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Ecological Research on Nature Conservancy Preserves in Arizona

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The Nature Conservancy in Arizona
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Introduction

The Nature Conservancy (TNC) is a global organization dedicated to conserving the lands and waters on which all life depends. TNC was founded by ecologists and remains a science-based organization. The organization now operates in more than 80 countries and in all 50 US states, with TNC scientists across the globe using science to identify the most important lands and waters to protect, and influence policies and collaborative conservation efforts to achieve large-scale outcomes for nature and people. While TNC's land protection efforts have evolved over the years, owning and managing lands remains a core strategy that grounds the organization in place-based actions that benefit nature and people. They also provide testing grounds for scientific hypothesis and demonstrate conservation actions that could be used elsewhere.

TNC preserves and other properties have long been hubs of scientific research as they provide myriad benefits to researchers. These lands often offer relatively intact "control sites" that contrast with more disturbed sites elsewhere; they tend to be sited in the most biologically rich locations within any region; they have some assurance of longevity in their natural state; they have ready-made audiences of stakeholders interested in research results; and they often boast a level of natural beauty that makes even grueling research feel worthwhile. In addition, TNC lands typically have more flexible permitting requirements and procedures than nearby public lands–especially for non-destructive research projects—and are often more receptive to research efforts than nearby private lands. Available lodging, often in remote places, is an additional benefit and has supported the development of many early-career scientists. Lastly, the reputations of TNC preserves as research hubs has grown over time, as each new set of discoveries brings attention from a new field or a new generation of researchers.

TNC preserves in Arizona have the additional draw of being situated in some of the most biodiverse terrain in the United States. Most are in the "Apache Highlands" ecoregion, which includes the Madrean Sky Islands. In a grand swath of lands and waters between the Rocky Mountain and the Sierra Madre mountain chains, isolated forested mountain ranges rise like islands out of desert and grassland seas, forming a sort of land-based "archipelago" that blends the flora and fauna of the continents' two largest mountain masses. This Sky Island region also forms a low point in the Continental Divide, bringing together species from the western Sonoran and Mojave Deserts and eastern Chihuahuan Desert and Great Plains. This exceptional biodiversity is a foundation for prestigious research programs in all three state universities—University of Arizona (UA), Arizona State University (ASU), and Northern Arizona University (NAU)—and draws additional researchers from around the country and beyond. Many TNC Arizona staff have developed longstanding relationships with local research programs, and favorite research sites tend to build interest over time.

TNC benefits from this science activity in many ways. Some research is focused on questions that inform adaptive management choices, e.g. crafting effective restoration programs. This is especially common when TNC staff are involved in designing, implementing, and/or interpreting the research. More often, connections between research and management are less direct, but no less important. Research that compares dynamics across sites can provide insights into ecosystem tradeoffs as conditions

Lower San Pedro Preserves Manager, Dan Wolgast, uses a tablet to map a wet reach in Aravaipa Creek.
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change. Deep dives into processes such as nutrient cycling can bring new ways of understanding the relationships between plants and soils or predators and prey, and provide previews of how a web of life might be affected by changes at any one node. Lastly, field science activities develop additional constituents who care about natural lands, who may advocate for solutions in legal and policy arenas when key threats are identified, invest time and money in their well-being, and share the enthusiasm about how these lands contributions to the overall well-being of our society.

This narrative report shares highlights of ecological research TNC preserves in Arizona, focused on work led by researchers who are external to TNC. These researchers come from universities near and far, federal and state agencies, other conservation NGOs, and citizen science groups. This report is not meant to be comprehensive, but rather to illustrate the kinds of science efforts that add value to our work and enable TNC to more easily share new efforts and discoveries as they come to light. Most featured research dates from 2010 to 2026, with mention of older work that continues to bear fruit today. Information about additional studies, and more details about researchers and publications, can be found at the end of this report. This report is inevitably incomplete. It aims to provide a template that can be elaborated on in the future as research projects reach completion and publish results and as new discoveries come to light. Note also that this report does not include the many research and monitoring projects led by, initiated by, and contracted by The Nature Conservancy. Summarizing these would be a great service but is beyond the scope of this report.

Work outside the scope of this report

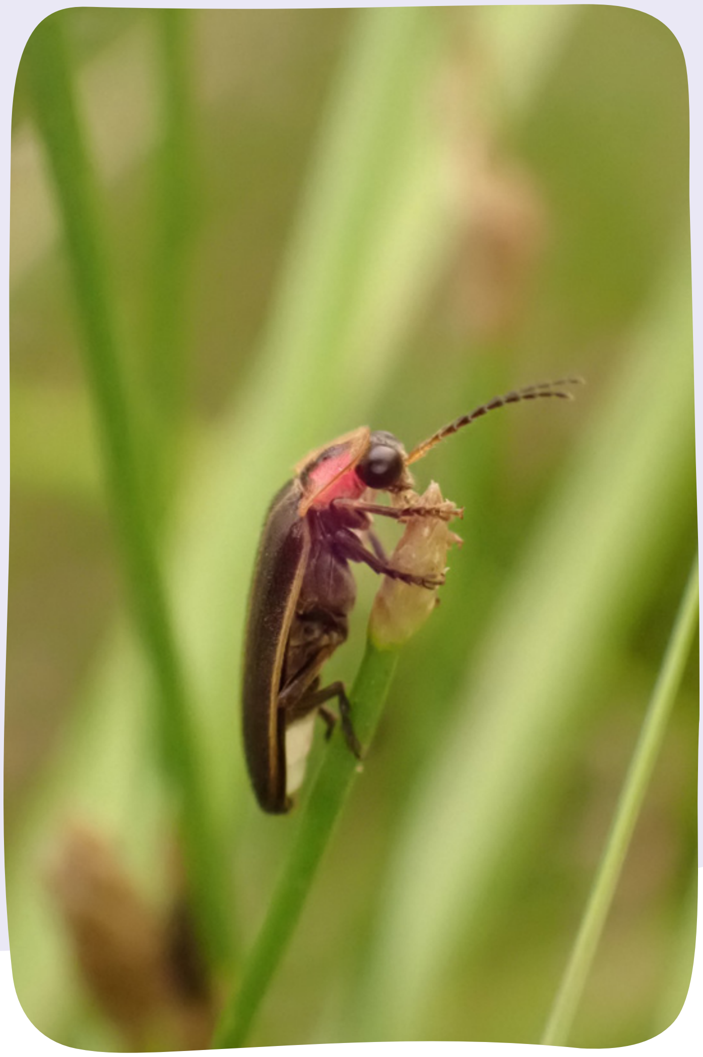
Three other types of research that involve TNC preserves would take additional effort to quantify and are thus largely outside the scope of this report: Remotely-sensed analyses, crowd-sourced efforts, and research conducted by agency staff in the regular performance of their duties.

Many broad-scale studies that use remote sensing methods include TNC lands. Unless they also incorporate field-based data, these are not recorded in the Arizona TNC permit system and may escape notice. Nevertheless, TNC lands can make important contributions by providing examples of land conditions that are attainable with conservation management, even in the midst of broad-scale stressors like climate change and drought. For example, a recent remote-sensing study led by the US Geological Survey evaluated the conditions and ecological dynamics of 31 cienega habitats across the Apache Highlands and included two TNC-managed sites.[1]

Emergence of crowd-sourced research via platforms like iNaturalist and eBird offer a whole new arena for discovery in and around TNC lands. In November 2025, TNC staff and partners harnessed this potential by sponsoring a “bio blitz” across the San Pedro watershed, which includes TNC-managed lands at Ramsey Canyon, Canelo Hills, Middle San Pedro, and across the Lower San Pedro. In one month of sporadic activity, 215 people documented over 900 species of plants, fungi, and animals across the watershed. TNC-managed lands served as hubs for hosting and training participants, as well as sites for observations of regional species like white-nosed coatis and Santa Rita hedgehog cacti. Meanwhile, other research facilities have digitized millions of plant and animal records from their collections and made these available to the public via platforms like SeiNET. Searching crowd-sourced and research databases for observations in and around TNC lands would be an increasingly rich way to expand our knowledge of these sites.

Multiple Arizona Sites: Research Across Preserves Leads to Broad Insights

Many on-the-ground research projects led by partners have included multiple TNC sites. Some of these are broad-scale studies that go far beyond TNC boundaries, such as crayfish studies that cover the Lower Colorado River Basin and include four TNC preserves. Other researchers have taken deeper dives in habitats that occur at more than one TNC site, such as firefly studies that focus on two TNC sites (but also report populations found elsewhere).



Bicellonycha wickershamorum/the Southwest spring firefly.

Rare fireflies

Key research partners: Rachel Laura, University of Arizona; Cheryl Mollohan, independent researcher; Ron Day, TNC (retired)

From 2021 to the present, two different teams of researchers have been making discoveries about rare fireflies,[2] the Southwest synchronous firefly *(Photinus knulli)*[3] and Southwest springs firefly *(Bicellonycha wickershamorum wickershamorum)*.[4] Before these studies, each of these firefly species was known from just a handful of locations in perennial wetlands of southeastern Arizona and Sonora; the latter has been petitioned for federal protection under the US Endangered Species Act.[5] Despite the flashy nature and global popularity of fireflies, these animals largely escaped notice in Arizona because they are small and usually hidden; adults make themselves visible at dusk for a few weeks in the humid heat of monsoon summertime. Targeted searches over the past few years (2021-2026) resulted in more than doubling the total number of known population locations[6] of these rare insects. They are now being studied at Muleshoe, Patagonia-Sonoita Creek, and Canelo Hills Preserves, and may yet be discovered at others.

Researchers have demonstrated that the life histories of both species are tightly tied to perennially wet rivers and springs. They have also disentangled how the two species avoid competing with one another. This research has let to new observation tools, including newly tested methods for estimating firefly abundance and a remote camera system that can detect fireflies and even identify which species is flashing.[7] This type of remote camera system has the potential to enable researchers to safely and efficiently document changes in abundance and activity timing across years, even in remote and rugged locations.

In addition, scientists discovered a third related species of firefly at two preserves: a "glowworm" whose females never change into flight attire and instead breed in their larval form. The identity of these glowworms remained a mystery for a whole year, until males were seen in 2025 and provided features that match them with descriptions of the species *Microphotus dilatatus*.

Rachel Laura with firefly volunteers.

Leopard frogs

Key research partners: Beth Hasl, Javan Bauder, and Jessi Rick, University of Arizona; Anna Savage, University of Central Florida; Martin Schlaepfer, The State University of New York; Audrey Owens and Ryn Davison, Arizona Game and Fish Department

Researchers looking at disease dynamics in leopard frogs (Chiricahua and lowland species, *Lithobates chiricahuensis* and *L. yavapaiensis*) have worked at Aravaipa, Muleshoe, Lower San Pedro, Hassayampa, Cienega Creek, Ramsey Canyon, and several other sites across southern and central Arizona.[8],[9] The relatively pristine conditions of ecosystems at TNC sites have been key to discoveries that extend far beyond frogs and site conservation. They discovered that frogs can "cure" themselves of deadly fungal infections by taking a soak in hot springs;[10] that with luck and time, these species and others can evolve resistance to disease;[11] and that disease resistance is generated by genetic diversity in the same area of the genome[12] that is responsible for immune function and parasite resistance in other animals.

This genomic area is termed the "Major Histocompatibility Complex." Applied research has shown that genes in this complex affect the human and natural world in a dizzying number of ways—from assisting with organ transplant matches in humans; to helping mice recognize a good mate by smell and ensure their selected partners are not related; to allowing cancers to become contagious in Tasmanian devils; and forming the foundation of immune systems in animals from fish to birds to humans. Investigations of these genes have shown similar function across animal lineages for at least 30 million years, so new discoveries in a group like frogs have implications across the animal kingdom. Papers based on this research have been cited in hundreds of later publications, on topics ranging from immunology to wildlife reintroductions.

Additionally, recent research on lowland leopard frogs (2024-2025) found relatively low genetic diversity in most southern Arizona populations, reflecting a history of population declines and bottlenecks at many sites.[13] However, frogs also show evidence of gene flow between populations, which keeps genetic diversity from falling further in these small populations. Gene flow is clustered within regional groups of sites, creating a nested pattern where populations within each regional group are closely related, but distinct from those in other groups. For example, frogs from various canyons of the Muleshoe preserve are all most closely related to one another and next most closely related to frogs at the Middle San Pedro Preserve; Aravaipa and Lower San Pedro frogs form a separate cluster that is distinct from those frogs at Muleshoe and the Middle San Pedro. Together, these clusters are more closely related to each other than to frogs in the Cienega Creek drainage area. The patterns observed from these genetic data can be used to understand what landscape or environmental features may be preventing the movement of individuals between populations, or more importantly, what can help to facilitate movement of frogs between locations.

> The TNC-protected lands and waters here in southern Arizona are critical for ensuring the persistence of these fish populations and their connectivity to one another. The majority of the sites where these species are found are on TNC lands, and each of those TNC populations seems to be doing really well despite the fact that they're all isolated from one another for most of the year (and for the whole year some years!). I know that's TNC's goal of protecting these lands, but I just wanted to mention that it really is clear with these fish species!
>
> **Dr. Jessi Rick**
> *University of Arizona*

Rare and endangered native fishes

Key research partners: Peter Reinthal, University of Arizona; Heidi Blasius, Bureau of Land Management; Wendell Minckley (1935–2001), Arizona State University. Genetics: Jessica Rick and Oliver Fahrner, University of Arizona

Presence of perennial streams with rare and endangered native fish was a key factor in TNC's acquisition of several sites. These fish remain important conservation targets and subjects of science investigations at Aravaipa, Muleshoe, Patagonia-Sonoita Creek, and Canelo Hills. Fish research and monitoring varies across sites, with partners that include university researchers, Arizona Game and Fish Department, US Fish and Wildlife Service, Bureau of Land Management, and Bureau of Reclamation. Recent work (2024–2026) by UA researchers on the genetics of desert suckers and Sonora suckers *(Catastomus clarkii* and *Catostomus insignis)* across Arizona shows that the two species can hybridize in places like Aravaipa and Muleshoe where both occur. This is the first genetic evidence of hybridization between these two species. Despite the two species being very genetically different from one another, they are still able to mate with one another and produce offspring that are viable and can also reproduce. With some species, hybridization can cause big problems; in this case the two native suckers naturally hybridize at low rates, with no apparent problems from that mixing. Desert sucker fish found at Sonoita Creek, which does not have a population of Sonora suckers, turned out to be genetically distinct from any other population, and are very genetically different from fish in the San Pedro River, which is just across one low watershed divide.[14] Studies like this and the prior study on leopard frog genetics help researchers and managers alike understand relationships between species, and inform management actions like where to protect and how to best reintroduce species from unique populations.

Invasive crayfish

Key research partners: Mathew Troia, University of Texas, San Antonio

Multiple TNC sites were included in an extensive study on the invasive crayfish (*Faxonius virilis).* Funded by the US Fish and Wildlife Service, sampling took place over three years and at 122 stream sites. Crayfish were consistently found at Canelo and Sonoita Creek, while they were absent in Aravaipa and Muleshoe. Results were used to map and model habitat suitability of this invasive in rivers across the Lower Colorado River Basin.[15] Isolation of streams from human activity and also from other streams was an important predictor for which streams might still be free from this problematic species and therefore host more native fish. These results provide further support for TNC's approach to protecting headwater streams and preventing invasion by non-native species whenever possible.

Riparian community ecology

Key research partners: Professor Julie Stromberg and numerous students, Arizona State University

Foundational research on riparian community ecology was developed on TNC's Hassayampa River Preserve,[16-18] and then expanded to San Pedro sites, Sonoita Creek, and elsewhere.[19-24] This research continues to have profound influence on riparian management and restoration efforts across the Southwest, including conservation work on the Verde and Bill Williams Rivers and management of the San Pedro Riparian National Conservation Area.

Hydrologic monitoring

Key research partners: Dana Lapides, Agricultural Research Service

Staff and partners work together to conduct hydrologic monitoring on all preserves, including wet-dry mapping, which tracks annual changes in perennial stream extents and informs activities like native fish reintroductions; depth-to-groundwater measurements in wells that show changes in aquifer conditions that support riparian forests, community water supplies, and streams themselves; and streamflow volume measurements that support water rights claims and help explain other observations like variations in fish populations. Combinations of staff and partner data on stream flows and flooding, fish populations, vegetation, and stream channel changes have all contributed to "environmental flows" guidance for larger river systems.[25]
In ongoing research that has not yet been published (as of May 2026), TNC staff are working with modeling experts at UA and the USDA Agricultural Research Service to feed wet-dry data taken on preserves and elsewhere into a machine learning model that will produce the first-of-its-kind map of surface flows in the San Pedro Basin. Prior attempts to predict and map perennial river flows in arid regions like Arizona have either been small scale and time consuming[26,27] or broader and inaccurate.[28,29] This approach of using satellite data and machine learning has the potential to solve the sticky problem of mapping perennial streams across the state and in other arid regions, especially in places where researchers can add field-based data collection that can dramatically improve model accuracy. Having good tools for mapping perennial stream segments will become increasingly important as drought and over-use continue to stress rivers across the globe, e.g. for tracking stream drying in places where people have assumed rivers would have perennial flow.

Azure bluebirds

Key research partners: Matt Jenkins and Renee Duckworth, University of Arizona

Azure bluebirds (*Sialia sialis fulva*) are a distinct subspecies of Eastern Bluebirds and have a range that occurs from the Sierra Madres of Mexico to southeastern Arizona. As of May 2026, a UA graduate student is studying this species in Ramsey Canyon, Canelo Hills, and Hart Prairie to evaluate nesting behaviors. In 2024, most of the bluebird activity occurred at Canelo Hills, though several nests had their eggs eaten by snakes. 2025 had few bluebirds at any site, but the January 2026 prescribed fire at Canelo has created ideal habitat conditions for this bird, so researchers anticipate stronger 2026 results.

Conservation management and research: A reciprocal relationship

Ecological research provides conservation managers with hypotheses on how management could influence ecosystems, and management actions provide researchers with a sandbox to test those hypotheses and make new discoveries.

In addition to the inherent interest in knowing more about an understudied and charismatic subspecies of bird, this research ties to a suite of surprising discoveries made elsewhere about epigenetics, specifically how experiences of one generation can affect the next generation without changing their genes. Previous research from the same team broke ground by documenting how stress-related hormones that mother bluebirds include in their eggs change their son's behaviors in ways that drive decades-long "cycles of replacement." Through this cycle, one bluebird species gradually replaces another, until a fire changes habitat in a way that favors the first species and the cycle starts over.[30,31] These first years of Azure bluebird research in Arizona may be just the beginning of a long discovery journey.

Monarch butterflies

Key research partners: Southwest Monarch Study

Research on Monarch butterflies and their milkweed hosts has identified several TNC properties as "monarch hotspots" and has used these sites to discover the migration routes and wintering grounds of Arizona populations of this charismatic species. Canelo Hills Cienega was one of the first sites to dispel the myth that monarchs did not frequent Arizona,[32] and continues to be a major research site for monarch movements and ecology, as does nearby Sonoita Creek.[33] Early research on milkweeds at Canelo Hills Cienega also produced foundational work on flower structure, pollination, and evolution[34] that has been cited in more than 280 other papers. For a few years, Muleshoe Ranch ran an active monarch rearing and tagging operation, with tagged individuals having been recovered by partners at wintering sites in both California and Mexico, as well as other Arizona sites.

Tick-born diseases

Key research partners: Henrey Deese and Sabrina McNew, University of Arizona

Tick-born diseases are drawing attention in Southeastern Arizona[35] and one graduate student is using riparian grasslands at TNC sites (Patagonia-Sonoita Creek, Middle San Pedro, and Canelo Hills) to uncover the full cycle ecology of an emerging disease organism called *Rickettsia parkeri*. This bacteria causes rashes and fevers in humans, similar to Rocky Mountain spotted fever but not as severe. The tick that carries this bacteria appears to be new to science, though it is related to the Gulf Coast tick (*Amblyomma maculatum*), which carries the same bacteria in other parts of the US. Because these ticks feed on birds, this research involves sampling birds for both ticks and bacterial infections. It also involves capturing ticks directly by "tick flagging," a method that uses white cloths that mimic wildlife ticks attach to.

Targeted *Amblyomma* ticks have been found at two of the three sites in varying numbers. Overall, 60-80 percent of ticks sampled are carrying *Ricketsia* bacteria. To the surprise of researchers, a different parasite called rabbit ticks (*Haemaphysalis leporispalustris*) were found on some birds at all three TNC sites. Rabbit ticks are known carriers of Lyme disease and Rocky Mountain spotted fever, which can be fatal in humans. Rabbit ticks do not typically bite humans, but if they and Gulf Coast ticks are feeding on the same hosts, it's possible that these pathogens could transfer between vectors. This may be an important research thread to disentangle, as Gulf Coast ticks and their kin do regularly bite humans. 2026 provides an opportunity to see if a prescribed fire at Canelo Hills reduced tick and bacteria numbers, and a chance for researchers to test the rabbit ticks for multiple pathogens. Preliminary results show that the prescribed fire dramatically reduced rabbit tick populations, with the average number of ticks per bird dropping nearly 70 percent post-fire. The team will continue to monitor bird and tick populations to see how quickly tick populations recover.

Individual Arizona preserves: Discoveries from microbes to megafauna

This section features research that focuses on one TNC site. Many of these studies also include the areas surrounding that preserve. The presentation of sites goes from North to South, starting on the high elevation Colorado Plateau and moving south and downhill into the Sky Island mountains and rivers of the Apache Highland ecoregion.

Bebbs willow trees in Hart Prairie Preserve.

Hart Prairie Preserve:

Situated at the base of Arizona's tallest mountains, Hart Prairie Preserve is a large high elevation preserve. This area on the Colorado Plateau has long been valued by research as a climatic transition zone and experimental restoration forest. The site itself sits at the foot of the San Francisco Peaks and consists of a broad meadow with mixed conifer and aspen forests, and a unique population of willows. Its beauty, hospitality, and proximity to Northern Arizona University has made it a favorite among researchers.

Bebbs willows

Key research partners: Joyce Maschinski, The Arboretum at Flagstaff; Gwendolyn Waring, Museum of Northern Arizona; Robert Blanchette and Benjamin Held, University of Minnesota; Amanda De La Torre, Northern Arizona University

Bebbs willow (*Salix bebbiana*) populations have been a research and monitoring focus at Hart Prairie for many years, with the Preserve hosting the largest willow population at the southern edge of the species' range. Studies in the 1980s and 1990s[36-40] initiated decades of researcher fascination with this particular stand of mature Bebbs and the lack of recruitment. These and subsequent studies that focus on growth, herbivory, survival, regeneration, and propagation methods are summarized in a 2015 paper.[41] One new study conducted in partnership with an NAU genetics lab is looking at the genetics of the Hart Prairie Bebbs population compared with others across the continent. Another is assessing microbial pathogens responsible for dieback, decline and mortality of the willows. This work will provide recommendations for managing the pathogens found to help safeguard and improve long-term willow health. Together, these studies illustrate why it is so important that ecosystems are protected in perpetuity, so that unique habitats can persist through time and new waves of science can build on the foundations laid by others.

Hydrology in high elevation meadows

Key research partners: Abe Springer and many students and colleagues, Northern Arizona University

Related research with NAU partners also looks at the hydrology of high elevation meadows, and how water dynamics change with forest thinning, prescribed fire, and climate fluctuations.[42,43]These findings were integrated into a review of effectiveness for arid land springs restoration projects in 2011.[44] Current TNC water monitoring has adopted a select set of these sites to continue measuring groundwater, so that conditions can be measured efficiently into the future and still be compared with the past.

Insects and Bebbs willows

Key research partners: Gary Alpert and Zane Holditch, Northern Arizona University

Another study is looking at the full suite of insects that rely on Bebbs willow habitat for survival.[45] For seven days, researches collected insects from willow trees over a four month period in 2024. Initial surveys found 62 different kinds of arthropods (counted as "morphospecies," some with species names assigned and others identified to family or genus only). These included many cryptic and unusual species. Typical for invertebrate diversity studies, cataloguing and photographing these insects took far longer than capturing them, and identifying them is an ongoing process involving many other specialist researchers. Researchers utilized the powerful crowd sourcing database BugGuide, an insect-focused and professional alternative to iNaturalist. With sophisticated photo methods that can bring every hair of a tiny animal to light, researchers captured 118 high-resolution images for 66 specimens and submitted most of these to Bugguide.net for help with identification. In this way, just seven days of insect collection have already yielded insight into diversity and ecology of insect communities in Bebbs willows in a way that will continue to build over time.

One of the most interesting findings to date involves the catkin willow fly. Bebbs willow trees are either male or female; surveys showed that both sexes attracted similar insects, including the catkin willow fly in the genus *Egle* that appears to be the willows' primary pollinator. After this highly unusual pollinator transfers pollen from male to female trees, it lays eggs on the female catkins. The fly eggs hatch into larvae that devour the very seeds their parents helped to create.

This work is ongoing. In addition to giving the scientific community more time to identify the first set of specimens, researchers are sampling more insects with other methods. After the initial survey, researchers set out several traps that capture insects in flight so they can continue to sample pollinators and other insects across seasonal changes in the host trees. More *Egle* catkin flies are being collected so they can be sent for DNA bar code analysis to determine exactly what species is involved.

> "To our astonishment, we realized that Hart Prairie Preserve, acquired by TNC to protect Bebbs willows, also protects a suite of rare and unusual insects that may represent a refugia of life forms surviving since the last ice age.
>
> **Gary Alpert**
> *Northern Arizona University*

Plants and soil

Key research partners: Bruce Hungate and Paul Dijkstra, with many colleagues and students, Northern Arizona University

Hart Prairie Preserve is one of four foundational sites in a set of experiments on how plants and soils respond to climate change. The research site's modest appearance—a fenced 30 meter by 30 meter square with a weather station—hides a huge scientific influence and a dizzying array of studies. This project was begun by Dr. Bruce Hungate in 2001 and has expanded since. In its simplest form, the study uses northern Arizona's natural elevation gradient to create an outdoor laboratory. In 2001, researchers took chunks of plants and soil ("mesocosms") from each location and transplanted them down one zone in elevation to simulate accelerated warming.[46] They then manipulated rainfall on these replanted mesocosms to create a gradient of rainfall at each location—from less rain, to average rain, to more rain. Sophisticated weather stations at each site track fluctuations and changes in sites' conditions. Plants and soils were then sampled over time, and transplanted mesocosms were compared with control ones across the warming (elevation) and rainfall gradient. A major paper published ten year into the study[47] showed that plant productivity increased with simulated warming, but that this response declined over time. Warmer mesocosms also lost more nitrogen compared with their cooler controls—the opposite of what the theory predicted. Warming almost completely changed plant species composition, especially for the mesocosms from the highest two elevation sites.

Longer term results have been alarming and perplexing. While many dynamics have shifted over time, the two decades of experimental warming have by now caused a 30 percent decline in stored soil carbon.[48] This large carbon loss appears to be mostly a direct result of warming; other aspects of the study ruled out indirect effects from changes in moisture and plant productivity. Major changes in the soil microbiome—bacteria, protists, etc.—seem to be driving this progressive decline in stored carbon, in a way that's eerily similar to other forms of ecosystem collapse. Warming reduced growth of a wide variety of soil bacteria, through a complex set of interactions. It now seems that a small set of predatory microbes has come to dominate more of the vast network of microbial interactions and may be responsible for suppressing productivity of the entire network.

Exploring the unexpected results from early years required researchers to dig deeper into complex and hidden world of soil microbiomes. Soils taken from these sites have been used in a suite of highly influential papers on mechanisms of carbon cycling and the ecology of soil biodiversity.[49-51] Dozens of researchers have participated in this effort, applying hundreds of years of collective research experience to understanding the foundational dynamics of the soil beneath our feet, and bringing millions of dollars of grant funding to Northern Arizona University and affiliated universities to continue this work. One recent grant-funded project (2022-2025) conducted five sets of interconnected field and lab experiments, during which at least 18 researchers looking at everything from the effects of altering microbial food webs to the biochemistry and genomics of how different microbes metabolize carbon. The study's original mesocosms were harvested in 2024, but research on these continues in labs and with some re-deployed in the field, and new work is being done at the same site.

Daybreak at he Muleshoe Ranch Cooperative Management Area (CMA).

Aravaipa Canyon

Isolated Aravaipa Canyon is one of Arizona's true natural wonders, featuring a desert stream, majestic cliffs and bighorn sheep. Located about 50 miles northeast of Tucson, the preserve includes lands at both the east and west end of Aravaipa Canyon, as well as preserve lands intermixed with public land on the canyon's south rim.

The 9,000 acres owned by The Nature Conservancy are managed in conjunction with about 44,000 acres of federal lands. Preserve elevation ranges from 2,800 feet at the west end of the canyon bottom to 6,150 feet on Table Mountain. The 10-mile long central gorge, which cuts through the northern end of the Galiuro Mountains, is a federal Wilderness Area managed by the Bureau of Land Management.

Fish monitoring, prescribed fire, and other conservation management activities on Aravaipa Canyon Preserve are directed toward ensuring the long-term protection of the stream system and its mixed broadleaf riparian forest composed of cottonwood, willow, walnut, alder and sycamore trees.

Native fishes across time

Key research partners: Peter Reinthal, University of Arizona; Heidi Blasius, Bureau of Land Management; Wendell Minckley (1935-2001), Arizona State University; Genetics: Jessica Rick and Oliver Fahrner, University of Arizona

Research and monitoring of native fish community composition at Aravaipa is the longest-standing set of fish studies in the state. Initial surveys began in 1943, followed by more thorough bi-annual repeat surveys run by ASU and UA beginning in 1963 and further standardized in 1975. Repeat bi-annual surveys were taken over by the current research group in 2002, yielding data from multiple segments of the creek almost every year from 1965 to the present day. These efforts are documented in detail by a 2005 report[52] and updated in a 2021 publication[53]. Within this time span, numerous shorter-term studies evaluated the impact of various invasive fishes; tracked the effectiveness of a 2001 fish barrier; documented fish responses to different streamflow dynamics as evidence to support legal protection of instream flow; and investigated many aspects of fishes' natural history from parasites to population ecology. Among other discoveries, this work shows that Aravaipa Creek continues to be one of the most important native fisheries in the Southwest; that endangered Loach minnow and Spikedace can thrive with natural flooding and with control of exotics; and that cleanup of Klondyke mine tailings is benefiting the creek and its wildlife. Aravaipa fish surveys have

Graduate student Oliver Fahrner with native Sucker fish.

© University of Arizona

> Using students to sample fish in Aravaipa Creek is a tradition going back at least 60 years. Just since 2001, I've had over 350 different students participate. Many have gone on to pursue careers in conservation and biology and resource management.
>
> **Peter Reinthal**
> *University of Arizona*

also been a training ground for a generation of wildlife biologists who now populate the ranks of many natural resource agencies and research groups.

Black hawks

Key research partner: Jay H. Schnell

Studies on the behavior and ecology of the Common Black Hawk (*Buteogallus anthracinus*) in Aravaipa Canyon began decades ago and formed foundational knowledge of this species, as can be seen in papers and book chapters Jay H. Schnell.[54] Through his research on Black Hawks, Dr. Schnell discovered that fledgling survival at Aravaipa was closely tied to the abundance of lowland leopard frogs. This led to annual leopard frog monitoring that began in 1977, which preserve staff continued for many years. The leopard frog database at Aravaipa runs from 1977 to 2021, one of the longest in Arizona, and documents a die-off in the 1980's attributed to the introduction of chytrid fungus, followed by a rebound after the removal of cattle from the riparian area. This work also documents a baseline to compare with current site conditions, and could help guide the preserve's grazing program. Meanwhile, data from the original Black Hawk studies was incorporated into a study of hawk diets from the Verde River system, which found that in some places, these birds can actually switch to eating fish, crayfish and reptiles where native frogs are less abundant.[55]

Soil health

Key research partners: Laura Norman and Natalie Wilson, U.S. Geological Society; Joseph Blankinship, University of Arizona

Research on soil health conducted with partners from the UA and USGS has shown that growing native grasses in old agricultural fields can dramatically increase soil stability and water holding capacity relative to unrestored fields and also relative to many other land cover types (rangelands, conventional croplands, and even some wetland types).[56] At the same time this practice benefits the preserve in several ways, including reducing noxious weed and dust problems, reducing sediment inputs into Aravaipa Creek, improving habitat conditions for native fish, providing raw materials for grassland restoration, and producing livestock forage—and does so with lower inputs of water and chemicals per acre than conventional farming of crops like alfalfa or cotton require. Initial surveys of soil carbon, though, have raised as many questions as they have answered, and warrant more study.

Watershed modeling

Key research partner: Laura Norman

TNC-supported watershed modeling with the United States Geological Survey described and quantified how working lands provide ecosystem services, and modeled how land conversion from development would reduce those services.[57] The Aravaipa Watershed Conservation Alliance is using this report to prioritize, plan, and fund watershed improvement projects.

Students help monitor fishes in Aravaipa Creek.
© Jeremy Welch/TNC

Invasive plants

Key research partners: Phil Hedrick, Arizona State University (retired); Heidi Blasius, Bureau of Land Management; Mark Haberstich, The Nature Conservancy (retired); Emma Rosenau, University of Vermont

Aravaipa's strand of vibrant green cottonwood and willow trees threading through its dry red canyonlands has made it a target for research on the invasive plants that threaten that special riparian habitat. A 2019 publication gives an overview of invasive plants in Aravaipa Canyon,[58] with history and management implications for each species. This work represents many years of tracking the spread of and control efforts for invasive plants throughout the canyon. This publication is co-authored by three people: an agency partner who has advocated tirelessly for native fish in the region,[59] a TNC preserve manager, and a retired ASU faculty member who has also written a book about the canyon.[60] In addition, a 2023 undergraduate honors thesis analyzes factors that affect the success of invasive species control efforts.[61,62]

Together, these research efforts have informed management strategies and contributed to the overall health of this watershed. A few indications of this success include recent re-introduction of Gila Topminnow in 2022, documentation of a thriving Southwest Willow Flycatcher population in the Canyon 2024, and 2025 data showing increasing ground water levels, which make Aravaipa TNC's only Arizona preserve to become noticeably wetter during regionwide drought times.

Muleshoe Ranch Cooperative Management Area

The Muleshoe Ranch Cooperative Management Area (CMA) is 56,000 acres of rugged beauty and lush riparian areas, a mosaic of public and private land cooperatively managed by The Nature Conservancy, Bureau of Land Management and Coronado National Forest. These three partners work together to conserve and enhance the unique ecosystems found here and to protect endangered species and the areas they depend upon.

Gila monster individuals can be recognized by their unique body patterns.

The Muleshoe Ranch CMA encompasses most of the watershed area for seven permanently flowing streams, representing some of the best remaining aquatic habitat in southeast Arizona. Some 80 percent of the region's wildlife species depend upon streamside communities like these at some time in their lives.

Insects and sotol

Key research partners: Gary Alpert and Zane Holditch, Northern Arizona University

In 2023, a retired Harvard entomology professor, now affiliated with NAU, decided to expand his work photographing and documenting insects at Ramsey Canyon to include a study at Muleshoe. This study of insects that live on sotol, the iconic desert yucca-like plant *Dasylirion wheeleri*, was designed to repeat collections done in the same canyons in 1887.[63] Collectors ultimately sampled at a larger population of sotol plants nearby to minimize their impacts. They found more than 100 species of insects, including what they termed "some of the rarest beetles in North America." As with Ramsey arthropods sampling, this sotol survey work has just scratched the surface of biodiversity discoveries waiting to come to light.

Reptile behavior

Key research partners: Melissa Amarello, Advocates for Snake Preservation; Jeffrey Smith, The Nature Conservancy

In 2011, two researchers learned to recognize individual Gila monsters and black-tailed rattlesnakes—opening up a world of discovery of animal behavior. Subsequent snake research here and similar sites nearby revealed that these snakes' social lives were far more elaborate than previously known, with extensive parental care, interacting neighbors, and communal dens.[64,65] After leaving Muleshoe, the two expanded their conservation and research work by founding a non-profit called Advocates for Snake Preservation.[66] Their research brings a deeper appreciation for the lives of the animals that call TNC preserves home, and highlight places within the landscape that need additional protections.

Bryophytes

Key research partners: Jason Brooks, California Academy of Sciences

A specialist on bryophytes (mosses and their kin) from the California Academy of Sciences targeted Muleshoe for an inventory of these ancient non-vascular plants. During field trips conducted between 2023-2024, this researcher collected 210 specimens and identified 64 species. The published summary of this survey[67] reports detailed taxonomic and ecological observations for each of these species, and compares findings with studies done in the Grand Canyon, the other best-known site for bryophytes in Arizona.

Desert bighorn sheep and prescribed fire

Key research partners: Rana Murphy, Arizona Game and Fish Department; Ron Day, The Nature Conservancy (retired)

Advocates for desert bighorn sheep made epic efforts to

reintroduce this species to the rugged canyonlands of Muleshoe and Aravaipa in 2016.[68] Additional GPS-collared bighorn have been released since. Tracking these returnees using satellite signals in the years after reintroduction showed that members of the Muleshoe and Aravaipa herds travel long distances, but did not appear to be intermixing.[69] Agency land managers have since been applying prescribed fires in areas of dense brush between the herds' current ranges, and bighorn advocate groups are funding efforts to test the hypothesis that fire can improve, expand, and connect bighorn habitat. Wildlife researchers believe the animals avoid dense brush because the heavy vegetation easily conceals predators like mountain lions from view. Bighorn advocates hope that bringing back natural fire regimes that reduce brush cover over time can improve bighorn survival, as well as allow them to move across large landscapes so contact between herds can sustain genetic diversity.
Data collected since 2016 suggest that fire has succeeded in expanding the area suitable for bighorn and has closed the gap between the two herds from about eight miles to just four miles, though no collared animals have yet fully completed the crossover to unify the herds (Rana Murphy, pers com. 2026).

Fire effects research is an ongoing Aravaipa. Novel methods include using remote wildlife cameras to record fire behavior and wildlife responses, as well as fitting neighboring ranchers' cattle with radio collars to see how they choose grazing sites after fires. Meanwhile, research from the late 1990s on the effects of prescribed fire on fish habitat and watershed health[70] continues to bear fruit decades later in environmental reviews of prescribed fire proposals.[71]

Bighorn sheep at Muleshoe CMA.

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Middle and Lower San Pedro River

TNC land holdings and management responsibilities on the San Pedro River north of Benson, Arizona (i.e., the "lower" river) start with the Middle San Pedro Preserve and go downstream to several disjunct properties that TNC owns and several that TNC staff manage under contract with other owners. These properties are relatively remote yet entwined with the dispersed rural communities surrounding them. Spanning some 50 miles of river that alternate between perennial and seasonal flows, this array of properties offers insights into a broad spectrum of river conditions and land use histories. Some of these lands have experienced a long history of human degradation and impact and serve as restoration sites.

Researchers Collin Gillespie (left) and Dr. Jia Hu (right) measure a large bosque mesquite tree and prepare to take samples of water inside tree tissues to figure out what mix of rainfall and aquifer water the tree has been using.

Mesquite bosque forest

Key research partners: Collin Gillespie and Jia Hu, University of Arizona; Russ Scott, Agricultural Research Service

Work with ecohydrologists and bird researchers at the University of Arizona (2020-2025) on the Middle San Pedro River Preserve showed that mesquite bosque forests can be effectively restored in places with suitable soil and groundwater conditions.[72] This research showed dramatic differences in plant life and bird communities between upland mesquite scrub on dry hillsides versus mature mesquite bosque near the river channel; second-growth mesquite thickets on former farm field terraces were more similar to the mature bosque. Ecohydrology (evapotranspiration estimates, plant water stress measurements, and plant water isotopes) showed that the two near-stream habitats use a mix of rainfall and deeper water provided by the aquifer and by deep soil moisture from prior seasons.[73] Trees in the upland scrub also access some deep soil moisture, but their lower total water needs can be met with local rainfall across recent seasons.

Desert riparian dynamics

Key research partners: Arizona State University lab groups of Stromberg, Sabo, and Bateman

ASU lab groups of Stromberg, Sabo, and Bateman have led dozens of students to work on the San Pedro, looking at topics from hydrology to plants, reptiles, birds, and mammals. Publications and participants are too numerous to list here except as examples, but it is fair to say that these researchers provided key insights into desert riparian dynamics, and that important parts of this work were done on TNC owned and/or managed sites on the Lower San Pedro River.[74] Early on, this work helped document water needs for cottonwood, willow, and other riparian trees.[75,76] Collectively, these researchers' studies continue to be widely used in restoration and environmental flows projects across the West.[77] Environmental flows work pioneered approaches to taking site-based knowledge about the water needs of individual plant and animal species and building those into broad understandings of how river ecosystems function under different flow regimes.[78] These approaches also rely on the cumulative expertise and insights of scientific experts. For many of these experts, both their actual data and their views of ecosystem function have been shaped by experiences on lands where TNC staff have spent decades working to support natural processes.

Wildlife communities

Key research partners: Julie Stromberg, Heather Bateman, John Sabo, and numerous students and colleagues, Arizona State University

Sites in the Lower San Pedro have long served to compare vegetation and wildlife communities between sites with more and less water in the stream and shallow aquifer. Some results have been surprising, such as the finding that intermittent streams have more plant diversity than either perennial or ephemeral reaches. [79] Comparison of bat, lizard, bird, mammal, and toad communities across sites have also shown how water benefits wildlife, how native trees make better habitat than exotics even in the same water conditions, and how removing exotic trees without restoring natives can do more harm than good to wildlife.[80,81,82,83,84,85] ASU partners have also helped TNC staff show the benefits of protecting water levels by reducing the amount of groundwater pumping for agriculture.[86] Relatedly, the Lower and Middle San Pedro sites were the focus of a recent Master's thesis looking at recovery of native vegetation on abandoned farm fields.[87]

Local water sources

Key research partners: Chris Eastoe, University of Arizona (retired) and Barbara Clark, TNC (retired)

To understand local water sources and recharge timing along the Middle San Pedro River, a study published in 2018 looked at chemical and isotope composition of water samples drawn from 65 distinct locations, some of which were sampled in multiple times.[88] The study also looked at how groundwater levels are changing through time to help community members and conservationists manage that water sustainably. For over three decades now, neighbors and TNC staff have worked together to measure water depth of wells in and around the village of Cascabel. Analyses revealed two distinct aquifers in this 27km length of river, one within the main San Pedro River channel, and another originating from the Hot Springs Wash tributary that runs down from the Muleshoe Preserve and into the San Pedro. Comparing water level changes in wells that tap into each aquifer continues to help tease apart influences of regional forces such as droughts, floods, and over pumping of groundwater in different places.[89]

Rivers of Carbon Project

Key research partners: Lauren Tomas and Kathryn Lininger, Colorado State University

The Rivers of Carbon project, started in 2025, aims to improve the ability to estimate the highly variable[90] carbon capture benefits of rivers across the continent. Arid land rivers like the San Pedro have received relatively little attention by carbon researchers, so studying sites here will help fill a gap in regional and global modeling efforts. This project also aims to compare carbon storage of river segments in different conditions—intact, degraded, and restored—so researchers can see what's at stake in keeping rivers healthy and what can be gained by restoring degraded reaches.[91] In addition to hosting researchers, TNC staff helped them understand the dynamics of intermittent river systems and find sites that fit their spectrum of conditions within this particular context.

Soapberry trees

Key research partners: Daniel McNair, WestLand Resources, Inc.

Impressive stands of Soapberry trees (*Sapindus Saponaria var. drummondii*) have attracted attention at 7B Ranch, which was managed by TNC at the time. Research mapped and described local stands, finding more than 5,000 stems in one clonal grove, including some of the largest trunks ever reported for this species. After reviewing and comparing this site with several other notable stands, the authors concluded that this Lower San Pedro site harbors "the largest soapberry thicket currently known to occur in Arizona." The project also reviews taxonomy, pollinator relationships, and identification of the plant from aerial photos and from direct observation.[92]

Wildlife migration

Key research partners: Edwin Juaros, AGFD; Matt Webb, Bird Conservancy of the Rockies

To provide insights into the lives of many wide-ranging animal species, a Motus radio receiver tower was installed on Middle San Pedro Preserve in 2025. Motus is a global research initiative that uses an open source network of strategically placed receivers that can track the movements of birds, bats, and insects.[93] Projects around the world outfitting wildlife of interest with tiny transmitters that relay data to these stations any time the animal flies near. Over time, records from multiple towers can show the routes and timing of an individual animal's migration. Records from multiple animals can show broad scale patterns of migration and habitat use, and responses to land use changes and weather shifts. The TNC tower installation is part of a broader initiative led by the Arizona Department of Game and Fish, with support from collaborators including the U.S. Bureau of Reclamation and Bird Conservancy of the Rockies. This partner project is gradually establishing a statewide network of receivers, with this tower covering a key location on the San Pedro River's continental migratory flyway. As more tagging efforts are added, the network's value will increase. In its first year, TNC's station recorded 12 tagged birds and one bat. One Wilson's phalarope (*Phalaropus tricolor*) recorded in August of 2025 has been reported by 25 other stations since 2023, from Idaho to southern Mexico. See more at Motus.org.

Patagonia-Sonoita Creek

The first project for TNC in Arizona, Patagonia-Sonoita Creek contains the first two miles of permanent flow of Sonoita Creek and the floodplains adjacent to the streams, along with much of the biological diversity associated with these habitat types. The watershed is mostly undeveloped, and the natural processes of flooding are mostly intact and functioning.

The 1,000+ acre preserve protects a magnificent example of the rare Fremont cottonwood-Goodding willow riparian forest. Some of the trees are among the largest (more than 100 feet tall) and oldest (130 years old) Fremont cottonwood trees in this country. This is one of the few remaining sites in Arizona where this once-common forest type still persists. Arizona black walnut, velvet mesquite, velvet ash, netleaf hackberry and various willows are found in slightly different habitats throughout the preserve.

The preserve has been actively engaged in hydrologic research and monitoring and is the site of some of the first community-based activities seeking to build understanding and support for conservation in southern Arizona. It has been a platform for promoting the work of TNC and a site of several innovative environmental education activities.

Ocelot wildlife camera

Key research partners: Jim Rorabaugh, U.S. Fish and Wildlife Service (retired); Marc and Peggy Foucher

A wildlife camera study on the preserve, run from 2024-2025 by a retired USFWS biologist, was set up to look for rare ocelots that have been seen frequently just south of the border[94,95] and appear on cameras (and unfortunately as road fatalities) every few years in Arizona. Seven cameras were set up in places ocelots like to move, like logs that cross the stream, and produced almost 3,000 animal sightings (13,000 images of animals, with multiple pictures of the same animal around the same time).[96] The cameras did not find ocelots, but they did document 17 other medium-large mammals. Analyses described activity patterns and habitat preferences for various abundant species, and found that high human activity appeared to affect some animals but not others. The report concluded that "although the vegetation structure and composition of the habitat at Patagonia-Sonoita Creek appear suitable for ocelots, human use and presence, as well as the proximity of Highway 82 and the town of Patagonia, may preclude the occurrence of resident ocelots, which are sensitive to human disturbance and vulnerable to mortality on highways."

Puma strolls past a wildlife camera.

Another camera study, run since 2023 by a team of long-time preserve volunteers, has amassed 88,000 wildlife photos of at least 55 bird and mammal species. With this number of images, analyses are not yet complete but promise many more insights into habitat use and animal behavior on the preserve. A few patterns already emerge: white-tailed deer and javelina are the most abundant sightings; racoons and their tropical cousins coatis appear in almost equal numbers; all four species of Arizona's skunks find space on the preserve; and sightings overall decline on weekends when the Preserve has more human visitors.

Wildlife camera photo of black bear at Patagonia-Sonoita Creek Preserve.

Wildlife-vehicle collisions

Key research patner(s): Volunteers from TNC volunteers, Borderlands Restoration Network, Arizona Department of Transportation, Arizona Game and Fish Department, Coalition for Sonoran Desert Protection

A related study is the collaborative "Roadkill Rangers" project, through which staff and volunteers from TNC, the Borderlands Restoration Network, the Arizona Department of Transportation, and others record and photograph wildlife fatalities encountered along the 23-mile stretch of Highway 82 that runs parallel to Patagonia-Sonoita Creek. In its first year, the project documented 232 animal carcasses from at least 24 species. The project will run for at least two years, and data collected will be used to make improvements to the wildlife corridor and to increase highway safety

Native fishes across time

Key research partners: Peter Reinthal, University of Arizona; Heidi Blasius, Bureau of Land Management

Sonoita Creek has been a focal site for research on native fish communities. Surveys began in the late 1990s, with some gaps. Most surveys focus on the presence/absence of native fish; these provide a sense of species community composition and ratios of adults vs juvenile fish. The addition of depletion sampling[97] in select years (every 3 years starting in 2022, plus some prior years) can estimate population sizes in ways that other surveys cannot. The sampling of aquatic insects in Sonoita Creek and its tributaries, which have varying geology and mining history, has enabled researchers to investigate how acid mine wastes impact insect communities, which are then used to understand water quality differences across longer time frames.

Prehistoric vegetation

Key research partners: Owen Davis, University of Arizona; Tom Minckley, University of Wyoming

When researchers studying prehistoric vegetation discovered that pollen found in sediment cores were full of charcoal (including cores from Patagonia-Sonoita Creek and TNC's Los Fresnos property in Sonora), they used the cores to investigate natural fire regimes across desert wetlands.[98] Dramatic declines in burning during historic times is linked to major changes in cienega vegetation, including a transformation from herbaceous to woody wetland plants. This study also notes that co-occurrence of charcoal and corn pollen in pre-contact sediment layers suggests these cienegas may have been burned frequently by Indigenous People as a management tool to open them to use for prehistoric agriculture. This area has a very long history of prehistoric farming, as documented by studies in the adjacent Cienega Creek watershed.[99] Other sources in the area document the Sobaipuri Peoples' residence and farming patterns across the region surrounding the time of Spanish contact, but do not elaborate on the use of fire in farming.[100]

Hummingbird courtship

Key research partners: Rick Simpson, Arizona State University

An ASU graduate student used Patagonia-Sonoita Creek Preserve as one of eight sites for research on the disco-like courtship displays of six different hummingbird species.51 Across the six species, these studies compared the iridescent color characteristics of male feathers at various angles and used video cameras to record the movements that males of each hummingbird species makes when dancing to impress (temporarily captive) females. Results showed that species with more exaggerated dance displays created more "flashy" color changes with their feathers during courtship, while species with bigger patches of iridescent neck feathers relied more on maintaining the consistent brightness of their feathers rather than fancy moves and color changes. Patagonia-Sonoita Creek's own black-chinned hummingbirds have the smallest patch of bright feathers, but their aerial dances are so broad and so fast that researchers had to use two cameras to capture their movements—and videos show the female bird observers also spinning to keep up with the acrobats' moves.

Prescribed fire in the Canelo Hills, 2026.

Canelo Hills Cienega

Canelo Hills Cienega Preserve was TNC Arizona's second preserve. Its pocket of rare stream and wetland habitat encompass 260 acres and has been the location for myriad multi-site studies, including the firefly, tick, crayfish, and sucker studies described earlier in this report. The site has less human influence than Patagonia-Sonoita Creek or Ramsey Canyon, but is more accessible than Aravaipa or Muleshoe. This context, as well as its natural beauty, make it a favorite among researchers and visitors alike. Several rare wetland species call this site home, including imperiled forms of springsnails,[101] garter snakes,[102] and treefrogs.[103]

Rare orchids & juniper trees

Key researcher partners: Orchid study: Andrew Salywon and Steve Blackwell, Desert Botanical gardens; Melissa McCormick, Smithsonian Environmental Research Center. Juniper ecohydrology: Susan Bush, Kevin Hultine and Andrew Salywon, Desert Botanical Gardens

Canelo Hills Cienega Preserve was purchased in 1969 due, in part, to the presence of a rare wetland orchid, then called *Spiranthes graminea*. This orchid was first discovered in the US in 1968 in the Canelo Hills by legendary paleoecology researcher Paul S. Martin (1928-2010).[104] By 1990, botanists had realized that the orchid was a separate species from other populations of *Spiranthes graminea*, and named it *Spiranthes delitescens* with the common name "Canelo Hills ladies tresses" in honor of the type locality.[105] In recognition of its rarity and precarious status, it was put on the US Endangered Species List in 1997.[106]

Recent partner surveys for the endangered Canelo Hills ladies' tresses at this and three nearby sites suggest that the species may be heading towards extinction, and that sites may be getting dryer and more overgrown by other plants.[107] Combining these survey results with TNC research on this site from the 1990s[108] suggest that fires and other disturbances may be needed to maintain the orchid, and argue for management intervention to save the species.

These findings spawned a slew of new research and management efforts, from major erosion control projects to stabilize soil and raise water tables, to elaborate studies on how trees use water and whether juniper trees may be contributing to water declines across this wetland.[109] Junipers are native to the area, but are typically found on the dry hillsides rather than down wetlands where their deep roots can access almost unlimited amounts of water. In January 2026, this attention culminated in a 300-acre prescribed fire (conducted by the US Forest Service and crew members from other agencies) designed to improve orchid habitat and refresh vegetation across the wetland. As of May 2026, TNC and partners are examining how plants and water dynamics are responding to a prescribed fire that was completed in February 2026.

Meanwhile, the Desert Botanical Gardens and Smithsonian Institution have broken new ground by identifying a soil fungus that the orchid depends on. This work includes utilizing scent-detection dogs to find the soil fungus on the preserve.[110,111] These researchers also figured out how to propagate orchids in the lab with help from the fungus. With competing plants knocked back by the fire, Desert Botanical Gardens planted lab-grown orchids back on the preserve in spring 2026, in an experimental array that will allow them to test effects of various planting and habitat differences.

Climate patterns and sediment cores

Key researcher(s): Andrea Brunelle, University of Utah; Thomas Minckley, University of Wyoming

Canelo Hills Cienega Preserve has been part of myriad multi-site sediment core studies. A study published in 2018 reconstructed climate patterns from the past 8,000 years, using sediment cores (with pollen and charcoal) from the preserve and three other cienega sites.[112] The study suggests that cycles of frequent El Nino weather events are responsible for much of the past aquifer recharge in the region, which has created and maintained cienega habitats. This study also compared vegetation types and fire frequencies across sites, to give a broad picture of the region's changes through time, and fill in a geographic gap to create a cohesive picture across the continent.

A second paper analyzed charcoal in more detail and showed that frequent El Nino weather events are also tied to increases in desert cienegas' fire frequencies, presumably by growing more continuous fine fuels needed to carry fire in arid ecosystems.[113] The charcoal record at the preserve has some similarities with that of Patagonia-Sonoita Creek. In general, charcoal accumulation rates increase slowly from the core's oldest date (approximately 3,000 years ago) to the present. There is a brief, very sharp decline in charcoal a few hundred years ago and then it quickly rises again. Charcoal declines again in the very recent sediments but is still higher than the site's long term average, suggesting that fire frequencies may have varied over time but that fire has always been important here.

Cienega source waters

Key researcher(s): Adam Stratman and Jennifer McIntosh, University of Arizona

A study completed in 2022 used stable isotopes and water chemistry to figure out where water in the cienega and stream comes from, and how long it takes to travel through the landscape underground.[114] For clues, the study sampled seasonal rainfall, surface waters, and wells in a broad area surrounding the preserve. Overall results show that waters in the area come from mountain front recharge miles away where the Huachuca and Canelo Hills meet valley sediments, and are fairly old (most recharged 60-500 years ago, some closer to 5,700 years ago). Most of this recharged water seems to have originally fallen as summertime mid-elevation mountain rain. Isotope and chemical details, however, show differences between clusters of samples, revealing that the preserve's springs and creek are each fed by somewhat different mixing of sources and flow paths. This mixed source of replenishment suggests that both land restoration and aquifer protection will benefit the cienega—and both are probably necessary if the wetland and all that depend on it are to survive long term.

Preserve Manager Aaron Mrotek collecting flow measurements at Sonoita Creek.

Ramsey Canyon

Southeastern Arizona is an ecological crossroads, where the Sierra Madre of Mexico, the Rocky Mountains and the Sonoran and Chihuahuan deserts all come together. The abrupt rise of mountains like the Huachucas from the surrounding arid grasslands creates “sky islands” that harbor tremendous habitat diversity and form stepping stones to the tropics. This combination of factors gives Ramsey Canyon Preserve its notable variety of plant and animal life.

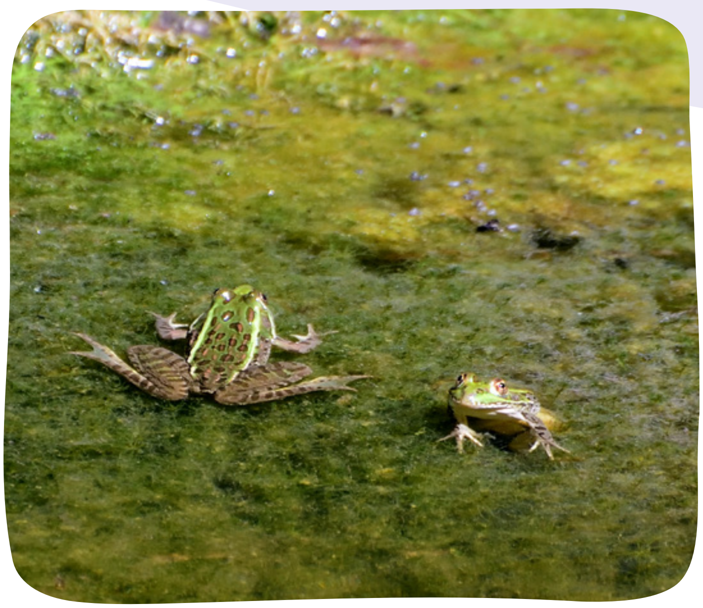
Although the 380-acre preserve is best known to the public as an international birding destination, Ramsey Canyon has also attracted the attention of researchers looking at a wide variety of arthropods like insects and spiders, and at wide-ranging bats. A key feature of this rugged mountain canyon preserve is Ramsey Creek, which starts as a perennial stream high in the Huachuca Mountains and then dives under the rocky canyon floor of the Preserve. It continues to flow underground through the preserve and towards the San Pedro River, but surface flows become seasonally intermittent. These dynamic flows are enough to support many water-dependent species like the endangered Chiricagua leopard frogs (*Lithobates chiricahuensis*) and a rich forest of sycamore and maple trees, but not enough for fish. Ramsey's leopard frogs were once thought to be a unique species and were intensively studied and managed on site,[115] but were officially recognized as a member of the more widespread but still endangered Chiricahua species in 2012.[116-118]

Aquatic insects

Key researcher partners: Michael Bogan, University of Arizona; Dave Lytle, Oregon State University; Eric Moody, Middlebury College

Ramsey Canyon has revealed some very interesting patterns of diversity and ecology in aquatic insects. Studies illustrate the high diversity and unusual species found at this site and across the region.[119] Studies of both perennial and ephemeral stream communities are helping researchers understand the implications of climate change and stream drying, recognize the value of non-perennial waters, and build a foundation for developing bioindicators that work in ephemeral and intermittent streams.[120-121122] Papers published on comparisons across these aquatic invertebrate communities have become foundations of both theoretical and practical understandings of how variable and changing environments shape biodiversity and ecosystems.[123,124] The preserve has also been a pioneering site in the development of new technologies that track flows in non-perennial rivers.[125]

Other studies focus on the fascinating behaviors and ecological contrasts of individual species. Researchers have discovered that flightless giant water bugs (*Abedus herberti*) walk out of their creek homes when it rains to avoid being washed away by floods.[126] Insects collected from Ramsey Canyon were included in cross-site comparisons of behaviors that showed they are highly adapted to their creeks, with flood-escape response times matched to the watershed size and flood predictability of each stream system.[127,128]



Chiricahua leopard frog at Ramsey Canyon.

Ramsey Canyon and Muleshoe were also included in genetics studies that show animals are genetically distinct across sites, that populations diverged tens of thousands of years ago, and that each site's nearest kin tend to be from the same mountain headwaters (as with mountaintop endemic species) and not from the same river network (as with most fish). Genetic patterns in other species have been published since.[129] Analytical methods and findings from these studies have been cited hundreds of times and remain influential across several fields of genetics, conservation, and biogeography.

A study published in 2018 showed that stream-dwelling caddisfly larvae, well known for their ecosystem function of shredding and recycling leaf litter, can also climb up the trophic ladder and eat dead animals.[130]

Comprehensive insect surveys

Key researcher partners: Gary Alpert, Zane Holditch, Elyse Guerena and Northern Arizona University.

To aggregate data on Ramsey Canyon insect populations, researchers are attempting to record as many of Ramsey's insects as possible in digital databases. These scientists have specialized in cataloguing global hyper-diverse tax like ants,[131] and in making catalogued records available to others. They estimate that there may be some 10,000 arthropod species within Ramsey Canyon Preserve's 380 acres and have set a goal of photographing 5,000 species of the more common arthropods. This effort began in 2021, with more species as researchers are able to travel to the preserve or obtain specimens from other individuals and institutions. Photography is an important aspect of the project, with high-resolution images designed to help other experts identify species, and to engage the public to boost appreciation of these insects.

Bat migration

Key researcher partners: Mallory Davies and Kathryn Stoner, University of Arizona

Ramsey Canyon has also played a role in the study international bat migration. Three species of nectar-feeding bats—Mexican Long-tongued Bat (*Choeronycteris mexicana*); Mexican Long-nosed Bat (Leptonycteris nivalis), and Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*) reach their northernmost range limits in the Apache Highlands Ecoregion. The Lesser Long-nosed Bat was federally listed as Threatened in the US until 2018, when it populations were deemed secure enough to be de-listed. These bats roost together in large colonies, with just a handful of caves serving as maternity roosts where pups are raised. Each year these bats follow seasonal waves of cacti and agave flowers to fuel migrations of up to 2,000 kilometers from southern Mexico to the borderlands of Arizona and New Mexico.

To match the epic scale of their migrations, an extensive network of international researchers have collaborated to study these bats across their range. This extended research group has now captured and put radio tags on over 4,000 individual bats and installed tag readers at 12 major roost sites, and have documented epic travel distances and complex movement patterns among roost sites.[132] At the more local scale, two of the 12 roost sites with tag readers are in the Huachuca Mountains, at Fort Huachuca and at Coronado National Memorial. Tagging bats at Ramsey Canyon, right between these roosts, has allowed researchers to study the finer-scale movement choices of bats on their nightly foraging flights, and add to the international study. In 2022, this team captured nine Lesser Long-nosed bats and 19 Mexican Long-tongued Bats at Ramsey Canyon.[133] All of the long-nosed bats were later detected at the Fort Huachuca roost site. Mexican Long-tongued Bats caught at Ramsey Canyon may also represent the first reproductive males of this species ever documented in the US. This team has also helped prove high-tech methods for identifying which bats have been visiting nectar sources by swabbing those for bat DNA left behind by their saliva; in 2025, this approach reported the first confirmed detection of a Mexican Long-nosed bat in the US.[134]

A lesser long-nosed bat visiting a nectar feeder at night in Ramsey Canyon Preserve.

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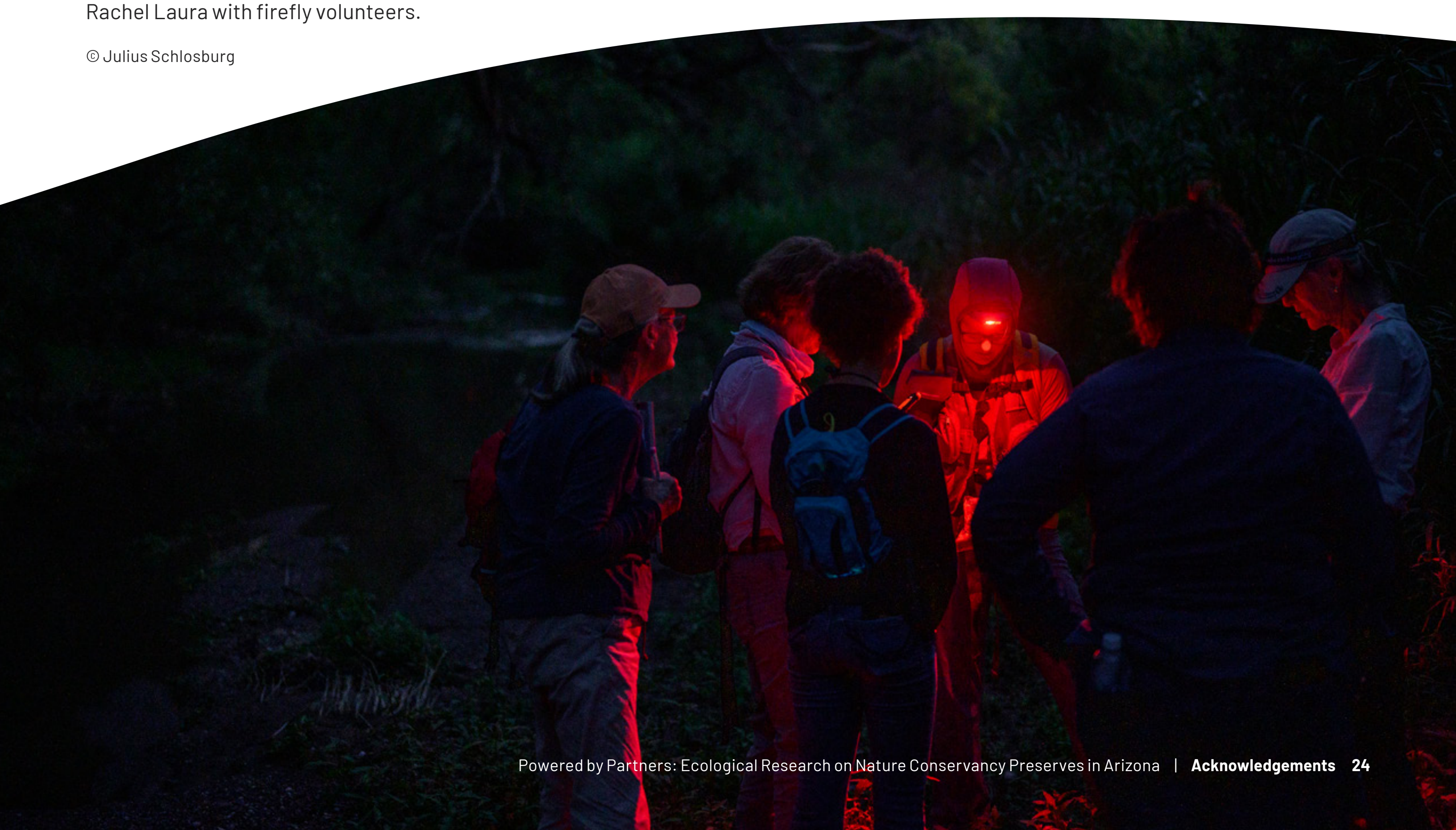
For more information, or to share research that should be include in future iterations of this report, please contact Gita Bodner at gbodner@tnc.org.

Rachel Laura with firefly volunteers.



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