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Introduction

Aldo Leopold's vision gave us the Gila Wilderness in 1924—the world's first dedicated wilderness area and a forerunner of the global conservation movement of half a century later. Issues facing the nascent conservation movement of 1924 are still with us, and greatly increased environmental, population, conservation, and scientific concerns, locally and globally, bring new challenges. The Third Natural History of the Gila Symposium, held on the campus of Western New Mexico University in mid-October 2010, focused on these fascinating and critical issues, invoking science, education, management, and aesthetic and lifestyle impacts on this great natural resource. A tradition has been set that this and future Gila Natural History Symposia are open to all without charge.

In the earliest days of conservation it was almost enough to “just leave it alone” but that idyllic situation is no longer feasible. Active management, restoration, and political action—our stewardship—are required if future generations, human and non-human, are to inherit the Gila forests even close to what we enjoy nowadays. It is worth realizing and appreciating that the forest and wildlands of the Gila Region in southwest New Mexico are unlike anywhere else in the world. There are indeed few places elsewhere supporting such an expansive natural region that is so accessible.

Our symposium brings scientists, natural resource managers, and the general public together for interchange of research and ideas encompassing geology, management, botany, zoology, archaeology, ethnobotany, hydrology, education, howling wolves, and more. Forces local and global shape our forests as we witness impacts of climate change and devastating wildfires consuming far more forest than desired. To know the forest, the land, the waters, the rocks, and creatures large and small, and our own impacts, gives us tools to maintain a great and vital natural heritage. Knowledge based on scientific research is the necessary base for meaningful management and conservation.

More than one presenter at this symposium reminded us that human population and human actions are the most likely cause of higher threatened and endangered species rates. As dire as some of our predictions may be for the future of our natural heritage, we also have powerful tools heretofore not available. And of course we cannot know the future, although predictions based on the best available scientific data are valuable and necessary.

Van Cothier reminded us in his presentation that “rivers are to be treasured and respected, never bullied or coerced.” James O'Hara told us of his research on tachinid flies, which reach their highest diversity in the Southwest, common but easily overlooked insects that exact a terrible toll on caterpillars, beetle larvae, true bugs, and a few other insects that they feed upon. Several presentations made us stop to realize that even small and seldom seen predators are significant cogs in

the wheel of biodiversity that makes up our natural world. As with so many plants and animals in the Gila Region, O'Hara reminds us that new discoveries, new species, are yet to be found here.

Native fishes are certainly among the most obvious and imperiled major life forms in the Gila Region. David Propst and others provided increased research-based knowledge of direct importance for management, emphasizing the fragile waterways and impacts of non-native species. Keeping the Gila River, one of the last free-flowing rivers in the Southwest, dam free was voiced as an ongoing major conservation and cultural concern. Although present-day climate change and ever-increasing human population are unprecedented in recent history, the local archaeological record shows that human-induced environmental change, sometimes quite devastating, occurred in prehistoric times.

Our symposium presented details of powerful, open-access databases such as SEINet and gilaflo.com; these provide unfettered access to thousands upon thousands of specimen records of regional plants and some animals. For example, in SEINet we can access regional specimens such as the hundreds of herbarium collections by E. O. (Elmer Otis) Wootton from 1892 to 1906. Or we can view intricate details of more than a thousand species of vascular plants at gilaflo.com, shown in more than 14,000 images. These exceedingly useful resources were not available only a few years ago and are all open access.

It was our pleasure to honor Marian and Dale Zimmerman with the symposium's award for recognition of their more than a half century of immense contributions to research, education, and conservation. Gene Jercinovic's biography vividly brings forth two giants. An evening gathering at the Buckhorn Saloon in Pinos Altos and diverse field trips further fueled friendships and interest in the Gila Region.

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 also owe a special debt to Sarah Johnson, who spent many hours copyediting and formatting these proceedings. We also thank T&E, Inc., for funding that supported publication of these proceedings.

We hope that you also enjoy the Fourth Natural History of the Gila Symposium October 24–27, 2012. A great resource and tradition has been established. Thank you all for helping to make it happen.

—Richard Felger, on behalf of steering committee members Marcia Andre, Carol Campbell, Jack Carter, Richard Felger, Kelly Kindscher, William (Bill) Norris, Martha Schumann, Ellen Soles, and John Titre

Some Things Going On in the Gila National Forest That You May Find Interesting

Richard Markley

Forest Supervisor, Gila National Forest

I would like to thank the symposium organizers for the opportunity to speak to you today. The Gila National Forest is truly a national treasure and symposia like this one provide an opportunity to focus attention on the issues affecting and influencing the Gila Region and to share advances in knowledge and understanding of the region.

There are three general areas I will cover this afternoon concerning the Gila National Forest. First, I will describe some of the important work that has been accomplished in six key areas of forest management:

1. Landscape-scale restoration
2. Fire management and the reintroduction of fire into the forest ecosystem
3. Community protection from wildfire
4. Collaborative forest restoration
5. Recreation-site and facility improvement
6. Wildlife-habitat improvement

Second, I will describe some of the present-day challenges facing the Gila National Forest, including travel management planning, the effects of increasing urbanism in the U.S., the wolf-reintroduction program, watershed-restoration funding, and the challenges associated with the national economic recovery.

Lastly, I will share my thoughts on a significant opportunity that exists that could reap benefits for the Gila National Forest in the future.

Accomplishments

Landscape-Scale Restoration

Signal Peak Ecosystem. The Signal Peak area is located north of Silver City and Pinos Altos and encompasses a large, 360,000-acre planning unit. Over the past several years an extensive program of planning and implementation of forest thinning, prescribed fire, and other work has been undertaken in partnership with The Nature Conservancy, Upper Gila Watershed Alliance, Center for Biological Diversity, Gila Woodworks, New Mexico State Forestry, and the Bureau of Land Management. The multiple goals of the work include ecosystem restoration, reduction of risk of uncharacteristic wildfires, and economic development through the harvest of sustainable wood products.

Slaughter Mesa. The Slaughter Mesa project is located in Catron County near Quemado Lake. This 31,000-acre project involves thinning of piñon-juniper woodlands and prescribed burning to improve wildlife habitat for pronghorn, spotted

owl, and other species. The major partner in the project is the New Mexico Department of Game and Fish.

Black Range Area 74. This is another large forest-restoration project involving prescribed burning of approximately 15,000 acres and forest thinning of about 9,000 acres. It is located in the Black Range near Beaverhead.

With the enactment of the Cooperative Forest Landscape Restoration Act in 2010, there is the potential for additional funding for landscape-scale work on the Gila National Forest in the coming years.

Fire Management and the Reintroduction of Fire into the Forest Ecosystem

Recent national changes in fire policy have affected and will continue to affect how fires are managed on the Gila National Forest. National policy now recognizes two types of fire—prescribed fire and wildfire. No longer is there a distinction drawn between wildfires that are managed for resource benefits and fires that are suppressed. A wildfire is a wildfire, and for naturally caused fires, a variety of strategies may be employed, ranging from full suppression to various management strategies that may be less aggressive but are more considerate of ecosystem, wildlife, and other values that may benefit from careful management of wildfire. Additionally, managers now have the flexibility to move in and out of suppression or management strategies, and portions of a fire may now be managed with different objectives. For example, one flank of a wildfire that is threatening valuable resources or property may have a full suppression strategy, while another flank of the fire, which is burning toward a more remote area of the forest where low-intensity fire is needed to improve wildlife habitat, will be managed rather than suppressed. The exception is human-caused fires, which will be suppressed, not managed. The Gila National Forest has long been a leader nationally in implementing new wildfire-management strategies, so it is not surprising that the Forest was one of several forests in the U.S. that was chosen to pilot the new approaches prior to their becoming national policy.

The prescribed fire program on the Gila National Forest is one of the largest in the Southwest Region, averaging about 25,000 acres per year. In selecting locations for prescribed fires, the Forest strategically assesses the need across the forest and places a priority on introducing prescribed fire where it will help ensure protection of communities, where it will improve or enhance wildlife habitat, or where it will contribute to watershed-restoration efforts.

The number of acres burned by wildfires each year varies

depending on a number of factors, including drought, fuel conditions where starts occur, and weather at the time the fires start. Management strategies also affect the number of acres burned to the extent that the above-mentioned factors allow. In 2009, wildfires burned about 52,000 acres of Gila National Forest land. Of this total, 51,000 acres of wildfire were managed to achieve resource benefits.

Community Protection from Wildfire

Protecting communities has been a major focus of the fire-management program. Both mechanical fuel reduction, like forest thinning, and prescribed fire are employed adjacent to communities to provide protection from wildfires. This work serves to reduce fuel loadings, break up the continuity of fuels, and provide a defensible space for firefighters to work should a future wildfire threaten a community. Often this work is done in conjunction with other agencies, like the Bureau of Land Management or the New Mexico State Forestry, which facilitates fuel-reduction work on private lands. In the past several years, significant fuel-reduction work has been completed around Silver City and Pinos Altos, adjacent to the Burro Mountain Homestead and Flying A subdivisions, adjacent to the Rancho Grande Estates near Reserve, and around the historic community of Mogollon.

Collaborative Forest Restoration Program

This program, which is unique to the National Forests of New Mexico, is a source of funding for restoration projects, particularly those that involve partnerships with other organizations and agencies, those that utilize small-diameter timber, and those that provide for community economic development. The purpose of the program is to encourage the collaborative, science-based ecosystem restoration of priority forest landscapes. Some of the key projects that have been funded include:

Signal Peak. This project on the Silver City District described above has benefited from several CFRP grants totaling over \$700,000.

Reserve Sawmill. A 2009 grant of \$360,000 to K & B Timberworks has helped to retool this mill to allow it to more efficiently process small-diameter logs removed from forest-restoration projects. By being able to turn heretofore unmerchantable trees into lumber, the costs of doing restoration may eventually be reduced or offset by the revenue from the sale of these small-diameter derived-wood products.

Eastern Gila Forest and Community Restoration Project. This landscape-restoration project in Sierra County will restore forest lands, test the economic value of various tree-harvest and processing techniques, and involve the local community in several aspects of the project. The project received a CFRP grant in 2008 of \$360,000.

Burro Mountain Homestead Restoration Project. This \$360,000 project will help restore piñon-juniper and ponderosa pine stands in the Burro Mountains and reduce fire danger to the Burro Mountain Homestead residents.

RC Forest Products Firewood Processor. A \$199,000 grant to RC Forest Products of Reserve provided for the start-up of a firewood-processing operation in Reserve that will utilize small-diameter logs from forest-restoration projects.

Sheep Basin Restoration. This \$360,000 grant to Kellar Logging of Reserve will be utilized to implement forest-restoration treatments in the Sheep Basin area of Catron County.

Collaborative Landscape NEPA Analysis for Forest Restoration in the Upper Mimbres Watershed. This \$199,000 grant to The Nature Conservancy will be used to accomplish the required planning and environmental analysis for future landscape-scale restoration work covering about 68,000 acres in the upper Mimbres watershed.

Recreation Site and Facility Improvement

Through the American Recovery and Reinvestment Act (ARRA), the Gila NF received in 2009 over \$6 million in funding for a variety of projects, including:

Trail Maintenance. Over 500 miles of much-needed trail maintenance is being performed by organizations such as the Southwest Conservation Corps, the Wellness Coalition, and private contractors.

Trail Construction. Thirty-four miles of new trail are being constructed in the Mangas Mountain area south of Quemado.

Recreation Site Improvements. Work to upgrade and improve recreation facilities at Mesa Campground, Upper End Campground, Aldo Leopold Vista, and Little Walnut Picnic Area is being accomplished with ARRA funding.

North Star Mesa Road. Road resurfacing, culvert replacement, vegetation clearing, and other safety and watershed-restoration improvements are being implemented with ARRA funding on a 48-mile stretch of this important forest access road.

In addition to the ARRA-funded projects, the Forest is completing work on the Gillita Creek Campground and the Willow Creek Road damaged by flooding several years ago.

Lastly, the Black Range District is restoring the historic Monumental Cabin located above the town of Cloride, and it will soon be available to the public through the Southwest Region's cabin-rental program. This will be the first historic cabin on the Gila NF to be included in the rental program.

Wildlife-Habitat Improvement

Much wildlife-habitat improvement is accomplished through the careful management of wildfires and through prescribed-fire projects. Forest-thinning projects, such as those accomplished through the CFRP program, also benefit wildlife. Improved grazing management and riparian-area protection are also critical to wildlife-habitat improvement. Some of the key species that have benefited from this improvement work include:

Mexican Spotted Owl. Fire managers work closely with

wildlife biologists to take advantage of wildfires that can be managed so as to benefit spotted owl habitat. Under the right conditions, fires can be allowed to burn at low to moderate intensity in dense mixed-conifer forest stands, thus reducing the potential for high-intensity stand-replacement fires, which would be detrimental to the owl habitat.

Gila Trout. The work to recover the Gila trout is a real Endangered Species Act success story. Beginning in the 1930s, the reintroduction of Gila trout into streams they formerly occupied has progressed to the point where delisting may be possible in the not-too-distant future. This week, 21 miles of the west fork Gila River and tributaries are being restocked with Gila trout. Additionally, the Forest will be investing \$380,000 of recovery act funds to replace the important fish barrier in Black Canyon that keeps non-native trout from expanding upstream.

Chiricahua Leopard Frog. Work is taking place to retrofit steel stock tanks to provide refugia for the frogs on both the Wilderness and Black Range Districts.

Chihuahua Chub. The Gila NF has developed a conservation plan, in conjunction with the Office of the State Engineer, that allows water-rights holders along the Mimbres River to contribute to the conservation of the chub by allowing them to elect to forego agricultural-water diversion in given years without fear of losing their water rights. By forgoing water diversions that are not needed for agriculture, the water is retained in the stream, which benefits the fish.

Mexican Wolf. The interagency group that consists of federal, state, tribal, and county governments is developing a new memorandum of agreement that will redefine the roles of the various agencies with respect to the U.S. Fish and Wildlife Service, which oversees the reintroduction effort. The reintroduction of the Mexican wolf has been controversial and the numbers of individuals and packs that were envisioned when the program began have not been reached. The Gila NF has implemented extensive measures to reduce wolf-livestock conflicts. One project is a three-mile fence that is being constructed in partnership with the New Mexico Department of Game and Fish and the Defenders of Wildlife. The fence will allow for greater livestock and wolf management flexibility, including movement of livestock to other pastures when determined necessary to separate them from denning wolves.

Challenges

Some of the significant challenges facing the Gila NF are:

Travel Management Planning. This is a major effort that has been ongoing for the past five years. The result of the plan will be a map that designates motorized routes and areas within the forest. Once motorized routes are designated, cross-country motorized travel will be prohibited. This will be a major change for users of the Gila NF where motorized use has been relatively unrestricted. The biggest issues raised by

the public have concerned how the plan will affect dispersed-camping opportunities, motorized big-game retrieval, and firewood gathering. Other concerns have focused on what kind of motorized use, if any, will be allowed on specific roads and areas such as the San Francisco River. The Draft Environmental Impact Statement will be released for public comment early in 2011 and the final plan completed later in the year.

Mexican Wolf. Challenges facing the reintroduction of the wolf center on whether the interagency partners can reach agreement on a new MOU. Can the program be successful as it currently exists? Is the projected number of wolves achievable? Who will help bear the cost of compensating livestock owners for their losses due to wolf depredations?

Urban America. As Americans become increasingly urbanized, how will this affect the management of the Gila NF? Will this urban population continue to be tolerant of smoke produced by prescribed fires or managed wildfires? Will they continue to support appropriations for management of public lands that they use more infrequently and appreciate less? What will be the effect of the loss of connection to the outdoors, wildlife, and wildlands? The Gila NF, in partnership with the Gila Conservation Education Center, is working to educate and inform young people about the outdoors and natural-resource conservation. Conservation education must reach all kids—those in Birkenstocks and those in cowboy boots. The Forest Service's "More Kids in the Woods" program has been successful nationally in connecting kids with the outdoors. One such program on the Wilderness District will engage kids in stream monitoring, camping, and other outdoor activities this coming year.

Watershed-Restoration Funding. Funding is needed to implement decommissioning of those roads that are no longer needed as part of the Forest transportation system. Some roads will naturally restore themselves without major investment in decommissioning, but most others will need culverts removed and road beds rehabilitated to reduce the watershed impacts of these closed roads. Funding of this work is an investment in the future.

National Economic Recovery. With a growing national budget deficit, trade imbalance, and a growing national debt, the nation will be challenged to pay the costs of defense, Medicare, Social Security, and other nondiscretionary programs. What funding will be available for managing the nation's public lands? How much will an increasingly urban and cash-strapped nation be willing to invest in its public lands?

Opportunity

There are many opportunities for restoring, improving, developing, and maintaining the resources of the forest, which Gila National Forest personnel, other agency partners, non-governmental organizations, and others could and should focus on. However, there is one opportunity that, if tackled, could positively influence all of the other efforts. The opportunity

I am thinking of is the opportunity we have to change the nature of the dialogue surrounding contentious Forest issues. All too often, it seems, the dialogue among the many varied interest groups in the Gila Region is expressed in ways that lead to “win/lose” solutions, rather than in ways that lead to collaborative problem solving where competing interests can come together to find constructive, mutually agreeable solutions to difficult problems. Whether it concerns the reintroduction of the Mexican wolf, the management of off-highway vehicles, or the smoke effects of prescribed or managed fire, I believe that to continue the rancorous and often hostile tone in public dialogue over these issues is not conducive to the long-term management and health of the Gila National Forest. We must ask ourselves, What is the Gila Region to be known for? A battleground where competing interests pursue win/lose agendas, where the wounds of the battles never heal, and people with different perspectives give up trying to talk with those with an opposing view? Or is it possible to engage in the issues in such a way that creative and innovative solutions to problems can be found that don't require that one

side win and the other lose? Will it continue to be lawyers and lawsuits, or will it be people with diverse interests and with a real passion for the issues of the Gila Region coming together, sitting down, and finding common ground? We see it happening in other parts of the country and even in other areas of New Mexico. Is there an opportunity for another approach to the public engagement in contentious issues in the Gila Region? I think so.

Pollyanna thinking? Maybe so. Maybe there is just too much history, mistrust, and animosity for diverse people to come together in the Gila Region. Maybe ranching interests and environmental interests, motorized interests and quiet-recreation interests can never sit down at the table. However, I do think there is room for hope that a different kind of dialogue can emerge. Just last week my wife and I were driving through Las Cruces and passed a store that sells Wranglers, boots, and other Western wear. What caught my eye was a big red-and-white sign in the front window that said BIRKENSTOCKS ON SALE! That sign tells me that anything is possible!

For Birds: Dale and Marian Zimmerman

Gene Jercinovic

I. Dale

The migration of chimney swifts (*Chaetura pelagica*) to their summer range carries them from their wintering ground in South America as far north as the Canadian border. Massive flocks fill the skies all over the eastern United States as they sail crazily through the air, harvesting tiny insects. To a young preschool child in Imlay City, Michigan, their aerobatics were completely thrilling. He watched, frozen, as a swirling cloud with a mystical intelligence funneled to roost in a tall chimney beside the school building a couple of blocks down the street, a school he would ultimately attend. Dale Zimmerman was hooked on birds.

Pearl and Landis (Doc) Zimmerman had only one child, Dale Allen, born on June 7, 1928. Doc was a successful dentist and dental surgeon in Imlay City. The family lived in a two-story house a short walk down the street from the Imlay City school grounds. Pearl and Doc imbued Dale with a passion for knowledge and encouraged his every curiosity. The house was full of books. Pearl was a teacher, as was her sister, "Aunt Ruby," who lived not far away in Imlay City. Both spent many hours reading to the youngest Zimmerman. Even before he began to read, he would pull down books and page through them. He could spend hours under the dining room table with books on Africa, poring over the pictures of lions, elephants, and giraffes. By the time he entered kindergarten, he was reading and was startled to see that many other students were just beginning to learn the alphabet.

But it was outdoors where his real interest lay. As he grew older, he found a world filled with creatures to be observed, to be captured, to be studied. Both parents cultivated an interest in natural history, which flowed smoothly into Dale. Swifts actually nested in the Zimmerman chimney.

"I can remember as a youngster climbing up. We had this peak on the roof, this one peak that went up toward our chimney. I would see swifts going down there occasionally and so I had to determine whether or not we had chimney swifts nesting in our chimney. One day I climbed up and I took a flashlight and I looked down the chimney and there not two feet below the top was this wonderful nest of twigs glued together with their saliva."

He began collecting insects and embarked on the study of butterflies, a hobby he continued into high school, leading to his lifetime involvement with Lepidoptera. With the assistance of Doc and through his own reading he became familiar with Linnaean binomial nomenclature before he was even ten years old.

By the time he was in junior high, Dale felt the need to begin preserving dead birds he found. The Zimmerman library included a number of books by the noted naturalist Ernest Thompson Seton, in which the basics of animal speci-

men preparation were outlined. Doc was a hunter, had been a trapper, and knew a good deal about skinning animals. In addition, as a dental surgeon he was very skillful with scalpels and needles. Thus, while still in junior high, Dale began a long career of collecting and preserving bird specimens. Pearl was supportive in her own way.

"Mother was very tolerant of having dead birds and partially skinned birds and other things in her refrigerator."

It was during this time that he started sketching and drawing birds. He also began to dabble in photography of birds, but was frustrated by the extreme slowness of film at the time.

Meanwhile, there was the issue of going to school. To Dale, school was a place to which every person between the ages of six and eighteen was sentenced with no early release program for good behavior.

"My own education came from my parents and my own reading and from my adult associates elsewhere."

For the first few years he dutifully did what he was expected to do, just like other children, enduring times tables and spelling tests. By junior high school, he began to rebel. The worst problem was study hall.

"... because the assignments were so infantile that you could dispose of them in ten or fifteen minutes and you had another half-hour, forty-five minutes to sit there and do very little."

He read some, but soon he and another like-minded student got started drawing cartoons, often involving school administrators.

"We would have run into difficulties if they were discovered."

He also got into writing.

"I started writing a story, a novel, The Life of Mabel Hastings. Gradually it grew into several volumes over several years of high school. It was not the sort of thing you would show around. It was a little bit blue in places, like deep indigo."

Other forces were at work as well.

By the time he entered high school, some pleasant spots appeared in the curriculum. One of the few teachers he enjoyed taught all the sciences. Dale enjoyed basic chemistry. The elegance of the periodic table of the elements impressed him. The formation of compounds made great sense. Test tubes and flasks tasted of real science. He and Doc set up a serious chemistry lab upstairs at the house. Biology was also an enjoyable class, although his own exploration of the local biological environment occasionally left him biting his tongue. In terms of subject matter in school, there was only one subject area that was really problematic for Dale. That was math. Arithmetic, fractions, decimals and the like were simple enough, but algebra was a disaster.

"It was not making any sense to me. I remember very well doing homework in algebra at the kitchen table every evening."

I never had to do homework in other classes because I'd dispose of these in short order while I was in school. I'd have it all done and have plenty of spare time to get into trouble while I was in school. I can remember sweating and having both Mother and Dad, especially Mother, explaining how to do these things. . . . I would go over and over this stuff and it still made no sense."

He somehow managed to make it through Algebra I. He was actually fairly successful in geometry, but other higher-level math classes were horrid. From this point forward, math was anathema to him.

By the end of his junior high school years, he found study hall unbearable.

"I played hooky by the time I was old enough to carry our gigantic wooden step ladder, which weighed a ton. There was a wooded lot close to our house. I would race home. I'd just go out of the building. I'd leave school, get the ladder, go down to the woods and watch birds."

He continued the habit into high school. After he was old enough to drive, he would tie the ladder to the side of the "big blue Dodge" and drive several miles to a nearby lake to study birds. He worked hard at sneaking out of the building and getting people to cover for him, but eventually a staid and stiff principal summoned Pearl to discuss the exploits of her errant son.

"I don't remember whether I actually overheard this statement or whether Mother mentioned it later but he [the principal] said: 'Your son is just not normal. He doesn't behave normally. He doesn't do the things that normal children or normal people do.'"

Pearl was incensed that he could say her son was not normal. The relationship between Dale's parents and the school administration remained forever uncomfortable.

Despite issues with the public school, there were very positive developments in Dale's high school years. His

involvement with the study of birds had grown quite serious. In his forays into the woods he had begun to photograph birds successfully. He began to use Doc's darkroom in the basement. His dexterity in preserving bird specimens was growing. He was keeping extensive records on birds migrating through and living in the area. He was not only sketching birds but had begun painting them as well. Dale was quite familiar with the bird artistry of George Miksch Sutton, who painted from live or freshly killed specimens. Dale tried to do the same. The family came into possession of an eastern screech owl (*Megascops asio*) that had been found on the highway with a badly injured wing. Doc built a large cage for it. It became a family pet named Otis (the genus name at the time was *Otus*). Dale would carry him upstairs and place him on a perch beside an easel to be painted. The watercolor, completed years later, hangs in Dale's home. Perhaps these activities were not "normal," but their significance eluded no one in the Zimmerman household.

Dale's ongoing study of birds familiarized him with not only the work of George Sutton but also that of Josselyn Van Tyne, ornithologist, both then at the University of Michigan at Ann Arbor. He began corresponding with both and received their encouragement and support. Doc, a University of Michigan graduate, made frequent trips to Ann Arbor, about sixty miles southwest of Imlay City. He attended dental conventions there and took short courses in specialized techniques. Dale made arrangements with Van Tyne for a tour of the research facilities at the Museum of Zoology at



Dale (age 17) with his pet owl, Otis



"Otis," painted by Dale

the university. Doc accompanied him. They took a special elevator that opened behind the large iron gates that separated the research section from the public museum. Dr. Van Tyne gave a thorough tour of the bird division. Over the remainder of Dale's high school days, he made numerous trips to Ann Arbor with Doc, and spent all of his time at the Museum in the bird division. He got to know Van Tyne, Sutton, and other staff members, and gained a great deal of knowledge about proper methods of specimen preparation, general ornithology, and techniques in drawing and painting. With this remarkable affirmation of Dale's passion for birds, high school was only a matter of endurance. His future was clear. In the fall of 1946, he became a fixture at the Museum of Zoology by enrolling at the University of Michigan. His plan was to major in zoology and become an ornithologist.

The freshman curriculum at the University of Michigan was standardized, with quite limited choices for students. Dale attended his classes and did the required work. His spare time was spent at the Museum surrounded by the actual pursuit of science. By the spring semester of his sophomore year he had more course options. He expected that his time in the Museum of Zoology would make for a smooth transition into the zoology department at the university, but it turned out that, although Museum staff members occasionally taught in the zoology department, the two divisions were not closely related. In fact, there was friction.

"All of the people in the zoology department knew that I was very closely aligned with these other people over there in the Museum and they didn't really like it. . . . This bothered me no end."

In his junior year, Dale became a botany major, although continuing to take zoology courses he considered important for his long-term goals in ornithology.

The botany department was planning a significant collecting expedition deep into Mexico for the summer of 1949. Dale and a fellow birder from the forestry school decided to join the group. His contacts in the Museum and his new-found friends in the botany department arranged for the appropriate permits. Dale borrowed the big blue Dodge from Doc, and the pair set off for Mexico. They drove south to Louisiana and did some birding along the Gulf Coast before entering Mexico at Matamoros. They began collecting plants as they drove through the shimmering heat of Tamaulipas on the way to Mexico City where they were to pick up their firearms permits. Once past Mexico City, heading west through Michoacán, they couldn't resist visiting Paracutín, the volcano that appeared in a cornfield in 1943 and was still erupting. Finally, some ten days after leaving Michigan, they reached Autlán in Jalisco, their base of operations for the next couple of months. Days were spent in the field collecting plants, birds, and even small mammals, all specimens carefully labeled. In the late afternoon they would return to their quarters in the picturesque, old-time adobe Hotel Valencia. With the car parked safely in the courtyard, they could have dinner and prepare for the next day. But even their dinner could become an adventure.

"One evening several people came in, quite rough-looking hombres. There must have been six or eight of them. They were sitting along the sides of the table and at each end. They didn't

serve liquor there, but these guys did have some liquor they brought with them. It was getting rowdier and rowdier, and noisier and noisier. It didn't take very long, because all this took place while we were ordering our evening meal, waiting for it and getting and eating it, but these guys were getting pretty unruly and, at one point, suddenly it just was like a scene from some damn Wild West movie. The guy at one end of the table jumped up and back. His chair went over behind him and he drew his gun and shot at the other person at the far end of the table. Well, it was just one of those things. We didn't know what was going to happen. It was all over in just a few minutes, but boy, were they hot-blooded individuals. They were wild. It was truly scary, just like a scene out of some movie. Nobody was hurt. The shot went wild. Maybe it went wild intentionally. Probably did . . . but that was life at the Hotel Valencia."

At the end of the summer, they packed the Dodge full of specimens and returned to Ann Arbor for the beginning of Dale's senior year.

II. Marian

Christmas was always an exciting time at the Allen house in the rural town of Kresson, about six miles east and south of Haddonfield, near Camden, New Jersey. There were the usual shopping trips to Philadelphia and the hanging of stockings on the mantle and the decorating of the tree, but this Christmas morning was special. A loosely tied cardboard carton was handed to the smallest Allen. Before she could untie the string, some fur appeared in the gap between the flaps and the little girl knew she had the most wonderful gift she had ever received, a pet kitten.

Marian Jeanette Allen was the second (and last) child of Pearl and Horace Clifford (Cliff) Allen. She was born on the 8th of July in 1930 in Camden, New Jersey. Her brother Bob was born in 1926. Cliff was an electrical engineer. He had started his career with General Electric in Schenectady, New York, but had accepted a job with RCA in Camden in the late 1920s. The Allens lived in a three-story brick house. The third floor was an unfinished attic filled with out-of-season clothes and a trove of old trunks and odds and ends. The floors of the house were hardwood, with linoleum in the kitchen. Heating was accomplished with radiators filled with steam from a coal furnace. The furnace and coal bin were in the basement, along with two other rooms. The first was quite large, with a photographic darkroom at one end and a metal-working lathe, a workbench, grinding tools, bench saw, and hand tools. The other room was smaller, with shelves for fruit preserves and canned vegetables. The kitchen had an electric refrigerator and an electric stove, but the old coal-burning stove graced the sun porch when Marian was very young.

Pearl and Cliff had elected to live in a country setting rather than in the city environment of Camden. Marian could remember listening to the whip-poor-wills calling as she went to sleep at night.

"Once Cliff took us into the woods behind the yard, across a little stream where purple violets and dog tooth violets grew, and showed us a woodcock on a nest with eggs."

Cliff built a number of birdhouses for the back yard. One by the back door was used regularly by a pair of house wrens. Another, mounted on a silver maple, was special for bluebirds. Birds were an important aspect of country life for the Allens.

"We had three small bird guides with paper covers, each a different color, which I used to study."

Concord grape vines covered an arbor beside the driveway. During summers when the vines bore heavily, Pearl, with Marian's help, would put up juice, jelly, and jam. Fruits and vegetables from their large garden were preserved in Mason jars.

Inside the house, reading was a common pastime. Both parents frequently read to Marian when she was young. As they grew up, reading was important to both Allen children. They often received books as Christmas and birthday gifts. The radio was also part of almost every day—Jack Benny, the Lone Ranger, Fibber McGee, the Green Hornet, concerts from the New York Philharmonic. On Saturday, there were the Metropolitan Opera broadcasts. Since Cliff worked for RCA, the Allens were able to acquire a phonograph early on, and amassed a large collection of "78s." Cliff and Pearl were serious opera buffs. They not only enjoyed performances on the radio and on the phonograph, but also would travel to Philadelphia to attend live performances, even bringing Bob and Marian on occasion. The parents even belonged to an opera study group, which sometimes met at the Allen house. Music was a constant presence. Pearl played the piano, Cliff the violin. Now and then they would play together. Pearl gave both Marian and Bob lessons on the piano.

Both children attended the Kresson School. The school consisted of two rooms separated by a long hall. Entering from the front of the school, the room on the left was for grades one through four with Mrs. Wood and the room on the right for grades five through eight with Catherine Smith, who also served as principal.

"The only toilets were behind the school, separate for boys and girls, each enclosed by a square of adult-height walls."

The playground was between the back of the school and the toilets. The school was a mile and three-quarters from home. She walked to and from school until she was old enough to ride her bicycle. Marian was quite comfortable with school. She was there with friends and found school-work pleasant enough. The closest she got to trouble came as she approached the end of her elementary school years.

"By fifth or sixth grade, Beverly, Pearl, Ruth and I sometimes left the playground, going straight back and uphill to a small grove of pines. There we played 'pretend games,' including characters from Pinocchio (the film) such as the blue fairy. When the bell announced end of recess, we had to run to get back to the building."

During her sixth-grade year, the United States entered World War II. In the summer of 1942, Cliff was transferred to a new RCA facility in Princeton, New Jersey, to do research for the war effort. Marian's time in the Kresson School was at an end. The Allens moved north to Princeton. At the point she was to enter seventh grade, she found herself in a completely new world.

"I went from there [Kresson] to Princeton Township School,

which was a big school in which they had separate teachers for different disciplines, and you went from one room to another for your English and so on. It was quite a change."

Yet the education she received in Kresson, coupled with much she had learned at home, allowed her to easily make the transition to the Princeton schools. The family's new house sat just outside the Princeton city limit. As a result, she had to attend the Princeton Township School, requiring her to take a bus to the other side of town. Despite this difficulty, her seventh- and eighth-grade years passed smoothly.

In the fall of 1944, she began her career at Princeton High School.

"I was a B student. In high school I was on the B honor roll. Sometimes got As. I had good-quality teaching in Princeton. That's where I got interested in plants, in botany . . . through a science teacher. He had us make plant collections for one quarter. My folks were always interested and knowledgeable in the outdoors and plants, but that's where I actually made a plant collection—my first one. I was a freshman in high school."

Marian took four years of math, with the hope that she wouldn't need to take any more in college. She joined choirs as soon as she got into high school. When she was a junior a select group of girls' voices was formed. She was not selected. She discussed this with the director, who indicated that he had assumed that on account of her long bus ride she would have problems with after-school practice. Marian found another bus available later in the day and became a member of the select choir. During her senior year, the music department decided to put on the Gilbert and Sullivan comic opera *The Pirates of Penzance*. Marian auditioned and she was selected as one of three girls to sing the lead role of Mabel. She



Marian (age 17), as Mabel

did a matinee performance for the students at the high school and also one evening performance for a wider audience.

"That opened up new worlds for me. It gave me all sorts of confidence."

As her senior year drew to a close, it was time to make plans for college. She had an uncle who had attended Syracuse University. Pearl's brother taught at the University of Michigan. Marian applied to both. Syracuse was a private university. Tuition costs were "pretty high." The University of Michigan, as a state college, had more reasonable tuition. Marian also began to feel that she wanted to be someplace farther away, someplace different. In the fall of 1948, she entered the University of Michigan. She had visions of becoming a medical technician.

She got right into the swing of things. She pledged in Alpha Gamma Delta sorority and began living in the league house. There wasn't sufficient room in the actual sorority house for freshmen. She joined a choir at the Presbyterian Church and a university choir. Her freshman year was fairly structured. She took a biology course and beginning chemistry. She couldn't seem to master the use of a slide rule.

"I ended up my first year with maybe one B, mostly Cs. It was really disappointing, but the one highlight was the one lecturer in the general botany course, very well spoken and very interesting to listen to. So I went to see him at the end of the year and said, 'Do you think I could major in botany?' He said, by all means, try it, and he ended up presenting me with my own copy of a little book called Michigan Trees. I had always been interested in pressing leaves and figuring what they were and this sort of thing."

With her first year of college under her belt, Marian made a fateful decision to major in botany, and in the fall of 1949 she signed up for two classes in the botany department, one in applied botany and one in dendrology.

III. DAZMAZ

Fresh from the excitement of his first Mexican adventure, Dale began his senior year fully engaged with his scientific future. Having become a botany major during his junior year, he needed to pick up a few basic botany courses. For the fall semester of 1949 he enrolled in two courses. One of them was Professor C. D. LaRue's dendrology class, which met at the University of Michigan Botanical gardens.

"All of the students and perhaps a couple of assistants were sitting on the ground under some trees discussing some botanical matter, I don't remember what, but that's when I first saw her. She was wearing a beige corduroy skirt and a beige corduroy jacket."

He soon discovered that the same girl was also in his other botany class. Dale had met Marian Allen. They became friends.

"He and I just started chatting a little and discovered that we had some things in common and ended up walking to one of the local drugstore places or something one afternoon to sit down and go have a coffee or a soda or something-or-other and spent all afternoon chatting."

Neither Dale nor Marian was particularly involved in the social scene at Michigan. Marian was not enamored of sorority life. Dale had absolutely no use for fraternities. They discovered that beyond the fact that both of their mothers were teachers named Pearl and Dale's middle name was the same as her surname, they had much in common and there were many immediate empathies between them. By the end of that semester it was clear to each that their relationship was deepening. Marian actually met Dale's parents for the first time in December of 1949. Pearl and Doc came to Ann Arbor in order to drive Dale and Marian to Detroit so that Marian could catch a train back to Princeton for Christmas.

During the spring semester of 1950, they began attending dances and concerts. Marian had done very little dating, but quickly realized that she had found someone special in Dale.

"And he found someone that was very unusual at Michigan, somebody who didn't smoke, who was in a sorority but didn't go out and get drunk and soused all the time and wasn't high on all the sorority things. So he didn't let me slip through his fingers."

Dale decided to accompany Marian to Princeton during spring vacation to meet her parents. He borrowed the car from his parents.

"We drove out. I think we had one of the girls from the sorority that lived in New York or somewhere out in the east, Philadelphia perhaps, I think we took her along and maybe stayed overnight at her place. Back in those days, you know, you just didn't take your girlfriend and drive across the country unchaperoned."

Dale spent a week in Princeton getting acquainted with Pearl and Cliff.

That spring Marian completed her sophomore year and returned to Princeton. Dale graduated with a B.S. in botany. By this time, they'd decided that they were engaged. Dale decided that he would try to teach at a community college for a year to make enough money so that they could get married. This required his enrollment in a couple of education courses over the summer. He found them almost unbearable. In the meantime, war was rapidly brewing in Korea. By the end of June, it had become clear that U.S. troops would be involved. Unmarried young men were going to be drafted beginning in August. In early July, he called Marian in Princeton and hinted at "advancing our plans." He wrote a letter to Pearl and Cliff asking for Marian's hand in marriage.

Marian's parents approved of Dale and agreed to the marriage with two conditions. First, Marian was to stay in school and get her bachelor's degree. Second, she was not to get pregnant. The wedding occurred on the 29th of July at the Zimmerman house in Imlay City and Marian became Marian Allen Zimmerman. The newlyweds honeymooned in Doc's deer-hunting cabin near Luzerne, in Oscoda County in northern Michigan. Shortly thereafter, Dale abandoned his plan to teach at the community college and applied for graduate study at Michigan. That fall, Marian began her junior year and he entered grad school. He received an M.S. in botany in 1951 and began working towards his PhD. He continued to spend much time at the Museum of Zoology, where he had workspace provided by Van Tyne. Dale continued to work



Wedding July 29, 1950

with Van Tyne and others on specimen preparation and other ornithological matters, and with Sutton on painting and drawing birds. Both Van Tyne and Sutton would spend occasional weekends birding with Dale at Doc's cabin on forty acres in northern Lapeer County, not far from Imlay City.

The next year Marian completed her B.S. in botany and got a job in the circulation department at the general library in Ann Arbor. By this time Dale had decided to do his dissertation on the flora and ecology of the jack pine community of northern Michigan. Conveniently, this allowed him to study Kirtland's warbler, for him a special member of the community. He received his PhD in the spring of 1956.

Dale and Marian decided to spend the summer on an extended trip into Mexico. They entered Mexico at Matamoros, following the same route Dale had taken in 1949. They drove a Plymouth Suburban station wagon with room enough for two five-gallon "carboys," glass water jugs in wooden crates, two five-gallon gasoline cans, as well as the rest of their gear. Their first big stop was Rancho del Cielo in southern Tamaulipas, a "Mecca for naturalists" entering Mexico in those years. They were quartered in a guest hut with a thatched roof, complete with lizards and bats.

"I remember the first morning Marian went out to wash. We had a wash basin on a stand, a little tripod-like arrangement out in front of the only door of our little dwelling. The little wash basin was settled into this little basket-like affair with a water pitcher to fill it. And when Marian went out to wash, here was this gigantic spider, must have had this three, three-and-a-half-inch leg spread, with the most intriguing lavender eyes. I didn't know how she was going to react to this sort of thing, but she thought it was the most intriguing arachnid and she too was intrigued by its eye color."

This typified Marian's spirit in finding the joys and fascinations in every adventure.

After a few days at the Rancho, they headed south into San Luis Potosí, Hidalgo, and the Distrito Federal, and began

an expedition that would take them to every Mexican state but Sonora. The route had to be planned very carefully since gasoline was not universally available, nor was it of consistent quality.

"We had once, maybe twice, major problems with the fuel line clogging up because of materials in the gas. It was not refined gasoline at all. Pretty crude stuff. I can remember we'd have to overnight in some towns where there'd be a mechanic and we'd have to leave the car out on the street because the mechanic didn't have a shop in which to work. They worked on the street, little cobblestone streets in those villages. I can remember looking with horror at the car, sometimes two or three days in succession with all these parts scattered around on the sidewalks, in the gutter."



Marian & Plymouth in Oaxaca

Water was also a serious concern. It was possible to exchange an empty five-gallon jug for a new one at a bottling plant, but pure, uncontaminated water was never a certainty. Halazone tablets were constant companions. For the most part, they camped out, sleeping in their jungle hammocks or in sleeping bags in the back of the unloaded Plymouth. They ate canned goods, consumed many bolillos, and washed it all down with a glass of Nido, powdered milk that came in resealable cans useful for storing specimens.

Part of their purpose south of the border involved working with Irby Davis, a somewhat prickly expert in recording bird sounds. With him, they decided to go into the Yucatán Peninsula, an area without roads at that time. To enter they needed to go by train, so the three of them secured Irby's jeep to a flat car and they rode the rails across the border. They spent a few days exploring where they could and then secured the jeep again for the ride back across the border. At the border between Campeche and Tabasco, a railroad employee checking each car discovered that only Irby had a ticket and told Dale he would need to disembark and purchase tickets. As he was receiving the tickets, he noticed that the train was rapidly leaving the station. He sprinted out the door and dashed after the train, just barely catching hold of the ladder of the last

car on the train. The train then proceeded onto a long bridge a hundred feet above a river where cars were switched out of and into the train with much banging and clanging. Dale, still clinging to the ladder for dear life, thought he surely would never see his wife again. Eventually, the switching was completed and Dale finally was able to rejoin Irby and Marian on the flat car. Adversity has always been an essential portion of adventure.

That summer established a pattern for what would become many journeys all over the world. For the moment, however, Dale and Marian headed back to Michigan. It was time for Dale to become gainfully employed. They traveled to New Jersey to investigate a possible position with the Audubon Society. The job did not work out. While there, Marian realized that she was pregnant. With no alternatives in the east, they returned to Ann Arbor. Marian was able to land a temporary position at the library. Dale went to an employment service and found a job at the University of Michigan Women's Hospital doing cytological examination of pap smears. In the spring of 1957, he began exploring for employment more suitable for his skills. On May 26, Allan Dale Zimmerman was born at the Women's Hospital. Since Dale was working there, the birth cost them very little.

Early in the summer, Dale found out about a couple of possible opportunities, one in the midwest and one in the northwest. Neither particularly appealed to them. Suddenly they got notice of an opening for a teaching assistant at a small teacher's college in a place called Silver City, New Mexico. Familiar with Silver City from bird records in Florence Merriam Bailey's *Birds of New Mexico*, and definitely pleased with its proximity to Mexico, Dale accepted the job. The Zimmerman family arrived in August, ready to build a future.

A new science building had just been completed. For Dale, there was much work to do in preparing for his teaching assignment. They rented a house on Mississippi Street just a few blocks from campus, but felt that the price was a bit high. One of Dale's students was a senior and lived just around the corner on West Florence Street. It turned out that he and his wife had built their little house themselves, but were now planning to leave town. They offered to sell the house to Dale and Marian in the spring of 1958. The Zimmermans bought the house that would be their home from that time forward. The next couple of years flew by.

By 1961 Dale felt well enough established to consider pursuing old interests. He decided that he had to fulfill a childhood dream of going to Africa to study birds. He read an advertisement in *Audubon Magazine* giving suggestions for trans-African guides and responded. A guide from Nairobi wrote back and the project was underway. Dale spent his spare time over the winter preparing his own Kenyan bird guide. Arrangements were made for Marian and Allan to stay in Imlay City and Dale flew off toward the Dark Continent. His letters back displayed the immeasurable mystery and majesty of Kenya, and conveyed his strong desire for Marian to experience the taste of Africa. He was also able to spend time in both Uganda and Tanzania. Two years later Marian was able to spend four weeks with Dale in the plains and



Dale with Masai tribesmen

forests of east Africa observing and photographing birds and other animals. Six-year-old Allan stayed in Michigan with Pearl and Doc. In 1965, Dale secured a National Science Foundation grant for two summers' work surveying Kenya's birds. Both Allan and Marian were able to come along. Birds were observed, collected, documented, photographed, and had their songs and calls recorded. Marian, in fact, became the recording specialist. Fieldwork in Kakamega Forest was the height of joy. For the next several decades, Dale and Marian would continue seeking and studying birds in the world's wild and natural places.

Of course, most of each year was spent in Silver City. When Dale first arrived, the biology department was a single individual, John Harlan. There was no herbarium. There were fewer than ten pressed plant specimens and no bird or mammal specimens. There were courses to be designed, field studies to be done, students to be taught. In those early days, every academic year was a challenge. In Dale's third



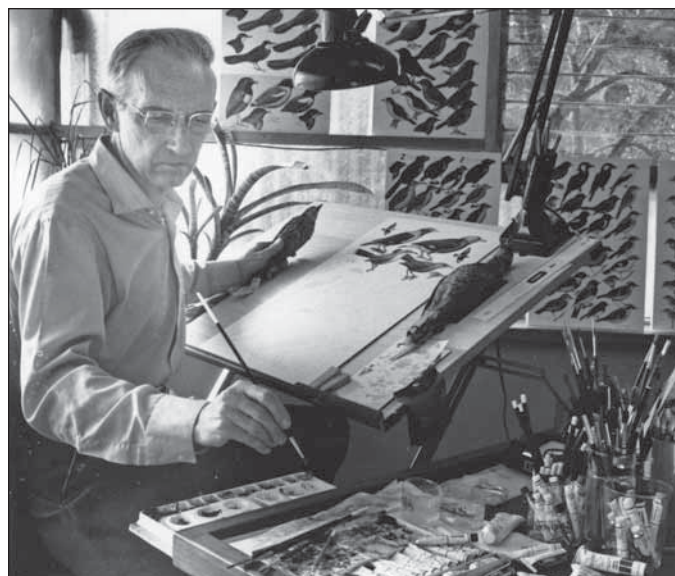
Marian recording birds

year, Bruce Hayward, a mammalogist, was hired and took over courses in mammalogy, genetics, and others that Dale disliked. By 1965, Dale had become an associate professor, and upon John Harlan's retirement, took over as department chair. He collected plants extensively and initiated a thorough study of the flora of the Pinos Altos Range of Grant County, establishing Western New Mexico University's first herbarium. Both in Africa and locally he collected many birds. His most important African specimens were placed in the American Museum of Natural History in New York City. Some of the African birds and his local specimens, supplemented by gifts from his old associates at the Museum in Ann Arbor, formed the basis of the first major bird collection at Western New Mexico University. He also prepared a small number of mammal specimens, the inception of a mammal collection greatly enhanced by Bruce Hayward. In the late 1960s Marian worked with others in Silver City to found the Gila chapter of the Audubon Society, the first chapter in the state. Visits to Panama and the Galápagos Islands closed the decade for the Zimmermans.

By the early 1970s, Allan had already become quite interested in plants, animals, and insects. He began making collections. Herbarium records indicate that he made more than 450 collections of plants in New Mexico, as well as serious collections of moths and butterflies, before entering college in 1975. Dale became a full professor and continued gathering specimens locally and abroad. No decade would have been complete without time in Kenya. The first of several trips that decade came in 1970. In the fall of 1973, Dale took a leave of absence from the university to investigate an unknown corner of the world. After a stint in Kenya, he toured southern Africa, including a visit to the Namibian Desert, where he observed the strange endemic plant *Welwitschia*. Then he was off to India, Nepal, and Bhutan. Other travels for Dale and Marian in the seventies included Australia, New Zealand, Fiji, New Guinea, Columbia, Peru, Trinidad, Venezuela, Surinam, Madagascar, and once again Ecuador and the Galápagos.

In the spring of 1981 Dale undertook a somewhat more perilous trek that he considered unsafe for Marian, visiting Russia and traveling across Siberia to Mongolia. After returning to Moscow, he caught a flight to Nairobi, arriving just in time to join Marian and Allan in order to lead an east African tour. Over the next few years, journeys included the Himalayas via India, Southeast Asia, Malaysia, Borneo, Argentina, Morocco, and Kenya again. During the Eighties notable changes would develop for the Zimmermans. At the beginning of the decade, Dale began work on preparing the illustrations for *Birds of New Guinea*, a book being written with two other authors for Princeton University Press. For five years, when not teaching, collecting, or travelling, he worked designing and painting watercolor plates. This often involved acquiring bird specimens from his contacts in museums around the country. Each plate contained from 9 to more than 35 true-to-life bird images painted by hand. Dale created 38 of 47 color plates and 6 of 8 black-and-white halftone plates. The volume was published in 1986.

In 1985 Allan received his PhD in botany from the Uni-



Dale painting bird plates

versity of Texas at Austin. Also in 1985, WNMU hired a new president, who began instituting numerous changes. Dale began to feel uncomfortable, but continued teaching. In 1986, he undertook a new project, becoming senior author, once again with two other authors, on another book for Princeton, *Birds of Kenya*. Once again he began designing and painting plates.



Kenyan bird plate

Then, in 1988, disaster struck. Marian was in Florida visiting Pearl and Cliff. Dale was driving outside of Tucson when he suddenly noticed all the power poles and tree trunks were no longer straight, but had a bulge in them. Ophthalmologists discovered he had developed a macular hole. Surgery was performed to stop the hole from enlarging, but central vision in the eye was permanently damaged. With his situation at the university continuing to decline, he retired that year. Having spent decades collecting plant specimens and feeling that the herbarium was threatened under conditions at that time, he and Allan moved the specimens to the University of Arizona until 1995. He also placed his African bird specimens and important state record bird specimens at the Museum of Southwestern Biology at the University of New Mexico in Albuquerque.

Work on the book slowed but continued to progress. Dale and Marian also returned to Kenya in 1988 to do more research for the book. They reexamined certain areas and tracked down species for which more information was needed. In 1991, they spent several weeks in England and Scotland visiting and meeting with a co-artist, co-authors, and the publisher. They managed to squeeze in some birding in the Farne Islands in the North Sea. That summer they were able to relax for a month of birding in Ecuador. Dale spent the first five weeks of 1992 back in Kenya visiting areas he had not seen and locating and studying ten more bird species. In June they had a week of birding in Churchill, Manitoba. Late in 1993 they spent three weeks on a dream vacation, flying to Chile and then taking a tour ship from the Falkland Islands to South Georgia Island and Antarctica. The early nineties, however, were primarily devoted to the completion of *Birds of Kenya*. Dale designed all of the 124 plates and painted 80. The last of them were completed in 1995. Of the 1114 species then known from Kenya, all but 9 were illustrated. Dale wrote the vast majority of the text. Marian and Allan assisted with editing. The book appeared in 1996.

As the Nineties progressed, serious health issues began to dog both Dale and Marian, considerably curtailing their activities. In 1997, they were able to spend three delicious weeks birding in Alaska, from Anchorage to Point Barrow to Nome, even visiting offshore islands. During that winter they returned to the Hudson Bay area to observe and photograph polar bears. Despite setbacks, the century ended on a special note for Dale. In 1999, he was elected as a Fellow of the American Ornithologists Union. With the possibility of foreign travel diminished, Dale had to turn his energies to more local projects. He began drafting a memoir of his life and times in Africa. He also rekindled his intermittent avocation in studying Lepidoptera, particularly moths. In April of 2003, Marian dragged Dale to Harlan Hall at WNMU "on a ruse." There, a surprise crowd awaited the dedication of the Dale A. Zimmerman Herbarium. In 2007, Dale and Marian decided on one more trip to South America. He headed to Peru in mid-July to hunt for the spatuletail hummingbird. Luck was with him. At the end of July he met Marian in Quito for a bit more birding in Ecuador.

* * *

Any attempt to capsulize lives as busy and complex as those of Dale and Marian would always be incomplete. There were many

more trips to Mexico. Dale and Allan intermittently spent ten or fifteen years travelling in Arizona, New Mexico, Texas, and Mexico studying cacti. Dale and Marian were receiving royalties for the use of many of their photographs in a number of books and magazines. Dale published almost ninety scientific papers on both ornithological and botanical matters. During his thirty-year career at WNMU, he saw biological science at the school develop from humble beginnings to a serious natural history curriculum. Marian contributed much time and effort to the Gila chapter of the Native Plant Society of New Mexico. Dale served in a number of advisory and editorial positions. They led many birding tours in many places. Their contributions to ornithology and ornithological organizations have been numerous and significant. Records at the Museum of Southwestern Biology credit Dale with 3240 plant specimens, making him the eighth-most-prolific collector in the state's history. At the time he was actively collecting New Mexico's birds, his collections, with the exception of vagrants and particularly rare birds, represented all birds known in the state at that time. A massive collection of Lepidoptera still remains downstairs at the Zimmerman house.

Before Dale left for his extended journey in 1973, Marian decided that he needed a companion. She created a cloth beanbag in the shape of a frog, which became known as Gleep. Dale traveled with his amphibian associate on the trip. Gleep eventually accompanied Dale and Marian to every continent on the planet over the next quarter of a century, surviving merciless attacks from several wild creatures.

"No one ever realized how silly Marian and I were."

Their times had silliness. And days of joy. And days of sadness. And moments of mystery. And moments of discovery. Dale came out of childhood with a strong sense of purpose. There would be birds. There would be Africa. Marian became perfectly part of both. The future that grew carried them to anywhere birds could fly. They captured the sights and the sounds. They produced science and art. They escorted their dreams to fruition.

Marian's death, just after Thanksgiving in 2011, stole the wind from his sails for a time. Yet, for Dale, the treasures of their quests together continue to breathe life into all that has been. He has completed the text of his memoir and is gathering appropriate photographs from his vast reservoir of images. Resting about the house there are miniature habitats in which various moth pupae and larvae are proceeding to maturity. There will always be time for more study.



Gleep botanizing

Visions of *Dulcinea*

Mike Fugagli

Say it with me: *The Gila River is the last major undammed river in New Mexico*. How many times have you heard that? An awful lot, I hope, because the phrase carries some weight. It seems to matter. But why? Have you thought about what it really means? It means that early in the twenty-first century, at the end of the age of oil, as human population crests globally in a catastrophic ecological bottleneck, and CO₂ concentrations rocket past 380 parts per million in the atmosphere—perhaps the point of no return, at least in terms of maintaining both stable and favorable habitats for our own species—we find ourselves parked along the banks of a glorious desert river still governed largely by the wild. It's astonishing, really—a part of our natural heritage that yet remains emergent, connecting the faraway past to a future held nervously in the palms of our hands.

The Upper Gila River *is* surprisingly intact, not because we have been overly thoughtful stewards, but because it remains governed, fundamentally, by a natural hydrologic regime. It still floods, big on occasion, and that force, that boundary condition, still provides the river its catastrophic and creative pulse.

Fluvial geomorphology: Now there's a term to leave at the office. It's the science of the interplay between water and land. It's the shape of the river corridor, the movement of the channel, the slithering sine curve of friction and gravity. It is the big floods that give the Gila its fluvial-geomorphological character. And it's the occasional big flood that presents life with an ultimatum. It says, "Look, life—look at my watershed: 2200 square miles with headwaters above 10,000 feet. Look at my climate: wet enough to make a snowpack, but warm enough to lose it overnight. Most of the time I am asleep, but when I am awake, I am a freight train off the rails. I have nothing against you. But I am what I am."

Because the Gila River is governed by a catastrophic ecology, the species that compose its ecosystems have evolved to withstand periodic large-scale flooding events. They are used to catastrophe. In fact, they depend on it. And, thus, unlike our upland landscapes that are absolutely dependent upon the very slow process of soil formation for their vigor, rivers like the Gila are highly resilient. Knocked down, they spring back up again, almost overnight. It is the trees that do the heavy lifting: the cottonwoods, the willows, and the sycamores. They stand in armies to do battle with gravity. They answer back to the flood: "Is that all you have—36,000 cubic feet per second? Don't you know that I am life, and that I am very old? I have come a long way just to slow your waters down, and spread them softly across a fertile piece of earth." Life, then, as it has done for 3.8 billion years, finds its way, and the rest is gravity: the black hawks, the cuckoos, the

greater sandhill cranes, even my own son, burrowing in the tall grass on the river's edge.

Loren Eiseley wrote, "If there is magic on this planet, it is contained in water." Magic is hardly the word when you visit one of the Gila's oxbow lakes or backwater sloughs. What are we to make of a Virginia rail, on the sly, in a desert marsh? How do we measure the lives of bats, feasting at night above an improbable riot of rushes and reeds? A marsh in the desert is a crescendo, an exclamation point. There is nothing rarer in the desert than a marsh. Yet marshes belong here, as rare and precious as Mimbres polishing stones. They belong wherever desert rivers like the Gila emerge from their mountain strongholds and spill out onto broad, low-gradient floodplains like the Cliff-Gila Valley. A valley is a release valve; it literally sets the river free. And released from the walls of its canyon, the river is free to rise up into thick clouds of cottonwoods and swirl in the sky, shape-shifted, into a thousand red-winged blackbirds, their calls piercing the air and their epaulets shining like jewels.

Of course, we don't have to dam a river to kill it. We're smarter than that. Heck, we can channelize it if we want to, and send those floodwaters down a narrow, straightened channel just as fast as they can go. Catastrophic scouring and channel incision being a small price to pay, some might say, for unfettered access to rich floodplain soils. It's so hard to think like a beaver. It's hard to admit that the river's floodplain is the river too, and so we turn valley reaches into canyon reaches and remove the ideals of beaver and otter from our minds.

When we turn a broad, alluvial floodplain like the Cliff-Gila Valley into a canyon reach through river channelization, it is the river's potential we are taking away. We are removing one important source of the river's creativity. The Gila River, as it makes its way down the Cliff-Gila Valley, has been under the spell of channelization for more than fifty years now, and it's clear what the costs have been. Gone, mostly, are the wetlands, and the wet meadows. Gone are the floodplain grasslands, the semi-riparian woodlands, and the mesquite bosques. On the river corridor, there *is* no release valve, except where the levees have failed. The river incises, cutting down like a knife. And the cottonwoods are battered, time and again, by floodwaters shot down a barrel.

And now, strangely, we are entertaining the possibility of a diversion. Strange, indeed, considering what we know about the importance of resilience and the challenges of the decades just ahead. Yes, the twenty-first century will be a century of loss. You'd better get used to it. It is our story now. We're living through a bottleneck, a spasm, an extinction event, similar in scale to five other events in the Earth's long history, events so fantastic in scale that we tack on "mass" as

the appropriate descriptor. They are each impressive, teaching us that life's biggest stumbling blocks—randomness and natural catastrophe—are largely responsible for guiding the pattern of life's journey through time. So, have we learned the river's lesson of resilience? No! Instead, it is as if we have channelized the entire planet and now the big one's coming down. Can we stand in the way like cottonwoods? Are there enough of us that care to even slow the water down?

Proponents of a diversion often tell us that the river is sick, that there's *too much* water. And it's true, in a sense. We have certainly experienced a significant alteration of hydrological function in our upper watershed. Peak flow events, since the catastrophic episode of soil loss and channel incision that occurred around the turn of the twentieth century, have had their peaks raised in direct relation to the landscape's decreased ability to capture, hold, and release water slowly back into the river. For the plants and animals trying to hold their ground along the river corridor, it is as if the size of their watershed has been significantly increased. They are forced to deal with more catastrophic energy on a more regular basis. That is the deal we made with the river when we chose to graze these lands, alter their fire regimes, and pretend their future would not be inexorably linked to our own. And so we are told that for the benefit of nature, we can reduce those dangerous peaks, not by improving hydrological function in the upper watershed, but by skimming them off and selling them to the highest bidder. In the same breath we are told not to worry, there will be no ill ecological effects. After all, they say, what's the difference between a 20,000 cubic-foot-per-second flood and a 19,700? Exactly, that's the point: At that scale, what is the difference? You can't have your cake and eat it too. At 19,700, the river's still a freight train.

It's the little floods I worry about, the ones that bring us mother's milk—that chocolate-brown, Willy Wonka offering of fertility from the upper watershed; the ones that ride on the back of destruction, laughing, while sowing the seeds of creation. The ones that pick up the chisel and begin giving inanimate Nature its living face. It is the little floods that are threatened most by a diversion. If you're ever going to capture 14,000 acre-feet of Gila River water, reliably, on an annual basis, you would have to flip on the switch at a much lower threshold, maybe at 1000, or 500, or 300 cubic feet per second. It doesn't matter, because once the infrastructure is there, the rules can always be changed. Ecologically, there is a fundamental difference between a 500 cfs flood and a 200; even more so between a 400 and a 100. The smaller the flood and the closer its peak is to the river's base flow, the more times that particular magnitude of flood can be seen in the hydrological record. Small floods are just more common, and they're anticipated, reflected in the expectation of the ecosystem's collective genome. Big floods set the stage for life, but small floods nourish the actors. A small flood means to the life of the river what taking breakfast in the morning means to us.

It's not enough, I think, to see the river as it is; you have to look beyond to see the river as it could be. High-walled dams, channelization projects, river diversions: Those are all

win-lose scenarios, providing short-term gains at significant ecological costs. Each, in its own way, reduces the river's potential and stifles its creativity. Each, in its own way, is a dagger into the heart of possibility.

Drill, drill, drill. Dam, dam, dam. It's the drumbeat of scarcity, a rain dance, not to fertility, but futility. It's as if Mary Poppins were wrong and "enough *isn't* as good as a feast." As if the people of New Mexico were not already putting that 14,000 acre-feet to its highest and best use. Those waters are working hard, nursing a mystery that lies, ultimately, beyond our comprehension—a process so old, so complex, and so completely out of our *purposeful* control that we stand before it like a child staring into the eyes of a great horned owl.

Often, when I'm sinking into a dust-in-the-wind kind of existentialism, I think, "Nature has failed us as a god because she makes no judgments." We're left to stew in our own juices, not only free to choose but forced to choose—a reminder that behind the freedom of choice is the tyrant of responsibility, a tyrant protected by a praetorian guard of memory cells, capable of harnessing time into the flip-pages of a book, there to be judged like any story for its specific merits. Climate change is a big story. Peak oil is a big story. Mass extinction is a big story. These are stories, not of problems, but of predicaments. Problems can be solved, predicaments cannot. Predicaments are boundary conditions, like the size and shape of a watershed, or the distance to the moon. Or like a levee, restricting within a catastrophic corridor all further potential, erasing those storylines and voices not suited to energetic canyon life.

Sometimes I wonder if there is anything about a river that isn't grist for metaphor. Ah, the flowing river—what a metaphor it is. For life itself, remember, *is* a flowing river: continuous, lyrical, magical, blossoming. And what are we but the face in the mirror, life's inward eye, one singular part of an infinitely creative, ultimately mysterious, autonomous and self-maintaining unity that, through a glorious evolutionary accident, has become aware of itself, at last. And, of course, it's true, we do not get to choose the moment of our birth; we're born victims of circumstance. But here we are, on the banks of a desert river, its future in the balance. It's time, I think, to make a peace offering to the emergent. It's time to take our shoes off, to get our feet wet. It's time to go into a cuckoo slough and feel its coolness and its high humidity. A cuckoo does not fear the desert sun. It is consilient with Nature. Its story and Nature's story are one. We, however, who have borne the burdens of consciousness not particularly well, have laid down that old book, Nature, tired, perhaps, of the storyline, or fearful of the next chapter. We have instead chosen to play Monopoly with the planet. Fun for a while, but incompatible with physical reality, the potentialities of matter, and the living world that we have emerged from just as an apple emerges from a tree. We did not come into the world, we came out of it. That, on its own, should give us pause. Of course, the cuckoo's story is our story too; we can't just put it down. All we can do—all we have ever been able to do—is help in the writing.

Box Canyon Road

Sharman Apt Russell

I walk out of my house onto a country road. If I go north three miles, I'll be in the Gila National Forest, three million acres of pure southwestern New Mexico: ponderosa pine, piñon pine, scrub-oak, juniper, yucca, prickly-pear. These are familiar names and deeply comforting, like beads on a rosary. Mountain lion, black bear, elk, javelina, coatimundi, rattlesnake. If I go south four miles, I'll hit Highway 180 and could find my way to anywhere, Dallas or Paris or Bangkok. By God (and here comes my first imitation of Walt Whitman) I live in the best of places! The best of times! My pleasures as democratic as the cloud-tossed sky.

I choose north, low hills of mesquite and shrub brush on my left, the cottonwoods of the Gila River on my right. In thirty minutes of fast walking, I pass one, two, three houses of part-timers like myself for whom jobs or family commitments keep us from living in the Gila Valley year-round. It is the bane of country life: how to make money. I pass the dog barking in front of his double-wide trailer, the home of a husband and wife who work for the state highway department. Across the road from them, a sign reads "War is not the answer," the gate to an intentional community where people live frugally—reducing, recycling, gardening—without jobs. Next to their compound is a rancher whose grandfather worked for the Forest Service here in 1907, when the Forest Service was still a new idea. His cows sometimes run loose on this road, which is why we have so many cattle guards. As the paved asphalt turns to dirt, I pass the driveway of a telecommuting editor originally from New York, an archaeological site (the mounds of a village dating from about 500 AD), a grazed-down field with a mule and two horses (perked ears and the slow amble-over), and the barn of someone named Tex.

This is the diversity of the rural West, perhaps of all rural America. Walt Whitman would have put us in one of his lists—poet of the carpenter, the deacon, the duck-shooter, the milkmaid, the stevedore, the crone. We're Baptists and pantheists; we eat beef and drink soymilk; we like wolves and hate wolves and we're new and old and rich and poor. What we have in common is a feeling that some of us would be uncomfortable talking about, and some of us talk about all the time. We love this place. We are the bride of this place and we are the groom.

The idea is so strange to contemporary culture that we need new words to describe it. The philosopher Glenn Albrecht—who coined *solastalgia* for the pain humans feel when their home environment is degraded or destroyed—is now promoting *soliphilia* from the Greek *philia* (love of), the French *solidaire* (interdependent), and the Latin *solidus* (solid or whole). *Soliphilia* is "the love of and responsibility for a place, bioregion, planet, and the unity of interrelated interests within it." The term joins *biophilia* (love of living systems, described by psychologist Eric Fromm in 1964 and later

promoted by biologist E. O. Wilson) and *topophilia* (from the Greek *topo* for place, used by mid-century poets like W. H. Auden and Alan Watts). When I was a college student majoring in environmental studies in the 1970s, we preferred mouthfuls like bioregionalism and ecopsychology and the mysterious-sounding deep ecology. All these neologisms built on the work of America's first ecophilosophers, Thoreau and Emerson, who built in turn on previous philosophers and world cultures. Indigenous voices swell the chorus. In the most modern version, we wonder now if "love of place" is hardwired. Can we find that spot in the brain? Make it light up the PET scan? And more pertinently, turn it up a notch?

In less than an hour's walk, I'm at the National Forest boundary, looking down over fields of prickly-pear and mesquite, an undulating rise and fall of land lifting into the rocky hills above the Gila River, rock eroded into giant cones or Stetson hats, and the cliffs rearing beyond them, the rim rock of Watson Mountain pink and orange and white. Then, more grandeur, the bright blue New Mexican sky, a deep azure contrasted with the white and gray of a storm in the distance. My chest feels hollow, as though heart and lungs have evaporated. Within that emptiness, something flowers against the ribcage. A pressure, an ache. That's how I feel my love. This only happens, of course, when I am paying attention.

My body responds physically to the Gila Valley, most often to its expansive views, but also down in the irrigated pastures, with the sleepy cows and smell of alfalfa, and by the river with its modest flow, sunlight on water and the lift of a heron. Love of place opens me to the beauty of the world, which can be found everywhere, city and suburb, desert and rainforest. A world full of places that people love.

Love of place makes me feel larger. When I open to the world, the boundaries of self, my worries and fears, what makes Sharman happy, what makes Sharman sad, the particulars of childhood and family, talents and flaws, that day in high school!, this new pain in my knee—diminish against the lift of land, colors and cliffs. I'm as big as this view, five miles wide. I'm as powerful as the gathering storm—but also calm. Time passes. Seasons turn. The river floods and changes everything, and then everything changes again. No worries. No flaws. Nothing is untoward.

I feel grateful. I feel special. And then, because I am so very human and flawed, I feel smug. I'm so cool to live in this place.

The cultural historian (or ecotheologist) Thomas Berry once described human consciousness as "the universe reflecting on itself." The Big Bang, birth of stars and planets, evolution of life on Earth and specifically of *Homo sapiens* all resulted in a woman standing before this view of mountains and clouds. She notes her feelings: calm, blessed, self-congratulatory.

Maybe the universe could have chosen more wisely, but let's not spoil the moment.

* * * *

I'm in a women's group that meets every six weeks. In rural areas, we go to groups instead of entertainments like plays or concerts. The Gila Valley has gone through many variations of the group, a men's group and a couples' group and a drumming circle and a book club, not to mention the Bible studies and entertainments of people I don't know. In my newest art group, we take turns leading each other in activities like weaving or watercoloring, a kind of play date for the middle-aged. Today we're exploring voice, literally the different noises we can make with our throats and mouths. We've watched the YouTube videos, the exuberant ululation of Darfur refugees and the truly strange Mongolian throat singing—sustained harmonic thrums that represent, with different pitches and tone, particular landscapes. A deep gurgling thrum for the river and forest. A more nasal vibration for the Gobi desert.

Expectantly, we look to our leader. She suggests we go out into nature and listen. We are sitting on my porch and nature is the immediate yard around my house, irrigated fields below, canopied irrigation ditch behind. It is late summer, a time of year when we get most of our meager annual twelve inches of rain. The desert hills are colored green and the native sunflowers a forest of tall leafy stalks. We disperse, and when we return, we each bring back a sound.

One woman begins to duck and whine. A mosquito. Another drops her chin, extends it forward, opens her mouth wide, and blares. A bull frog. Someone tries to buzz like a cicada but lacks the male's drum-like membranes on the abdomen. Someone mimics a lizard rustling in grass. I do a high-pitched do-wop version of the western meadowlark, trying to evoke that jaunty soul feeling if not the actual melody. We use our saliva to imitate water in the ditch. We hum with clenched teeth. A fly. Tongues curl against the roof of the mouth. The *klock-klock* of a raven. We tighten throat muscles. The *skreeeeet* of an insect. We put it all together. We think we sound pretty good.

You laugh—but these women know their world. They have seen the cicada's last molt, that slit in the nymph's skin, the pale adult emerging like some spirit-creature unfurling transparent wings, the creepy brown shell left behind. They know the habits of foxes. They know which plants can be eaten and which are poisonous. They know how to grow food in heat and wind and plagues of grasshoppers. In their ten or twenty or thirty years here, they have watched the night skies and hiked the trails and banded birds for scientific study and caught moths for the local entomologist. They've cleaned up trash along Box Canyon Road, monitored the highway department's spraying of herbicide, and pulled up the invasive yellow star-thistle by its determined tap root.

Like most humans, they like novelty but not change. They want the weather to be predictable and the birds to keep to their familiar migrations. More personally, they don't want to

grow old or have their children leave home. They are searching for wisdom to know when change must be accepted and when it must not. They are looking for ways to live fully in this place.

* * * *

It's all less wonderful than it sounds. For nearly thirty years, local environmentalists have held off the threat of a dam on the Gila River, successfully preserving the last free-flowing river in New Mexico. Today a dam or major diversion is again being considered, locally and at the state level, with the full support of some irrigators and farmers in the Gila Valley. From their perspective, southwestern rivers need to be controlled, their waters manipulated for human use. From my perspective, southwestern rivers need to flood, a natural process moving soil and seeds, braiding new channels, and providing habitat for native fish and other wildlife. Love of place doesn't mean we agree about what is best for place.

Moreover, *soliphilia* has its own dangers, no matter your politics or worldview. Love of place can lead to xenophobia, with long-time residents resenting newcomers, even (perhaps especially) when they come with good ideas. "Old" or "new" to the rural West, we are all in danger of becoming provincial, caught up in the intricate pleasures of home and ignoring our connections to the rest of the world. Certainly we can't retreat into our love of the Gila Valley—the descent of sand-hill cranes in winter, that golden afternoon light on the fields like some blessing laid over the earth, a hand over our brow, a voice whispering beauty, beauty—and forget about the Gulf of Mexico or Arctic Circle. Toxic chemicals, oil spills, global warming, exotic species. A stab of *solastalgia*! We can't protect our best place without protecting them all.

* * * *

Box Canyon Road dead-ends at a Forest Service campground on the Gila River, a healthy riparian *bosque* of cottonwood, sycamore, and willow, lime-green in spring, emerald-green in summer, yellow in fall, gray in winter—not a dull gray, I want to emphasize, but a shimmering luminous evocative gray like the fur of animals or layering of feathers, the gray of twilight in the interstices of branches. (Do I digress yet again? "Logic and sermons never convince," Walt Whitman wrote, "the damp of the night drives deeper into my soul.") Throughout the year, especially on weekends, the campground is well used. On any given Sunday, I might find an extended family with coolers of tamales and burritos, high school kids secretly drinking, or a young couple on a romantic picnic.

On some weekend walks, when I want to avoid being dusted by cars going to the campground, I'll turn left after the home of the telecommuting editor originally from New York onto a second, side dirt road, this one clearly signed "No Trespassing." Fortunately I have permission to be here, on the private land of my neighbor, the rancher. Regularly, we happen to meet, he in his ATV checking stock tanks and gates, and me bipedaling with my day pack, water bottle and chapstick,

paper and pen, perhaps a snack, maybe a book I might read as I walk. (I do this sometimes on a country road. I have great peripheral vision and am less afraid, as I get older, of being seen as eccentric.)

He always stops to talk. We always begin with the weather, a subject deeply satisfying to us both. We may stray into matters of personal health. Our adult children. Some local school event. For thirty years, his wife taught at the nearby elementary school. For eight years, I served on the school board. Twice, he's mentioned the apocalypse predicted by Revelations. I've tentatively broached climate change. At some point, one of us usually says, "Well, it's a beautiful morning,"

motioning to the nearby sky and grass. We mean something a bit more than this. But that's all we say.

Coming back, I rejoin Box Canyon Road, headed for home now. The clouds seem to follow me, billowy white boats out for a sail. A mourning dove calls. Perhaps my *very* favorite sound. A raven *thocks* from the top of a juniper. I think he's *thocking* to me. When I stop, he gets huffy and flaps into the distance, awkward grace and deliberate speed, arrowing above the rolling hills dotted with more juniper, with mesquite and scrub brush, black against blue, higher and higher, rising and falling—until he is joined, I see now, by another raven. Until they disappear and only blue remains. My chest feels hollow.

Exploring the Late Prehistoric Occupation of the Upper Gila Region Through Preservation Archaeology

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Abstract

Archaeology Southwest (formerly the Center for Desert Archaeology) has conducted field research in the greater Upper Gila region since 2008, combining a commitment to preservation archaeology with a research design focused on questions of migration and identity critical to understanding the late prehistoric Southwest. Previous researchers have speculated that following the collapse of the Classic Mimbres in the early 12th century, the Upper Gila River valley was depopulated. However, our work at the Fornholt site in Mule Creek, New Mexico, indicates the area had a sizeable 13th- to early 14th-century occupation. Fornholt's architecture, site layout, and ceramic assemblage resemble settlements to the north and west. While Fornholt was likely abandoned before the height of the 14th-century Salado occupation of the Upper Gila region, it appears that Fornholt was contemporaneous with an early occupation at the nearby 3-Up site. This early component of 3-Up probably included Kayenta/Tusayan immigrants, whereas Fornholt has no evidence of these immigrants. These cultural differences likely created tensions between the inhabitants of the two settlements. Our ongoing work in the Mule Creek community both contributes to the archaeological knowledge of this culturally diverse area and raises awareness of the importance of the archaeological resources of the Upper Gila region.

Practicing Preservation Archaeology

Archaeology Southwest has spent the last four years implementing a program of community-based preservation archaeology in Mule Creek and elsewhere in the Upper Gila region. Our partners in this program have been the local residents of Mule Creek, as well as a variety of academic institutions,

particularly the University of Arizona and Hendrix College. In 2008 and 2009, we conducted test excavations at 3-Up (LA150373), a local site with a substantial Cliff Phase (A.D. 1300–1450) Salado component (see table 1 for regional chronology). We also initiated limited test excavations at Gamalstad (LA164472), an extensively damaged site with a small Cliff Phase component, and Fornholt (LA164471), the topic of this paper, as part of the Mule Creek Archaeological Testing Project (MCAT). In the summer of 2010, a crew of Archaeology Southwest staff and volunteers returned to Fornholt and carried out low-impact wall clearing, producing a detailed site map in preparation for future work. In 2011 and 2012, the joint Archaeology Southwest/University of Ari-



Preservation archaeology field school students Emily Kvamme and Megan Smith excavating a remodeled room at the Fornholt site. Photo by Deborah Huntley, June 2012.

Table 1. Upper Gila Regional Chronology (After Lekson 1996, 3 and Brody 2004, 31)

Period	Phase	Date C.E.	Architecture	Topographic Setting	Diagnostic Ceramics
Pueblo	Cliff	1300–1450	Adobe pueblos	Variable	Gila Poly, Cliff Poly
	Black Mountain	1180–1300	Adobe pueblos	Variable	El Paso Poly, Chupadero Black-on-white
	Mimbres Classic	1000–1150	Cobble masonry pueblos	First river terrace, if available	Mimbres Classic Black-on-white (Style III)
Late Pit House	Three Circle	750/800–1000	Rectangular pithouses	First river terrace, if available	Three Circle Red-on-white, Mimbres Black-on-white (Styles I & II)
	San Francisco	650/700–750/800	Rounded rectangular pithouses with ramps	First river terrace, if available	Mogollon Red-on-brown
	Georgetown	550–650/700	Circular or D-Shaped pithouses with ramps	First river terrace, if available	San Francisco Red
Early Pit House	Cumbre	200–550	Circular, oval and amorphous pithouses with ramp or vestibule	Hill or ridgetop, if available	Plain wares, Mogollon early red ware

zona Preservation Archaeology field school spent five weeks in Mule Creek conducting test excavations at the Fornholt site. The data from this research is part of University of Arizona doctoral student Katherine Dungan's PhD research.

Archaeology Southwest research is guided by the principles of community-based preservation archaeology. This endeavor is directed by a conservation ethic, using limited excavation techniques to answer specific research questions with minimal site disturbance. For example, in the San Pedro Valley of southeastern Arizona our test excavations focused on trash middens, where representative artifact and environmental samples were recovered without significant impact to architectural remains. Preservation archaeology also includes

using non-destructive techniques, such as our intensive 2010 mapping effort at the Fornholt site, as well as surveys and infield analysis of previously under-reported areas.

Another aspect of preservation archaeology involves working with previously excavated collections that have not been thoroughly studied, such as the Jack and Vera Mills collections at Eastern Arizona College in Safford, and the Ormand Village collection (Wallace 1998) at the Laboratory of Anthropology in Santa Fe. In many cases the archaeological record benefits from the reanalysis of old collections using new techniques, such as Neutron Activation Analysis (NAA) and petrographic analysis of pottery to determine clay and temper sources (see Neff and Glowacki 2002), or X-ray Fluorescence (XRF) to pinpoint the geological origins of obsidian artifacts (see Shackley 2005). Finally, our community-based approach means working closely with local residents to help them protect and manage archaeological resources in their communities. In combination, these techniques have allowed us to address a number of interesting archaeological questions with minimal impact on nonrenewable archaeological resources, to train students in preservation techniques, and to protect archaeological sites as part of an integrated research, education, and outreach program.

Coalescence and Identity Formation in the Southern Southwest

Archaeology Southwest began archaeological investigations in the Upper Gila region in 2008 as part of our long-term study of late prehistoric (post-A.D. 1300) Salado¹ archaeology in the southern American Southwest. The Salado "phenomenon" is characterized by elaborate polychrome pottery with unique design elements and layouts. The meaning of the "Salado" has been a topic of debate for decades among Southwest archae-



Preservation archaeology field school students Tom Sprynczynatyk and McCabe Mattingly screening sediment to recover artifacts. Photo by Deborah Huntley, June 2012.

ologists (Crown 1994; Dean 2000; Gladwin and Gladwin 1935; Haury 1945; Nelson and LeBlanc 1986), and has been a primary focus of Archaeology Southwest's research. We believe that the term *Salado* describes both a culturally diverse group of people and a process of cultural change. This group developed a new identity or religion that resulted from extended contact between ancestral Puebloan immigrants from the Kayenta region in northeastern Arizona and local Hohokam and Mogollon groups in the southern Southwest.

Our research on the Salado began in the San Pedro Valley in southeastern Arizona more than twenty years ago (see figure 1 for regions and sites mentioned in the text). Using knowledge gained in the San Pedro, we examined adjacent basins and valleys in southern and central Arizona, including the Safford Basin. This research allowed us to identify a par-

ticular suite of material culture, including Maverick Mountain Series pottery (Lindsay 1987, 1992; Lyons 2003), perforated plates (Hill et al. 2004; Lyons and Lindsay 2006), entry boxes (Lindsay et al. 1968; Lyons 2003), and distinctive kivas (Di Peso 1958; Haury 1958; Neuzil 2008; Woodson 1999), associated with immigrants from above the Mogollon Rim. These immigrants, predominantly from the Kayenta region in northeastern Arizona, traveled over 300 km to the river valleys of southern Arizona (Clark 2001; Clark et al., forthcoming; Di Peso 1958; Lindsay 1987; Lyons 2003; Neuzil 2008) during the late 13th century A.D. Here they encountered established Hohokam irrigation communities with large populations. Despite their loss of homeland and subsequent dispersal, the Kayenta became a powerful minority in the areas where they resettled. They maintained a diasporic community in exile²



Fig. 1. Regional map showing areas and sites referenced in the text.

that persisted for nearly a century, influencing ceramic styles and circulating obsidian over a broad region. Much of the obsidian originated in the Upper Gila region, particularly the large Mule Creek source.

In contrast to diasporic communities, which connect groups scattered by migration based on a real or imagined shared cultural heritage (Andersen 2006; Boyarin and Boyarin 1993; Clifford 1994), multi-cultural coalescent communities formed in southern Arizona during the 14th century. Coalescent communities contained diverse populations with various cultural and religious backgrounds. We argue that Salado represents a new hybrid identity that formed in communities composed of local and immigrant groups that incorporated elements of both traditions (Clark and Lyons, in press; Clark and Laumbach 2011; Lyons et al. 2008). Salado identity served to unite diverse populations under a new ideology and mediate conflict between groups with divergent histories. The Salado identity was widespread but relatively short-lived. During the 14th century, communities across the southern Southwest experienced a demographic crisis that resulted in the widespread depopulation of the region by the early 15th century (Hill et al. 2004). The social, economic, and environmental causes of this decline are still hotly debated by archaeologists.

Several strands of evidence drew us to the Upper Gila region and Mule Creek. First, there were archaeological traces of Kayenta immigrants—concentrations of perforated plates and Maverick Mountain series pottery—at several Upper Gila sites. Second, we had evidence for a large 14th-century population influx and Salado polychrome pottery and architecture at sites in the Cliff Valley, the Mimbres Valley, and Mule Creek. Finally, we knew that the Mule Creek obsidian source was widely distributed in southeastern Arizona in the 14th century, with the densest concentrations in the San Pedro Valley found at Kayenta enclaves. Only one site (3-Up) from this time period was known to be situated in the fertile Mule Creek Valley near the primary deposit of this obsidian.

Previous Research on Late Prehistoric Occupations of the Upper Gila

Previous research in the greater Upper Gila region provides few clear expectations for the 13th-century archaeological record of Mule Creek—that is, for the time period immediately preceding and following the arrival of Kayenta immigrants (see table 1). Note that when referring to the Upper Gila region, we generally include only areas in New Mexico and far eastern Arizona surrounding the Gila River. Mule Creek itself drains north into the San Francisco, but with the exception of the problematic 13th-century sites discussed in this paper, the archaeology of Mule Creek resembles that of the Cliff Valley and other areas surrounding the Upper Gila River far more than that of the San Francisco or Blue Rivers. The Redrock and Cliff Valleys, to the south and southeast of Mule Creek (see figure 1), are supposed to have been occupied only sparsely, if at all, after the end of the Classic Mimbres period around A.D. 1150 (Fitting 1972; Lekson 2002). The

Mimbres Valley to the east is characterized by the still poorly understood Black Mountain Phase of the A.D. 1200s (Blake et al. 1986; Creel 1999; see also Nelson and LeBlanc 1986). At the same time, the southern edge of the Tularosa horizon, centered in west-central New Mexico and east-central Arizona, approached the eastern Safford Basin (Lekson 1996) and extended to Glenwood (Accola 1981; Robinson 1992), the Gila Cliff Dwellings (Anderson et al. 1986), the Black Range, and the Eastern Mimbres area (Laumbach 1992; Laumbach and Wakeman 1999; Nelson 1999). On the whole, however, 13th-century archaeological sites in the Upper Gila region are small and dispersed compared with the earlier large and aggregated room blocks associated with the Mimbres Classic period and the 13th- and 14th-century pueblos to the north and west in the Blue and San Francisco River valleys (Danson 1957; Hough 1907). Hence, we initially hypothesized that Kayenta groups entered a frontier area where they continued their culture and religion in relative isolation, unlike their relations in the heavily populated Hohokam area to the west.

There is evidence for a Salado overlay on many former Mimbres sites (Lekson 2002; Nelson and LeBlanc 1986). These are concentrated in the Cliff Valley, leading to the definition of the 14th- and early-15th-century Cliff Phase. Unfortunately, many sites in the Upper Gila region have been the target of looting and vandalism because of their decorated pottery. With a few notable exceptions (e.g., Lekson 2002; Nelson and LeBlanc 1986), Cliff Phase sites that have been investigated were excavated by avocational archaeologists such as Jack and Vera Mills (1969, 1972) and “Red” Ellison (Kwilleylekia) or as part of salvage operations (e.g., Hammack et al. 1966; see also Wallace 1998). For this reason, many collections were not obtained using the most current archaeological excavation techniques, nor were they studied using the most current analytical techniques.

In our initial research (Clark et al. 2008; Huntley et al. 2010), we postulated two pulses of immigration into the post-Mimbres Upper Gila region: a late-13th- or early-14th-century migration of Kayenta-affiliated groups and a mid- to late-14th-century migration of displaced Salado groups from southeastern Arizona. Their stay in southwestern New Mexico was brief, however; most, if not all, Upper Gila Salado sites were depopulated by the mid-15th century. Considering the large number of cremation burials and Salado polychrome pottery at very late sites like Hawikkuh, it is likely that some of these groups ended up at Zuni in the 15th century (Kintigh 2000).

As discussed below, we believe we have compelling evidence for a Kayenta migration into Mule Creek. After four seasons of fieldwork, we now also know that at least some areas of the Upper Gila were occupied by substantial populations when Kayenta groups arrived, requiring us to reconsider our original empty-frontier model. Research at the earlier Fornholt site, the main focus of the remainder of this paper, was conducted to examine the social and demographic context into which these immigrants entered.

The Fornholt Site: The Tularosa Phase at Mule Creek

The Fornholt site (LA164471; figure 2), located on a ridge overlooking Tennessee Creek, currently provides our clearest evidence for 13th-century occupation in Mule Creek. The latest component of the site consists of two slab masonry room blocks. Based on the area of the two room blocks and the size of rooms that we have tested or that are visible at the site surface, we estimate a total of about sixty rooms for the Tularosa

Phase occupation. The southern room block surrounds a large, rectangular depression. Excavations have demonstrated that portions of this room block stood two stories. A small Mimbres Classic component, visible only as a mound of river cobbles south of the southern Tularosa Phase room block, appears to have been heavily stone robbed in the construction of the late occupation. The site also has an extensive pit house component dating at least in part to the Late Pithouse period (see table 1); pithouse depressions and associated ceramics

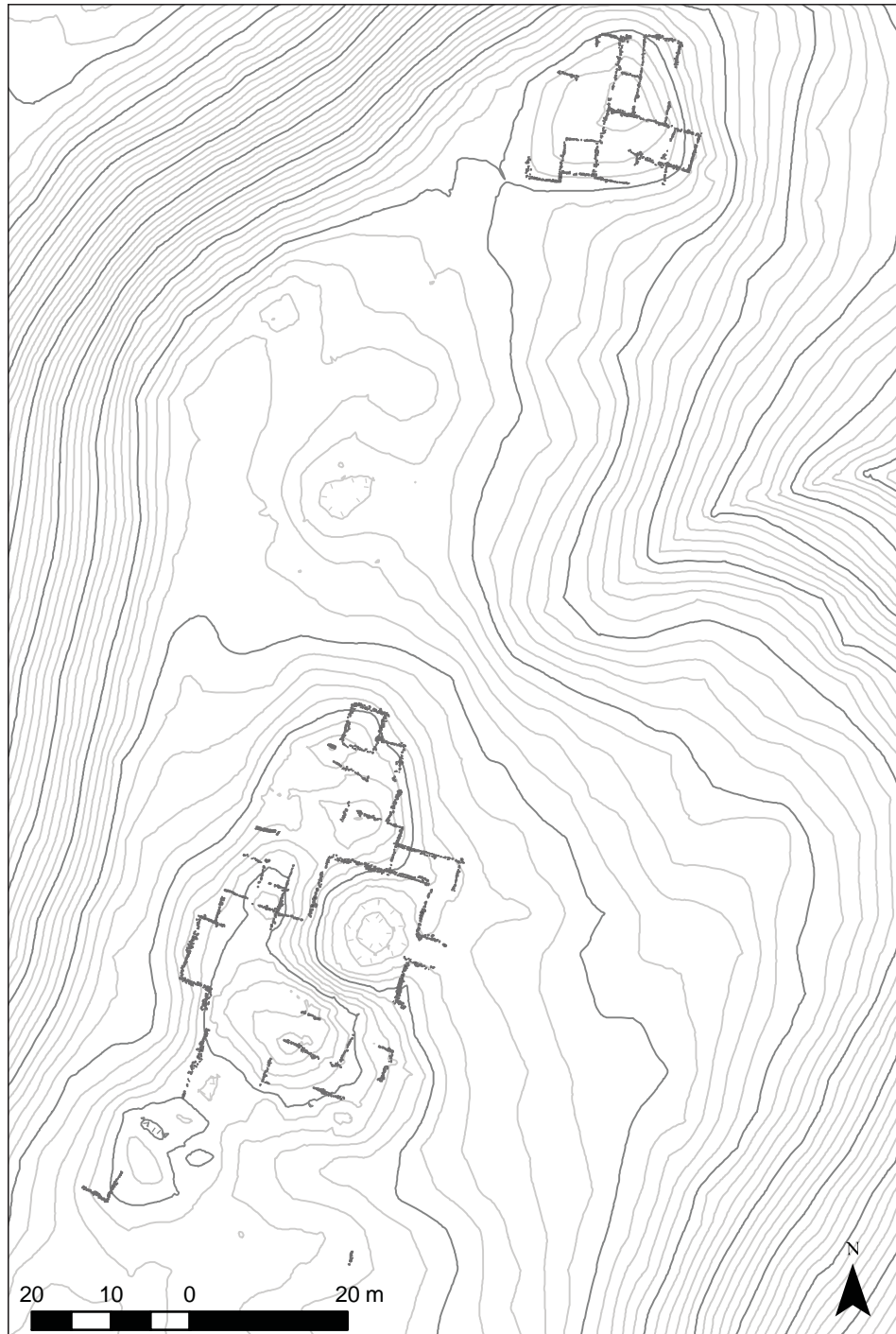


Fig. 2. Fornholt site plan. The contour interval is 20 cm.

cover the ridge top, extending well beyond the extent of the Tularosa Phase architecture and artifact scatter. Mimbres Classic and Late Pithouse period ceramics are found throughout the site's cultural deposits; in at least one case, earlier ceramics were visible as chinking within a Tularosa Phase wall.

Although analysis of the material recovered during the 2011 and 2012 field seasons is ongoing, we can say with certainty that Fornholt has architectural characteristics and a ceramic assemblage similar to Tularosa Phase sites to the north and west (Martin et al. 1956; Martin et al. 1957; Neely 1977; Rinaldo 1959; Robinson 1992). Characteristic Tularosa Phase ceramic types recovered from Fornholt include Tularosa Black-on-white, a Cibola White Ware type, and St. John's Polychrome, a White Mountain Red Ware type. In addition, the assemblage contains small quantities of Pinedale Black-on-white, a later Cibola White Ware type, suggesting the occupation extended into the early 14th century (Mills and Herr 1999). Several NAA sourcing studies of these wares (e.g., Peeples 2012; Schachner 2012) have demonstrated that they were produced in a relatively small number of locations above the Mogollon Rim.³ As is typical of Tularosa Phase assemblages, the Fornholt assemblage is dominated by corrugated brown ware pottery with a variety of surface treatments, including Tularosa Fillet Rim bowls. At the same time, the Fornholt ceramic assemblage also contains El Paso Polychrome and Playas Red Incised sherds (common in the Bootheel region of New Mexico) from the same subsurface contexts as the northern Cibola White Ware and White Mountain Red Ware types. While regional sourcing data for these types are not as clear-cut (Creel et al. 2002), their comparatively low frequency in Mule Creek suggests that these types also were not produced locally. The presence of a mix of "northern" and "southern" ceramic types has also been noted at Black Mountain Phase and Post-classic Mimbres sites (Nelson and Hegmon 1999, 180–82; 2001). At Fornholt, northern ceramics (i.e., Cibola White Ware and White Mountain Red Ware) are more prevalent, although all sherds with painted or incised decoration, including earlier Mimbres sherds, make up only about five percent of the total ceramic sample analyzed thus far. As discussed below, the architectural construction and site layout at Fornholt are comparable to Tularosa Phase settlements. Nevertheless, the presence of southern ceramic types is particularly interesting, as, to our knowledge, these types have not been recovered from any Tularosa Phase sites in the Blue or San Francisco River valleys⁴ with the sole exception of WS Ranch, where a few Playas Red Incised sherds were found (Robinson 1992, 196). The Gila Cliff Dwellings, located to the east on the West Fork of the Gila River, is another site situated at the southern edge of the Tularosa Phase distribution. It too contained southern ceramic types, including Cloverdale Incised and Chupadero Black-on-white (Anderson et al. 1986). Based on the relative frequencies of diagnostic decorated types, as well as the conspicuous absence of late Salado polychromes and other late types, we suggest the last occupation of the Fornholt site dates to somewhere between A.D. 1200 and 1325.

Based on the results of our 2010 wall clearing and the

2011 and 2012 test excavations, construction techniques at Fornholt fit well with the expected Tularosa Phase pattern. Walls were built primarily using conglomerate blocks, sometimes with a minimal degree of shaping. Irregular cobbles of finer-grained volcanic rock were used less frequently. Tabular stone and large sherds were used as chinking. The only non-masonry construction within the room blocks at Fornholt was uncovered during the 2012 excavations, in a room in which adobe wall stubs were remodeled into Tularosa Phase masonry walls. Unfortunately, the ceramics, which should provide some temporal context for the adobe walls, have not yet been analyzed. The slab-lined rectangular hearths found during the 2011 excavations, and their positions within rooms, are consistent with more northern Tularosa Phase sites.

The layout of the Fornholt site provides an interesting point of comparison with other Tularosa Phase settlements on the San Francisco and Blue Rivers, such as sites excavated by the Field Museum (Martin et al. 1956; Martin et al. 1957; Rinaldo 1959) and WS Ranch (Robinson 1992), excavated by the University of Texas–Austin. Considering the depth of the depression in the southern room block—roughly 40 cm below grade—we originally hypothesized that this was a large kiva, similar to the kiva excavated at WS Ranch, rather than a small plaza. Both structures appeared to be large, rectangular semi-subterranean rooms, enclosed within room blocks, with entrances facing slightly south of east (Neely 1977; Robinson 1992, 131–34; Tomka 1988). Three bounding walls and the entryway of the possible kiva at Fornholt were visible on the site surface after wall clearing in 2010. After limited test excavations in 2011 and 2012, this area of the site seems to be more complex. Buried walls paralleling the outer walls visible at the site surface were uncovered in the north and west portions of the feature, suggesting a smaller—but still sizeable—rectangular, semi-subterranean room nested within the larger rectangular enclosed area visible on the site surface.

Another large rectangular roofed area surrounded by a room block was recorded by the Field Museum at Foote Canyon Pueblo. Unlike the kiva at WS Ranch, this area had no floor features other than several large postholes, and, although the floor was lower than those of the surrounding rooms, the excavators recorded the space as a plaza (Rinaldo 1959, 181). This intermediate plaza/kiva space, or at least this apparent flexibility in the design of ritual architecture, may be a better analog for the structure at the Fornholt site. Large kivas set apart from room blocks are more common in the eastern Mogollon highlands than those built into room blocks. Excavated examples include a Tularosa Phase kiva at Higgins Flat, which was built over an earlier kiva directly between the site's two room blocks (Martin et al. 1957), and the great kiva at LA3279, which is adjacent—but not attached—to the main room block (Oakes and Zamora 1999).

Comparisons with the 3-Up Site

The nearby 3-Up site (figure 3) consists of several residential loci on a group of hills and ridges directly above Mule Creek, less than 3 km southwest of Fornholt. Given substantial

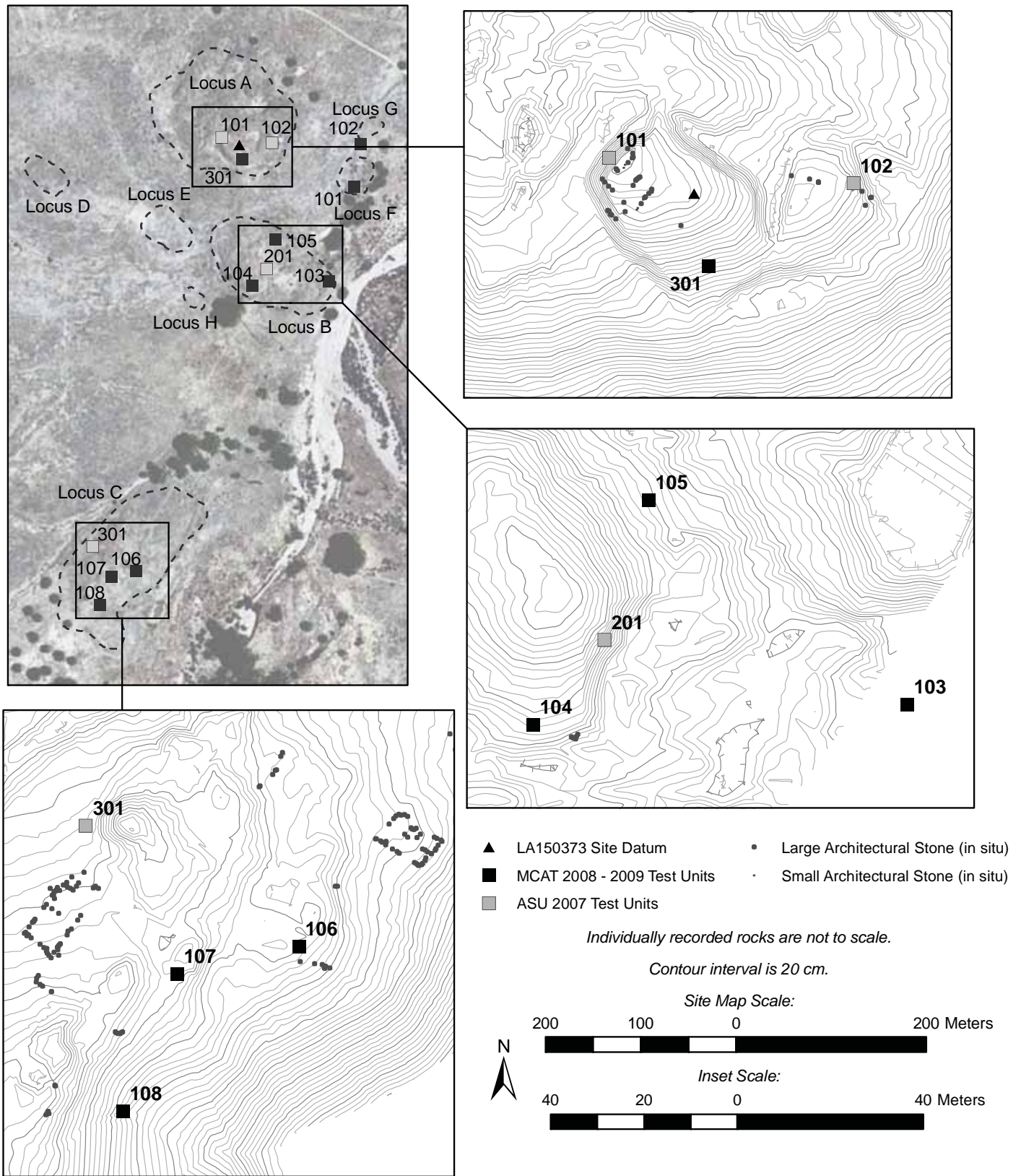


Fig. 3. 3-Up site plan showing loci and excavation units.

bulldozer disturbance and limited excavations at 3-Up, we have incomplete information about construction and site layout prior to its final, 14th-century occupation. Locus A and Locus B clearly have masonry architecture. At Locus A, however, slab masonry appears to be associated with the Cliff Phase, rather than the earlier 13th-century occupation. In profiling bulldozer cuts at Locus A, researchers from Arizona State University found a lower-story adobe wall remodeled into an upper-story masonry wall, as well as part of a room with adobe wall construction and a Tularosa Fillet Rim vessel in floor contact (Schollmeyer et al. 2007). The presence of this pottery type suggests that this buried part of Locus A at the 3-Up site was roughly contemporaneous with Fornholt. Likewise, there is no visible masonry associated with the 13th-century ceramic types found on the surface at unexcavated Locus D, although there is an area of possible adobe wall melt. The abundant shaped architectural stone visible in the bulldozer cuts at Locus B, however, may be associated with the 13th-century occupation of the site rather than later construction; if this were the case, it would be consistent with the construction style expected at a Kayenta immigrant enclave and different from the local tradition of cobble-footed adobe walls. The prevalence of adobe in the 13th-century architecture at 3-Up and the contrasting use of slab masonry at Fornholt may suggest technological differences stemming from different cultural backgrounds between the inhabitants of the two settlements.

Ceramic assemblage comparisons offer strong evidence for overlapping occupations at 3-Up and Fornholt (table 2), although Fornholt was ultimately depopulated before 3-Up. Test units and surface collections from Locus A and Locus B produced most of the same Cibola White Ware and White

Mountain Red Ware types recovered from Fornholt, as did a nonsystematic examination of surface ceramics from Locus D. Although these types make up only a very small proportion of the decorated ceramics at 3-Up, this is consistent with a scenario in which these 13th-century ceramics were being imported to 3-Up in the same small quantities we see at Fornholt. El Paso Polychrome and Playas Red Incised are also present at 3-Up. However, because of the long production periods for these types, it is possible that these sherds are from the later Cliff Phase occupation of the site. Quantitative differences between the utility ware assemblages at 3-Up and Fornholt await full analysis. However, qualitatively, the range of utility ware surface treatments at Locus A and Locus B of 3-Up seems similar to that at Fornholt, including the presence of Tularosa Fillet Rim. Fornholt does have a larger proportion of corrugated ceramics (59%) than any locus at 3-Up, with only Locus B (43%) approaching that of Fornholt.

In addition to limited architectural evidence, the argument for late-13th-/early-14th-century Kayenta immigration into Mule Creek hinges on the presence of substantial amounts of Maverick Mountain Series pottery at Locus B of 3-Up (around 27% of decorated sherds). Maverick Mountain Series ceramics are locally made⁵ vessels produced within the Kayenta and Tusayan decorated ceramic tradition (Lindsay 1987, 1992; Lyons 2003). Although these ceramics are only part of the suite of material culture that has been cited as evidence for Kayenta immigration along the San Pedro (Di Peso 1958), in the Safford Basin (Neuzil 2008; Woodson 1999), and at Point of Pines (Haury 1958; Lindsay 1987), we argue that the concentration of Maverick Mountain Series ceramics in our sample from 3-Up is suggestive of an immigrant presence, particularly in light of the masonry architecture associated

Table 2. Simplified ceramic comparison for 3-Up Loci and Fornholt (not including surface collections or data from ASU units).

Painted/Incised Ceramics	3-Up						Fornholt	
	Locus A		Locus B		Locus C			
Total Maverick Mountain Series	5	4%	40	27%	2	2%	0	0%
Total Salado Polychrome	36	29%	43	29%	83	90%	0	0%
Total Undifferentiated White-on-Red	5	4%	39	26%	2	2%	0	0%
Total Mogollon/Mimbres	51	41%	16	11%	0	0%	37	62%
Total Cibola White Ware	2	2%	1	1%	0	0%	9	15%
Total White Mountain Red Ware	2	2%	2	1%	0	0%	4	7%
Total Southern New Mexico Types	8	6%	2	1%	4	4%	6	10%
Total Other/Undifferentiated	15	12%	6	4%	1	1%	4	7%
Total Painted/Incised:	124		149		92		60	
Unpainted Ceramics								
Corrugated Ware	323	34%	791	43%	55	9%	746	59%
Plain or Other Surface Treatment	621	66%	1056	57%	589	91%	514	41%
Total Unpainted:	944		1847		644		1260	

with Locus B. The presence of a perforated plate with several late Salado polychrome vessels on a room floor at Locus C implies a continuation of Kayenta technological traditions into the 14th or early 15th century (Lyons and Lindsey 2006).

Despite intensive testing, not a single sherd of Maverick Mountain Series or Salado polychrome pottery has been recovered from Fornholt. Nevertheless, ceramic evidence suggests that Fornholt was occupied when Kayenta immigrants settled at the 3-Up site. Pinedale Black-on-white, one of the Cibola White Ware types recovered from both Fornholt and 3-Up, dates between A.D. 1270 and 1320 (Mills and Herr 1999), while Maverick Mountain Polychrome found at 3-Up has a suggested date range of A.D. 1275 to 1325 (Neuzil 2008, 48; Neuzil and Lyons 2006).

The Lure of Mule Creek Obsidian

For both local and immigrant populations, one of the principal attractions of Mule Creek was the abundant availability of obsidian. We have suggested elsewhere that the Kayenta (and, later, Salado) immigrants at Mule Creek were circulating Mule Creek obsidian through a regional diasporic network (Clark 2007; Clark and Lyons, in press; see also Neuzil 2008). We originally surmised this would be reflected in an increasing proportion through time of obsidian debitage at 3-Up, a major supplier of this raw material to settlements in southwestern New Mexico and southeastern Arizona. Indeed, obsidian proportions increase from 3-Up Locus A (the earliest locus, including a substantial Mimbres component), through the 13th-century Locus B, to Locus C, which is a late-14th-century Salado/Cliff Phase occupation.

Preliminary analysis of the Fornholt assemblage, however, suggests that obsidian frequencies there may be as high as those anywhere at 3-Up (table 3). Both settlements had access to ample obsidian in adjacent creek beds. Nevertheless, one or both sites may have had an interest in controlling access to primary obsidian outcrops, where nodules could be more intentionally selected for size than the secondary deposits in alluvial gravels. The Antelope Creek locality (northwest of Fornholt) and the North Sawmill Creek locality (west of 3-Up), constitute chemically distinct groups within the Mule



View of the Mogollon Mountains from the 3-Up site. Photo by Deborah Huntley, June 2008.

Creek source (Shackley 2008) and the former dominates assemblages throughout the large area where Mule Creek obsidian was distributed. Ongoing obsidian XRF analysis (see Shackley 2005) should allow us to differentiate local source use within the valley and track long-distance obsidian circulation. If 3-Up residents circulated obsidian among a network of Kayenta- (and later Salado-) affiliated villages, it seems plausible that the inhabitants of Fornholt also distributed obsidian to other Tularosa Phase settlements during the late 13th and early 14th centuries. Our XRF analysis has identified substantial quantities of Mule Creek obsidian at the Tularosa phase Victorio site along the Rio Alamosa to the north, supporting this assertion.

Summary and Speculation: A Tale of Two Settlements?

Relative dating of the Fornholt and 3-Up sites suggests that both overlapped in time during the 13th and possibly early 14th centuries. While the architecture and ceramic assemblage at Fornholt suggest strong similarities to other Tularosa Phase sites along the tributaries of the San Francisco River, the presence of El Paso Polychrome and Playas Red Incised suggests that Fornholt, and other sites at the “fuzzy” southern edge of the Tularosa horizon, may have had important connections to the south as well. The presence at Fornholt and 3-Up of most of the same 13th- and early-14th-century ceramic types, with the critical exception of Maverick Mountain Series polychromes, may reflect shared regional connections, as well as some degree of shared cultural background. At the same time, the little information we have about architecture at 3-Up seems to indicate early local use of adobe, which differs from the slab masonry used at Fornholt. Moreover, there appear to be differences in site layout at the two settlements. Wall clearing and excavation at Fornholt indicate the site was compact and formally planned, with one of two room blocks constructed around a plaza/kiva. Based

Table 3. Counts and weights of obsidian debitage relative to all chipped stone debitage by locus at 3-Up and in Unit 203 at Fornholt.

Site/Locus	% Obs. by Count	% Obs. by Weight
3-Up A	42	13
3-Up B	39	18
3-Up F	53	24
3-Up C	57	31
3-Up G	71	42
All 3-Up Units	46	19
Fornholt	67	37

on more limited architectural data, 3-Up had a number of room blocks that were not arranged in a coherent pattern, suggesting the settlement grew by accretion either through internal fissioning or through migration, with each new group building its own residence.

Of our two known 13th-century occupations, 3-Up, with its predominantly adobe architecture, seems to fit more criteria for the “Black Mountain Phase” and might have a strong Mimbres heritage. The other, Fornholt, may represent a southern outpost of the Tularosa tradition. The absence of Maverick Mountain Series pottery at Fornholt suggests that, if the site was still occupied when immigrants arrived at 3-Up, interaction between the two groups was either limited or hostile. Although we do not yet have the data to make a strong argument, tensions might have existed between two settlements with different occupation histories and cultural affiliations, tensions that were exacerbated by Kayenta immigration to 3-Up during the late 13th century. While obsidian is abundant in Mule Creek itself, access to sources and circulation of this obsidian in expansive regional networks may have been contested. Non-local ceramic frequencies indicate that 3-Up and Fornholt seem to have shared many of the same long-distance trading partners to the north and south.

Both 3-Up and Fornholt, with substantial pit house and Classic Mimbres occupations, are persistent places in Mule Creek. The occupation of Fornholt, however, ended by the early 14th century, while 3-Up developed into a substantial village during the 14th century and was probably occupied until the depopulation of the region in the early 15th century. Currently, we can only speculate about the circumstances surrounding the depopulation of Fornholt. We have clear evidence for at least one burned two-story storage room in the southern room block at Fornholt. This room contained the remains of hundreds of charred corncobs as well as charred beans, textiles, and basketry. The room was never cleaned out and reused after burning, suggesting this was a catastrophic event that occurred not long before the site’s abandonment.

Presuming that the burning in the southern room block coincides with the end of the occupation, we still are not in a position to distinguish an intentional act of closure from accidental burning or violent destruction. The residents of Fornholt could have been absorbed into the growing settlement at 3-Up, or might have left the region entirely. It is worth noting that when “Salado” groups did settle near Fornholt, sometime in the mid-14th century, they reoccupied Gamalstad, a Mimbres site on a low rise at the confluence of Tennessee and Mule Creeks, rather than Fornholt.⁶ Additional work at Fornholt should help clarify the relationship between the inhabitants of the two sites as well as Fornholt’s connections to other Tularosa Phase settlements. This period warrants future study in terms of both reconstructing the complex social landscape of the 13th century and setting the stage for the subsequent Cliff Phase Salado occupation. Archaeology Southwest remains committed to continuing our research and preservation program in the Upper Gila and Mimbres Valleys.

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References Cited

- Accola, R. M. 1981. Mogollon Settlement Patterns in the Middle San Francisco River Drainage, West-Central New Mexico. *Kiva* 46 (3): 155–68.
- Anderson, B. 2006. *Imagined Communities*. London: Verso.
- Anderson, K. M., G. J. Fenner, D. P. Morris, G. A. Teague, and C. McKusick. 1986. *The Archaeology of Gila Cliff Dwellings*. Publications in Anthropology 36. Tucson: National Park Service, Western Archaeological and Conservation Center.
- Blake, M., S. A. LeBlanc, and P. E. Minnis. 1986. Changing Settlement and Population in the Mimbres Valley, SW New Mexico. *Journal of Field Archaeology* 13:439–64.
- Boyarin, D., and J. Boyarin. 1993. Diaspora: Generational Ground of Jewish Identity. *Critical Inquiry* 19 (4): 693–725.
- Brody, J. J. 2004. *Mimbres Painted Pottery*, rev. ed. Santa Fe, NM: School of American Research Press.
- Clark, J. J. 2001. *Tracking Prehistoric Migrations: Pueblo Settlers Among the Tonto Basin Hohokam*. Anthropological Papers of the University of Arizona No. 65. Tucson: University of Arizona Press.
- . 2007. *Precontact Population Decline and Coalescence in the Southern Southwest*. Final Report for National Science Foundation Project No. 0342661.
- Clark, J. J., J. B. Hill, and D. Huntley. 2008. *Communities in Crisis: Kayenta Diaspora and Salado Coalescence in Southwestern New Mexico*. NSF Award No. 0819657.
- Clark, J. J., and K. W. Laumbach. 2011. Ancestral Puebloan Migrations in the Southern Southwest: Perspectives from Arizona and New Mexico. In *Movement, Connectivity, and Landscape Change in the Ancient Southwest*, edited by M. Nelson and C. Strawhacker, 297–320. Boulder: University Press of Colorado.
- Clark, J. J., and P. D. Lyons. In press. *Mounds and Migrants: Late Prehistoric Archaeology of the Lower San Pedro River Valley, Arizona*. Anthropological Papers No. 45. Tucson: Center for Desert Archaeology.
- Clark, J. J., P. D. Lyons, J. B. Hill, S. Lengyel, and M. Slaughter.

- Forthcoming. Migrants and Mounds in the Lower San Pedro Valley, A.D. 1200–1450. In *The Archaeology of a Land Between*, edited by H. Wallace. Tucson: University of Arizona Press.
- Clifford, J. 1994. Diasporas. *Cultural Anthropology* 9 (3): 302–38.
- Creel, D. G. 1999. The Black Mountain Phase in the Mimbres Area. In *The Casas Grandes World*, edited by C. F. Schaafsma and C. L. Riley, 107–20. Salt Lake City: University of Utah Press.
- Creel, D. G., M. Williams, H. Neff, and M. D. Glascock. 2002. Black Mountain Phase Ceramics and Implications for Manufacture and Exchange Patterns. In *Ceramic Production and Circulation in the Greater Southwest: Source Determination by INAA and Complementary Mineralogical Investigations*, edited by D. M. Glowacki and H. Neff, 37–46. Los Angeles: The Cotsen Institute of Archaeology, University of California–Los Angeles.
- Crown, P. L. 1994. *Ceramics and Ideology: Salado Polychrome Pottery*. Albuquerque: University of New Mexico Press.
- Danson, E. B. 1957. *An Archaeological Survey of West-Central New Mexico and East-Central Arizona*. Papers of the Peabody Museum of Archaeology and Ethnology Vol. 44, No 1. Cambridge, MA: Harvard University.
- Dean, J., ed. 2000. *Salado*. Albuquerque: University of New Mexico Press.
- Di Peso, C. 1958. *The Reeve Ruin of Southeastern Arizona: A Study of a Prehistoric Western Pueblo Migration into the Middle San Pedro Valley*. The Amerind Foundation No. 8. Dragoon, AZ: The Amerind Foundation.
- Fitting, J. E. 1972. Preliminary Notes on Cliff Valley Settlement Patterns. *The Artifact* 10 (4): 15–30.
- Gladwin, W., and H. Gladwin. 1935. *The Eastern Range of the Red-on-Buff Culture*. Medallion Papers No. 16. Globe, AZ: Gila Pueblo.
- Hammack, L. C., S. D. Bussey, and R. Ice. 1966. *The Cliff Highway Salvage Project*. Preliminary Report by the Museum of New Mexico, Santa Fe. On file, Archaeological Records Management Section, Historic Preservation Division, Santa Fe.
- Haurly, E. 1945. *The Excavation of Los Muertos and Neighboring Ruins in the Salt River Valley, Southern Arizona*. Papers of the Peabody Museum of American Archaeology and Ethnology No. 24 (1). Cambridge, MA: Harvard University.
- . 1958. Evidence at Point of Pines for a Prehistoric Migration from Northern Arizona. In *Migrations in New World Culture History*, edited by R. Thompson, 1–6. University of Arizona Social Science Bulletin No. 27. Tucson: University of Arizona Press.
- Hill, J. B., J. Clark, W. Doelle, and P. Lyons. 2004. Prehistoric Demography in the Southwest: Migration, Coalescence, and Hohokam Population Decline. *American Antiquity* 69 (4): 689–716.
- Hough, W. 1907. *Antiquities of the Upper Gila and Salt River Valleys in Arizona and New Mexico*. Bureau of American Ethnology Bulletin No. 35. Washington, DC: Smithsonian Institution.
- Huntley, D. L. 2012. Ceramic Production and the Development of Salado Identity in the Upper Gila Region of the American Southwest. Poster presented in the symposium “Exploring the Upper Gila: Center for Desert Archaeology Research in Mule Creek and Beyond,” 77th Annual Meeting of the Society for American Archaeology, Memphis.
- Huntley, D. L., J. Clark, R. Jones, K. Dungan, and J. B. Hill. 2010. Get Back: Kayenta and Salado Migrations into Southwest New Mexico. In *The Collected Papers from the 15th Biennial Mogollon Conference, Silver City, New Mexico, 2008*, edited by Lora Jackson Legare, 51–72. Special Report No. 12. El Paso, TX: El Paso Archaeological Society.
- Kintigh, K. W. 2000. Leadership Strategies in Protohistoric Zuni Towns. In *Alternative Leadership Strategies in the Prehispanic Southwest*, edited by B. Mills, 95–116. Tucson: University of Arizona Press.
- Laumbach, K. W. 1992. *Reconnaissance Survey of the National Park Service Ojo Caliente Study Area, Socorro County, New Mexico*. Tularosa, NM: Human Services Research.
- Laumbach, K. W., and J. L. Wakeman. 1999. Rebuilding an Ancient Pueblo: The Victorio Site in Regional Perspective. In *Sixty Years of Mogollon Archaeology: Papers from the Ninth Mogollon Conference, Silver City, New Mexico, 1996*, 183–90. Tucson, AZ: SRI Press.
- Lekson, S. H. 1996. Southwestern New Mexico and Southeastern Arizona, A.D. 900 to 1300. In *The Prehistoric Pueblo World A.D. 1150–1300*, edited by M. A. Adler, 170–76. Tucson: University of Arizona Press.
- . 2002. *Salado Archaeology of the Upper Gila, New Mexico*. Anthropological Papers of the University of Arizona No. 67. Tucson: University of Arizona Press.
- Lindsay, A. Jr. 1987. Anasazi Population Movements to Southeastern Arizona. *American Archaeology* 6 (3): 190–98.
- . 1992. Tucson Polychrome: History, Dating, Distribution, and Design. In *Proceedings of the Second Salado Conference*, edited by R. Lange and S. Germick, 230–37. Phoenix: Arizona Archaeological Society.
- Lindsay, A. Jr., J. R. Ambler, M. A. Stein, and P. Hobler. 1968. *Survey and Excavations North and East of Navajo Mountain, Utah, 1959–1962*. Flagstaff, AZ: Northern Arizona Society of Science and Art.
- Lyons, P. D. 2003. *Ancestral Hopi Migrations*. Anthropological Papers of the University of Arizona No. 68. Tucson: University of Arizona Press.
- Lyons, P. D., J. B. Hill, and J. J. Clark. 2008. Demography, Agricultural Potential, and Identity among Ancient Immigrants. In *The Social Construction of Communities: Archaeological Studies of Agency, Structure, and Identity in the Prehispanic Southwest*, edited by M. D. Varien and J. Potter, 191–213. Lanham, MD: AltaMira Press.
- Lyons, P. D., and A. Lindsay Jr. 2006. Perforated Plates and the Salado Phenomenon. *Kiva* 72 (1): 5–54.
- Martin, P. S., J. B. Rinaldo, and E. R. Barter. 1957. *Late Mogollon Communities: Four Sites of the Tularosa Phase, Western New Mexico*. Fieldiana Vol. 49, No. 1. Chicago: Chicago Natural History Museum.
- Martin, P. S., J. B. Rinaldo, E. A. Bluhm, and H. C. Cutler. 1956. *Higgins Flat Pueblo, Western New Mexico*. Fieldiana Vol. 45. Chicago: Chicago Natural History Museum.
- Mills, B. J., J. Clark, D. Huntley, W. R. Haas Jr., B. McMahan, S. C. Ryan, M. Trowbridge, M. S. Shackley, R. L. Breiger, and J. M. Roberts Jr. 2010. The Southwest Social Networks Project: Prehistoric Dynamics in the Southwest U.S. Paper presented in the symposium, “New Approaches in Regional Network Analysis,” at the 75th Annual Meeting of the Society for American Archaeology, St. Louis.
- Mills, B. J., and S. A. Herr. 1999. Chronology of the Mogollon Rim Region. In *Living on the Edge of the Rim: Excavations and Analysis of the Silver Creek Archaeological Research Project 1993–1998*, edited by B. J. Mills, S. H. Herr, and S. Van Keuren, 269–94. Arizona State Museum Archaeological Series 192, vol. 1. Tucson: University of Arizona.
- Mills, J. P., and V. M. Mills. 1969. *The Kuykendall Site: A Pre-Historic Salado Village in Southeastern Arizona*. Special Report Number Six. El Paso, TX: El Paso Archaeological Society.

- . 1972. The Dinwiddie Site: A Prehistoric Salado Ruin on Duck Creek, Western New Mexico. *The Artifact* 10 (2): i–50.
- Neely, J. 1977. The Archaeology of the WS Ranch Site, West-Central New Mexico: The 1977 Season, Department of Anthropology, University of Texas at Austin. Manuscript on file. Tucson: Arizona State Museum Archaeological Records Office.
- Neff, H., and D. M. Glowacki. 2002. Ceramic Source Determination by Instrumental Neutron Activation Analysis in the American Southwest. In *Ceramic Production and Circulation in the Greater Southwest: Source Determination by INAA and Complementary Mineralogical Investigations*, edited by D. M. Glowacki and H. Neff, 1–14. Monograph 44, The Cotsen Institute of Archaeology. Los Angeles: University of California–Los Angeles.
- Nelson, B., and S. LeBlanc. 1986. *Short-Term Sedentism in the American Southwest: The Mimbres Valley Salado*. Albuquerque, NM: Maxwell Museum of Anthropology and University of New Mexico Press.
- Nelson, M. C. 1999. *Mimbres During the Twelfth Century: Abandonment, Continuity, and Reorganization*. Tucson: University of Arizona Press.
- Nelson, M. C., and M. Hegmon. 1999. Social Contexts of the Post-classic. In Nelson (1999), 167–85.
- . 2001. Abandonment Is Not as It Seems: An Approach to the Relationship between Site and Regional Abandonment. *American Antiquity* 66: 213–35.
- Neuzil, A. 2008. *In the Aftermath of Migration: Renegotiating Ancient Identity in Southeastern Arizona*. Anthropological Papers of the University of Arizona No. 73. Tucson: University of Arizona Press.
- Neuzil, A., and P. Lyons. 2006. *An Analysis of Whole Vessels from the Mills Collection Curated at Eastern Arizona College, Thatcher, Arizona*. Center for Desert Archaeology Technical Report 2005-001. Tucson: Center for Desert Archaeology.
- Oakes, Y. R., and D. A. Zamora, eds. 1999. *Archaeology of the Mogollon Highlands: Settlement Systems and Adaptation*. Archaeology Notes 232. Santa Fe: Museum of New Mexico Office of Archaeological Studies.
- Peoples, M. A. 2012. *Identity and Social Transformation in the Prehispanic Cibola World: A.D. 1150–1325*. PhD diss., Arizona State University.
- Rinaldo, J. B. 1959. *Foote Canyon Pueblo, Eastern Arizona*. Fieldiana Vol. 49 No.2. Chicago: Chicago Natural History Museum.
- Robinson, D. G. 1992. *Pueblo Period Societal Differentiation in the Middle San Francisco River Valley Region, West-Central New Mexico*. PhD diss., University of Texas–Austin.
- Schachner, G. 2012. *Population Circulation and the Transformation of Ancient Zuni Communities*. Tucson: University of Arizona Press.
- Schollmeyer, K. G., S. Swanson, C. Strawhacker, and M. Peoples. 2007. 3-Up Site (LA150373): Report on 2007 Test Excavations. Report on file at the School of Human Evolution and Social Change, Arizona State University–Tempe.
- Shackley, M. S. 2005. *Obsidian: Geology and Archaeology in the North American Southwest*. Tucson: University of Arizona Press.
- . 2008. Mule Creek Regional Source, Arizona and New Mexico. Electronic Document, <http://www.swxrflab.net/mulecr.htm>. Accessed January 13, 2011.
- Tomka, M. S. F. 1988. The Societal Implications of the Great Kiva at the WS Ranch Site, Alma, New Mexico. MA thesis, Department of Anthropology, University of Texas–Austin.
- Wallace, L. T., ed. 1998. *The Ormand Village: Final Report on the 1965–1966 Excavation*. Office of Archaeological Studies Archaeology Notes 229. Santa Fe: Museum of New Mexico.
- Woodson, M. K. 1999. Migrations in Late Anasazi Prehistory: The Evidence from the Goat Hill Site. *Kiva* 65 (1): 63–84.

Notes

1. Although we refer to “Salado” and “Kayenta” people in this paper, we are aware that, in the past as in the present, individual and group identities are layered and complex.
2. See Clifford (1994) for a review of the concept of diaspora and specific examples.
3. While we have not conducted sourcing studies of the material from Fornsolt, our examination of their paste and temper characteristics makes us confident that these wares were imported from a source in east-central Arizona or west-central New Mexico.
4. Our information on this point is from the Southwest Social Networks Database (Mills et al. 2010), maintained by the University of Arizona and Archaeology Southwest. Unfortunately, because the database coverage does not extend east of the continental divide, we were unable to include assemblages from the Mimbres or eastern Mimbres in this comparison.
5. Ceramic sourcing using NAA indicates that Maverick Mountain Series pottery from 3-Up was made from the same range of locally available alluvial clays containing characteristic volcanic sand temper found near 3-Up and other Upper Gila region sites (Huntley 2012).
6. Salado polychromes, as well as other 14th- and 15th-century ceramic types such as early Zuni Glaze Ware, are present at Gamalstad.

Review of Tachinid Fly Diversity in the Gila National Forest, New Mexico

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Abstract

Tachinid flies (Diptera, Tachinidae) are common but easily overlooked insects that are parasitoids of other arthropods. There are about 1350 species in America north of Mexico and they reach their highest diversity in the American Southwest. They are plentiful in the Gila National Forest (GNF) and new species are still being discovered there in the richer habitats. Six methods are described for collecting tachinids in GNF: hand netting, sweeping, sugaring, Malaise trapping, hilltopping, and black lighting. A preliminary list of the 241 tachinid species known from GNF is appended. The following species are newly recorded from New Mexico: *Admontia offella* Reinhard, *Chrysoexorista dawsoni* (Sellers), *Eucelatoria leucophaeata* (Reinhard), *Gaediopsis rubentis* (Reinhard), *Heliodorus cochisensis* Reinhard, *Plagiomima euethes* Reinhard, *Tachinomyia similis* (Williston), *Tsugaea nox* Hall, and *Uramya pristis* (Walker). *Carcelia* subgenus *Euryclea* Robineau-Desvoidy is recorded from the New World for the first time based on an undescribed species of the subgenus.

Introduction

Flies, which are classified in the order Diptera, are a ubiquitous component of insect life on our planet. There are about 150,000 described species and they occupy a diversity of habitats throughout the world. They display a wide range of life history strategies, particularly in their larval (or maggot) stage. Fly larvae may, for instance, feed on living plants, develop in decaying organic matter, live in varied aquatic habitats, or kill and consume other invertebrates. Some flies, like house flies, black flies, and mosquitoes, are a nuisance to man, whereas others, like root maggots and screwworms, affect the crops and livestock that we depend upon for food. Certain flies also transmit some of the most serious diseases known to man, such as malaria, sleeping sickness, and leishmaniasis.

Another life history strategy practiced by flies is the development of a maggot on or in a living host organism that ultimately results in the pupation of the maggot and the death of the host. Insects with this macabre habit are termed parasitoids. About 20% of all flies are parasitoids and this life history strategy has evolved numerous times in different families of Diptera (Feener and Brown 1997).

My research concerns one family of flies, the Tachinidae, which consists entirely of parasitoids. It is a large family with nearly 10,000 described species worldwide that exhibit considerable morphological diversity (fig. 1). All species are

endoparasitoids of other arthropods, almost exclusively other insects. The majority attack caterpillars (Lepidoptera), beetles (Coleoptera), true bugs (Heteroptera), and sawflies (Hymenoptera), but a few are parasitoids of such hosts as grasshoppers, cockroaches, earwigs, centipedes, and scorpions. Tachinids may be generalists or specialists with respect to the number of host species they can parasitize. They have evolved many adaptations related to host location, fecundity, oviposition, and larval type (Stireman et al. 2006; O'Hara 2008).

I first visited Gila National Forest (GNF) in 1980 while pursuing a Master's thesis on the tachinid genus *Siphona* Meigen. I found a new species of *Siphona* on that trip at Cherry Creek Campground and subsequently named it *Siphona pisinnia* (O'Hara 1983). This species became the second tachinid with a type locality within GNF. I have since returned to GNF and other mountain ranges in southeastern Arizona and southwestern New Mexico over a dozen times in search of rare and new tachinid species. Accounts of some of these trips have been published in newsletter articles (O'Hara 1993, 1995, 2000).

My collecting efforts in GNF have mostly concerned four sites within 50 miles of Silver City: Cherry Creek Campground, Gomez Peak, Signal Peak, and Meadow Creek (coordinates given in Appendix). These are sites that I have found over the years to have especially high tachinid diversity. Overall, the tachinid fauna recorded from these sites is impressively rich and as equally diverse as the moist canyons

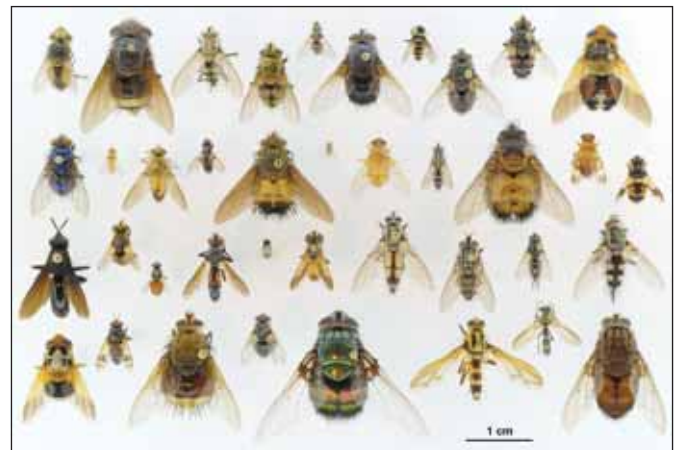


Fig. 1. An assortment of world Tachinidae illustrating the great variation in size, shape, and coloration within the family (from O'Hara 2008).

of the Chiricahua, Graham, Huachuca, Santa Rita, and Santa Catalina Mountains in Arizona.

Below I discuss the tachinids of GNF, the methods used to collect them, and the four sites most frequently sampled. I conclude this paper with a preliminary list of the tachinids known from GNF. I stress the word "preliminary" because most of the National Forest has not been sampled and some species are so infrequently encountered that a complete list from any one site is not possible. Nevertheless, no list of Tachinidae exists for GNF, or even for New Mexico, so the list provided here, however preliminary, may serve as a starting point for future studies on the Tachinidae of GNF.

Tachinidae of Gila National Forest

Tachinid diversity

The names and known distributions of the Tachinidae of America north of Mexico were documented in a catalog by O'Hara and Wood (2004), and the classification therein is followed here. That work recognized 303 genera and 1345 species of Tachinidae in the region. Distributions were given as ranges rather than as state and province records because the distributions of most species in the United States and Canada are poorly known. It is not possible, for instance, to estimate with any accuracy how many species occur in New Mexico.

In a separate and ongoing study of Tachinidae, I have divided continental United States and Canada into 16 subregions and estimated the number of species in each based on the distributions in O'Hara and Wood (2004). The subregion comprising Arizona, New Mexico, Nevada, Utah, and Colorado has an estimated 703 species, which is more than any other subregion and represents more than half of all the species known from America north of Mexico. The actual number is certainly higher because tachinid species are seldom so well known that their distributions can be reported with much accuracy.

Within the aforementioned subregion the highest diversity of Tachinidae is in Arizona and New Mexico, and in particular within the "sky islands" of southeastern Arizona and southwestern New Mexico. On the edge of the sky islands, and from my experience equally as diverse in terms of the tachinid fauna, is GNF. The reason for such high diversity in this part of North America is largely a consequence of its unique position at the crossroads of the Nearctic and Neotropical Regions, which has given rise to a mixture of temperate and tropical elements. Added to this have been the gradual paleoenvironmental development of the southwestern deserts, the associated isolation of the sky islands, and periodic major climatic fluctuations, all of these factors influencing, and for groups like Tachinidae increasing, biodiversity.

In recognition of the high diversity of flies in southern Arizona and New Mexico, the North American Dipterists Society has twice held field meetings in the area: first at the Southwestern Research Station near Portal in the Chiricahua Mountains (AZ) in 1991 (see report by Brown 1991) and more recently at Western New Mexico University in Silver

City (NM) in 2007 (see report by O'Hara 2007 and related article by Stireman 2008).

Collecting methods

Tachinid flies are common in GNF but are not commonly observed by most people. They are seldom attracted to humans or our food. Their activities center around feeding, reproduction, and oviposition, and knowing where and when tachinids will engage in these activities is the key to finding them. They are good flyers and are most active and conspicuous on warm and sunny days.

Below I review six collecting methods that have worked well for catching tachinids in the varied habitats of GNF. Another that I have not tried and that is not practical during brief field trips is to collect potential hosts and rear them until either a tachinid appears (as a larva or an adult from a larval or pupal host) or an adult host. The rate of parasitism fluctuates from species to species and from year to year, but is frequently less than 5%. Although rearing is therefore the most labor-intensive way to obtain tachinids, the host records and ecological data that result from it contribute to a better understanding of host-parasitoid interactions and ecosystem dynamics (e.g., Janzen and Hallwachs 2009).

Hand netting The simplest and most common way to collect tachinids is to search for them in a variety of habitats and to capture them with an insect net. Tachinids can be found in greatest diversity and numbers visiting flowers for nectar and landing on sunlit leaves. Among the flowers that attract the most tachinid species in GNF are those of *Ceanothus fendleri* (commonly known as buckbrush), a plant that blooms early in the rainy season of late summer at mid-elevations. A good proportion of the tachinids collected from Cherry Creek Canyon were taken from flowers of this plant, especially from bushes located across from the entrance to Cherry Creek Campground. The canyon wall in that location rises sharply just a few meters from the pavement on the west side of the road, creating a natural flight way for tachinids and other insects. Tachinids tend to be more common on flowers and vegetation along flight ways than in more uniform situations. A natural flight way can follow a canyon wall, a stream bed (wet or dry, such as Cherry Creek), or an edge of sunlit vegetation (e.g., along a road).

Two common species on flowers of *C. fendleri* in Cherry Creek Canyon are *Pararchytas decisus* (Walker) and *Pararchytas apache* Woodley (fig. 2). The two species are very similar in appearance and the latter was not recognized as a distinct species until relatively recently (Woodley 1998). The type locality of *Pararchytas apache* is Cherry Creek Campground. One rare species that I have collected only once in my career is the wasp-like *Cylindromyia (Ichneumonops) mirabilis* Townsend (fig. 3), taken on *C. fendleri* at Cherry Creek Campground in 1999.

One of the largest tachinids in North America is *Trioxodes obesus* Coquillett. The male positions itself on the trunk of a prominent tree at about eye height, with head pointed downwards (fig. 4). From this vantage point it awaits a passing



Fig. 2. *Pararchytas* sp. on *Ceanothus fendleri* at Cherry Creek Campground. Body length = ca. 13 mm.

female with which to mate. Only certain trees are selected for this purpose and are used year after year by different generations of *T. obesus*.

Sweeping Sweeping is a special form of hand netting. It is the sweeping of an insect net back and forth as one walks through a meadow or along a path, or the sweeping of branches of a bush or tree. It differs from regular hand netting in that tachinids are not seen prior to their capture; a net is passed through places where tachinids are suspected to be and then its contents are examined for tachinids. This is an effective way of catching smaller tachinids as they fly through vegetation in search of hosts or nourishment (the latter generally being flower nectar or aphid-produced honeydew).

There are a few small grassy meadows immediately south of Cherry Creek Campground between the road and the east canyon wall. These have been swept on a number of occasions but with little success. In contrast, the aptly named Meadow Creek location farther to the north has good tachinid diversity and sweeping can be used to advantage there. The meadow (fig. 5), surrounded by hills of ponderosa pine and bordered on one side by a small stream (Meadow Creek), is rich in tachinid-attracting wildflowers during the rainy season.



Fig. 3. *Cylindromyia (Ichneumonops) mirabilis* Townsend collected from flowers of *Ceanothus fendleri* at Cherry Creek Campground. Body length = 12.4 mm.



Fig. 4. A male of *Trixodes obesus* Coquillett on a tree trunk at Cherry Creek Campground. Body length = ca. 18 mm.

There is one small undescribed tachinid species belonging to *Siphona* subgenus *Aphantorhapha* Townsend (fig. 6) that I have taken in small numbers at Meadow Creek. It was first noticed in sweep samples but later traced to the flowers of *Potentilla thurberi* growing along the edge of the meadow.

Sugaring This, like sweeping, is another variation of hand netting. A spray bottle is filled with a mixture of honey, water, and cola (a "recipe" developed by D. M. Wood) and sprayed on sunlit leaves. Under the right circumstances this mixture attracts a wide variety of tachinids. Interestingly, it is nearly impossible to predict what the results of sugaring will be on any single occasion. What appears to be an ideal spot can attract almost nothing or result in phenomenal activity all day long, with some species appearing in large numbers and others being represented by only a specimen or two. Respraying the leaves every 20 minutes or so will ensure that activity does not wane. It is thought that the success of sugaring is related to the availability of honeydew or nectar nearby. Sugaring has been especially effective at attracting tachinids



Fig. 5. A view of the large meadow at the Meadow Creek location. A variety of tachinids are attracted to the nectar of the wildflowers abundant here during the rainy season.



Fig. 6. A small undescribed species of *Siphona* subgenus *Aphantorhapha* Townsend that frequents the flowers of *Potentilla thurberi* at Meadow Creek. Body length = 3.8 mm.

in the Cherry Creek Campground area. The colorful *Paradejeania rutilioides* (Jaennicke) is one of the larger tachinids that is attracted to sugared leaves (fig. 7).

Malaise trapping There are various types of traps for collecting insects: pitfall traps, flight-intercept traps, carbon-dioxide emitting traps, sticky traps, baited traps, emergence traps, and so forth. The most effective for catching tachinids is the Malaise trap (fig. 8). This trap is based on the principle that many flying insects will fly upwards when they encounter a barrier, such as the black center screen of a Malaise trap. Insects flying upwards in a Malaise trap first reach the tent-like white screen that is attached to the center screen, then continue upwards and work their way to the high end of the trap. There they pass through a hole in the screen and drop into a jar of 75% ethanol. Insects can be kept preserved in ethanol or dried and mounted on pins.

A well-positioned Malaise trap in a good habitat will generally collect a small percentage of tachinid species not commonly collected by other methods. Some of these are small and easily missed while hand netting (e.g., *Nigrilypha gnoma*



Fig. 7. *Paradejeania rutilioides* (Jaennicke), a large, strikingly colored, and bristled tachinid that is common at Cherry Creek Campground. It is shown here on a sugared oak leaf in the Manzano Mountains near Albuquerque. Body length = ca. 17 mm.



Fig. 8. A Malaise trap across the road from the entrance to Cherry Creek Campground and placed along an insect flight way.

O'Hara), whereas a few are active at night and consequently rare in collections (e.g., *Mauromyia picticornis* (Reinhard), fig. 9). I have placed Malaise traps in different locations in the Cherry Creek Campground area but by far the best spot has been across from the campground and backing against the canyon wall, just a few feet from the pavement of Highway 15 (fig. 8). The holotype of *Exoristoides sabroskyi* O'Hara was described from a specimen collected from a Malaise trap placed in this location in August 1999 (O'Hara 2002).

Hilltopping The Tachinidae are among a select group of insects that have evolved a special strategy called "hilltopping" for finding potential mates (Skevington 2008). Both sexes of such insects instinctively fly to the top of prominent landforms. Males arrive and await females, and presumably mate with multiple females if given the opportunity. Females, on the other hand, stay on a hilltop only long enough to find a mate. As a result, males of hilltopping species are much more



Fig. 9. *Mauromyia picticornis* (Reinhard), a rare species collected in a Malaise trap and at black light at Cherry Creek Campground (from O'Hara 2002). Body length = 4.8 mm.

commonly encountered than females. It is not unusual to catch only males on a given day.

The instinctive behavior of hilltopping in tachinids is much more finely tuned than simply guiding the flies to a hilltop. Once a hilltop has been reached, males of each species are attracted to particular locations. A species may prefer the topmost branch of the tallest tree near the center of a hilltop, or the twigs of a bush on one side of a hilltop (e.g., *Macromyia crocata* Reinhard, fig. 10), or foliage on a particular bush, or tree trunks, or the ground beneath a bush, and so on. Males of each species also have a preferred time of day for hilltopping, which results in a temporal turnover of species throughout the day.

Not all tachinid species hilltop, but many do and some species are unlikely to be seen anywhere else. Sometimes males may be taken at hilltops and females in other places, for example where hosts occur. A few species are essentially hilltoppers except that they position themselves a short distance downslope and do not visit the actual summit.

It is difficult to predict with any certainty whether a hilltop will attract many tachinid species. I have visited about 20 hilltops in the American Southwest and most have had low tachinid activity. However, the hilltop with the highest tachinid diversity is within GNF: Gomez Peak, just a few miles north of Silver City (fig. 11). The number of tachinid species recorded in the Appendix from this hilltop is 99. O'Hara (1996) provided a preliminary list of hilltopping tachinids in the American Southwest and Stireman (2008) listed 26 tachinid species taken on Gomez Peak on a single day. I have collected on the summit of nearby Eighty Mountain only a couple of times but this site appears to be a moderately good tachinid hilltop.

I have collected on several occasions on Signal Peak in GNF with good success. It is higher than Gomez Peak and deeper in the Pinos Altos Mountains, and has a somewhat different tachinid fauna. It is difficult to assess the true diversity of the fauna because the hilltop is large and partly forested with tall ponderosa pines. There are undoubtedly



Fig. 11. A view of Gomez Peak from the south with Little Walnut Road in the foreground.

species that hilltop on Signal Peak that are seldom seen because they remain high in the trees.

Black lighting An ultraviolet light, or black light, is commonly used for collecting nocturnal insects like many moths and beetles. The light is placed over a white sheet (fig. 12) and powered by an electrical source, which in the field is generally a battery or small generator. Not many tachinids are active at night, but black lighting is a useful method for attracting such species. One of the rarest tachinids collected at black light in GNF is *Mauromyia picticornis* (Reinhard; fig. 9), a small, dark species currently known from seven specimens from Arizona and New Mexico (O'Hara 2002). Two were taken at Cherry Creek Campground, one at black light and the other in a Malaise trap. This species has also been taken outside GNF during the day on vegetation.

Further black lighting in GNF will likely reveal the presence of *Ormia* Robineau-Desvoidy. Several species of this genus are common in the American Southwest. The noctur-



Fig. 10. *Macromyia crocata* Reinhard, a species that lands on twigs in the bushes that line the east side of the summit of Gomez Peak. Body length = ca. 17 mm.



Fig. 12. A black light sheet and lights suspended across the dry stream bed of Cherry Creek at Cherry Creek Campground.

nal adults are robust, yellow flies. Females locate their cricket hosts by homing in on their calling songs using a pair of tympanal organs located under a modified prosternum.

Preserving tachinids

Specimens that are hand collected and destined for a permanent collection like the Canadian National Collection of Insects (Ottawa) or National Museum of Natural History (Washington) are best killed in the field and pinned while fresh. Popular killing agents are ethyl acetate, cyanide, and 1,2-dichloroethane. Specimens that are collected into ethanol (such as those captured in a Malaise trap) can be dried and mounted using the method described by O'Hara (1994). A technique for preserving specimens for molecular study was given by O'Hara (2011).

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Literature Cited

- Brown, B. V. 1991. North American Dipterists' Society meeting: May 31–June 2, 1991. *Fly Times* 7:2–4.
- Feener, D. H., Jr., and B. V. Brown. 1997. Diptera as parasitoids. *Annual Review of Entomology* 42:73–97.
- Janzen, D. H., and W. Hallwachs. 2009. *Dynamic database for an inventory of the macrocaterpillar fauna, and its food plants and parasitoids, of Area de Conservación Guanacaste (ACG), north-western Costa Rica*. Available from: <http://janzen.sas.upenn.edu>. Accessed 1 May 2011.
- O'Hara, J. E. 1983. Classification, phylogeny and zoogeography of the North American species of *Siphona* Meigen (Diptera: Tachinidae). *Quaestiones Entomologicae* 18 (1982): 261–380.
- . 1993. On the track of unknown tachinids in Arizona and New Mexico. *Fly Times* 11:7–9.
- . 1994. Mounting tachinids from ethanol. *Tachinid Times* 7:3–4.
- . 1995. The American Southwest revisited. *Tachinid Times* 8:6–8.
- . 1996. Hilltopping Tachinidae from the American Southwest. *Tachinid Times* 9:4–5.
- . 2000. An account of a collecting trip to the mountains of southern Arizona and New Mexico, USA. *Tachinid Times* 13:4–7.
- . 2002. Revision of the Polideini (Tachinidae) of America north of Mexico. *Studia dipterologica, Supplement* 10.
- . 2007. Field meeting of the North American Dipterists Society, Silver City, New Mexico, 13–16 August 2007. *Fly Times* 39:3–5.
- . 2008. Tachinid flies (Diptera: Tachinidae). In *Encyclopedia of entomology*, 2nd ed., ed. J. L. Capinera, 3675–86. Dordrecht, Netherlands: Springer.
- . 2011. Collecting and preserving tachinid legs for molecular study. *Tachinid Times* 24:11–14.
- O'Hara, J. E., and D. M. Wood. 2004. Catalogue of the Tachinidae (Diptera) of America north of Mexico. *Memoirs on Entomology, International* 18.
- Skevington, J. H. 2008. Hilltopping. In *Encyclopedia of entomology*, 2nd ed., ed. J. L. Capinera, 1799–807. Dordrecht, Netherlands: Springer.
- Stireman, J. O., III. 2008. Tachinid collecting in southwest New Mexico and Arizona during the 2007 NADS field meeting. *Tachinid Times* 21:14–16.
- Stireman, J. O., III, J. E. O'Hara, and D. M. Wood. 2006. Tachinidae: Evolution, behavior, and ecology. *Annual Review of Entomology* 51:525–55 + 2 pls.
- Townsend, C. H. T. 1897. Diptera from the headwaters of the Gila River.—I. *Psyche* 8:38–41.
- Wilder, D. D. 1979. Systematics of the Nearctic *Ptilodexia* Brauer and Bergenstamm (Diptera: Tachinidae). *Proceedings of the California Academy of Sciences* 42:1–55.
- Wood, D. M. 1987. Tachinidae. In *Manual of Nearctic Diptera*, vol. 2, ed. J. F. McAlpine, B. V. Peterson, G. E. Shewell, H. J. Teskey, J. R. Vockeroth, and D. M. Wood, 1193–269. *Agriculture Canada Monograph* 28.
- Woodley, N. E. 1998. A revision of the genus *Pararchytas* Brauer and Bergenstamm (Diptera: Tachinidae). *Proceedings of the Entomological Society of Washington* 100:409–20.

Appendix. Preliminary List of Tachinidae of Gila National Forest

This list is based primarily upon specimens I collected during 14 trips to GNF between 1980 and 2011. It has been supplemented by valuable material collected by my colleague D. Monty Wood during trips to the area in 2001 and 2007. All specimens collected by us are housed in the Canadian National Collection of Insects (CNC) in Ottawa.

There are 241 species of Tachinidae recognized from GNF, as identified from nearly 3000 specimens. This relatively high number of species is indicative of the high tachinid diversity in the area, yet undoubtedly is much lower than the actual number of species in GNF. Tachinid populations cycle through periods of low and high numbers in response to host populations and other factors, thereby affecting the number and composition of species that are likely to be collected in any given year. Collecting efforts have been concentrated in a few localities in the southern portion of GNF,

further reducing the likelihood of obtaining an accurate list of GNF Tachinidae. Nevertheless, it is my hope that this first list will encourage others to add to it and in this way gradually develop a better knowledge of the GNF fauna.

The vast majority of specimens (95%) upon which this list is based were collected from the following five locations. Species recorded from these locations are identified in the list by superscript numbers that correspond to the numbers given here.

1. Cherry Creek Campground, 14 miles north of Silver City on Highway 15, 6850 ft., 32°54.8'N 108°13.6'W; 1526 specimens (including 43 from nearby McMillan Campground), 160 species. The elevation of Cherry Creek Campground is given in error as 7400 ft. in National Forest booklets and some other sources and this elevation was used on my insect labels until 2010.
2. Gomez Peak, north of Silver City on Little Walnut Road, summit, 6500 ft., 32°51.0'N 108°17.0'W; 764 specimens, 99 species.
3. Signal Peak, ca. 24 miles north of Silver City, summit, 8900 ft., 32°55.5'N 108°10.8'W; 202 specimens, 41 species.
4. Meadow Creek, ca. 20 miles north of Silver City, 7100 ft., 32°57.2'N 108°10.3'W; 201 specimens, 44 species.
5. Black Range, ca. 34–40 miles east of Silver City on Highway 152 (including, from west to east: Lower Galinas Campground, 6500 ft., 32°53.5'N 107°50.0'W; Railroad Canyon Campground, 7050 ft., 32°54.5'N 107°49.0'W; Iron Creek Campground, 7300 ft., 32°54.5'N 107°48.3'W; Wright's Cabin Picnic Area, 7500 ft., 32°54.5'N 107°47'W; Emory Pass, 8230 ft., 32°54'N 107°45'W); 141 specimens, 47 species. Most specimens were collected by D. M. Wood.

I am aware of only three tachinid species reported from GNF prior to the 1980s. Two were reported by Townsend (1897) from the West Fork of the Gila River: "*Dejeania corpulenta* Wied." (likely a misidentification of *Adejeania vexatrix* (Osten Sacken)) and Townsend's new species *Myobia gilensis* (now considered a synonym of *Leskia occidentalis* (Coquillett)). The third species, *Ptilodexia maculata* Wilder, was described by Wilder (1979) from "14 miles ... north of Silver City" (most likely Cherry Creek Canyon).

The Tachinidae are among the most difficult of Diptera to identify to species. There are many cryptic species and species complexes that have yet to be resolved, and many new species to be described. In GNF there is the added complexity of species described from south of the United States that have yet to be recognized from north of the border. In determining the species comprised in the following list, I relied upon Wood's (1987) key to genera, other published keys, and especially identified material and types in the CNC. I was aided in the identification of some of the more difficult species by D. M. Wood, the foremost expert on New World Tachinidae. Additionally, the CO1 DNA barcoding of 465 GNF specimens helped with the resolution of a few taxonomic problems that defied traditional morphological study.

The following explanation will help with the interpretation of the format used in the list of species:

Uramya indita (Walker)—The identification is considered accurate.

Uramya ?indita (Walker)—The species might be *U. indita*.

Uramya nr. *indita* (Walker) sp. 1—The species is thought to be undescribed and close to *U. indita*.

Uramya sp. 1—The species is thought to be an undescribed species of *Uramya*.

Uramya sp.—The species cannot be identified but is quite possibly a described species.

?*Uramya* sp. 1—The species is thought to be an undescribed species and possibly belongs to *Uramya*.

There are 80 species in the list that are identified by numbers (e.g., "sp. 1"), representing 33% of the known tachinid fauna of GNF. The majority are undoubtedly undescribed species, but a portion are expected to be species described from south of the United States that are unrecognized north of the border or species known from the United States but not properly identified from GNF.

The species list is arranged alphabetically by subfamily, tribe, genus, and species and follows the classification of O'Hara and Wood (2004). Species that are clearly new records for New Mexico are so indicated.

DEXIINAE

CAMPYLOCHETINI

Campylocheta ?nasellensis (Reinhard)^{1,2,4}

Campylocheta sp. 1¹

Campylocheta sp. 2¹

DEXIINI

Dinera griseescens (Fallén)²

Dolichocodia furacis Reinhard^{1,2}

Dolichocodia sp. 1²

Euchaetogyne roederi (Williston)^{1,2,5}

Mochlosoma illocale Reinhard²

Ptilodexia agilis Reinhard^{1,2}

Ptilodexia arida (Curran)¹

Ptilodexia conjuncta (van der Wulp)^{1,2,4}

Ptilodexia contristans (van der Wulp)³

Ptilodexia maculata Wilder¹

Ptilodexia major (van der Wulp)¹

Ptilodexia planifrons (van der Wulp)^{1,4}

Trixodes obesus Coquillett^{1,5}

Ursophyto nigriceps (Bigot)^{2,3}

Zelia gracilis (Reinhard)¹

DUFOURIINI

Oestrophasia calva Coquillett^{1,2}

EUTHERINI

Euthera setifacies Brooks²

Euthera tentatrix Loew²

URAMYINI

Uramya halisidotae (Townsend)^{1,2}

Uramya indita (Walker)¹

Uramya pristin (Walker). **New record** for New Mexico (previously known from "Michigan to New Hampshire, south to Georgia (S&A, 1965), Arizona, Québec (CNC), Florida (FSCA)"; O'Hara and Wood 2004, 51).

VORIINI

Athrycia cinerea (Coquillett)¹
Cyrtophleba nr. *coquilletti* Aldrich sp. 1¹
Cyrtophleba horrida Giglio-Tos^{3,5}
Eulasiona comstocki Townsend¹
Hypovoria cauta (Townsend)¹
Kirbya (*Hesperophasia*) sp. 1⁴
Kirbya (*Hesperophasia*) sp. 2¹
Meleterus montanus Aldrich¹
Muscopteryx ?*parilis* Reinhard¹
Muscopteryx sp. 1¹
Periscepsia (*Ramonda*) *helymus* (Walker)¹
Periscepsia (*Ramonda*) *laevigata* (van der Wulp)^{1,5}
Plagiomima euethes Reinhard¹. **New record** for New Mexico (previously known only from Arizona; O'Hara and Wood 2004).
Trafoia sp. 1^{1,2}
Trochilodes skinneri Coquillett^{1,2}

EXORISTINAE

BLONDELIINI

Admontia offella Reinhard¹. **New record** for New Mexico (previously known only from Arizona; O'Hara and Wood 2004).
 Genus nr. *Angustia* sp. 1¹
Blondelia polita (Townsend)^{1,2,3,5}
Chaetonodexodes vanderwulpia (Townsend)²
Cryptomeigenia sp.²
Eribella sp. 1^{2,3,5}
Eribella sp. 2⁵
Eucelatoria armigera (Coquillett)¹
Eucelatoria nr. *armigera* (Coquillett) sp. 1
Eucelatoria nr. *armigera* (Coquillett) sp. 2
Eucelatoria nr. *dimmocki* (Aldrich) sp. 1²
Eucelatoria leucophaeata (Reinhard)¹. **New record** for New Mexico (previously known only from Arizona; O'Hara and Wood 2004).
Medina barbata (Coquillett)^{1,4}
Meigenia submissa (Aldrich & Webber)^{1,4}
Myiopharus ?*ancillus* (Walker)²
Myiopharus doryphorae (Riley)¹
Myiopharus levis (Aldrich & Webber)²
Myiopharus sp. 1²
Opsomeigenia pusilla (Coquillett)^{1,2}
 ?*Oswaldia* sp. 1²
Phasmophaga meridionalis Townsend¹
Vibrissina mexicana (Aldrich)^{1,2}
Zaira ?*arrisor* (Reinhard)^{1,2}
Zaira sp. 1^{1,4}
Zaira sp. 2¹
Zaira sp. 3
 Undescribed blondeline genus and sp.²

ERYCHINI

Ametadoria harrisinae (Coquillett)¹

Apomya theclarum (Scudder) species complex^{1,2}
Carcelia (*Carcelia*) *reclinata* (Aldrich & Webber)⁵
Carcelia (*Carcelia*) sp. 1^{1,4,5}
Carcelia (*Carcelia*) sp. 2⁵
Carcelia (*Euryclea*) sp. 1^{4,5}. **New record** for this subgenus in the New World. The species is undescribed.
Drino (*Drino*) nr. *incompta* (van der Wulp) sp. 1^{1,2,4}. The identity of true *D. incompta* is uncertain and could be *D. nr. incompta* sp. 1 or sp. 2, or a different species.
Drino (*Drino*) nr. *incompta* (van der Wulp) sp. 2
Drino (*Drino*) *rhoeo* (Walker)⁵
Eunemorilla nr. *effeta* (Reinhard) sp. 1²
Eunemorilla nr. *effeta* (Reinhard) sp. 2²
Eunemorilla longicornis (Reinhard)^{1,2}
Eunemorilla paralis (Reinhard)^{1,2}
Heliodorus cochisensis Reinhard⁵. **New record** for New Mexico (previously known only from Arizona; O'Hara and Wood 2004).
Lespesia schizurae species complex⁴
Lespesia sp.^{1,2}
Lydella radialis (Townsend)^{1,2,4}
Madremyia saundersii (Williston)^{2,4}
Nilea disparis (Reinhard)^{1,2,5}
Nilea sp. 1^{1,2,4}
Phebellia ?*erecta* (Sellers)²
Phebellia helvina (Coquillett)¹
Tsugaea nox Hall². **New record** for New Mexico (previously known from "British Columbia, Oregon, California, Nevada (S&A, 1965), Colorado, Mexico (CNC)"; O'Hara and Wood 2004, 141).
Zizyphomyia crescentis (Reinhard)

ETHILLINI
 "Winthemia" *antennalis* Coquillett^{1,2}. This species has long been treated as a member of *Winthemia* in Winthemini (e.g., O'Hara and Wood 2004) but belongs in Ethillini. A new genus is being proposed for this species by P. Cerretti, D. M. Wood, and J. E. O'Hara (in prep.).

EXORISTINI
Austrophorocera nr. *sulcata* (Aldrich & Webber) sp. 1^{1,5}
Bessa harveyi (Townsend)¹
Chetogena claripennis (Macquart) or *C. edwardsii* (Williston)¹.
 These two nominal species cannot be reliably identified.
Chetogena parvipalpis (van der Wulp)^{1,2}
Chetogena tachinomoides (Townsend)^{1,2,5}
Exorista (*Exorista*) *mella* (Walker)^{1,5}
Tachinomyia similis (Williston)¹. **New record** for New Mexico (previously known from "British Columbia to Manitoba, south to California and Arizona (S&A, 1965)"; O'Hara and Wood 2004, 156).

GONIINI
Belvosia bifasciata (Fabricius)²
Chaetogaedia nr. *desertorum* (Townsend) sp. 1^{3,4}
Chaetogaedia nr. *desertorum* (Townsend) sp. 2^{1,3}
Chaetogaedia nr. *desertorum* (Townsend) sp. 3^{1,2,3}
Chaetogaedia monticola (Bigot)^{1,2,3,4,5}
Chaetogaedia sp. 1^{1,2,5}

Chrysoexorista dawsoni (Sellers)^{1,5}. **New record** for New Mexico (previously known only from Arizona; O'Hara and Wood 2004).

Chrysoexorista ochracea (van der Wulp) species complex^{1,2,3,5}. Data from CO1 DNA barcoding suggests there are three or more species of this complex in GNF.

Chrysoexorista fulgoris (Sellers)^{1,2,3}

Chrysoexorista sp. 1¹

Cyzenis nr. *ustulata* (Reinhard) sp. 1²

Erynnia tortricis (Coquillett)²

Frontiniella festinans (Aldrich & Webber)^{1,2,5}

Frontiniella parancilla Townsend²

Frontiniella regilla (Reinhard)^{1,2,5}

Frontiniella ?*spectabilis* (Aldrich)⁵

Gaediopsis nr. *lugubris* (van der Wulp) sp. 1^{1,3,5}

Gaediopsis nr. *lugubris* (van der Wulp) sp. 2^{1,3,5}

Gaediopsis rubentis (Reinhard)^{1,3,4,5}. **New record** for New Mexico (previously known only from Arizona and Mexico; O'Hara and Wood 2004).

Gaediopsis setosa Coquillett^{1,2,3,5}

Gaediopsis nr. *sierricola* (Townsend) sp. 1^{1,2,5}. The identity of true *G. sierricola* is uncertain.

Gaediopsis nr. *sierricola* (Townsend) sp. 2¹

Gonia sequax Williston²

Hesperomyia petiolata (Townsend)²

Houghia sp. 1⁵

Houghia sp. 2⁵

Hyphantrophaga collina (Reinhard)^{1,5}

Hyphantrophaga ?*virilis* (Aldrich & Webber)^{1,5}. Data from CO1 DNA barcoding suggests this species might be different from *H. virilis* in northeastern North America.

Leschenaultia adusta (Loew)^{2,3}

Leschenaultia ?*brooksi* Toma^{1,5}

Leschenaultia grossa Brooks¹

Patelloa nr. *facialis* (Coquillett) sp. 1²

Patelloa nr. *facialis* (Coquillett) sp. 2^{1,2}

Patelloa nr. *facialis* (Coquillett) sp. 3^{1,2}

Patelloa pluriseriata (Aldrich & Webber)^{1,2,3,4,5}

Patelloa nr. *specularis* (Aldrich & Webber) sp. 1¹

Platymya sp. 1²

Platymya sp. 2²

Spallanzania hebes (Fallén)²

Spallanzania hesperidarum (Williston)⁴

MASIPHYINI

Masiphya confusa Aldrich^{2,3}

WINTHEMIINI

Nemorilla pyste (Walker)¹

Winthemia aurifrons Guimarães³

Winthemia ?*rufonotata* (Bigot)^{1,5}

PHASIIINAE

CATHAROSIINI

Catharosia sp.^{1,2}

CYLINDROMYIINI

Cylindromyia (*Apinocyptera*) *nana* (Townsend)¹

Cylindromyia (*Cylindromyia*) *uniformis* Aldrich⁴

Cylindromyia (*Ichneumonops*) *mirabilis* (Townsend)¹

Hemyda aurata Robineau-Desvoidy¹

LEUCOSTOMATINI

Leucostoma gravipes van der Wulp³

Leucostoma simplex (Fallén)^{1,4}

PHASIIINI

Euclytia flava (Townsend)²

Phasia aeneoventris Williston¹

Phasia aldrichii (Townsend)³

Phasia purpurascens (Townsend)²

TRICHOPODINI

Trichopoda (*Trichopoda*) *indivisa* Townsend¹

Xanthomelanodes arcuatus (Say) or *X. californicus* Townsend¹.

These two nominal species cannot be reliably identified.

TACHININAE

ACEMYIINI

Acemya tibialis Coquillett¹

Ceracia dentata (Coquillett)^{1,2}

ERNESTIINI

Bombyliomyia soror (Williston)^{1,2,3}

Linnaemya (*Linnaemya*) ?*comita* (Fallén)². This supposedly Holarctic species may comprise more than one species in North America.

GRAPHOGASTRINI

Phytomyptera aenea (Coquillett)^{1,2}

Phytomyptera nr. *amplicornis* (James) sp. 1^{1,2}

Phytomyptera longicornis (Coquillett)²

Phytomyptera melissopodis (Coquillett)¹

Phytomyptera ruficornis (Greene)²

Phytomyptera ?*tarsalis* (Coquillett)^{1,2}

Phytomyptera vitinervis (Thompson)²

Phytomyptera sp. 1¹

Phytomyptera sp. 2

LESKIINI

Clausicella nr. *geniculata* (Townsend) sp. 1¹

Clausicella setigera (Coquillett)^{1,3}

Clausicella sp. 1¹

Clausicella sp. 2¹

Drepanoglossa lucens Townsend¹

Ginglymia ?*johnsoni* (Coquillett)^{1,3,4}

Leskia occidentalis (Coquillett)¹

Phantasiomyia atripes (Coquillett)¹

Phantasiomyia sp. 1¹

Phantasiomyia sp. 2¹

MEGAPROSOPINI

Microphthalma disjuncta (Wiedemann)¹

Microphthalma obsoleta (van der Wulp)^{1,3,4,5}

MINTHOINI

Paradidyma aristalis Reinhard²

Paradidyma singularis (Townsend)^{1,2,5}

Paradidyma sp. 1¹

Paradidyma sp. 2^{1,2}

Paradidyma sp. 3²

Paradidyma sp. 4¹

Paradidyma sp. 5³

MYIOPHASIINI

Cholomyia inaequipes Bigot¹

Cholomyia sp. 1¹

Gnadochaeta sp. 1^{1,2,4,5}

NEMORAEINI

Macromya crocata Reinhard^{1,2,5}

Xanthophyto sp. 1³

Xanthophyto sp. 2^{1,4,5}

Xanthophyto sp. 3^{1,2}

There are two described species of *Xanthophyto* in America north of Mexico, *X. antennalis* (Townsend) and *X. labis* (Coquillett). Their types must be examined to determine the identities of these named species. One or both might be represented in the three species recognized from GNF.

POLIDEINI

Exoristoides sabroskyi O'Hara¹

Hystricia abrupta (Wiedemann)^{1,3}

Mauromyia picticornis Reinhard¹

Nigrilypha gnoma O'Hara^{1,3}

SIPHONINI

Actia autumnalis (Townsend)^{1,4}

Actia diffidens Curran⁴

Siphona (Aphantorhapha) arizonica (Townsend)²

Siphona (Aphantorhapha) sp. 1 [as "*S. (Aphantorhapha)* sp. 3" in O'Hara (1989, 92)]¹

Siphona (Aphantorhapha) sp. 2 [not known at the time of O'Hara (1989)]^{1,4}

Siphona (Ceranthis) sp. 1 [as "*S. (Ceranthis)* U.S. sp. 3" in O'Hara (1989, 103)]^{1,2,4}

Siphona (Pseudosiphona) sp. 1 [as "*S. (Pseudosiphona)* sp. 3" in O'Hara (1989, 108)]¹

Siphona (Siphona) cristata (Fabricius)^{1,4}

Siphona (Siphona) futilis van der Wulp¹

Siphona (Siphona) ?multifaria O'Hara^{1,4}. This is probably a species complex in North America according to CO1 DNA barcode data.

Siphona (Siphona) pisinnia O'Hara^{1,4}. This is probably a species complex with more than one species in GNF

according to CO1 DNA barcode data. The type locality of *S. pisinnia* is Cherry Creek Campground, GNF (O'Hara 1983).

Siphona (Siphona) sp. 1⁴

Siphona (Siphonopsis) nr. *plusiae* Coquillett sp. 1¹

Siphona s. lat. sp. 1 [as "Unplaced *Siphona* sp. 1" in O'Hara (1989, 131)]²

STRONGYGASTRINI

Strongygaster robusta (Townsend)¹

Strongygaster triangulifera (Loew)¹

TACHININI

Adejeania vexatrix (Osten Sacken)^{1,3,4}

Archytas (Nemochaeta) metallicus (Robineau-Desvoidy)^{1,5}

Copecrypta ruficauda (van der Wulp)^{1,4}

Deopalpus contiguus (Reinhard)^{1,2,3}

Deopalpus sp. 1²

Deopalpus sp. 2^{1,2,3}

Jurinella lutzi Curran^{1,3,4}

Juriniopsis aurifrons Brooks¹

Paradejeania rutilioides (Jaenicke)^{1,2,3,4}

Pararchytas apache Woodley^{1,2,3,4,5}

Pararchytas decisus (Walker)^{1,3}

Peleteria (Oxydosphyria) iterans (Walker)^{2,3,4,5}

Peleteria (Peleteria) flaviventris (van der Wulp)⁴

Peleteria (Peleteria) nr. *tegulata* (Townsend) sp. 1^{3,4}

Peleteria (Peleteria) sp. 1

Peleteria (Sphyrimyia) compascua (van der Wulp)^{1,5}

Peleteria (Sphyrimyia) obsoleta Curran^{2,3}

Peleteria (Sphyrimyia) nr. *obsoleta* Curran sp. 1¹

Peleteria (Sphyrimyia) setosa Curran²

Peleteria (Sphyrimyia) sp. 1^{2,5}

Peleteria (Sphyrimyia) sp. 2¹

Protodejeania echinata (Thomson)^{1,4}

Protodejeania hystricosa (Williston)^{1,3,4,5}

Tachina (Nowickia) cordiforceps (Rowe)¹

Tachina sp. 1

Xanthoepalpus bicolor (Williston)^{1,3,4}

THELAIRINI

Spathidexia (Spathidexia) clemonsi Townsend¹

Overview of the Geomorphology of the Upper Gila River Basin, NM

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Abstract

Evolution of the Upper Gila River Basin in New Mexico has been controlled by tectonic geology, lithology, climate, and, over the last century, human activity. Tectonic processes—volcanism, faulting, folding, magma intrusion—provided the basin's structural form. Lithology, the mineralogical composition of rocks, was generated by widespread volcanism, intrusion, and differential weathering and erosion. Climate over the last several millennia significantly impacted basin hydrology, sediment movement, and biodiversity. The relatively recent effects of human activity—livestock grazing, min-

ing, recreation, logging, water ponding, and diversion—and subsequent climatic change reflected in warmer temperatures and reduced snowpack are modifying the sediment patterns, streamflow, flora, and fauna. The extent of future impacts on the basin will depend on the adaptability of biophysical properties of the land and water under uncertain changing conditions.

Introduction

The Upper Gila River Basin in southwestern New Mexico encompasses exceptional diversity in landscapes, ecosystems, and riparian areas. It is drained by the last undammed large river in the state and one of the few remaining free-flowing rivers in the Southwest (fig. 1). Three major tributaries form the headwaters of the Gila River: East, Middle, and West Forks. The river transports large quantities of water and sediment through the basin and delivers it to the Colorado River in the southwest corner of Arizona near Yuma. Irrigation, municipalities, and industry utilize most of the water before it reaches the Colorado River.

The basin covers 9,300 square kilometers (3,590 square miles), excluding the San Francisco River Watershed, which drains into the Gila River in eastern Arizona. Elevations in the basin range from 1,152 meters (3,780 feet) in the Gila River valley on the Arizona–New Mexico state border to 3,321 meters (10,895 feet) at Whitewater Baldy Peak in the Mogollon Mountains. The southeastern, eastern, and northern parts of the basin are bounded by the Continental Divide. The bordering basins are the Animas Basin (south), Mimbres Basin (southeast), Rio Grande Basin

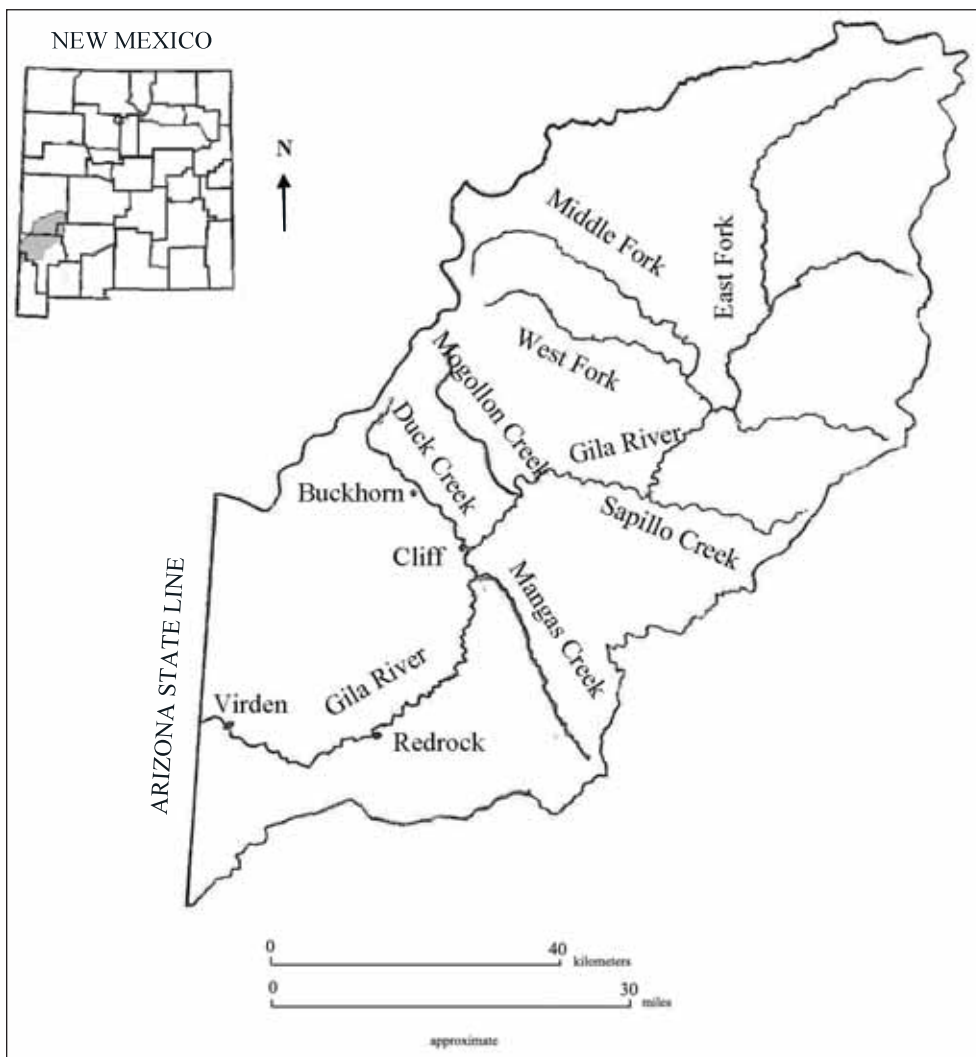


Fig. 1. Upper Gila River Basin, New Mexico.

(east), San Agustin Basin (north), and San Francisco River Watershed (northwest).

The uplands within and bordering the river basin are non-glaciated. The western and northwestern highlands include the Mule, Summit, and Mogollon Mountains. Highlands in the northern, eastern, and southeastern parts include the Mogollon-Datil volcanic field (ridges and plateaus); Elk Mountains; Black, Pinos Altos, and Silver City Ranges; and Big and Little Burro Mountains.

The Gila National Forest covers roughly two-thirds of the basin. The Gila Wilderness, the first congressionally designated wilderness in the U.S., lies mainly in the northern part of the basin, while the Aldo Leopold Wilderness lies partly in the northeastern area.

The basin occurs within two similar ecoregions. The majority of the basin lies within the Arizona/New Mexico Mountains Ecoregion. A small portion of the southern basin lies within the Mountains and Bajadas subregion of the Chihuahuan Deserts Ecoregion (U.S. Environmental Protection Agency 2006). Numerous vegetation assemblages occur here, including coniferous forest, woodland, savanna, grassland, scrubland, and riparian (Dick-Peddie 1993). Together they support a diverse array of soils, plants, wildlife, and aquatic organisms.

The two major land-use/land-cover categories in the basin are forests and rangeland. Land uses include livestock grazing, timber harvesting, mining, and recreation. Small areas of agriculture are located near Buckhorn, Cliff, and Virden. Mineral processing occurs in the upper Mangas Creek valley. A few small towns occur on the Gila River and its tributary, Duck Creek—Cliff, Gila, Redrock, Virden, and Buckhorn.

The following is an overview of the geomorphology of the Upper Gila River Basin. Emphasis is placed on landscape development and the role of the Gila River. For detailed studies of landforms, surficial deposits, soils, vegetation, paleo-climate, drainage, geomorphic processes, and geomorphic threshold conditions in the basin, see Connell et al. (2005), Pazzaglia and Hawley (2004), Wittler et al. (2004), Hawley et al. (2000), Waters and Haynes (2000), Brown (1994), and Leopoldt (1981).

Basin Development

Over three-quarters of the Upper Gila River Basin is in the Datil-Mogollon section of the Transition Zone physiographic province. As the name implies, this province exhibits a structural transition dividing the Colorado Plateau province, to the north of the basin, and the Mexican Highlands section of the Basin and Range province, comprising the southern part of the basin (fig. 2; Connell et al. 2005; Pazzaglia and Hawley 2004; Hawley et al. 2000). The Transition Zone is not sharply defined and forms a northwest-trending structural belt approximately 65–80 kilometers (40–50 miles) wide within southwestern New Mexico.

Characteristics of the southeastern Colorado Plateau, the Datil section, are found in the Transition Zone, including igneous intrusive magma and extrusive volcanic material. Broad plateaus, mesas, buttes, and escarpments are underlain mostly by gently dipping sedimentary rock with igneous

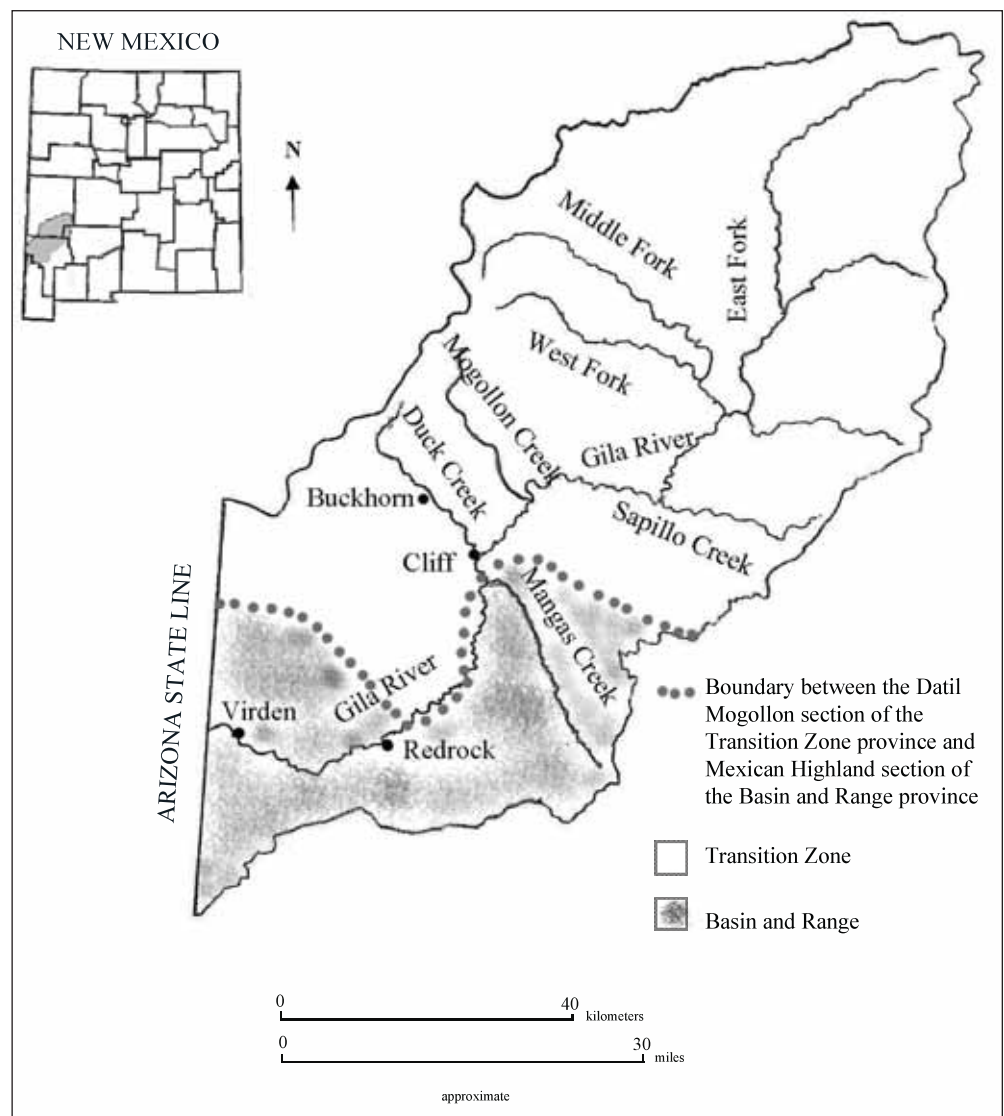


Fig. 2. Physiographic provinces in the Upper Gila River Basin.

(Adapted from Hawley et al. 2000, 14.)

intrusive and extrusive rocks. The broad plateaus, canyons, and deeply entrenched valleys have been tempered by erosion and sedimentation over time.

Structural features of the Mexican Highland section of the Basin and Range are exhibited in the low-lying southern part of the river basin and, to a lesser degree, in the northern Transition Zone. The physiographically diverse area of the Basin and Range is dominated by block faults (normal faults), magma intrusion, volcanism, erosion, and sedimentation beginning roughly 20–30 million years ago. Extensional processes formed northwest-trending fault-block mountains, volcanic highlands, and intervening basins that filled with

sediment eroded from the mountains. Today’s mesas and steep canyons are evidence of that erosion.

The region’s structural history was a major influence on the geomorphic evolution of the area (Hawley et al. 2000). The structural foundation of the river basin has forerunners that date back as much as 2 billion years. The last major orogenic interval (basin uplift and magma intrusion) in the Transition Zone occurred from the late Cretaceous to the early Tertiary (70 to 40 million years ago), the Laramide Orogeny.

Between about 40 and 24 million years ago, the Mogollon-Datil volcanic field was formed in southwestern New Mexico during eruptions of lava and tuff from andesitic to silicic volcanoes, domes, and calderas (Chapin, Wilks, et al. 2004; McIntosh et al. 1992). The volcano-tectonic structures were part of an expansive period of volcanism and a major source of volcanic layers in the area (Ratté et al. 1979). About 28 million years ago two large subsidence calderas, the Bursum and Gila Cliff Dwellings calderas, formed during extensive volcanic activity near the Gila headwater drainage (KellerLynn 2008; Chapin, McIntosh, et al. 2004). Later resurgence of the Bursum volcanic structure most likely accounts for today’s areal topography.

From 23 to 5 million years ago, volcanism, faulting, and mountain uplift occurred in the Basin and Range portion of the region. A main geologic feature in the river basin, the Mangas structural trench, probably began forming in the early Miocene (about 20–22 million years ago). Referred to as the Mangas Trench by Trauger (1965), the Mangas Basin by Mack (2004), and heretofore the Mangas Structural Basin, this feature divides today’s river basin into two nearly equal parts (fig. 3). The arcuate structure extends across the Basin and Range and Transition Zone provinces in the river basin and merges to the southeast with the Mimbres Basin (fig. 4; Hawley et al. 2000; Hanson et al. 1994; Leopoldt 1981; Elston 1981). The northern structural basin merges with the

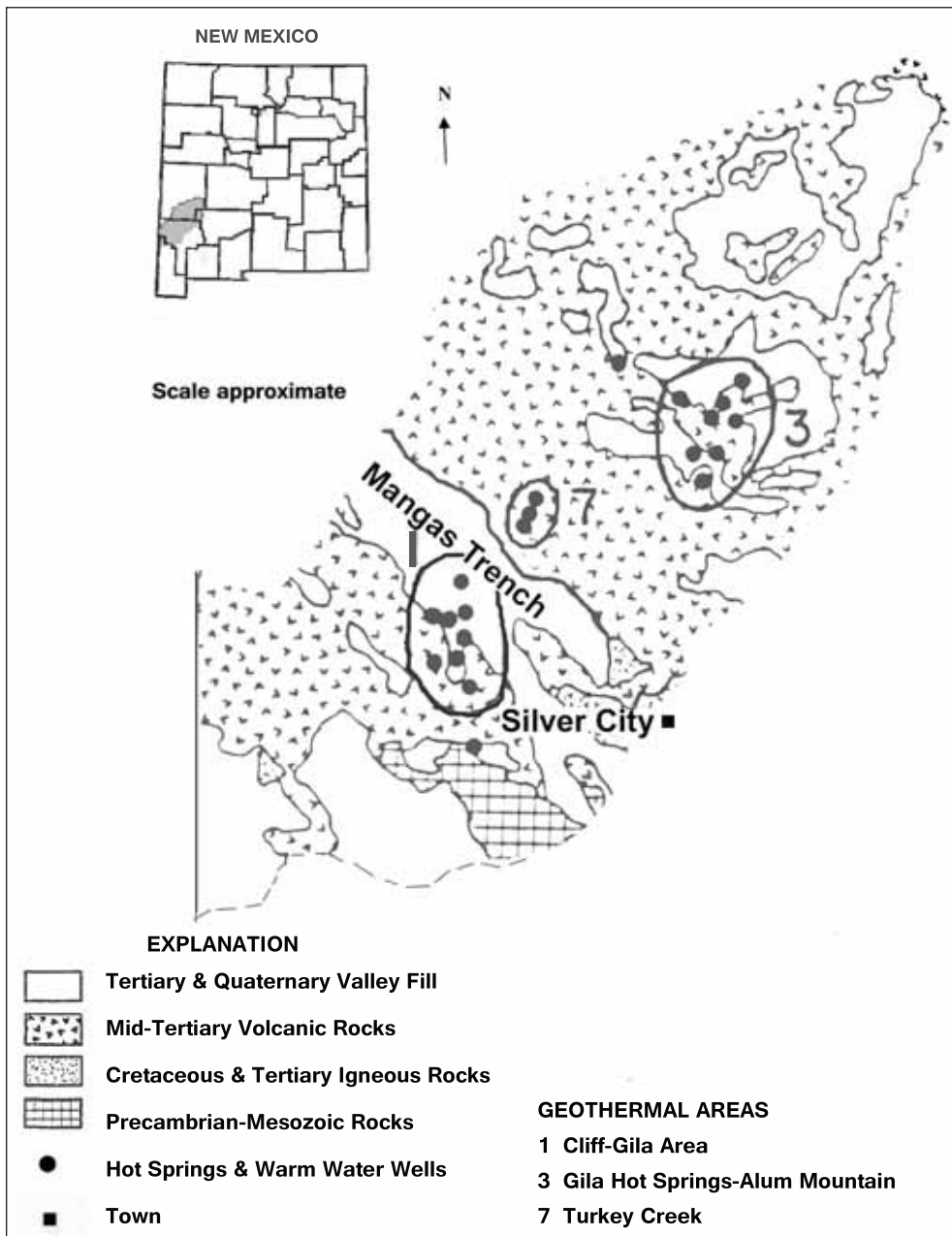


Fig. 3. Geologic and geothermal sketch map of the Upper Gila River Basin. Map scale is close to that of the geologic sketch map, figure 4. (Adapted from Elston 1981, 4.)

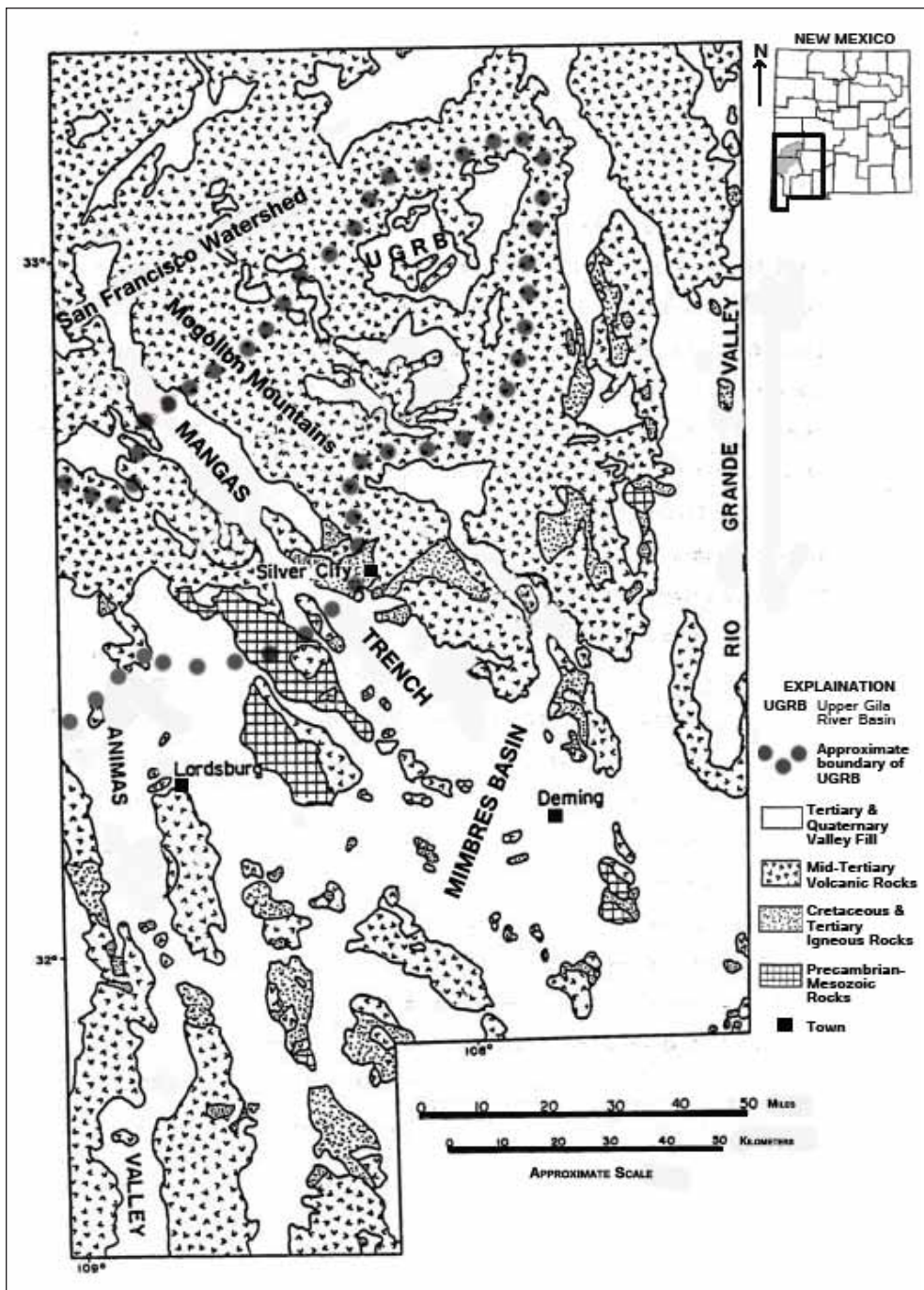


Fig. 4. Geologic sketch map showing the regional extent of the Mangas Trench.
(Adapted from Elston 1981, 4.)

San Francisco Watershed. Study by Mack and Stout (2005) indicated that the structure is a half graben or depressed crustal unit bounded on the eastern side by faults that uplifted the Mogollon Mountains. The Duck Creek, Gila River, and Mangas Creek valleys (fig. 1), marking the northwestern border of the structure, have a long history of hot spring (geothermal) activity, beginning at least 5 million years ago in the Pliocene (fig. 3).

Infilling of rock and sediment from active volcanism, fault-

ing, folding, mass movement, and alluviation in the river basin occurred sporadically since the Basin and Range mountain building began in the early Miocene. Continuing through the Pliocene to Middle Pleistocene, the basin fill material, as shown in the stratigraphic sections (fig. 5), was derived mainly from large catchments of the Mogollon Mountains (fig. 6). Alluvial fans, alluvial-fluvial sediments, and lacustrine facies formed prominent regular sequences in the valleys (Mack and Tabor 2008; Mack and Stout 2005; Leopoldt 1981). Leopoldt (1981) found fossil horse teeth that indicated an early Miocene age (20–23 million years ago) for older sediments in the Cliff/Gila area. The biostratigraphic age determinations were supported by the age of volcanic ash beds. Mack and Stout (2005) determined that much younger sediments of the ancestral lake Buckhorn (fig. 6) near Cliff and Buckhorn were no older than late Miocene (about 5.6 million years ago), although most sediments were Pliocene in age (about 2 million years ago).

The basin fill material is included in the designations of the Gila Group, Gila Conglomerate, and Gila Formation. According to Connell et al. (2005), Hawley et al. (2000), and Leopoldt (1981), the Gila Conglomerate was elevated to group status, subdivided into formations, and expanded to include a wide variety of basin and valley fill sequences west of the Rio Grande, lying 112 kilometers (70 miles) east of the basin (fig. 4). The

U.S. Geological Survey (2012) indicated that the nomenclature is still being developed.

Approximately three million years ago ephemeral lakes (e.g., lake Buckhorn [fig. 6]) and marshes expanded over the central portions of the Mangas Structural Basin (Mack and Stout 2005; Hawley et al. 2000; Leopoldt 1981). Deep valley and canyon incision occurred in the uplands. The lakes, marshes, deltaic and alluvial plains, and streams formed a segmented series within multiple closed basins, i.e., no drain-

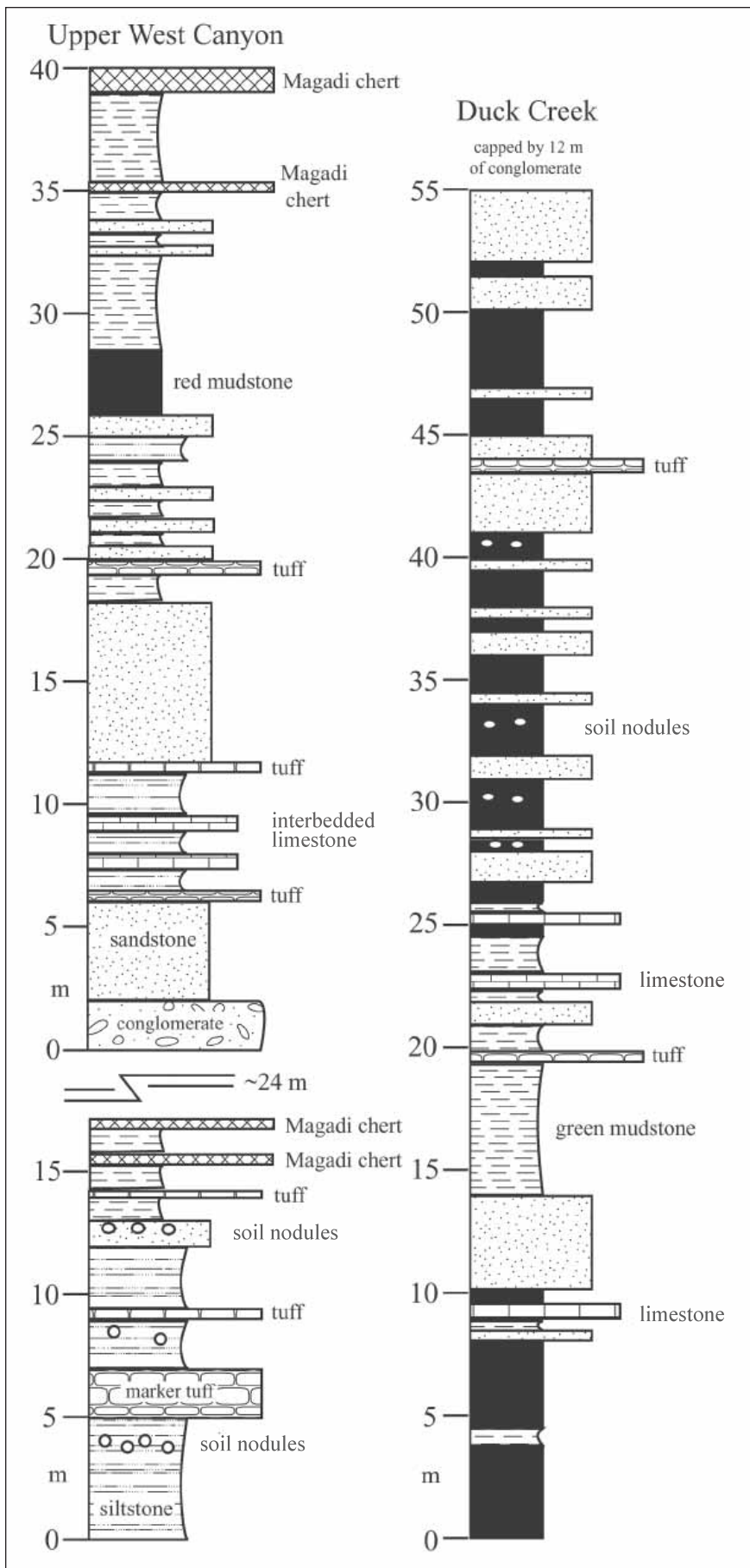


Fig. 5. Logged sections of the Gila Formation near Buckhorn. See figure 6 for location of the sample sites.
(Adapted from Mack and Tabor 2008, 161.)

age outlet. Coalescing alluvial fans and playa flats fringed the region. Sedimentation in the lakes and playas marked the end of major aggradation in the Gila Basin around 1.5 million years ago (Hawley et al. 2000).

About one million years ago the lakes, streams, and marshes shaping the segmented drainage assemblage began to interconnect and integrate. The integrated segments resulted in the advancement of drainage into the Duncan Basin in southeastern Arizona (Connell et al. 2005; Leopoldt 1981; Morrison 1965). This was the beginning of the Gila River. Greg Mack (personal communication, January 31, 2009) suggested that, although the exact time of integration remains very poorly controlled, it may be similar to that of the neighboring river system, the Rio Grande, occurring 800,000 years ago. Connell et al. (2005) concluded that the process of drainage integration occurred during basin filling and spillover across slowly subsiding basins. Stream capture from other adjacent internally drained basins probably played an important role in the progression of the integration. Although not well documented, river integration does not appear to coincide with major climatic events, but it might be due to progressive filling where aggradation was faster than the slow or inactive subsidence of the basins. Further description of river integration is in the following subsection, "Climate."

The river and its tributaries subsequently developed the distinctive basin features of deeply entrenched canyons surrounded by open mountain plateaus and mesas, nearly flat valleys, elongated alluvial plains, and prominent terraces. Today's stepped sequences of alluvial and pediment terraces may reflect canyon carving, downcutting of the channel, and alternating river levels during a wetter climate of the Pleistocene (KellerLynn 2008).

Basin Controls

The Gila River Basin is a physical system that follows an evolutionary development in response to local conditions over geologic and historical time (Wittler et al. 2004;

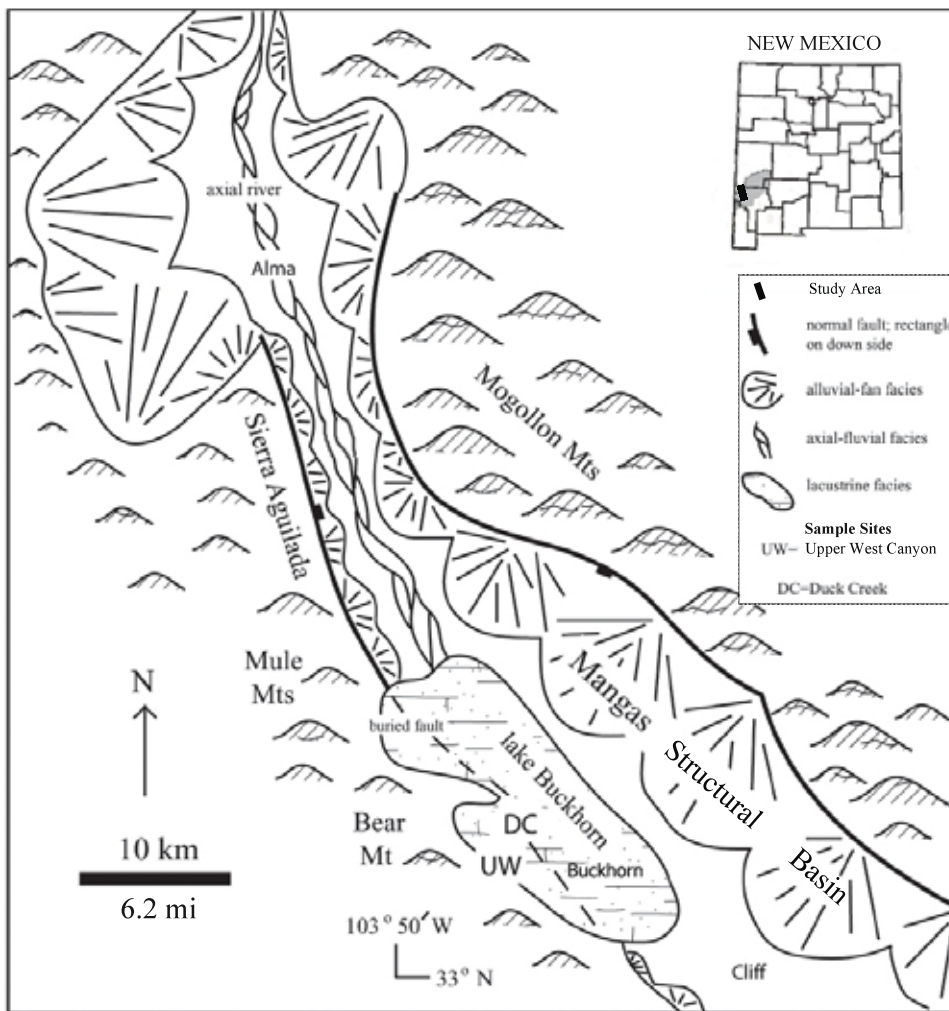


Fig. 6. Pliocene paleogeographic and paleotectonic map of the Mangas Structural Basin study area. Locations of the sample sites (logged sections in figure 5) are shown. (Adapted from Mack and Tabor 2008, 160.)

Hawley et al. 2000; Trush et al. 2000). Overall, four major factors have governed the development and ongoing transformation of the basin: (1) tectonics, (2) lithology, (3) climate, and (4) human activity over the last century.

Tectonic geology encompasses the faulting, folding, metamorphism, igneous intrusion, and volcanism occurring in the region of the basin beginning about 2 billion years ago (Hawley et al. 2000; Woodward 1970). The tectonic processes, described in the previous section, provided the basin's relief (difference in elevation of the land surface), which is a driving mechanism for physical and chemical weathering, mass wasting, erosion, incision, and sedimentation. Volcanism and associated fracture patterns may have controlled the channel courses, particularly the Middle Fork (James Ratté, personal communication, December 16, 2008). According to Ratté (2008) and Elston (1981) the location of geothermal areas (fig. 3) suggested that hot-spring occurrences are structurally controlled by the intersection of northwest-trending Basin and Range faults and volcanic ash-flow tuff.

Since the Pliocene and early Pleistocene the basin has been relatively quiescent, with very low basin subsidence

(Hawley et al. 2000; Leopoldt 1981). The upper part of the basin fill is largely non-deformed, indicating no tectonic activity since its deposition. The youngest faulting documented by Leopoldt (1981) is on a Middle Pleistocene (~ 1 million years ago) pediment terrace surface. Taggart and Baldwin (1982) described a series of magnitude-5.5 earthquakes occurring in 1938–1939 near the Middle Fork in the Mogollon Mountains.

Lithology comprises the types and mineralogical composition of surface and subsurface rocks, which greatly influence the landscape and drainage patterns. Rocks in the Upper Gila River Basin range in age from Quaternary to Precambrian (fig. 3). The dominant rocks include widespread volcanic extrusions of dark-colored basalt and andesite, broad volcanic ash-flow tuff sheets, and local magmatic intrusion of granite (Hawley et al. 2000; Elston 1981; Leopoldt 1981; Trauger 1972). Volcanism was followed intermittently by differential physical and chemical weathering and erosion, producing an array of sedimentary material. The rocks weathered and disintegrated in varying degrees as evidenced by the wide assortment of coarse- to fine-grained sediment and rock debris, volcanic ash, and lacustrine deposits within the basin system (fig. 5). High relief and large catchments (fig. 6) provided the sediment yield necessary to sustain broad alluvial fans and fill the lower drainage (Mack and Stout 2005).

The Gila Group in the Upper Gila River Basin is 700 meters (2,300 feet) thick in some areas and composed of clastic sediment, conglomerate, well-consolidated to unconsolidated alluvium, alluvial fan deposits, and colluvium (Mack and Stout 2005; Leopoldt 1981). Layers and lenses of lake clays, eolian sands, volcanic ash, lava rock, sandstone, mudstone, and limestone occur locally. The Gila Group and local volcanic layers function as an important and extensive groundwater aquifer system in the region (Hawley et al. 2000).

Climate includes all aspects of precipitation (type, timing, distribution, rate, duration) and temperature over time. Climate is a particularly significant factor controlling the (1) hydrologic character of the basin, (2) biodiversity that can stabilize or modify the terrain, and (3) quantity of sediment delivered to and carried by the channels.

Topographic features and the geographic location of the Upper Gila River Basin create steep gradients in tempera-

ture and precipitation across the desert and mountain environments. Climate conditions range from arid to subhumid, although semiarid conditions prevail. According to records at the National Weather Service, Santa Teresa, New Mexico, the average annual precipitation at lower elevations is 23 centimeters (9 inches). This increases to over 51 centimeters (20+ inches) at higher elevations. Approximately half of the precipitation occurs during summer thunderstorms. The remaining precipitation occurs as rain or snow during the fall and winter months, and usually less during the spring. Average annual evaporation rates (based on surface water pan evaporation) are reported by the National Weather Service to be as high as 2.7 meters (108 inches) at lower elevations and half that rate at elevations above 2,130 meters (7,000 feet).

Variable seasonal precipitation and flash flooding occur during the monsoon season, from roughly mid-June through mid-September. The monsoonal rains occur when winds come from a more south-southeast direction, importing moisture from the tropical eastern Pacific Ocean, Gulf of California, and Gulf of Mexico. Variable drainage discharge rates and high levels of sediment-filled runoff commonly occur during precipitation events. Precipitation amounts can vary widely from year to year due to the basin's location with respect to large-scale atmospheric circulation and monsoonal flow.

Climate change over the last several million years has impacted the basin development. During the late Pliocene and Pleistocene, glaciation in the northern U.S. resulted in a cooler, wetter climate, corresponding to the pluvial (rainy) stages in the southern non-glaciated regions such as the Gila Basin. The pluvial stages produced lake expansion and ponding in structural depressions or bolsons (Connell et al. 2005; Hawley et al. 2000). In the northern area of the Gila Basin, rock glaciers were active in the Gila Wilderness and Mogollon Mountains (field work by the author and Glenn Cress, September 2000; Blagbrough 1994). During the interpluvial stages, valleys were excavated and water bodies generally diminished in size.

Studies of the pluvial and interpluvial stages in the Upper Gila River Basin indicated that drainage development does not appear to be related to major climatic events (Douglass et al. 2009; Connell et al. 2005; Hawley et al. 2000). Mechanisms of the progressive integration of the Gila River drainage are not clearly understood, although climatic shifts (oscillations) might be a major factor affecting fluvial processes. According to studies by Connell et al. (2005), valley incision might have been driven by an increase in frequency and amplitude of climate shifts during the Pliocene and Pleistocene. Paleo-environmental factors and a slowly subsiding basin may also have played a role in augmenting climate shifts. Douglass et al. (2009) concluded that the closed basins were integrated through fluvial overflow or flooding across topographic highlands as active tectonism waned. Hawley et al. (2000) noted that, while tectonism was influential, climatic shifts over the past 2.5 million years played a major role in integrat-

ing the internally drained lakes and streams, ultimately forming a through-flow river system.

Gutzler's (2007) climate studies showed that New Mexico is warmer now than at any time in the last century. Many climate models using data for the last 30–50 years indicated that the western U.S. may be an epicenter of warming, second to the Arctic. Using numerous climate models, David Gutzler (personal communication, June 5, 2008) summarized the effects of modern climate change on the Southwest, including the Gila Basin. The chief model-based predictions were increased temperature, higher evapotranspiration (soil evaporation and plant transpiration), reduced or no mountain snowpack, lower streamflow, and more severe episodic droughts. Because regional precipitation has been highly variable, no trends in precipitation were denoted by the models.

Human activity over the last several thousand years, excluding the last century, was minimal in the basin, reflecting sparse populations with low technology located mainly near drainages (Sandor et al. 2008; Soles 2003). Many Mimbres-culture villages were found in the area. Ancient Native American remnants from the 13th and 14th centuries are protected within the Gila Cliff Dwellings National Monument near the confluence of the Middle and West Forks of the Gila River (KellerLynn 2008; National Park Service 2001).

Over the last century human activity has increased in intensity. Land-use practices such as livestock grazing, timber harvesting, mining, recreation, fire suppression, river management practices, and transportation corridors have created substantial landscape changes. Excessive grazing has been associated with a decrease in vegetative ground cover, nutrient dispersion, soil compaction, arroyo or channel entrenchment, and bank erosion (Milchunas 2006; Ohmart 1996). Timber harvesting has exposed large tracts of land to erosion and rapid runoff, thereby decreasing the volume of water and topsoil remaining on-site. Mining roads and, later, fire roads and recreational roads and trails have reduced soil infiltration and often functioned as conduits for rainfall and snowmelt runoff, with ensuing soil erosion. Livestock water tanks and irrigation diversions have also modified drainage patterns.

Levees, diversion dams, and bridges have affected river flow, sediment transport, nutrient dispersion, and floodplain inundation and scour to varying degrees (Trush et al. 2000). According to the work by Wittler et al. (2004) and Klawon and Levis (2003), the probable cause of geomorphic change in channel and floodplain morphology in the Cliff/Gila valley was levee construction/failure and river diversions. Similar conclusions were made by Soles (2003, 2008) in an investigation of the human and natural impacts on the Cliff/Gila valley from 1880 to 2000. Soles (2003) concluded that levee repair and restoration activities may have had undesirable consequences, e.g., increased channel incision, bank instability, loss of upstream irrigation diversion points, and loss of river bank-side vegetation. Historical data and groundwater monitoring results indicated a complex interplay between natural

and anthropogenic processes within the valley's hydrologic system (Soles 2008). Overall the river valley's inherent resiliency appeared to be weakened, in part, by human impacts on the land and water. Likewise, work by Waite Osterkamp (personal communication, Gila Science Forum, Southwest New Mexico Stakeholders Group, June 3, 2009) concluded that stress applied to any part of the drainage, e.g., water diversion, will ultimately affect all biophysical processes throughout the watershed.

Thomas and Pool (2007) studied streamflow in the San Pedro River, a tributary to the Gila River in eastern Arizona. They concluded that precipitation and man-induced factors such as seasonal groundwater pumping, runoff-detention structures, timber harvesting, and cattle grazing were all factors in the decreasing trend in total streamflow from the 1930s to 2000. Based on studies such as this, further monitoring of the Upper Gila River Basin's response to human activities is required to determine the significance of man-induced processes.

Data from many climate studies like those of Gutzler (2007) in New Mexico and suites of climate models were assessed by a collaboration of interdisciplinary scientists (Schlesinger et al. 2007). The scientists, from different regions of the world, agreed that climate change is having an impact on the earth and concluded with 90 percent certainty that human activity is the driving mechanism of change.

Retrospective studies of New Mexico watersheds from 1970 to 2006 were done by Enquist and Gori (2008a, 2008b). The studies concluded that human-induced climate change is having an effect on the landscapes and ecosystems today and for at least the last 15 years. Their landscape-level studies analyzed trends in an ecologically relevant climate variable (combined temperature-precipitation variable) and snowpack. Results confirmed that the entire state, particularly mountain ranges, experienced a significant increase in mean annual temperatures and a significant decline in snowpack. An exception to this trend included the mountainous habitats around the headwaters of the Gila River and three other mountainous sites in the state. Here, the mean temperatures and snowpack remained relatively unchanged.

It appears intuitive that vegetation is a major controlling factor in watershed development and channel stability. However, research by Millar (2006), Schumm (2005), Trush et al. (2000) and Schumm and Lichty (1965) suggested that vegetation can have a great or negligible impact depending on site-specific conditions. It may influence local channel form as seen by agricultural fields along portions of the Gila alluvial channel near the town of Cliff. Work by Kathy Whiteman (personal communication, February 2, 2009) indicated that nonnative tamarisk or salt cedar (*Tamarix chinensis* Lour.) has modified the channel and floodplain form along the East Fork. Whiteman's study showed that cattle grazing, removal of apex predators, and removal of beavers have altered the river flow regimes, thereby encouraging tamarisk invasion with subsequent changes in riverine morphology.

Drainage

The Upper Gila River drainage is a major contributor to the Colorado River Basin. The length of the perennial (permanent or continuous) river from the Middle Fork to the Arizona–New Mexico state line is 228 kilometers (142 miles), while the entire length of the Gila River is 1044 kilometers (649 miles). The main tributaries range from perennial to intermittent (discontinuous) flow.

Bedrock channels, mainly in the northern part of the basin, are structurally controlled, i.e., the drainage is controlled by bedrock fractures, faults, and local intrusive rocks. The entrenched meanders contain riffles and pools, and the bedrock terraces form near-vertical cliffs with heights of up to 600 meters (2000 feet; fig. 7). The canyon channels form pronounced meandering patterns under low flow conditions, as shown in figure 8a. Several bedrock channel sections have evolved within box canyons (steep-walled gorges of limited extent) in the central and lower river reaches: Upper Box (northeast of Cliff/Gila); Middle Box (Redrock, NM); Lower Box (east of Virden, NM).

Wide valleys with alluvial channels are found in the south-central part of the basin, e.g., near Cliff/Gila, Redrock, and Virden. The river is bordered by terraces and the streamflow is often braided or anastomosing, with multiple sinuous channels under low flow conditions (fig. 8b; Soles 2008; Mussetter Engineering 2006; Wittler et al. 2004; Hawley et al. 2000; Leopoldt 1981). Stepped alluvial terraces and pediment surfaces shown in figure 9 are common in the south-central part of the basin. Migration and partial backfilling of the river channel over time have resulted in suites of massive terrace deposits and valley fans forming insets on the valley fill (fig. 10). Study by Mussetter Engineering (2006) documented geomorphic and hydrologic changes in the Gila River from the downstream boundary of the Gila Wilderness Area (~16 kilometers [10 miles] north of Cliff) to the Arizona–New Mexico state line.

Today, prevailing semiarid climatic conditions produce highly variable annual streamflow (table 1), which is a function of precipitation, overland flow, shallow groundwater inflow, and springs. Peak streamflow usually occurs during the monsoonal months and a lesser peak occurs during the winter snowmelt. Strong variability of streamflow over short time intervals is the norm, as exhibited in the three-year peak flow oscillations of the Gila River near Redrock (fig. 11).

The modern Upper Gila River remains dynamic, with episodic destruction of bordering terraces through rapid shifts in the flow direction of the main channel. An important determinant of the alluvial channel is the occurrence of infrequent large-magnitude floods that cause erosion, channel widening, channel shifting, and diversion. Pazzaglia and Hawley (2004) concluded that incision of the fluvial system is the most important geomorphic process currently shaping the landscape of the basin. Channel incision allows preservation of extensive terraces and piedmont surfaces, and provides a source of sediment for alluvial aggradation as well as eolian sand and silt.



Gila Sapillo Confluence
Map Created January 2009
DOQQ from 2005 New Mexico
Statewide Orthophotography Project

0 200 400 800 Meters



Fig. 7. Entrenched bedrock channel near the Gila River/Sapillo Creek confluence.
(From New Mexico Resource Geographic Information System Program 2005.)

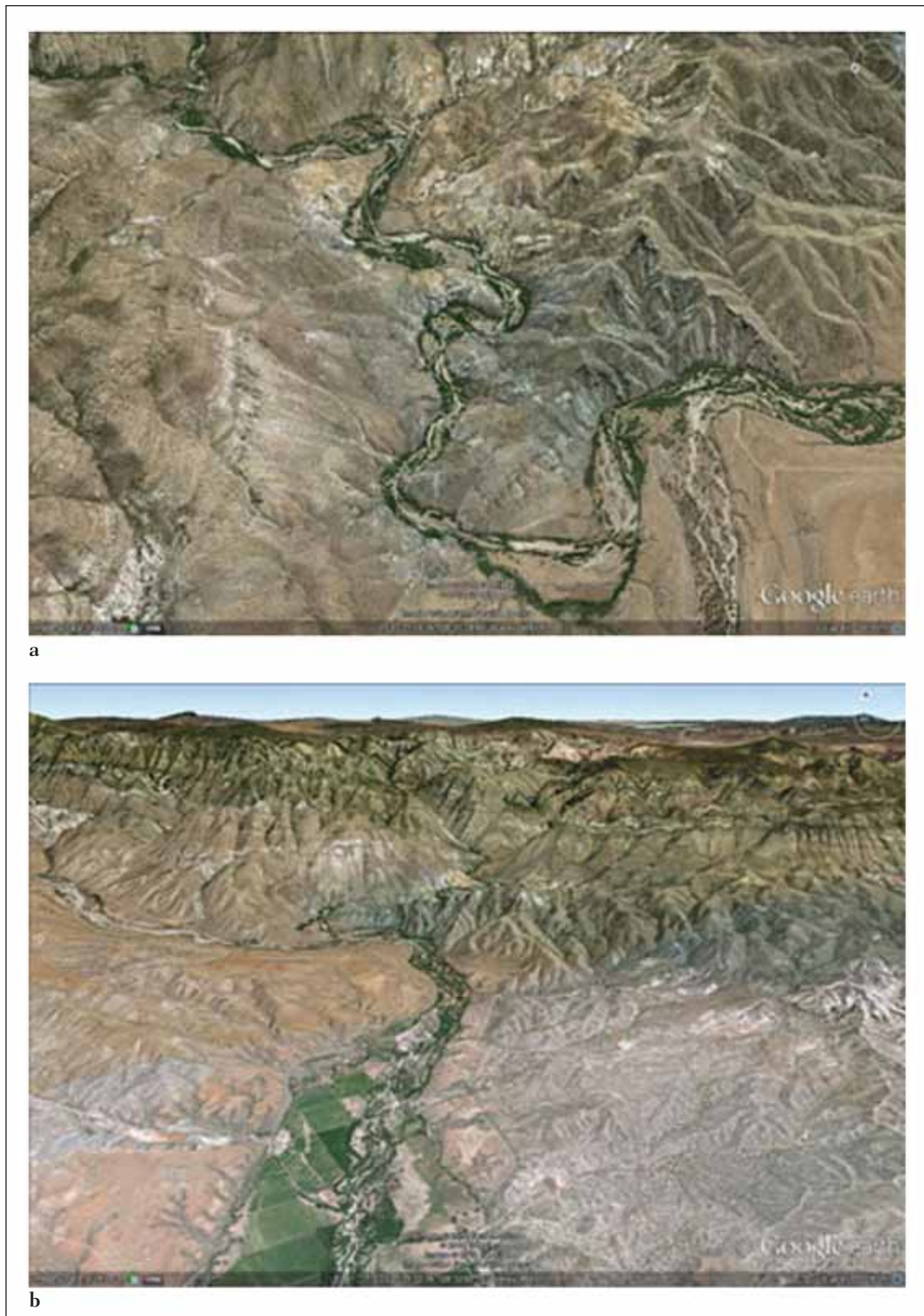


Fig. 8. Gila River flow in the bedrock canyon and open valley. a: Low flow meander belts in the bedrock canyon channel under low flow conditions north of Cliff/Gila; b: Anastomosing channel under low flow conditions in the broad Cliff/Gila valley. (From Farm Service Agency 2011.)

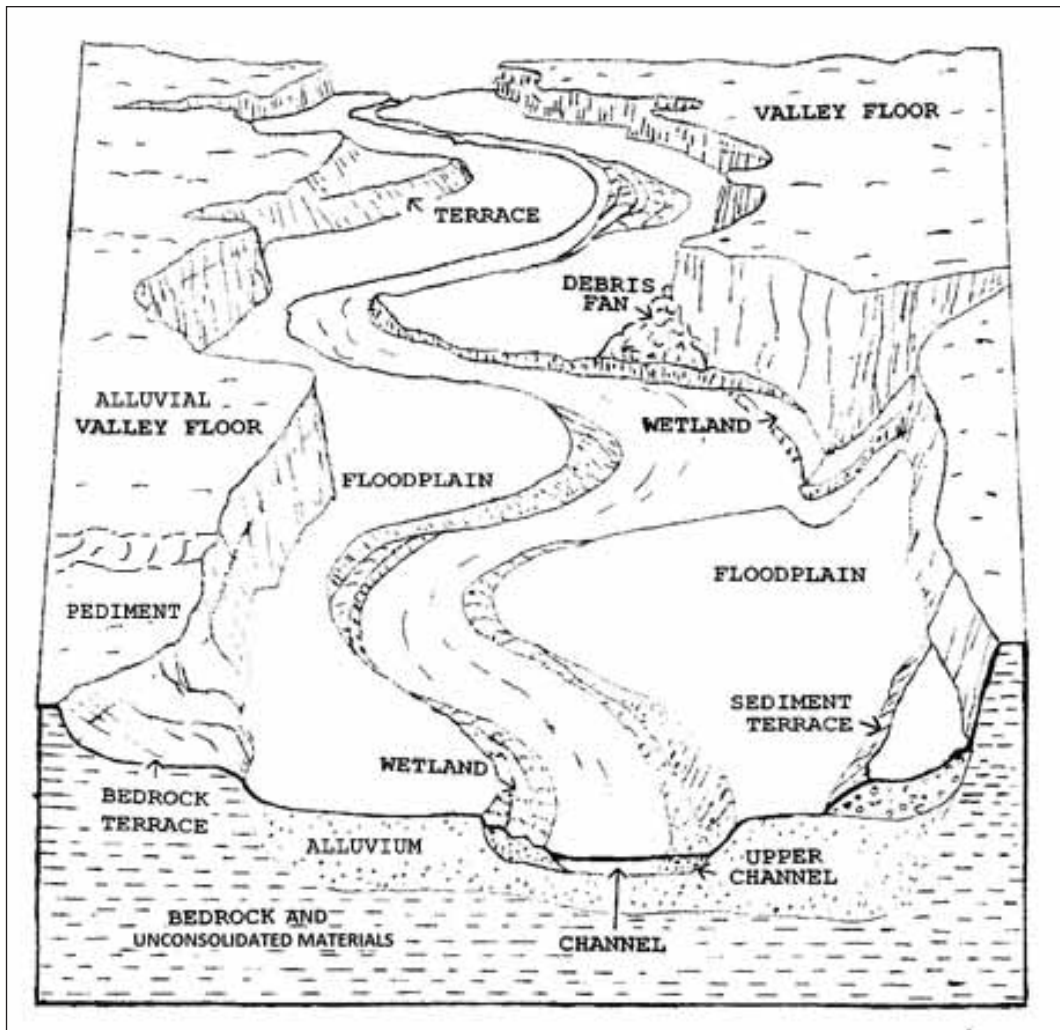
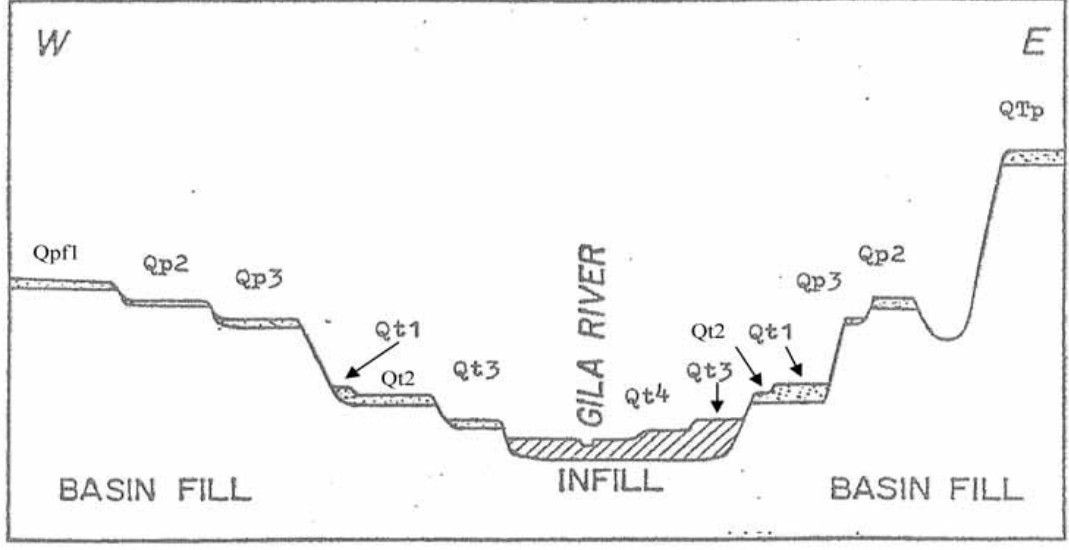


Fig. 9. Plan view of alluvial channel and valley floor. (Adapted from Love 1983, 200.)

Fig. 10. Cross-sectional diagram of the Upper Gila River gravel deposits. Increased height above the river correlates with increased age. The cut and fill relations of the terraces are not depicted. (Adapted from Leopoldt 1981, 62.)



Q = Quaternary
 T = Tertiary
 t = stream terrace
 p = pediment
 pf = fan pediment

Table 1. Annual stream flow discharge at the Gila River station near Gila, NM from 1928 to 2010. Incomplete data were used for statistical calculation.

(From U.S. Geological Survey 2010.)

Water Year: WY		Discharge, cubic feet per second: CFS			
WY	CFS	WY	CFS	WY	CFS
1928	111.5	1956	47.8	1983	279.7
1929	109.1	1957	110.4	1984	190.2
1930	124.4	1958	216.7	1985	422.6
1931	154.0	1959	66.5	1986	211.8
1932	196.0	1960	145.8	1987	176.6
1933	114.3	1961	62.1	1988	264.4
1934	68.8	1962	215.3	1989	89.5
1935	98.5	1963	142.1	1990	80.5
1936	95.4	1964	85.2	1991	308.6
1937	218.6	1965	114.8	1992	331.5
1938	100.0	1966	267.0	1993	428.4
1939	90.1	1967	85.3	1994	75.7
1940	131.4	1968	299.3	1995	314.0
1941	378.3	1969	72.1	1996	87.2
1942	158.8	1970	72.2	1997	211.0
1943	84.0	1971	54.8	1998	204.1
1944	80.8	1972	197.5	1999	103.1
1945	127.9	1973	431.2	2000	50.6
1946	64.5	1974	63.2	2001	156.2
1947	72.1	1975	229.1	2002	59.3
1948	92.1	1976	110.1	2003	66.5
1949	329.3	1977	83.8	2004	107.1
1950	66.1	1978	155.9	2005	346.1
1951	51.4	1979	476.9	2006	186.5
1953	70.8	1980	141.9	2007	151.1
1954	69.6	1981	72.5	2008	195.2
1955	70.2	1982	134.0	2009	78.2

Grant County, New Mexico Hydrologic Unit Code 15040001

Gila River near Gila, NM site # 09430500

Latitude 33°03'41.41", Longitude 108°32'14.59" NAD83

Drainage area 1,864 square miles; Contributing drainage area 1,864 square miles

Gage datum 4,654.80 feet above sea level NGVD29

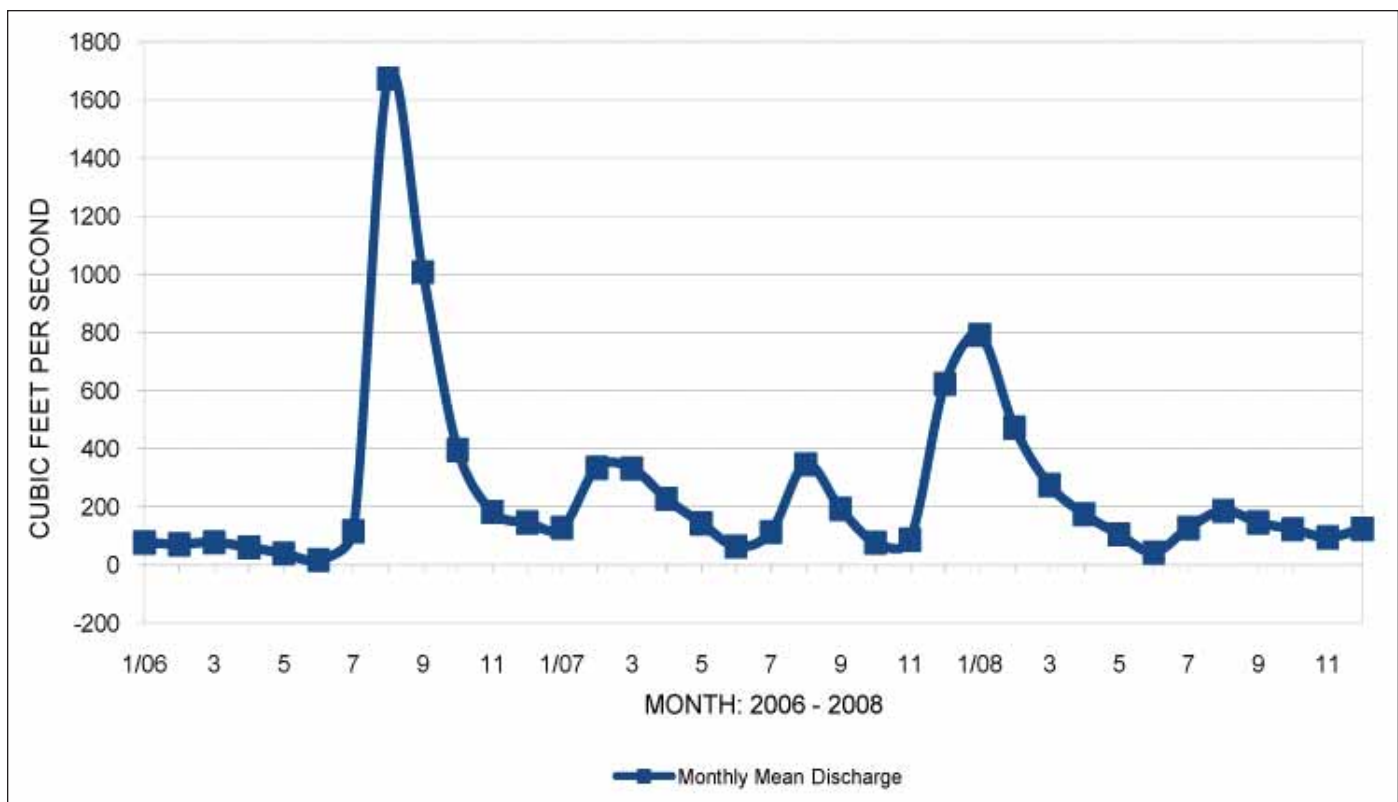


Fig. 11. Gila River 2006–2008 monthly discharge rates near the Redrock station, NM. Note the high monsoonal peak flow in 2006. (From U.S. Geological Survey 2011.)

Summary and Conclusions

The Upper Gila River Basin is drained by the last undammed mainstem river in New Mexico. The headwaters of the river drain the northern, non-glaciated highlands and flow through deep canyons. Continuing southwest, the drainage enters the lowlands of broad plains, linear mountain ranges, and alluvial valleys before crossing into Arizona and joining the Colorado River near Yuma, Arizona. Seven highly diverse ecosystems are sustained in this semiarid zone of southwestern New Mexico: Rocky Mountain subalpine forest, mixed conifer forest, ponderosa pine/savanna grassland, pinyon-juniper woodland, Madrean oak woodland, riparian wetland, and Chihuahuan desert grassland. The predominant land-use/land-cover categories in the basin are the expansive forests and rangeland. Livestock grazing, recreation, timber harvesting, and mining are the main land uses.

Three-quarters of the basin lies within the Datil-Mogollon section of the Transition Zone physiographic province. This province contains elements of the Colorado Plateau province, lying to the north of the basin, and the Mexican Highlands section of the Basin and Range province, encompassing the southern part of the basin. Characteristics of the Colorado Plateau include igneous intrusive magma and extrusive volcanic material, as well as relatively flat-lying beds. The Basin and Range is highly deformed with features resulting from faulting, folding, volcanism, and magmatic intrusion over time.

The Mangas Structural Basin crosses the Gila Region from the northwest to the southeast and began forming around 20–22 million years ago during the development of the Basin and Range. The structure filled with sediment and rock debris from extensive volcanism, faulting, folding, and mass movement in the bordering Mogollon Mountains. Shallow lakes, marshes, and discontinuous streams began forming over the central portions of the region.

About one million years ago the water bodies and channels integrated and drained to the southwest, forming the Gila River. The drainage system generally evolved into a broad transition of entrenched canyons in the northern area to alluvial channels and distinctive stepped terraces in the southern area.

Tectonic activity, lithology, climate and, over the last century, human activity have controlled the form and evolution of the river basin. Tectonic processes, e.g., faulting, folding, volcanism, and magma intrusion, provided the river basin's overall relief and structural forms of entrenched canyons and mountain ridges. The basin reflects different tectonic behavior of both the Basin and Range and Colorado Plateau provinces.

Lithology encompasses the mineralogical composition of the rocks and sediment within the basin. Highly variable rock types were formed by widespread volcanism and intrusion, followed intermittently by weathering and erosion.

Climate is a significant factor controlling the basin's hydrology and sediment movement, as well as vegetation and wildlife. Although the mechanisms of climate oscillations are not clearly understood, drainage integration approximately one million years ago was probably related to fluvial episodes linked to the frequency and amplitude of climatic shifts during Pliocene-Pleistocene time. Today's landscape reflects the ongoing changes of geomorphic processes acting within the context of climate change over the last several million years.

Although incision of the fluvial system is considered to be the main geomorphic process shaping the basin landscape today, a relatively new basin stress, in geological terms, is affecting the basin to an uncertain degree: human activity and subsequent climate change. The synergistic effects related to disturbance from man-induced processes and climate change on the land and water resources are complex. Together, the cumulative effects of human activity (e.g., mining, grazing, logging, recreation) and climate impact (warmer temperatures and reduced snowpack) appear to be impacting the diverse ecosystems to an uncertain degree, e.g., modifying the topography, sedimentation patterns, nutrient dispersion, rates of streamflow, and flood levels in the basin. Further changes in the basin hydrology may occur in the future if diversions are implemented within the context of the 2004 Arizona Water Settlements Act.

The question remains: Can the basin system be resilient to the current and predicted climate change and natural resource management? It is imperative that river managers and public land policymakers bear in mind the crucial fluvial assumption: Native species (plants and wildlife) have evolved with the natural water flow regime over eons of time. Violating this assumption, e.g., water diversion, may result in hydrologic, biologic, or geomorphic changes that are difficult to reverse. The extent of future impacts from uncertain changing conditions will most likely hinge on the degree of adaptability of the basin's diverse ecosystems.

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References Cited

- Bates, R. L., and J. A. Jackson, eds. 1984. *Dictionary of Geological Terms*. Garden City, NY: Anchor Press/Doubleday.
- Blagbrough, J. W. 1994. Photointerpretation of Late Pleistocene-Holocene Rock Glaciers on Sacaton Mountain and Escudilla Mountain, Datil-Mogollon Upland, West-Central New Mexico and East-Central Arizona. In *Mogollon Slope (West-Central New Mexico and East-Central Arizona)* (Field Conference Guidebook 45), ed. R. M. Chamberlin, B. S. Kues, S. M. Cather, J. M. Barker, and W. C. McIntosh, 315–21. Albuquerque: New Mexico Geological Society.
- Brown, D. E. 1994. *Biotic Communities: Southwestern United States and Northwestern Mexico*. Salt Lake City: University of Utah Press.
- Chapin, C. E., W. C. McIntosh, and R. M. Chamberlin. 2004. The Late Eocene-Oligocene Peak of Cenozoic Volcanism in Southwestern New Mexico. In *The Geology of New Mexico: A Geologic History* (Special Publication 11), ed. G. H. Mack and K. A. Giles, 271–93. Albuquerque: New Mexico Geological Society.
- Chapin, C. E., M. Wilks, and W. C. McIntosh. 2004. Space-Time Patterns of Late Cretaceous to Present Magmatism in New Mexico—Comparison with Andean Volcanism and Potential for Future Volcanism. *New Mexico Bureau of Geology and Mineral Resources Bulletin* 160:13–40.
- Connell, S. D., J. W. Hawley, and D. W. Love. 2005. Late Cenozoic Drainage Development in the Southeastern Basin and Range of New Mexico, Southeasternmost Arizona, and Western Texas. In *New Mexico's Ice Ages* (New Mexico Museum of Natural History and Science Bulletin No. 28), ed. S. G. Lucas, G. S. Morgan, and K. E. Zeigler, 125–50. Albuquerque, NM: Museum of Natural History and Science.
- Dick-Peddie, W. A. 1993. *New Mexico Vegetation: Past, Present, and Future*. Albuquerque: University of New Mexico Press.
- Douglass, J. N., M. Meek, R. I. Dorn, and M. W. Schmeckle. 2009. A Criteria-Based Methodology for Determining the Mechanism of Transverse Drainage Development, with Application to the Southwestern United States. *Geological Society of America Bulletin* 121:586–98.
- Elston, W. E. 1981. *Assessment of the Geothermal Potential of Southwestern New Mexico*. New Mexico Research and Development Institute Report, EMD 2-67-2123.
- Enquist, C., and D. Gori. 2008a. *A Climate Change Vulnerability Assessment for Biodiversity in New Mexico, Part I: Implications of Recent Climate Change on Conservation Priorities in New Mexico*. The Nature Conservancy, New Mexico. Accessed 6/1/2011 at http://nmconservation.org/downloads/multi/category/climate_change/.
- . 2008b. *A Climate Change Vulnerability Assessment for Biodiversity in New Mexico, Part II: Conservation Implications of Emerging Moisture Stress Due to Recent Climate Changes in New Mexico*. The Nature Conservancy, New Mexico. Accessed 6/1/2011 at http://nmconservation.org/downloads/multi/category/climate_change/.
- Farm Service Agency. 2011. Image Terra Metrics, GeoEye. U.S. Department of Agriculture, Farm Service Agency. Accessed 8/7/2012 at [http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai; 33°01' 35.22" N 108°32' 00.25"W; 33°01'35.22"N 108°32'00.25"W](http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai; 33°01' 35.22).
- Gutzler, D. 2007. Climate Change and Water Resources in New Mexico, 1–4. In *New Mexico Earth Matters, v. 7.2*. Socorro, NM: New Mexico Bureau of Geology and Mineral Resources.
- Hanson, R. T., J. S. McLean, and R. S. Miller. 1994. *Hydro-Geologic Framework and Preliminary Simulation of Ground-Water Flow in the Mimbres Basin, Southwestern New Mexico*. Water Resources Investigations Report 94-4011. U.S. Geological Survey.
- Hawley J. W., B. J. Hibbs, J. F. Kennedy, B. J. Creel, M. D. Remmenga, M. Johnson, M. M. Lee, and P. Dinterman. 2000. *Trans-International Boundary Aquifers in Southwest New Mexico*, chap.

- 3, "Overview," 13–26, and chap. 8, "Gila River Basin System," 103–9. Technical Completion Report for U.S. Environmental Protection Agency–Region 6 and International Boundary and Water Commission–U.S. Section, Dallas, TX.
- KellerLynn, K., ed. 2008. *Geologic Resource Evaluation Scoping Summary, Gila Cliff Dwellings National Monument, New Mexico*. Unpublished report. Washington, DC: National Park Service.
- Klaus, K. E., J. P. Neuendorf, J. P. Mehl Jr., and J. A. Jackson, eds. 2005. *Glossary of Geology*. Alexandria, VA: American Geological Institute.
- Klawon, J. E., and D. R. Levish. 2003. Geomorphic Response of the Upper Gila River, Arizona and New Mexico, to Levees, Diversion Dams, and Floods. *Congress of the International Union for Quaternary Research* 16:111–12.
- Leopoldt, W. 1981. *Neogene Geology of the Central Mangas Graben, Cliff-Gila Area, Grant County, New Mexico*. Unpublished MS thesis, University of New Mexico.
- Love, D. W. 1983. Quaternary Facies in Chaco Canyon and Their Implications for Geomorphic-Sedimentologic Models. In *Chaco Canyon Country* (American Geomorphological Field Group Guidebook), ed. S. G. Wells, D. W. Love, and T. W. Gardner, 200. Washington, DC: U.S. Department of Interior, National Park Service.
- Mack, G. H. 2004. Middle and Late Cenozoic Crustal Extension, Sedimentation, and Volcanism in the Southern Rio Grande Rift, Basin and Range, and Southern Transition Zone of Southwestern New Mexico. In *Geology of New Mexico: A Geologic History* (Special Publication 11), ed. G. H. Mack and K. A. Giles, 389–406. Albuquerque: New Mexico Geological Society.
- Mack, G. H., and D. M. Stout. 2005. Unconventional Distribution of Facies in a Continental Rift Basin: The Pliocene–Pleistocene Mangas Basin, South-Western New Mexico, USA. *Sedimentology* 52:1187–205.
- Mack, G. H., and N. J. Tabor. 2008. Paleoclimatic Implications of Stable Oxygen and Carbon Isotopes of Lacustrine and Pedogenic Calcite from the Gila Conglomerate (Plio-Pleistocene), Mangas Basin, West-Central New Mexico. In *Geology of the Gila Wilderness–Silver City Area* (Fall Field Conference Guidebook 59), ed. G. H. Mack, J. Witcher, and V. W. Lueth, 159–66. Albuquerque: New Mexico Geological Society.
- McIntosh, W. C., C. E. Chapin, J. C. Ratté, and J. F. Sutter. 1992. Time-Stratigraphic Framework for the Eocene-Oligocene Mogollon-Datil Volcanic Field, Southwest New Mexico. *Geological Society of America Bulletin* 104 (7): 851–71.
- Milchunas, D. G. 2006. *Responses of Plant Communities to Grazing in the Southwestern United States*. U.S. Department of Agriculture, Forest Service RMRS-GTR-169.
- Millar, R. G. 2006. *Influence of Bank Vegetation on Alluvial Channel Patterns*. U.S. Geological Survey, Water Resources Research, 36.4.1109-1118.
- Morrison, R. B. 1965. *Geologic Map of the Duncan and Canador Peak Quadrangles, Arizona and New Mexico*. U.S. Geological Survey Miscellaneous Geologic Investigations Map I-442, scale 1:62,500.
- Mussetter Engineering. 2006. *Geomorphology of the Upper Gila River within the State of New Mexico*. Santa Fe: New Mexico Interstate Stream Commission, MEI Project 05-23.
- National Park Service. 2001. *Gila National Monument Administrative History*. Washington, DC: National Park Service. Accessed 6/1/2011 at www.nps.gov/archive/gicl/adhil/adhil.htm.
- National Weather Service. 2009. *National Weather Service Glossary*. Silver Spring, MD: National Oceanic and Atmospheric Administration, National Weather Service. Accessed 8/25/2012 at <http://w1.weather.gov/glossary/>.
- New Mexico Resource Geographic Information System Program. 2005. Statewide Orthophotography Project, DOQQ. Accessed 6/1/2011 at http://rgis.unm.edu/data_entry.cfm.
- Ohmart, R. D. 1996. Historical and Present Impacts of Livestock Grazing on Fish and Wildlife Resources in Western Riparian Habitats. In *Rangeland Wildlife*, ed. P. R. Krausman, 245–79. Denver, CO: Society for Range Management.
- Pazzaglia, F. J., and J. W. Hawley. 2004. Neogene (Rift Flank) and Quaternary Geology and Geomorphology. In *Geology of New Mexico: A Geologic History* (Special Publication 11), ed. G. H. Mack and K. A. Giles, 407–38. Albuquerque: New Mexico Geological Society.
- Ratté, J. C. 2008. The Early Oligocene Copperas Creek Volcano and Geology along New Mexico Highway 15 between Sapillo Creek and the Gila Cliff Dwellings National Monument, Grant and Catron Counties, New Mexico. In *Geology of the Gila Wilderness—Silver City Area* (Fall Field Conference Guidebook 59), ed. G. H. Mack, J. Witcher, and V. W. Lueth, 129–40. Albuquerque: New Mexico Geological Society.
- Ratté, J. C., D. L. Gaskill, G. P. Eaton, D. L. Peterson, R. B. Stotelmeyer, and H. C. Meeves. 1979. *Mineral Resources of the Gila Primitive Area and Gila Wilderness, Catron and Grant Counties, New Mexico*. U.S. Geological Survey Bulletin 1451.
- Sandor, J. A., J. W. Hawley, R. H. Schiowitz, and P. L. Gersper. 2008. Soil-Geomorphic Setting and Change in Prehistoric Agricultural Terraces in the Mimbres Area, New Mexico. In *Geology of the Gila Wilderness—Silver City Area* (Fall Field Conference Guidebook 59), ed. G. H. Mack, J. Witcher, and V. W. Lueth, 167–75. Albuquerque: New Mexico Geological Society.
- Schlesinger, M. E., H. S. Khesghi, J. Smith, F. C. de la Chesnaye, J. M. Reilly, T. Wilson, and C. Kolstad, eds. 2007. *Human-Induced Climate Change: An Interdisciplinary Assessment*. Cambridge: Cambridge University Press.
- Schumm, S. A. 2005. *River Variability and Complexity*. Cambridge: Cambridge University Press.
- Schumm, S. A., and R. W. Lichty. 1965. Time, Space, and Causality in Geomorphology. *American Journal of Science* 263:110–19.
- Soles, E. 2003. *Where the River Meets the Ditch: Human and Natural Impacts on the Gila River, New Mexico, 1880–2000*. Unpublished MA thesis, Northern Arizona University.
- . 2008. "Where the River Meets the Ditch: Effects on Riparian Regeneration of Floodplain Geomorphology, Floods and Surface Flow Diversion in the Cliff-Gila Valley, New Mexico," in "Natural History of the Gila: A Symposium," ed. K. Kindscher and W. Norris, special issue no. 1, *The New Mexico Botanist*, 68–84.
- Taggart, J., and F. Baldwin. 1982. Earthquake Sequence of 1938–1939 in Mogollon Mountains, New Mexico. *New Mexico Geology* 4:49–52.
- Thomas, B. E., and D. R. Pool. 2007. *Trends in Streamflow of the San Pedro River, Southeastern Arizona, and Regional Trends in Precipitation and Streamflow in Southeastern Arizona and Southwestern New Mexico*. U.S. Geological Survey Professional Paper 1712.
- Trauger, F. D. 1965. Geologic Structure Pattern of Grant County, New Mexico. In *Southwestern New Mexico II* (Field Conference Guidebook 15), ed. J. P. Fitzsimmons and C. L. Balk, 184–87. Albuquerque: New Mexico Geological Society.
- . 1972. *Water Resources and General Geology of Grant County, New Mexico: Hydrologic Report 2*. Socorro, NM: New Mexico Bureau of Mines and Mineral Resources.

- Trush, W. J., S. M. McBain, and L. B. Leopold. 2000. Attributes of an Alluvial River and Their Relation to Water Policy and Management. *Proceedings of the National Academy of Sciences* 97 (22): 1158–63.
- U.S. Environmental Protection Agency. 2006. *Level III Ecoregions of the Continental United States (Revision of Omernik, 1987)*. Map M-1. Corvallis, OR: U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory.
- U.S. Geological Survey. 2007. Geologic Glossary; Water Science Glossary of Terms; U.S. Geological Survey Fact Sheet 2007-3015. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. Accessed 6/1/2011 at <http://www.usgs.gov>; <http://water.usgs.gov/nwsum/WSP2425/glossary.html>; <http://pubs.usgs.gov/fs/2007/3015/index.html>.
- . 2010. Surface Water Data for USA: USGS Surface-Water Annual Statistics. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. Accessed 6/1/2011 at <http://waterdata.usgs.gov/nwis/annual>.
- . 2011. Surface-Water Monthly Statistics for the Nation, USGS 09431500 Gila River Near Redrock, NM. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. Accessed 6/1/2011 at <http://waterdata.usgs.gov/nwis/monthly>.
- . 2012. GEOLEX Database, National Geologic Map Database, URL. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. Accessed 7/5/2012 at http://ngmdb.usgs.gov/ngmdb/ngm_catalog.ora.html.
- Waters, M. R., and C. V. Haynes. 2000. Late Quaternary Arroyo Formation and Climate Change in the American Southwest. *Quaternary Research* 54 (1): 49–57.
- Wittler, R. J., D. R. Levish, J. E. Klawon, R. E. Klinger, B. P. Greimann, and M. R. Delcau. 2004. *Upper Gila River Fluvial Geomorphology Study, Final Report*. Denver, CO: U.S. Department of the Interior, Bureau of Reclamation.
- Woodward, L. A. 1970. Precambrian Rocks of Southwestern New Mexico. In *New Mexico Geological Society, 21st Field Conference*, ed. L. A. Woodward, 27–31. Albuquerque, NM: New Mexico Geological Society.

Glossary

From U.S. Geological Survey 2007; Bates and Jackson 1984; Klaus et al. 2005; National Weather Service 2009

- Aggradation:** The process of building up a surface by deposition of earth materials.
- Alluviation:** The deposit of alluvium along the stream course; aggradation of alluvium.
- Alluvium:** A general term for clay, silt, sand, gravel or similar unconsolidated material deposited during comparatively recent geologic time by the action of running water on a streambed, floodplain, delta, fan or at the base of a mountain. Alluvial streams flow within channels and floodplains composed of alluvium and are unconfined for the most part.
- Andesite:** A dark-colored, fine-grained extrusive igneous rock rich in silica. Andesite forms when volcanic magma cools rapidly, usually at or near the Earth's surface forming crystals that are extremely small.
- Arroyo:** A small, deep, flat-floored channel or gully of an

ephemeral or intermittent stream. An ephemeral stream flows briefly in direct response to precipitation.

- Basalt:** Dark-colored, fine-grained igneous rock, commonly extrusive, composed primarily of calcic plagioclase and pyroxene. Basalt forms when volcanic magma cools rapidly, usually at or near the Earth's surface forming crystals that are extremely small.
- Basin and Range Province:** The physiographic region where the earth's crust and uppermost mantle have been stretched, creating large faults. Along these faults linear mountain ranges were uplifted and flat valleys down-dropped, producing the distinctive topography of the Basin and Range province. The area extends from eastern California to central Utah, and from southern Idaho into the states of Sonora and western Chihuahua, Mexico.
- Block fault:** A type of normal faulting in which the crust is divided into several structural or fault blocks of different elevations and orientations.
- Bolson:** A term applied in the desert regions of southwestern U.S. to an extensive, flat, alluvium-floored basin or depression, almost or completely surrounded by mountains and from which drainage has no surface outlet; internally drained basin.
- Caldera:** A large basin-shaped volcanic depression. A collapse caldera is produced by collapse of the roof of a magma chamber owing to removal of magma by eruption or by subterranean withdrawal.
- Clastic:** Rock or sediment composed principally of broken fragments that are derived from preexisting rocks which have been transported from their place of origin, as in sandstone.
- Colluvium:** General term for loose and incoherent deposits of earth material, usually at the foot of a slope or cliff and brought there chiefly by gravity. Talus and cliff debris are included in such deposits.
- Colorado Plateau Province:** The physiographic region of plateaus, mesas, and deep canyons whose walls expose rocks ranging in age from billions to just a few hundred years old. For much of geologic time, the Colorado Plateau has remained structurally intact and insulated from surrounding geologically active zones, e.g., Rio Grande rift structural deformation. The relatively horizontal nature of the rocks is a major distinguishing feature. Relatively little rock deformation, e.g., faulting and gentle folding, has affected this high, thick crustal block within the last 600 million years. But intrusive rock and volcanic material have modified the southeastern section. The area is roughly centered on the Four Corners region of southwestern United States—western Colorado, northwestern New Mexico, southeastern Utah, and northern Arizona.
- Conglomerate:** Coarse-grained sedimentary rock composed of rounded to sub-angular fragments greater than 2 millimeters in diameter set in a fine-grained matrix of sand or silt and commonly cemented by calcium carbonate, iron oxide, or hardened clay.
- Dome:** An uplifted structure, circular or elliptical in outline, in which the rocks dip gently away in all directions.

Eolian: Pertaining to the wind, especially said of such deposits as loess and dune sand.

Evaporation rate: In hydrologic terms, the quantity of water, expressed in terms of depth of liquid water, which is evaporated from a given surface per unit of time. It is usually expressed in inches depth, per day, month, or year.

Fault: A fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture.

Fluvial: Pertaining to a river or stream.

Geologic Time Chart: See chart below.

Geomorphology: The study of the earth's surface features; the study of the classification, description, nature, origin, and development of landforms and their relationships to underlying rock and structures.

Graben: An elongate, relatively depressed crustal unit or block that is bounded by faults on its long sides. A half-graben is bounded by faults on one side.

Granite: Quartz-rich, crystalline igneous rock formed from magma that has cooled and solidified. When magma cools slowly, usually at depths of thousands of feet, crystals grow from the molten liquid, and a coarse-grained rock forms.

Headwater: The source and the upper part of a stream.

Igneous: Pertaining to rock or mineral that solidified from molten or partly molten material, i.e., from magma. Igneous rocks constitute one of the three main classes into which rocks are divided, others being metamorphic and sedimentary.

Lacustrine facies: Any areally restricted part of a stratigraphic unit that exhibits characteristics of lake sediments, and may include associated lake organic material.

Laramide Orogeny: A time of mountain building when sev-

eral phases extended from late Cretaceous until the end of the Paleocene. Intrusives and accompanying ore deposits emplaced at this time are commonly called Laramide.

Lava: Streams of molten rock that pour or ooze from an erupting vent. Also, the same material solidified by cooling.

Lithology: The physical characteristics of a rock; the mineralogical composition and grain size of a rock.

Magma: Naturally occurring molten rock material, generated within the earth and capable of intrusion into surrounding earth material, and extrusion onto the earth's surface, from which igneous rocks have been derived through solidification and various processes.

Mass movement: Down slope movement or wasting of earth material under the influence of gravity; sometimes aided by water. Mass movement includes creep, earth flows, landslides, slumps, and rock fall.

Meander: One of a series of regular freely developing sinuous curves, bends, loops, turns, or windings in the course of a stream.

Metamorphic: Pertaining to the mineralogical, chemical, and structural adjustment of solid rocks to physical and chemical conditions imposed at depth below the surface zones of weathering and cementation, which differ from the pressure/temperature conditions under which the rocks originated. Metamorphic rocks constitute one of the three main classes into which rocks are divided, others being igneous and sedimentary.

Normal fault: A fault that drops rock on one side of the fault down relative to the other side. The angle of dip is usually 45–90 degrees.

Pediment: Gently sloping erosion surface or plain of low relief formed by running water in arid or semiarid region at the

Geologic Time Chart

Cenozoic	Quaternary		Holocene: Present time–0.01 million years ago (mya)
			Pleistocene: 0.01–1.8 mya
	Tertiary	Neogene	Pliocene: 1.8–5.3 mya
		Paleogene	Miocene: 5.3–23.0 mya
			Oligocene: 23.0–33.9 mya
			Eocene: 33.9–55.8 mya
			Paleocene: 55.8–65.5 mya
Mesozoic			
			Cretaceous: 65.5–145.5 mya
			Jurassic: 145.5–199.6 mya
			Triassic: 199.6–251.0 mya
Paleozoic			
			Permian: 251.0–299.0 mya
			Pennsylvanian: 299.0–318.1 mya
			Mississippian: 318.1–359.2 mya
			Devonian: 359.2–416.0 mya
			Silurian: 416.0–443.7 mya
			Ordovician: 443.7–488.3 mya
			Cambrian: 488.3–542.0 mya
Precambrian:			542.0 mya– ~ 4.5 billion years ago

base of a receding mountain front. A pediment is underlain by bedrock that is typically covered by a thin, discontinuous veneer of soil and alluvium derived from upland areas. Much of the alluvial material is in transit across the surface, moving during episodic storm events or blown by wind.

Playa: Dry, barren area in the lowest part of an undrained (hydrologically closed) desert basin typically underlain by stratified clay, silt or sand and commonly marked by an ephemeral lake.

Pluvial: Pertaining to rain, or to precipitation; said of a climate characterized by relatively high precipitation

Precambrian: Geologic time period including about 90% of all geologic time and spanning the time from the beginning of the earth, about 4.5 billion years ago to 542 million years ago.

Rift: A long, narrow continental trough that is bounded by normal faults; a graben of regional extent.

Rock glacier: A tongue-like or lobate mass of angular boulders and fine material with interstitial ice or an ice core. It occurs in high mountains and is derived from a cirque wall or steep cliff. Rock glaciers have the general appearance and slow movement of small valley glaciers.

Runoff: That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains, or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or groundwater runoff.

Sedimentary: Pertaining to, or including, sediments, or formed by its deposition. Sedimentary rocks constitute one of the three main classes into which rocks are divided, others being igneous and metamorphic.

Subsidence: Sinking or downward settlement of the earth's surface.

Tectonic Geology (Tectonics): A branch of geology dealing with major structural or deformational features, their origin and evolution.

Terrace: A relatively flat bench or steplike surface bordering a stream channel. Terraces are generally composed of either alluvial material (remnants of past channel deposits) or bedrock.

Transition Zone Province: The physiographic region exhibiting the transitional structural features of the Colorado Plateau and Basin and Range Provinces. The northwest-trending structural belt extends from northwest Arizona to central New Mexico.

Tuff: Volcanic rock made up of rock and mineral fragments in a volcanic ash matrix. Tuffs commonly are composed of shattered volcanic rock glass—chilled magma blown into the air and then deposited.

Volcano: A vent in the surface of the earth through which magma and associated gases and ash erupt; also, the form or structure, usually conical, that is produced by the ejected material.

Volcanism: Processes by which magma and its associated gases rise into the earth's crust and are extruded onto the earth's surface and into the atmosphere.

Watershed: The land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large basins, like the Mississippi River Basin, contain thousands of smaller watersheds.

Abstracts

Land-Use Change in the Greater Gila Ecosystem

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Biodiversity is a well-known indicator of ecological health. Energy flows (trophic dynamics) of ecosystems are maintained through complex interactions of plants and animals. Fish and wildlife are important to the food web and our society. Approximately 10% of New Mexico's fish and wildlife are listed as state endangered or threatened. Comprehensive planning and actions to recover threatened and endangered species is controversial and expensive, but necessary in order to restore ecosystem health in New Mexico. Using The Nature Conservancy ecoregion boundaries that make

up the "Greater Gila Ecosystem"—Arizona–New Mexico Mountains, Chihuahuan Desert, and Apache Highlands—I analyze human demographic and environmental indicators by county. Pearson correlation statistical analysis was performed on Census-derived socioeconomic data and threatened and endangered species counts provided by the New Mexico Department of Game and Fish. Among the socioeconomic indicators, population density was the most likely cause of higher threatened and endangered species rates.

Values of Fire for Resource Benefit and the Effects on State and Private Lands in the Gila Sub-Region

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State and private lands make up a vital part of the landscape in the Gila Sub-Region of southwest New Mexico. While these state and private lands are not usually considered highly productive in the fiber-production sense (wood products) and in some areas are small and seem inconsequential, they are critical components of a region that places a high value on historical uses, unfragmented landscapes, watershed protection and restoration, wildlife habitat protection, and recognition of customs and cultural uses of this resource by its residents.

Overlapping issues complicate the region's management of

federal lands, such as endangered species management, complex environmental analysis requirements, and economic realities. As a result, "fire for resource benefit" is one of the best tools that federal land managers have to protect the state and private lands from catastrophic wildfire in the long term. It is also the only way that forests and rangelands can be "protected" from these same catastrophic events, holding them in check until the time comes that other tools are made both politically and economically available to the professional natural resource manager.

Restoration of the Upper West Fork Gila

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Historically, Gila trout (*Oncorhynchus gilae*) inhabited the entire Mogollon Plateau of NM and Arizona. By the time Miller first described the species in 1955, its range had already been reduced to only a handful of small populations in headwater streams. Catastrophic fires, competition and hybridization with nonnative salmonids, unregulated angling, and habitat availability and degradation are the primary sources for their decline and led to the listing of the species in 1967 as endangered under the Federal Endangered Species Preservation Act of 1966, and subsequently under the Federal Endangered Species Act of 1973. Four distinct relict lineages have been identified, and efforts to protect and replicate these populations throughout their historical range are the main focus of our activities in the Upper Gila River Basin. Since 2003,

when the New Mexico Water Quality Control Commission accepted the New Mexico Department of Game and Fish's petition to remove nonnatives via Antimycin A-FINTROL, there has been an ongoing effort to renovate the entire West Fork Gila River (WFG) drainage upstream from waterfalls (approx. 0.5 km downstream of the White Creek confluence) and restore Gila trout to the entire upper WFG drainage. The project has overcome several obstacles and was completed in June 2010, thereby opening 32 km of the upper WFG and its tributaries for Gila trout. Gila trout will be reintroduced into the upper WFG in the fall of 2010, increasing the number of inhabited stream miles and established populations within the Gila River Recovery Unit.

Let the Water Do the Work: Induced Meandering— An Evolving Method for Restoring Incised Channels

Van Clothier

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As a science, induced meandering relies on the disciplines of geology, hydrology, fluvial geomorphology, biology, and ecology for knowledge and guidance. As an art, it strives to assist the stream in its career, using the power of floods to shape the channel and banks over time. I will describe which channel types are appropriate candidates for induced meandering techniques and provide an overview of the process. This

philosophy of “going with the flow” can inform all stream restoration projects as we strive to understand rivers as timeless entities governed by immutable rules, serving their watersheds, setting their own timetables, and coping with their own realities as they carry mountains grain by grain to the sea. Rivers are to be treasured and respected, never bullied or coerced.

Habitat Restoration in the San Simon Valley, AZ: Implications for Avian Species

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The Bureau of Land Management (BLM) is implementing wildlife habitat restoration projects in southeastern Arizona in the San Simon Valley. Water is scarce in this area and artesian springs supply an important source of water and shady vegetation in the Sky Islands area. Many of the artesian watering holes in the area are a result of historical drilling operations and the water is saline. Salt cedar has infested many of these wet spots, and the former size of the water bodies is much reduced from what it was in the 1950s and 1960s. The BLM Safford Field Office has taken on one project at a time to dredge old ponds, redrill wells, remove salt cedar, plant cienega grasslands, and demonstrate plantings of salt-tolerant native trees. Archive and recent bird data from one

of the San Simon project sites documents a remarkable list of avian species utilizing even the smallest water source. Data are compared to the “eight elements of the Comprehensive Wildlife Conservation Strategy” developed by Partners in Flight (PIF) and others. Eighteen priority bird species from nine PIF habitats will potentially benefit from the San Simon riparian and aquatic restoration efforts. Twelve of these were observed at Posey Well in 2006. Because the project locations are so close to New Mexico, the project will benefit both Arizona and New Mexico priority species. Bird species from the Chihuahuan Desert, Mexican Highland, and Mogollon Rim regional habitat types are represented.

Restoration at The Nature Conservancy's Gila Riparian Preserve

Martha S. Cooper

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For more than 25 years, the New Mexico program of The Nature Conservancy has focused its conservation efforts along the Gila River and its watershed. The Conservancy's Gila Riparian Preserve currently protects more than eight river miles and features exceptional examples of cottonwood-willow and sycamore forests. The diversity of plant and animal life of the Gila is exceptional and surprisingly intact. However, many of these plants and animals are threatened with extinction due to a variety of historical and current human-induced changes to the land.

Working with various partners, the Conservancy is undertaking both passive and active restoration projects on the Gila

Riparian Preserve. Examples of passive restoration include appropriate grazing and vehicular management in the riparian corridor. Active restoration projects include creating wetland habitat with irrigation water or reseeded floodplain grasslands. Restoration of floodplain habitats along the upper Gila River has a high probability of success, because the natural flow regime is largely intact. Many restoration projects fail to reestablish ecosystem functioning because major processes, such as flooding, are absent. Retaining natural flow regimes, along with reducing stresses, has enabled the riparian corridor in the Cliff-Gila Valley to begin to rebound from past degradation.

An Introduction to the Geology of the Gila River Basin in New Mexico

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The drainage basin of the Gila River in New Mexico is underlain by bedrock ranging from Proterozoic to Cenozoic in age that records the history of this region through geologic time.

The oldest rocks in the region are metamorphic and igneous rocks of Proterozoic age exposed in the Burro Mountains and the Silver City Range. Paleozoic sedimentary rocks, principally carbonates, are exposed in the Silver City Range. During the late Paleozoic there was a period of tectonic activity and the uplift of the Ancestral Rocky Mountains, includ-

ing the Florida-Burro uplift. Mesozoic sandstones and shales are exposed in a small area in the Silver City Range.

Most of the drainage basin is underlain by Cenozoic rocks. The Paleogene was dominated by volcanic activity and several large calderas have been mapped in the region. The Neogene was characterized by the formation of elongate fault-bounded basins, which filled with gravels. Initially closed, the basins filled and connected to form the present-day, through-flowing Gila River system.

The Night Sky of Southwest New Mexico

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The dark, clear skies of our area enabled the first people living here to make the connection between our earth, the life on it, and the universe around it. They saw our galaxy, the Milky Way, stretching from horizon to horizon and felt a connection to it that people today no longer have. These people have left many records of their observations in the rock art in our area.

For decades the southwestern U.S. has been home to some of the world's major observatories, but the growth of some of the major cities in the area have changed the quality of the skies. Now a few relatively small pockets of "natural dark skies" still remain in the Southwest. Southwest New Mexico still has true natural dark skies and efforts to maintain the sky quality in this area are beginning.

Stream Restoration: The Health of the Planet Is Not an Individual Matter

George Farmer

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This presentation chronicles the riparian restoration activities at Axle Canyon Preserve, a privately owned eco-preserve, begun in 2007. Axle Canyon Preserve is located in the Mulberry Canyon watershed at the northern end of the Burro Mountains in southwestern New Mexico. Audience members will gain an understanding of how to evaluate their own property, regardless of size, determine what they can do to improve its natural diversity, and use limited resources more wisely, and they will see why they need to consider all these points in the first place.

The restoration objectives are to repair the effects of numerous human activities on a high-desert watershed. The Mulberry Canyon watershed is also a tributary to the lower Gila River. Overarching management goals include improving the diversity of native plant, mammal, and bird species and managing rainwater runoff for maximum benefit for the ecosystem. Specific management goals and activities include these:

1. Protect Axle Canyon Preserve from degradation by motorized vehicles and cattle grazing;
2. Design and install specific stream bed solutions to cap-

ture suspended sediment in flood events and allow for natural stream bed and floodplain development;

3. Design and install site-specific structures to stabilize active erosion and prevent further degradation of the main stream bed and its tributaries using natural forms and processes;
4. Protect and enhance natural moisture-storage areas;
5. Establish diverse colonies of native vegetation to capture runoff and sediment; and reestablish native plants missing or declining within the Preserve.

Restoration activities connected to the Preserve management activities are monitored using before/after photos and ongoing log entries.

Participants will learn how any landowner can make a difference in reversing the detrimental effects of the human population on the planet by doing something restorative on their land, regardless of the amount of land they control, from a city lot to numerous acres.

The health of the planet is not an individual matter. It is not a few people doing a few big things but many people doing many little things, living with the health of the planet in mind.

Food Plants of the Gila Region, New Mexico

Richard Stephen Felger¹ and Kelly Kindscher²

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Traditional people in the Gila Region in southwest New Mexico made extensive use of the flora for subsistence. Approximately 23% (330 out of 1439) of the region's species have had use as food and beverage plants. We have compiled a list of plant species of the region from the USDA Plants database and compared this list to several ethnobotanical databases, as well as our own combined published and unpublished information. Wild plant staples included agaves (*A. palmeri*, *A. parryi*); junipers (*Juniperus deppeana*, *J. monosperma*); prickly pear (*Opuntia engelmannii*); mesquite (*Prosopis glandulosa*); oaks (especially *Quercus emoryi*); pinyons (*Pinus discolor*, *P. edulis*); wild cherries (*Prunus* spp.); grasses

(e.g., *Setaria macrostachya*, *Sporobolus wrightii*, etc.); banana yucca (*Y. baccata*); and annuals and herbaceous perennials, such as amaranths (*Amaranthus* spp.), goosefoots (*Chenopodium* spp.), hog potato (*Hoffmannseggia glauca*), and wild tepary (*Phaseolus acutifolius*). The information in the database came from over 18 tribes, with the most reported uses from the Apache, Navaho, Zuni, and Puebloan people. Seasonality, preparation, storage, and local ecological diversity played major roles in traditional use of wild plants in the region. This paper highlights the importance of the native Gila flora as food plants and we indicate potential modern economic uses.

SEINet: A Specimen-Based Online Species Identification Tool

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The Southwest Environmental Information Network (SEINet) web portal is a specimen-based virtual flora that fosters bio-collaboration through the integration of specimen data with the wealth of digitized biodiversity data (images, descriptions, morphological character data, etc.). Herbarium specimen records provide a geographic perspective that allows users to dynamically generate species lists for any given area based on expert-reviewed identifications. An innovative data model that stores morphological character data imbedded

within a taxonomic hierarchy enables an extremely efficient method for processing descriptive data to generate interactive keys for any specimen-based species list. The power of this model lies in its ability to handle species concepts for vastly different taxonomic groups in one system. The virtual flora environment has enormous potential, as it can be customized to meet a full spectrum of needs—from middle school students just being introduced to local species to professional taxonomists who expect a highly comprehensive dataset.

Fire Effects and the Use of Prescribed Fire on the Magdalena Ranger District, Cibola National Forest

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The Magdalena Ranger District of the Cibola National Forest has implemented a more aggressive use of prescribed fire since 2003 in an attempt to treat larger acres for restoration of natural landscapes. The District has looked at previous prescribed fire entries and large wildfire impacts and has for-

mulated burn plans to more closely follow natural fire effects. This presentation will look at the impacts of past fire-suppression history on the District's landscape and wildlife species and will present the initial qualitative monitoring results of the most recent fire projects.

Fire Management on the Gila National Forest

Gabe Holguin

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Pre- and Post-Monsoonal Habitat Use of the Narrow-Headed Gartersnake, *Thamnophis rufipunctatus*, along the Gila River

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Thamnophis rufipunctatus, found in central eastern Arizona, southwestern New Mexico, and western Chihuahua and Durango, Mexico, is a highly aquatic species that preys primarily on fish. During the recent past, populations of *T. rufipunctatus* have exhibited marked declines in Arizona and New Mexico. Potential causes of declines include increased siltation of stream habitats, disease, and the introduction of nonnative bullfrogs, crayfish, and several fish species.

Studies were conducted from May through August 2009 at four sites along the Gila River, Tularosa River (1880 m), and Whitewater Creek (1625 m) of southwestern New Mexico. Snakes of suitable size were captured and fed 1.2 g temperature-sensitive radio transmitters. Using radio transmitters, body temperatures, home range sizes, movements, and refuge types important to snakes were documented. No differences

in seasonal home range sizes were detected between the sexes or among sites, but were correlated with number of days tracked. Documented movements averaged 18.2 m (n = 81) with no differences among sites or between sexes. Snakes moved up to 56 m from the water. Females (\bar{x} = 14.7 m, n = 51) averaged greater distances from the water than males (\bar{x} = 6.3 m, n = 34). Males were found in water more often than females. Body temperatures (T_b) of snakes at Whitewater (\bar{x} = 23.2° C, n = 99) were cooler than snakes at Heart Bar (\bar{x} = 26.3° C, n = 91) and Tularosa (\bar{x} = 26.6° C, n = 54). Females (\bar{x} = 26.4° C, n = 162) maintained higher T_b than did males (\bar{x} = 24.3° C, n = 82). Rock cover objects were used more frequently at Tularosa and Whitewater. Accumulated debris and vegetation were used more often at the Heart Bar.

Flora of the Florida Mountains

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The current status of the ongoing effort to define the flora of the Florida Mountains in Luna County will be discussed and

analyzed. New additions to the flora in the last few years will be presented.

Medicinal Plants of the Gila Region, New Mexico

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There has been extensive use of the flora of the Gila Region in southwest New Mexico for medicinal use. Approximately 39% (563 out of 1439) of the region's species have had use as medicinal plants. We have compiled a list of plant species of the region from the USDA Plants database and compared this list to several ethnobotanical databases, as well as our own combined published and unpublished information. The Asteraceae was the most common family, representing 27% of all species, followed by Fabaceae (8%) and Brassicaceae and Onagraceae (both at 4.2%). Among the most commonly used

species were one-seed juniper, *Juniperus monosperma*; broom snakeweed, *Gutierrezia sarothrae*; and narrow-leaf stone seed, *Lithospermum incisum*. The information in the database came from over 18 tribes and even modern uses, with the most reported uses from the Navaho, Zuni, Apache, and Puebloan people. The most common uses of these plants were for dermatological aids, ceremonial medicine, gastrointestinal aids, emetics, and gynecological aids. This paper highlights the importance of the native Gila flora for medicinal purposes.

Ferns of the Gila National Forest

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Ferns are a common constituent of the flora of most areas within the Gila National Forest. The current study of the diversity of the ferns of the Gila National Forest has been ongoing since 2007. Thus far, 34 fern species representing 16 genera from 7 families have been identified in the field, with a few additional species found thus far only in herbarium collections. Since 1100–1200 species of vascular plants have

been identified during the same time in the Gila, the ferns represent roughly 3% of the total species diversity. This is the same percentage found in the flora in North America north of Mexico. The local predominance of the Pteridaceae (22 species) and the Dryopteridaceae (5 species) also reflects this trend on a more continental scale.

Cienega de San Vicente Wetland Project: Baseline Condition Report

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In 2009 the New Mexico Environment Department Surface Water Quality Bureau (SWQB) began implementation of a three-and-a-half-year project to survey, restore, and protect more than thirty acres of degraded riverine wetlands, creating opportunities for novel restoration demonstration and unique partnerships. SWQB has a Memorandum of Agreement with the Town of Silver City that provided more than 30 acres of intermittent stream channel and degraded floodplain adjacent to San Vicente Creek for the restoration project. SWQB contracted Dr. William Norris of Western New Mexico University to conduct a comprehensive survey of the condition, extent, and composition of locally existing wetland and riparian resources. The survey will increase understanding of critical

natural habitats, demonstrate methods to determine the state of riverine wetlands, and provide guidance for restoration at Cienega de San Vicente and similar degraded wetlands in the arid Southwest. SWQB also contracted Gila Conservation Education Center to develop and implement an outreach and education program to demonstrate wetland functions and protection strategies for the community. The first part of the project will focus on developing the site-specific baseline conditions related to the hydrology, vegetation community, and soils at the project site. The Baseline Condition Report will be used to drive the restoration phase followed by two years of post-restoration monitoring to evaluate the effectiveness of the project.

Fish Assemblage Dynamics as a Function of Life History Strategies of Native Fishes, Nonnative Predators, and Climatic Variability

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A complex interplay of biotic and abiotic factors mediated effects of hydrologic regime on the persistence of native fish assemblages in three headwater tributaries of the Gila River. Native fishes assemblage structure (abundance and richness, size- or age-structure of populations) was strongly and primarily affected by hydrological regime and secondarily by nonnative predators. Among small-bodied, short-lived native fishes, *Agosia chrysogaster* occupied the broadest range of habitats and nonnative predators strongly affected its abundance (n/m^2), but stream discharge was the primary driver affecting

abundance of species (*Meda fulgida*, *Rhinichthys osculus*, and *Tiaroga cobitis*) that occupied habitats not typically used by nonnative predators. For large-bodied native fishes, flow regime was the primary abundance driver for all life stages of *Gila nigra*, but both nonnative predators and flow regime affected abundance of *Catostomus insignis* and *Pantosteus clarkii*. Idiosyncratic responses of individual species to environmental conditions across sites indicate the spatial mosaic of habitats in the Gila River is essential for the persistence of different life stages and species of native fishes.

Stream Restoration at Black Canyon Creek, Gila National Forest

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Black Canyon Creek originates in the Black Range of southwestern New Mexico within the upper Gila watershed. Parts of the Black Canyon watershed burned at high intensity during wildfires in 1995 and 1996, and subsequent extreme runoff had significant morphological impacts on Black Canyon Creek. After the fire, much of the creek exhibited a shallow and wide morphology with many former pools filled in. This caused aquatic habitat degradation and temperature impairments by allowing sunlight to penetrate a greater percentage of the water column and reducing shade provided by riparian cover. Temperature variations affect the metabolism and mortality of fish and other aquatic organisms including Gila trout, which are now restricted to smaller headwater streams such as Black Canyon Creek. The immediate goals of this restoration project are to return natural hydroecological resiliency to

Black Canyon Creek by restoring channel configurations using bioengineering methods, increasing pool habitat and other aquatic habitat diversity, reestablishing riparian vegetation, and protecting wetland habitats by implementing a number of best management practices and monitoring the results. These actions will achieve the measurable goals of decreased width-depth ratio, increased canopy shade coverage, increased bank vegetation, reduced erosion, and decreased water temperature, with the ultimate goals of restored instream ecosystem function, a sustainable high-quality coldwater fishery, and watershed health. This collaborative project involves many entities, including the Gila National Forest, Gila Watershed Partnership, Natural Resources Conservation Service, Sierra Soil and Water Conservation District, and the Grant Soil and Water Conservation District.

A Current Look at Willow Flycatcher Populations along the Gila River in Southwestern New Mexico

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The federal and state endangered southwestern willow flycatcher (*Empidonax traillii extimus*) was first discovered in New Mexico in 1886 near Hachita, and along the Gila River in 1959. Populations of this species were not systematically censused along the river until 1993. Based upon these censuses, flycatcher numbers peaked in 1999, declined, stabi-

lized, and have been slowly increasing over the past few years. This presentation will discuss historical changes in willow flycatcher population numbers along the Gila River primarily from 1993 until 2010, and present several possible explanations for these changes.

Rare Plants in the Mogollon Floristic Region of New Mexico

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The Mogollon floristic region of New Mexico consists of several adjacent or interconnecting mountain ranges extending from the Mogollon and San Francisco mountains on the Arizona border, east to the San Mateo Mountains and Black Range near the Rio Grande. This region contains twenty-two

plant taxa that are regional endemics and an additional nine that are more widespread, but rare throughout their range. Four of these plants have not been seen in New Mexico for more than half a century.

Water Use and Establishment Patterns of Drought-Tolerant One-Seed Juniper in Riparian Areas of the Gila and Mimbres Rivers

Dr. Kathy Whiteman

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The increasing density and distribution of woody-plant species is one of the most important global-scale changes currently affecting terrestrial ecosystems. Woody-plant encroachment has the potential to alter biogeochemical cycles, affect ecohydrological relationships, alter species diversity, drive shifts in ecosystem productivity, and shift patterns of natural disturbance. The causal mechanisms explaining woody-plant encroachment are complex, and the consequences not well understood. Of particular interest in southwestern New Mexico is the expansion of *Juniperus monosperma* (Cupressaceae), one-seed juniper.

This particular species has expanded its range onto former grasslands, woodlands, and river or riparian habitats. The expansion of one-seed juniper into riparian habitats is of particular interest because this species is drought tolerant and riparian habitats are generally not limited by water availability. To further the understanding of juniper encroachment into riparian ecosystems, a variety of techniques were used to: (1) estimate the period of establishment along the Gila and Mimbres Rivers, (2) statistically quantify spatial distribution

patterns, and (3) demonstrate source-water acquisition in a variety of habitats.

Dendrochronological techniques revealed that the average age of riparian one-seed junipers was 38 years. Ripley's K-statistic demonstrated a significant clustering pattern of junipers beneath the canopies of large phreatophytic trees. The stable isotopes of hydrogen and oxygen showed that upland junipers used monsoon rains, while in riparian habitats juniper used water from all available sources, including groundwater. Depth to groundwater did not exceed 3.5 meters at any site during any season, suggesting that declining water tables may not be important in explaining juniper encroachment. Floods have apparently not been effective at removing juniper from floodplain habitats, although flood frequency and intensity has increased since the early 1970s.

Results from this study suggest that encroachment of juniper into riparian ecosystems has occurred recently, that phreatophytic trees may facilitate encroachment, and that one-seed juniper has the potential to affect ecohydrological interactions, but the magnitude of the effects at this time is not clear.

Relationships among Energy Availability, Trophic Level Abundance, and Food Chain Length in the Upper Gila River Basin, NM, USA

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Numerous nonnative species are present across the upper Gila River of New Mexico in spatially variable abundances. Many of these nonnatives function as predators in this predator-less system, thus creating a new trophic level. At present, it is unclear what mechanisms have allowed the establishment of this new trophic level, or are responsible for the spatial variation of nonnatives. To investigate the mechanism responsible for the observed patterns in addition to testing predictions from food web theory, the present

study sought to quantify the influence of primary productivity on food chain length, nonnative predators, and trophic level abundance. Quantification of primary production, trophic level abundance, and food chain length occurred seasonally across six longitudinally positioned sites between 2008 and 2010. It was determined that gross primary production varied substantially across sites, but food chain length, nonnative predator abundance, and abundance of other trophic levels did not respond to primary production as predicted.

Hawk Moths of the Gila: An Overview of the Family Sphingidae in the Gila Region of Southwestern New Mexico

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Based on collecting and observations dating from the late 1950s, 20 species of Sphingidae are known from lands on, or within two kilometers of, the Gila National Forest. Several range through nearby portions of the Gila River valley as well. These sphingids are distributed among eleven genera: *Sphinx*, including *Lintneria* (5 species), *Manduca* (4), *Eumorpha* (2), *Smerinthus* (2), *Pachysphinx* (1), *Paonias* (1), *Agrias* (1), *Sagenosoma* (1), *Erinnyis* (1), *Hyles* (1), and *Hemaris* (1). Additionally, *Erinnyis crameri* and *E. alope* each have been taken once as apparent strays from the Neotropics. Diurnal *Proser-*

pinus juanita breeds in eastern grasslands west at least to the Hurley-Deming area. Similar, little-known *P. vega* also may extend into this region.

Note: Since the 2010 presentation, location of a previously overlooked specimen of *Erinnyis crameri* (Schaus) from adjacent to the Gila National Forest, and collection of *Paonias excaecata* (J. E. Smith) in the Pinos Altos Range during the summer of 2011, bring the Gila Region's known sphingid species total to 22.