeholder proposals. Through public meetings and group presentations, the ISC strives to provide New Mexicans with accurate, timely information regarding how the AWSA works, along with the opportunities and challenges it presents. Many scientific studies have been completed. Many more studies are still in process. Fifteen projects proposed by local stakeholders are in varying stages of analysis. There have been some responses from the public to the ISC work. In this presentation, the ISC shares the status of its work to date.

Calibrating Our Progress toward Recovery of Amphibian Populations: An Area-Based Approach and Occupancy Modeling

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Like many amphibians worldwide, Chiricahua leopard frogs (*Lithobates chiricahuensis*) have experienced dramatic, rangewide declines during the past three decades and in 2002 were listed as threatened under the Endangered Species Act (ESA). A species recovery plan was finalized in 2007 that included four recovery criteria that, when reached, will have (1) established metapopulations and isolated robust populations, (2) managed necessary aquatic breeding habitats, (3) managed important dispersal corridors, and (4) reduced threats so Chiricahua leopard frogs no longer need the protection of the ESA. Although great progress has been made since federal listing, progress on recovery criterion 1 has been hampered by (1) the dearth of suitably configured landscapes that could "host" candidate metapopulations and (2) the difficulty of establishing and monitoring viable metapopulations given the limited human and financial resources available. In addition to outlining important reasons to survey and monitor Chiricahua leopard frogs, we develop a conceptual area-based approach to evaluate progress toward recovery that is applicable to Chiricahua leopard frog recovery. This approach utilizes occupancy modeling to gauge progress in establishing, managing, and monitoring viable metapopulations. It is easier to design and implement, makes fewer assumptions, and is less biased than the current "strict metapopulation" approach.

Are There Giants in the Gila Box RNCA?

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Arizona Bureau of Land Management (BLM) Safford Field Office conducted intensive survey of mesquite bosques, cottonwood and willow galleries, and big trees in the Gila Box Riparian National Conservation Area (RNCA) during summer 2013. Six miles of river corridor were inventoried and assessed to support BLM riparian assessment protocol. This paper discusses the patterns and processes observed along six miles of riparian corridor and the implications for riparian health. This paper is provided in partnership with Eastern Arizona College (EAC) and the EAC Agreement with BLM for Science, Technology, Engineering and Mathematics (STEM).

Genetics Helps Guide Recovery of Gila Trout following the Whitewater-Baldy Fire

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The 2012 Whitewater-Baldy Fire impacted nearly every wild population of Gila trout. There are important ecological questions relating to restoration. For example, how have stream habitats changed in response to fire and how long will it take until streams in burned areas can support fish? Another important question is how to ensure long-term survival of the species by restoring streams with captive-spawned fish such that genetic diversity is maximized and maintained while preserving genetic distinctiveness. Pre- and post-fire data were used to evaluate the role of genetics in restoration and recovery. Most relict lineages of Gila trout showed reduced genetic diversity post-fire, but previously undiscovered diversity was present in the Iron Creek lineage of Gila trout. We have a unique opportunity to restore this lineage through careful breeding practices in the hatchery prior to stocking, because the threat of hybridization and competition from non-natives has been eliminated in Iron Creek. We also consider the genetic benefits of stocking all Gila River lineages to Upper West Fork of the Gila River to restore a natural metacommunity (connectivity and gene exchange across lineages). Thus, the Whitewater-Baldy Fire presented big challenges and some new opportunities for recovery of iconic Gila trout.

Return of the Lobo to the Southwest

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Aldo Leopold wrote that "the key to intelligent tinkering is to keep all the parts." Mankind has often eliminated populations, species, and natural processes with little thought to the consequences. The elimination of a top predator, the Mexican wolf, from the Southwest resulted in a less diverse ecosystem. Though instrumental in the historic eradication of wolves through poisoning, trapping, bounties, and other methods, the US and state governments came together in the 1990s to develop plans for the return of the lobo to the landscape. In January 1998, 11 Mexican wolves were released from captivity into the Blue Range Wolf Recovery Area in Arizona. Within a year, wolves were moving into New Mexico. At the end of 2012, the annual count estimated that there were at least 75 wolves in the wild population, a number that remains below the goal of having at least 100 wild wolves. We will explore the successes, setbacks, and lessons learned during the 15 years of the reintroduction project, and will discuss the science behind proposals to change some of the rules by which the wild population is managed.

Splish Splash, Taking a Bath in the Gila Box RNCA

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Bureau of Land Management (BLM) Safford Field Office conducted water quality studies along six miles of the Gila River in summer 2013. Attributes included dissolved oxygen, water temperature, pH, conductivity, salinity, stream flow, and pebble count. These data are collected to inform the EPA water quality program, the BLM fisheries program, and the BLM assessment of riparian health. Patterns observed along the six miles are discussed. This paper is provided in partnership with Eastern Arizona College (EAC) and the EAC Agreement with BLM for Science, Technology, Engineering and Mathematics (STEM).

Recovery and Conservation Actions for the Chiricahua Leopard Frog on the Gila National Forest, 2008–2013

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The Chiricahua leopard frog (CLF; *Lithobates chiricahuensis*) has disappeared from significant portions of its historical range in Mexico, New Mexico, and Arizona, and was listed as threatened under the Endangered Species Act in 2002. Historically every waterway, stock tank, and pond on the Gila National Forest (GNF) had healthy populations of leopard frogs. Currently, there are only 20 known sites where Chiracahua leopard frogs still exist in New Mexico. GNF biologists have begun working in conjunction with the US Fish and Wildlife Service (USFWS) and recovery groups in New Mexico to conserve important extant populations and to augment and restore frogs to sites that have experienced population declines or local extinctions. Working with the USFWS, GNF biologists created a system to modify steel stock tanks to create a network of captive "refugia" tanks for frogs from across New Mexico. The use of these tanks stems from the observation that frogs naturally colonize these structures in areas where natural wetlands have been fragmented and lost. These structures can serve as viable assurance populations until these individuals or their offspring can be repatriated to the wild. Tanks are provisioned with floating vegetation and island habitats in an attempt to provide habitat for all frog life stages.