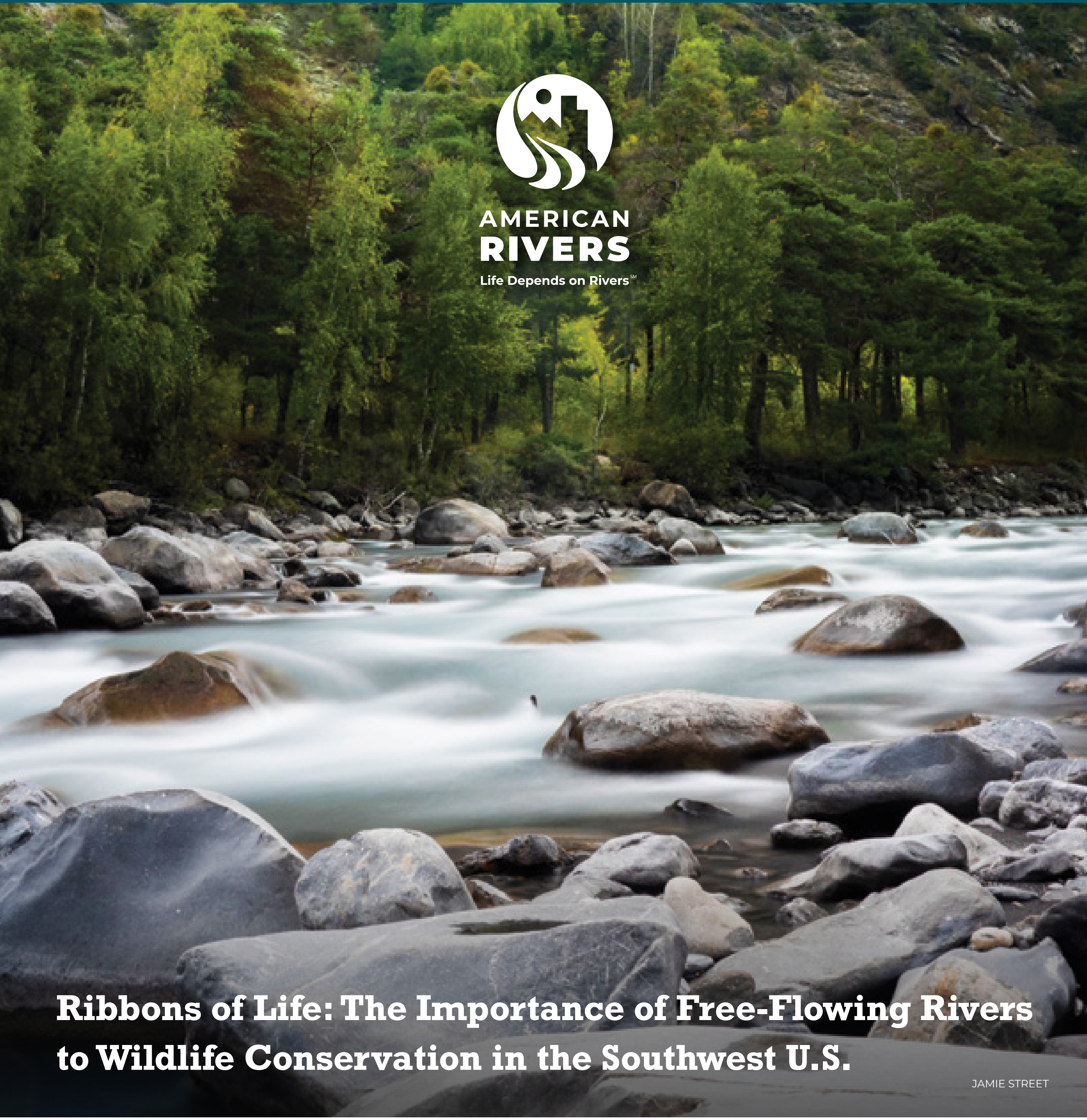

Ribbons of Life: The Importance of Free-Flowing Rivers to Wildlife Conservation in the Southwest U.S.

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EXECUTIVE SUMMARY

The Southwestern United States is a landscape largely defined by water. The canyons, ridges, mountains and playas of the Chihuahuan, Mojave, and Sonoran deserts, as well as the Colorado Plateau, have been carved by two great river systems, the Colorado River and the Rio Grande. The resulting habitat supports a wide diversity of fish and wildlife species, from the megafauna of alpine valleys and high mesas to the native fish, avian, and aquatic riparian species of deep desert streams and gorges. Rivers have an outsized importance for wildlife everywhere, but in the arid regions of Arizona, Colorado, New Mexico, and Utah, they are even more critical to the maintenance of biodiversity.

In May 2021 the United States National Climate Task Force recommended a 10-year campaign to protect and restore the lands and waters of the country. This science-driven campaign calls for collaboration and inclusivity in conservation at the local level that supports conservation priorities of Native Nations while fostering stewardship of private property through flexible and adaptive approaches. The goal of this agenda is to protect at-risk species, spawning and calving areas, wildlife migration routes, and areas that are largely intact, by protecting large-scale ecological processes at the landscape scale. On the heels of this timely and critical agenda, the International Union for the Conservation of Nature (IUCN) passed a motion at the World Conservation Congress in September 2021 calling for the protection of at least half the Earth's surfaces and waters, with an aim to conserve at least 30% of the Earth's ecosystems by 2030. As rivers are the great integrators of the landscape from the mountains to the oceans and because they provide key ecosystem functions for birds, fish, and wildlife, expanding the protection of free-flowing rivers and their riparian areas is a much-needed and vital component of achieving these important national and international conservation goals.

In the Southwest U.S., where rivers are inherently scarce, the Colorado River and Rio Grande (see Figure 1) are two principal basins in need of such protections. Most species in these basins spend at least a portion of their lifecycle in or around rivers, depending on riparian areas for habitat, food, and shelter. As increasing pressures are placed on these rare landscape features, wildlife species stand a greater risk of extinction or extirpation. The ever-increasing decline in species is alarming, not only for the intrinsic value of plants and animals, but because biodiversity plays a key role in providing the goods and services on which humans depend. Moreover, diversity at all scales (genetic, species, ecosystem, and landscape) is important for ecosystem resilience in the face of climate change. In turn, resilient riverine ecosystems are critical for the continued delivery of ecosystem services.

ECOSYSTEM SERVICES (ES) are the benefits people obtain from the environment and healthy ecosystems. There are four categories of ES.

SUPPORTING SERVICES include nutrient cycling, soil formation, and habitat for fish and wildlife.

PROVISIONING SERVICES include food, energy, and lumber.

REGULATING SERVICES lend to the purification of water, sequestering of carbon, and pollination.

CULTURAL SERVICES range from spiritual and recreational to educational and therapeutic services.

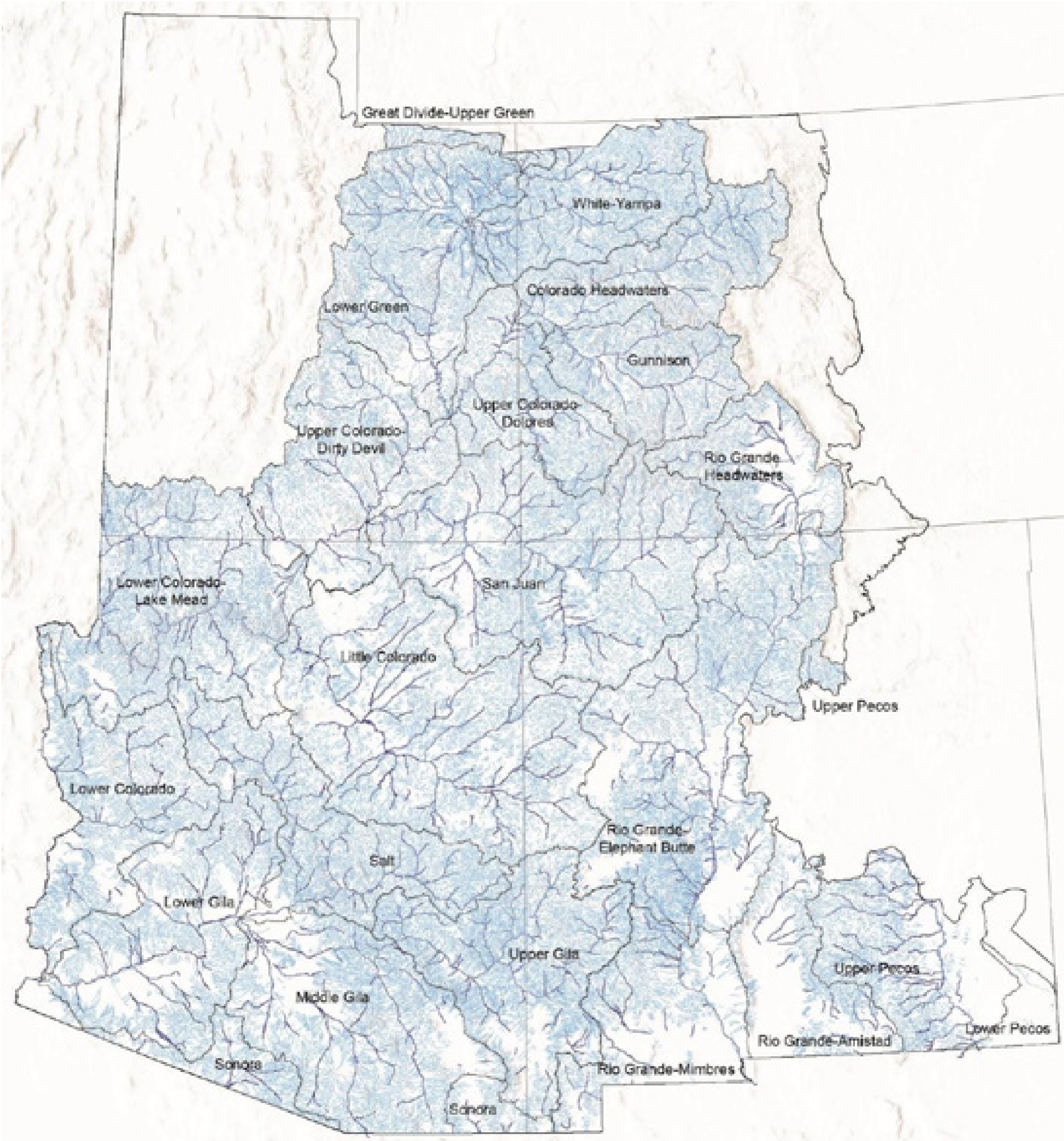

Figure 1. The Colorado River and Rio Grande flow collectively over nearly 350,000 (348,962.90) miles across the study region that encompasses more than 550,000 (551,555.48) square miles and spans four states, Utah, Colorado, New Mexico, and Arizona. The rivers are divided into 23 named Hydrologic Unit Codes (HUC) 4 subbasin units.

Yet never have these basins faced such pressures as they do today. Rising temperatures, changes in the timing and quantities of available water, a return to dam building and new diversions to meet growing energy and water demands, and unfettered population growth in desert cities add new stresses on these already overallocated and degraded river systems. Furthermore, decades of fire suppression coupled with aridification have created a tinderbox of the region's forests, further threatening watershed health and species habitat. Each of these unique and intertwining pressures plays a role in the biodiversity crisis facing this region. **Expanding the protection of free-flowing rivers and riparian areas exhibiting high rates of connectivity is paramount for wildlife and resilient riverine ecosystems.**

In this study, we explore the vital nature of free-flowing rivers and their riparian areas as habitat for fish and wildlife in the Colorado and Rio Grande basins. We then investigate key threats facing riverine ecosystems and the wildlife that depend upon them, from dams to development to climate change. We then assess the current and historic range of key river-dependent species, and streams that are projected to provide fish and wildlife refugia from rising temperatures. We explore policy options, such as upgrading land protection status to include biodiversity management, increasing free-flowing river protections through designations like the Wild and Scenic Rivers Act and Outstanding National Resource Waters, and restoring rivers and wildlife habitat, among others, as ways to protect and enhance riverine biodiversity habitat and ecosystem services.

Ultimately, there is room for the expansion of protections for the Colorado River and Rio Grande basins. With targeted conservation and restoration measures, the remaining intact riverine ecosystems in the Southwest can be protected and managed to ensure fish and wildlife species have the healthy habitat they need to thrive into the future. Without such protections, these already fragile and sometimes degraded ecosystems stand to be lost to changing climate and encroaching development. This study and its data can be used to support decision-making from the local to the national level on where and how to best protect these vital ecosystems. Time is of the essence.

PURPOSE AND AUDIENCE

This study considers the need to protect riverine ecosystems in the Rio Grande and Colorado River basins to safeguard fish and wildlife habitat while engendering ecosystem service resilience. It was developed to help land managers, landowners, advocates, and the engaged public understand policy options that can specifically benefit both biodiversity and specific wildlife species through a holistic approach that meets current and future conservation needs in these basins. It is particularly aimed at federal personnel within the four federal land management agencies with local jurisdiction, Native Nations with sovereign lands, state governments who adjudicate water rights in these basins, as well as private foundations and non-governmental organizations (NGOs) such as American Rivers with an interest in supporting the expansion of conservation mechanisms. Drawing on extensive spatial and policy analysis, the study reveals areas of critical conservation need and where conservation potential can be maximized. However, the types of policies used to protect vital habitat must be carefully selected based on the unique socio-political landscape of each river and the tributaries in its watershed.

PART ONE:

RIBBONS OF LIFE AND THE CALL FOR RIVER CONSERVATION

SOUTHWEST RIPARIAN AREAS, CONNECTIVITY, AND BIODIVERSITY

Riparian areas are often referred to as 'ribbons of life. Riparian areas are known to be the most productive habitats in North America.[1] They have a rich diversity in plant communities from trees and shrubs, grasses, and flowering plants, which provide habitat for terrestrial and aquatic species. These transition zones between a water body and upland areas are influenced by both surface and groundwater conditions as well as human and non-human activities that affect the composition of vegetation. In the Southwest U.S. (for the purposes of this report we focus the Four Corners states: Arizona, Colorado, New Mexico, and Utah), the vegetation in riparian areas is markedly different than that of the uplands. For instance, riparian areas often support vital populations of cottonwood, alder, and willow, among other common species **(see Figure 2 and Table 1)** while prickly pear, yucca, pinon and juniper, Douglas Fir, and Ponderosa Pines dominate upland areas.[2]

DECIDUOUS	EVERGREEN
Sycamore	Juniper
Cottonwood	White Spruce
Mesquite	Emory Oak
Aspen	Blue Spruce
Alder	Sagebrush
Russian Olive*	
Willow	
Ash	
Greasewood	
Salt Cedar/Tamarisk*	
Rabbitbrush	
Buckbrush	

Table 1. Common vegetation found in southwest riparian areas. Species marked with an Asterisk are invasive non-natives.

In the arid Southwest, where yearly evaporation rates exceed precipitation by at least 10 inches, riparian areas play a disproportionate role in supporting biodiversity. Less than 2% of the total land area in this region classifies as riparian, yet these ribbons of life serve as breeding, nesting, and foraging sites throughout some portion of most animals' life cycle, and in some cases, for the entirety of their lives. As such rare and vital features in an arid landscape, riparian areas are acknowledged as critical areas for wildlife. For example, in Arizona roughly 80% of invertebrates depend on riparian areas throughout their life while 70% of threatened and endangered vertebrates in the state depend on riparian habitat. In the 1970s, studies found that out of 166 bird species, 47% (78 species) entirely depend entirely on riparian areas and 30% (50 species) partially depend on these spaces. Other studies place the number of dependent bird species as high as 70% across the desert southwest region.[3]

Figure 2. Healthy maturing and juvenile cottonwoods and willows growing on the banks and a gravel bar in Westwater Canyon of the Colorado River.

[1] (Johnson et al., 1977; Chaney et al., 1990) moz-extension://d8735c3f-381d-4d3f-9780-7243ae05d881/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fextension.arizona.edu%2Fsites%2Fextension.arizona.edu%2Ffiles%2Fpubs%2Faz1432.pdf

[2] Dahl, T. E., Dick, J., Swords, J., & Wilen, B. O. (2009). A System for Mapping Riparian Areas in the Western United States. Data Collection Requirements and Procedures for Mapping Wetland, Deepwater and Related Habitats of the United States, (November), 85. https://www.fws.gov/wetlands/documents/A-System-for-Mapping-Riparian-Areas-In-The-Western-United-States-2009.pdf

[3] Ffolliott, P.F., L.F. DeBano, M.B. Baker, D.G. Neary, and K.N. Brooks. 2004. Hydrology and impacts of disturbances on hydrologic function. In: Baker, M.B. et al. (eds.), Riparian areas of the Southwestern United States Hydrology Ecology and Management. CRC Press, Boca Raton, FL. pp. 51-76.

Diverse and productive vegetation provides both food and shelter for terrestrial animal species. This vegetative covering also shades portions of the stream channel thereby regulating water temperature and enhancing the habitat of aquatic species. The macrobenthic invertebrates (e.g., Mayflies) provide essential food sources for economically viable fish species (e.g., trout). In woodland streams caddisflies are responsible for 37% of leaf litter breakdown, a key function for soil formation and water quality. Both Mayflies and Caddisflies provide food sources for fish such as trout, pike, and bass. The thick root systems keep riparian plants and trees in place during high flow events and stabilize the banks, reducing erosion. In addition, these roots increase the infiltration of water, reducing the impacts of floods. Less erosion and greater infiltration equate to higher water quantities and quality in the watersheds on which humans depend for drinking water, irrigation, and energy production. These interconnected examples are but a few of the numerous ecosystem services that riparian areas provide. These are services on which wildlife and humans depend.

Connectivity is a key component of healthy riverine ecosystems as rivers are the great integrators of the landscape. Connectivity as defined by the Convention on Migratory Species of Wild Animals and IUCN is "the unimpeded movement of species and the flow of natural processes that sustain life on Earth."[1] Intact riparian areas connected laterally to floodplains mitigate flooding by spreading out the water, slowing it down, and giving it time to infiltrate instead of running off at fast rates, thereby regulating erosion that otherwise can result in loss of land. Infiltration in turn recharges groundwater, mitigating drought effects on the river corridor and adjacent land.

STATS

Roughly 80% of invertebrates and 70% of threatened and endangered vertebrates depend on riparian areas throughout their life in Arizona. Between 30-70% of bird species in the southwest depend on riparian areas. Riparian areas make up only 2% of the total land area, making them invaluable for wildlife.

Additionally, connectivity enables daily movements and seasonal migrations that cultivate healthy and genetically-diverse species.[2,3,4] Along with serving as migration corridors, intact riparian areas provide habitat for feeding and rearing young. After disturbances such as floods, droughts, or fires, a highly-connected stream network allows for more rapid recolonization by affected species back into the disturbed area more than in networks fragmented by dams and other developments. **In other words, highly-connected free-flowing rivers and their riparian zones serve as buffers against disturbance events.**[5] Connectivity also allows the transport of important nutrients and sediment, which increases the resistance and resilience of the system in the face of disturbances.[6] **Riparian floodplains support high levels of biodiversity, are critical areas for numerous species of conservation concern, and protect economic and cultural values.** Aside from wildlife habitat, riparian areas with high connectivity provide cultural ecosystem services such as sacred sites, traditional uses, and recreation in the form of fishing, hunting, bird and wildlife viewing, camping, canoeing, rafting, and photography, among others.[7]

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[1] IUCN- CONSERVING AT LEAST 30% OF THE PLANET BY 2030- What should Count?.pdf. (n.d.). https://naturebeyond2020.com/wp-content/uploads/2021/09/Conserving-at-least-30-of-the-planet-by-2030-What-shouldcount-2.pdf

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[3] Tickner, D., Opperman, J. J., Abell, R., Acreman, M., Arthington, A. H., Bunn, S. E., ... Young, L. (2020). Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan Forum. BioScience, 70(4), 330–342.

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[5] Bouska, K. L., Houser, J. N., De Jager, N. R., Van Appledorn, M., & Rogala, J. T. (2019). Applying concepts of general resilience to large river ecosystems: A case study from the Upper Mississippi and Illinois rivers. Ecological Indicators, 101, 1094–1110. https://doi.org/10.1016/j.ecolind.2019.02.002

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[7] Ffolliott, P.F., L.F. DeBano, M.B. Baker, D.G. Neary, and K.N. Brooks. 2004. Hydrology and impacts 10 of disturbances on hydrologic function. In: Baker, M.B. et al. (eds.), Riparian areas of the Southwestern United States Hydrology Ecology and Management. CRC Press, Boca Raton, FL. pp. 51-76.

TAPPED OUT, DISCONNECTED, INVADED, AND THREATENED RIVER SYSTEMS

Despite the rarity of riparian landscape features upon which so much of the Southwest's biodiversity depends and the wide range of ecosystem services they provide, the legacy of nearly two centuries of dredging, mining, dam building, fire suppression, beaver removal, and poorly managed livestock grazing, as well as increasing population pressures have impaired the critical riparian areas of these basins.

As purveyors of irrigation and power generating waters, dams, reservoirs **(Figure 3)**, and diversions already capture the majority of available freshwater runoff in the Rio Grande and Colorado Basins. Aside from water, this infrastructure also captures sediment otherwise destined for deposition in the Gulf of Mexico and Gulf of California respectively. Throughout the rivers and their estuaries, sediment deposition is critical as it provides for aquatic and terrestrial habitat and for the stabilization of banks, beaches, and shorelines. From large water development projects such as Elephant Butte Dam on the Rio Grande and Glen Canyon Dam on the Colorado, to the smaller dams and diversions that truncate these basins, the result is habitat fragmentation and loss of ecosystem connectivity. Fragmentation, in turn, leads to changed physical environments (i.e., water, nutrient, and sediment fluxes) as well as increased potential pressures from invasive species, pollution, and other human activities. According to Disappearing Rivers, 54% of the mainstem Colorado River and 44% of the mainstem Rio Grande has been altered. These numbers do not include the many tributaries that are also altered by dams and diversions among other land uses.[1]

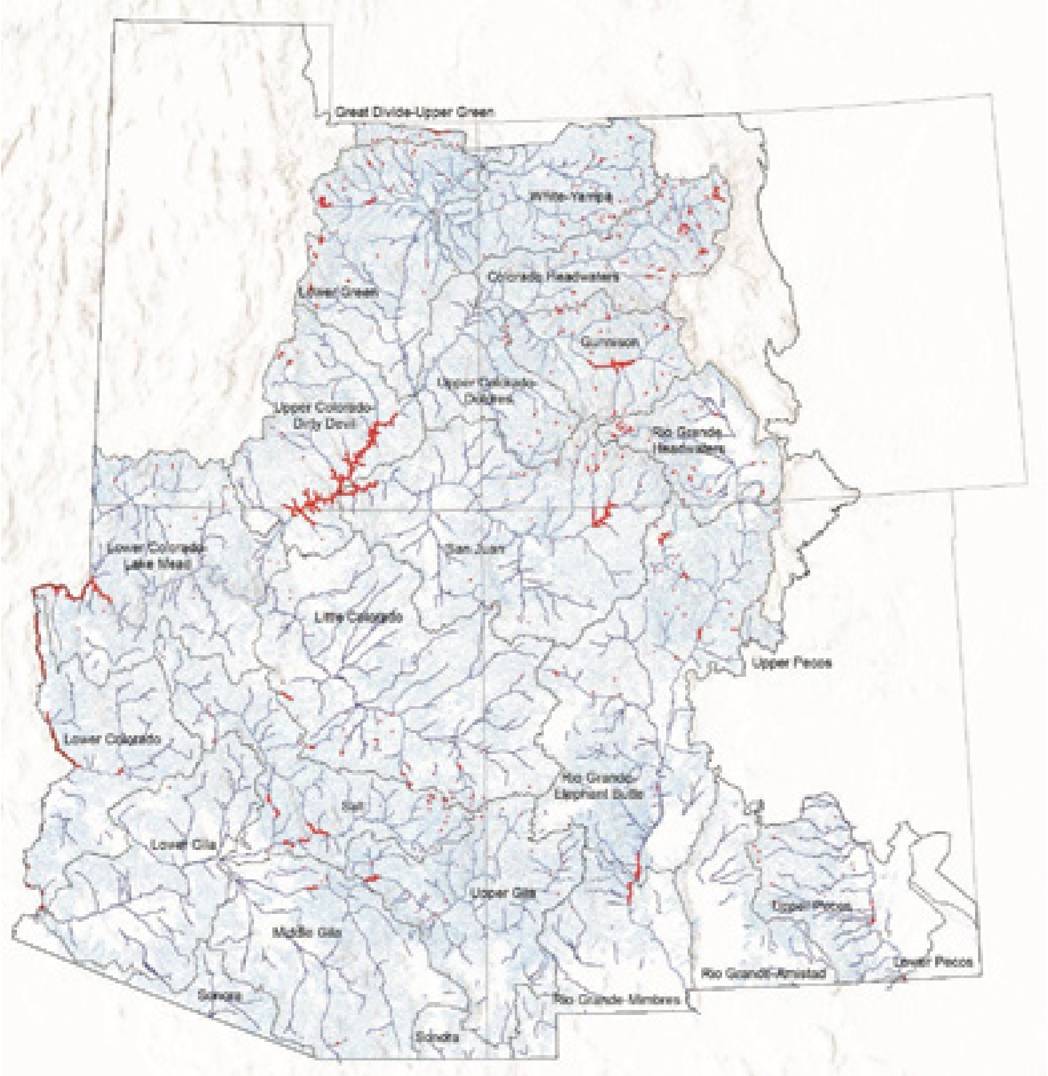

Figure 3. 1769 dams exist in the study area truncating rivers and reducing connectivity. 300 of those dams are situated on perennial rivers creating 4340 miles of reservoirs (red).

[1] Disappearing Rivers. (n.d.). Retrieved October 20, 2021, from https://disappearingwest.org/rivers/map/index.html

Aside from dams, unregulated livestock grazing is one of the most degrading activities in riparian areas. As seen in Figure 4, grazing cattle prefer these areas due to the abundance of forage material and the availability of water in a region otherwise largely devoid of surface water sources.[1] Grazing cattle can alter shoreline vegetation, creating inhospitable conditions for native species that depend on these areas for food, shelter, and refuge.

Unlike wildlife and birds that can range widely, freshwater aquatic habitats are insular in nature – freshwater species have small geographic ranges which are often limited to a singular basin. Consequently, high levels of endemism occur in these habitats. Endemic species are those found in only one location in the world. Endemism results in an overall diversity of species, or species richness, which can increase ecosystem services and goods. Nonetheless, water and land development projects have resulted in grave losses for riverine biodiversity. Both local extirpations and species extinction are directly linked to the high rates of endemism riverine ecosystems foster. Estimates indicate that in the U.S., more than one-third of aquatic species in a given taxon may be extinct, extirpated, or imperiled. **In Arizona alone, 90% of native fish species are now extinct, extirpated, or listed as endangered. In the Lower Colorado River Basin, 75% of fish species are listed under the US Endangered Species Act due to compounding impacts of hydrologic alteration, invasive species, and land modification.** One study found that the greatest indicator of native species richness in a river depends on the level of connectivity. The more dams that exist in a system, the greater the chance native species will decline.[2] **Connectivity is essential for healthy river systems.**

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CLIMATE CHANGE PRESSURES ON BIODIVERSITY AND THE NEED FOR CONSERVATION

Climactic changes will exacerbate biodiversity loss in riverine ecosystems in the Southwest. Increased temperatures and changing precipitation patterns are already altering flow regimes, and affecting hydrologic connectivity and patterns of stream intermittency.[1,2,3] These alterations stand to impact the range of species who depend on river corridors, from the invertebrates (e.g., butterflies, dragonflies, mayflies, mussels, mollusks, and snails) to the ungulates (e.g., elk, deer, bison, pronghorn, moose, bighorn sheep). In fact, acidification from increased carbon dioxide entering the system has already reduced the abundance of aquatic invertebrates – key components of aquatic and riparian food webs - altering their contribution to basic ecosystem processes.[4] The distribution and diversity of amphibians and reptiles, such as salamanders and snakes, across scales depends on specific climate conditions, making any change a threat to populations.[5] Increased competition from invasive aquatic and plant species enabled by the changing climate[6] may further disrupt biological communities and ecological linkages.[7] For instance, the Narrow-headed Garter Snake **(Figure 5)** that only inhabits riparian areas along free-flowing rivers depends on native fish as their only food source. Proposed dams, increasing water withdrawals, changes in temperature and precipitation, and loss of connectivity further threaten this already endangered species.[8,9]

Climate change is also driving proposals to build new dam and reservoir facilities to meet growing demands for freshwater. These projects in turn jeopardize already imperiled species by further reducing connectivity, altering stream conditions and flow regimes, and destroying habitat. Such is the case with the proposed pumped storage hydropower plants on the San Francisco River, tributary of the Gila River in New Mexico,[10] and in Arizona's Big Canyon of the Little Colorado River.[11] Both the Gila and Little Colorado Rivers, main tributaries to the Colorado River, contain critical habitat for several endangered endemic fish species, among other terrestrial species.

Figure 5. The narrow-headed garter snake depends on free-flowing rivers and their intact riparian areas for survival. This non-venomous snake eats native fish species. Due to habitat loss, this snake is federally listed under the Endangered Species Act. Protecting the remaining habitat will be critical for its survival.

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START BOX:

BOX 1. BEAVER, AND THEIR RECIPROCAL BENEFITS FOR TERRESTRIAL SPECIES

The North American Beaver (Castor canadensis) is a keystone species upon which multiple other species depend. Often referred to as 'nature's architects' or 'ecosystem engineers,' beavers create wetlands, lodges or dens, and dams that create ponds with their building expertise. These water features create habitat for numerous other species in a trophic cascade, from insects to fish, birds, amphibians, reptiles, and mammals. For instance, mammals such as muskrat, mink, and river otter take advantage of the lodges built by beavers. Small fish find refuge in the cool ponds that form when beavers dam streams. This refuge is critical as more streams in the desert southwest face increasing intermittency due to climate change and overuse. Beaver habitat also traps sediment and facilitates overbank flow that disperse nutrients and water over adjacent wetlands, recharges groundwater, and fertilizes the land **(Figure 6)**.[1] These 'beaver meadows'[2] rich with plant life support terrestrial species throughout their lifecycles including ungulates (e.g., elk, deer, bighorn sheep) and bear, among others. Thus, beavers are biological integrators of rivers and riparian areas who support biodiversity through their advanced and creative engineering prowess.

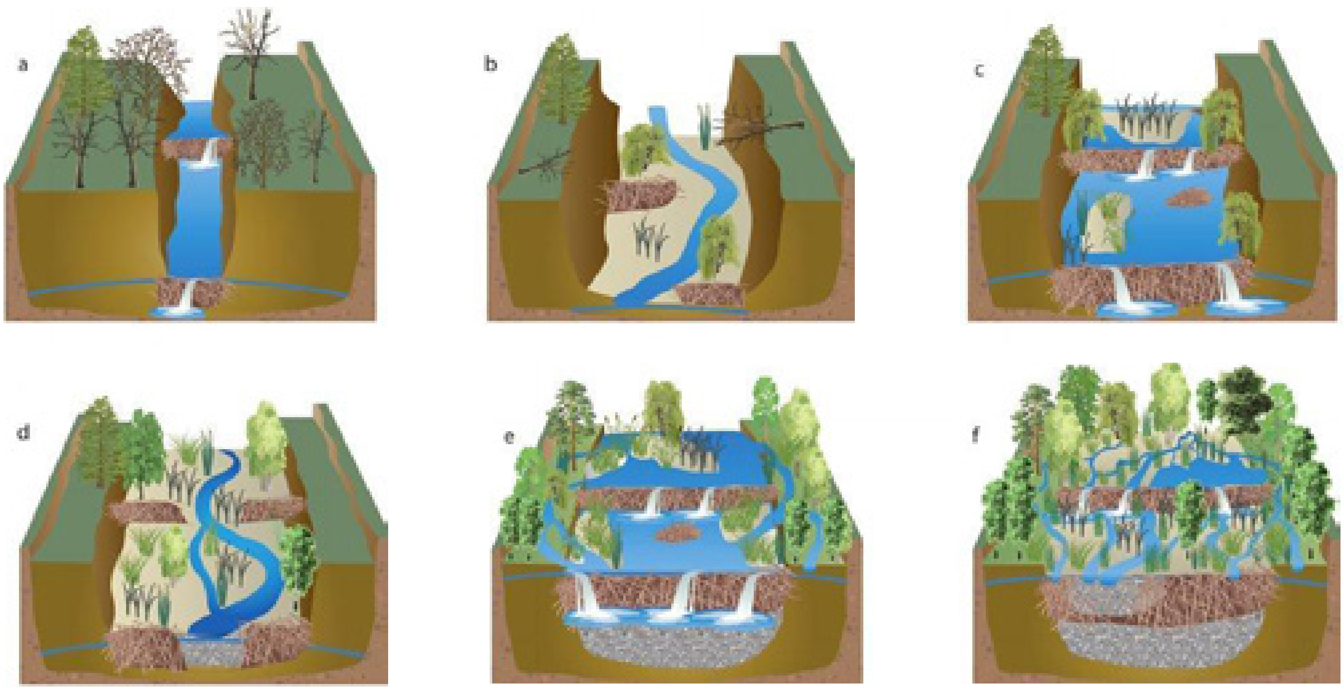

Figure 6. Beaver dams can improve conditions in incised streams. (a) Beaver dam streams in incision trenches that blowout and (b) help the floodplain to form. (c) The widened incision trench reduces stream power, enabling beaver to build stable dams. (d) The beaver ponds collect sediment that helps vegetation get established. (e) The repeating of this process results in the water table raising and the stream connecting to its former floodplain. (f) The new riverine ecosystem is complex containing materials to slow the water so groundwater can recharge. Multiple channels can form that connect to wetlands, thereby saturating the valley bottom.[3]

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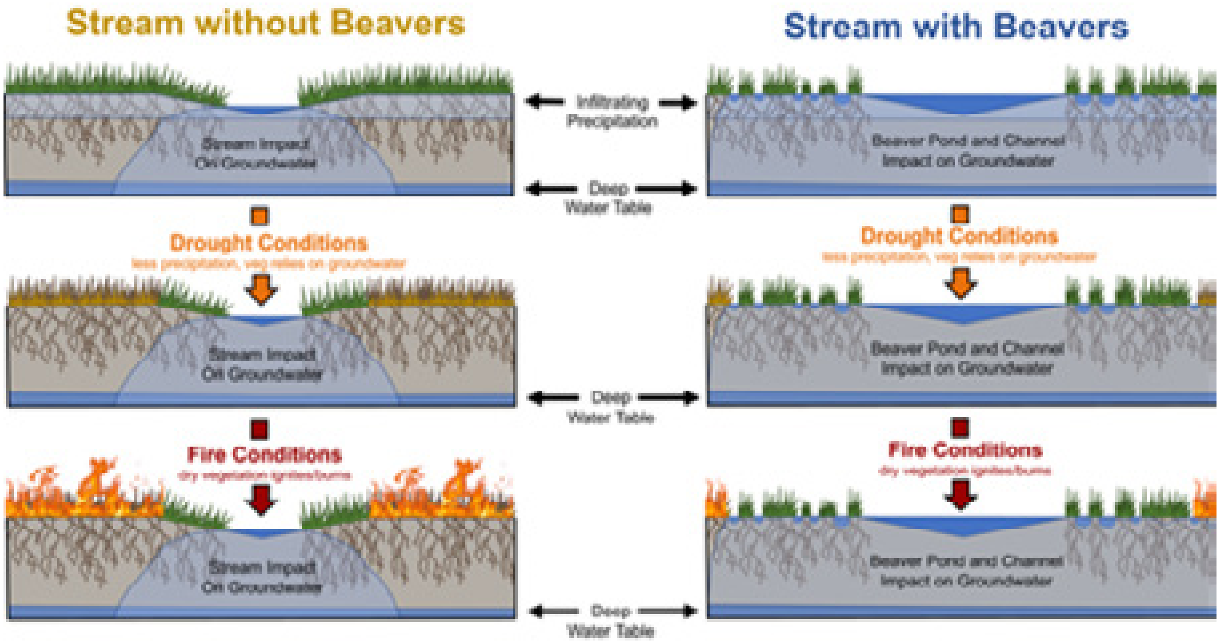

Figure 7. Conceptual model of river conditions in streams with and without beavers.[3]

As the Southwest faces more frequent and severe wildfires due largely to a history of fire suppression and increasingly frequent and long drought conditions brought by climate change, beavers are also proving to be mitigators of fire damage, increasing the resilience of riverine ecosystems. By helping maintain groundwater supplies that support lush riparian vegetation, these corridors are more resistant to burning **(see Figure 7)**.[1]

Aside from the vegetation remaining intact, these ribbons of life provide refuge and temporary habitat for bird and mammal species that could not otherwise escape the fires in time **(see Figure 8)**. Not only do beavers benefit species in need of refuge from climate change and fire, but they also help mitigate climate change by sequestering carbon in their ponds and wet meadows.[234]

In the Southwest, elk and other ungulates take advantage of riparian forests and stream valley shrublands. Whether they are migratory or nonmigratory, elk prefer riparian areas for their seasonal movements, especially during harsh conditions or important periods of their life cycle such as calving and lactation.[5] During the summer, riparian areas and adjacent wet meadows provide food and water and favorable conditions for the animals to graze and rest. The wet meadows are often the result of beaver dam engineering. Thus, to understand where elk may be present in summer months, investigating beaver presence can be an indicator of that likelihood. Protecting streams with beaver can provide reciprocal benefits for terrestrial species.

Figure 8. Elk taking refuge in the Bitterroot River during a wildfire. Note that the riparian vegetation is not burning. [4]

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5 Innes, Robin J. 2011. Cervus elaphus. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: www.fs.fed.us/database/feis/mammal/ceel/all.html

END BOX

Ultimately, *how* a riverine ecosystem is managed matters. In some cases, damages of direct human activities (i.e., agriculture, industrial, and urban development) may exceed climate change impacts while in others, climate change alone is enough to harm fish and river-dependent wildlife. Ecological integrity is directly linked to flow regimes. Therefore, whether by climate change or human development, alteration impacts the health of riverine ecosystems and biodiversity. That is why **expanding protections across the networks of remaining intact river systems with high rates of connectivity is integral to meeting both societal and wildlife needs in a changing climate.** The best method for ensuring resilient and intact riverine ecosystems is to protect them from disturbance, both laterally - meaning areas of the riparian zone perpendicular to flow between hillslopes - and longitudinally, along and within the channel. Lateral and longitudinal protections preserve connectivity between the river and its adjoining riparian zones while increasing available habitat for instream organisms, who can move more easily in unfragmented corridors in response to disturbances. **Protecting and managing rivers and riparian areas for biodiversity in turn has positive, reciprocal benefits for adjacent terrestrial lands**[1] (See Box for examples).

To contend with technological, economic, and political drivers of biodiversity loss while adapting to climate uncertainty, biodiversity protections require adaptive management strategies that foster resilience and resistance to new and anticipated conditions.[2] Building on and layering existing and emerging management strategies and conservation policies in these basins will maximize the potential for expanding and enhancing wildlife and ecosystem service protections.

[1] Abell, R. and Harrison, I. J. A boost for freshwater conservation Integrating freshwater and terrestrial conservation planning has high returns. Science 2020, 370, 38–39. https://science.sciencemag.org/content/370/6512/38?rss=1

[2] Pracheil, McIntyre, and Lyons. 2013. Enhancing conservation of large-river biodiversity by accounting for tributaries. Frontiers in Ecology and the Environment 11: 124- 128.

PART TWO:

RESEARCH QUESTIONS & METHODS

RESEARCH QUESTIONS

To that end, we set out to answer the following research questions:

RQ1: To what extent do free-flowing river and wildlife/ biodiversity protections already exist in the study region?

RQ2: What areas within the study region should be prioritized for expanding conservation strategies?

METHODS

To answer these questions, we coupled geospatial analysis with policy analysis to reveal the extent of and potential for riverine biodiversity habitat protections. The United States Geological Survey (USGS) maintains the Protected Areas Database of the United States (PAD-US) 2.1 to track U.S. progress towards achieving global biodiversity protection targets set by the United Nations Convention on Biological Diversity (CBD).[1] This inventory was created through the Gap Analysis Project (GAP) to provide assessments of areas managed primarily for the preservation of biodiversity (GAP Status Codes 1 and 2) such as National Parks, National Wild and Scenic Rivers, National Wildlife Refuges, National Monuments, Wilderness Areas, State Wildlife Management Areas, Land Trust Preserves, and Conservation Easements, among others. An area's GAP status measures how well we are preserving flora and fauna in that area. We used the PAD-US 2.1 to identify rivers and riparian areas already being managed for biodiversity (GAP 1 and 2) and areas where GAP Status codes could be upgraded by incorporating biodiversity management strategies either through new conservation policy applications or through land use changes.[2] In addition to protected areas, it is highly recognized that Indigenous territories contain some of the most biodiverse lands and waters.[3] As such, they are key locations in need of consideration for wildlife conservation goals. The PAD-US 1.4 dataset contains American Indian Lands and was used together with the PAD-US 2.1 for the analysis of land management type.[4]

The USGS GAP also includes species range, habitat, and distribution data for more than 2,000 species in the U.S. These data can be used to assess species occurrence (e.g., species richness) as a core part of assessing biodiversity protection status and needs in the study basin. We selected four riparian-obligate/ dependent species for this assessment: the beaver (*Castor canadensis*), a keystone riparian species; the Southwestern Willow Flycatcher (SWWF) (*Empidonax traillii extimus*), an endangered riparian-dependent migratory bird species; the narrow-headed garter snake (*Thamnophis rufipunctatus*), a threatened reptile species that requires free-flowing rivers for its habitat; and the North American River Otter (*Lontra canadensis*), a charismatic riparian resident.

The IUCN Red List of Threatened Species contains information about the range and habitat of species threatened with extinction, among other attributes. We used these species data to identify the historic, extant, and extinct range and suitable habitat for threatened fish species in these basins, namely the Bonytail Chub (*Gila elegans*), Colorado Pikeminnow (*Ptychocheilus lucius*), Gila Trout (*Oncorhynchus gilae*), Humpback Chub (*Gila cypha*), Razorback Sucker (*Xyrauchen texanus*), and Silvery Minnow (*Hybognathus amarus*).

Climate projections indicate that temperatures will rise several degrees in the study region over the next century which could detrimentally affect biodiversity of cultural significance.[5] However, climate warming may have less of an impact on high mountain streams, especially

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[1] Aichi Biodiversity Targets. (n.d.). Retrieved October 16, 2021, from https://www.cbd.int/sp/targets/

[2] U.S. Geological Survey (USGS) - GAP Analysis Project (GAP), 2021, Protected Areas Database of the United States (PAD-US) 2.1 - World Database on Protected Areas (WDPA) Submission (ver 1.1, April 2021): U.S. Geological Survey data release, https://doi.org/10.5066/P9IVLRSS.

[3] A global spatial analysis - Territories of Life. (n.d.). Retrieved October 16, 2021, from https://report.territoriesoflife.org/global-analysis/

[4] Protected Areas Database of the United States (PAD-US) 2.1 - World Database on Protected Areas (WDPA) Submission (ver 1.1, April 2021) - ScienceBase-Catalog. (n.d.). Retrieved November 20, 2021, from https://www.sciencebase.gov/catalog/item/602ffe50d34eb1203115c7ab

[5] Status of Tribes and Climate Change Working Group (STACCWG). (2021). Status of Tribes and Climate Change Report, Institute for Tribal Environmental Professionals, Northern Arizona University, Flagstaff, AZ. [Marks-Marino, D. (ed.)] http://nau.edu/stacc2021

those where the plant canopies shade against solar radiation.[1] These high-elevation streams serve as refugia for (genetically pure) native freshwater species adapted to cold temperatures. The cold conditions also largely prevent the colonization of invasive species. In the context of climate change, these streams are especially suited for those species already adapted to insular existence. The reciprocal benefits of protecting refugia for terrestrial species are numerous. As refugia, these locations will maintain their temperature and riparian vegetation communities, ensuring habitat for amphibians, birds, and large land mammals. **When considering management policies for vulnerable species, prioritizing protecting places that are also simultaneously considered climate refugia may require little management, freeing up scarce monetary and human resources to focus on more at-risk habitat.[2]** Thus to understand where cold-water species may find refuge in the face of increasing temperatures, we used Climate Shield data to identify critical refugia that will persist into 2080 for the Cutthroat Trout (*Oncorhynchus clarkii*), a popular sport fish species native to western waters.[3]

The National Wild and Scenic Rivers System (NWSRS) created by the Wild and Scenic Rivers Act of 1968 (WSRA) is the nation's (and world's) premier river conservation policy. As such, this analysis was grounded in the National Wild and Scenic Rivers System-NHDv2 Seamless Merge dataset that contains hydrologic data from the publicly available National Hydrography Dataset Plus (NHDv2) and a geospatial dataset for the NWSRS. These data include the already designated Wild and Scenic Rivers (WSR) segments and rivers that are listed on the Congressionally mandated Nationwide Rivers Inventory (NRI), a catalog of river segments identified as eligible for potential designation under the Act by the National Park Service - rivers that are free-flowing and possess at least one outstanding value.[4] In addition, river segments that have been identified as eligible for protection through periodic federal land management agency resource management plan updates by the U.S. Forest Service and Bureau of Land Management were analyzed using the National Wild and Scenic River Eligible and Suitable dataset.[5]

Understanding the size of streams **(Figure 9)** is important for gauging conservation potential and needs. In this analysis, we removed all stream order 1 and non-perennial (ephemeral and intermittent), reaches to "thin" the stream network.[6]

Figure 9. Conceptual model of stream orders.

The National Inventory of Dams (NID) consists of dams meeting at least one of the following criteria: 1) High hazard potential classification - loss of human life is likely if the dam fails; 2) Significant hazard potential classification - no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or impact other concerns; 3) Equal or exceed 25 feet in height and exceed 15 acre-feet in storage; 4) Equal or exceed 50 acre-feet storage and exceed 6 feet in height. We used the NID to identify dams within the study area that are reducing connectivity on perennial streams.

1 National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. Washington, DC: The National Academies Press. https://doi.org/10.17226/10327.

2 Barrett, K., Nibbelink, N. P., & Maerz, J. C. (2014). Identifying Priority Species and Conservation Opportunities Under Future Climate Scenarios: Amphibians in a Biodiversity Hotspot. Journal of Fish and Wildlife Management, 5(2), 282–297. https://doi.org/10.3996/022014-JFWM-015

3 Isaak, D., M. Young, D. Nagel, D. Horan, M. Groce, and S. Parkes. 2017. Climate Shield bull trout and cutthroat trout population occurrence scenarios for the western U.S. Rocky Mountain Research Station, U.S. Forest Service Data Archive, Fort Collins, CO. DOI: pending. https://www.fs.fed.us/rm/boise/AWAE/projects/ClimateShield/maps.html

4 Major, J., K. Guetz, D. Perry (2020). National Wild and Scenic Rivers System-NHDv2 Seamless Merge, HydroShare, https://doi.org/10.4211/hs.5a64a540b0384018ae252d9079de32e8

5 Forest Service, National Park Service, Bureau of Land Management, and Fish and Wildlife Service (2019). National Wild and Scenic River Eligible and Suitable Lines (Feature Layer). https://www.arcgis.com/sharing/rest/content/items/ec3257d2cc294a9fa9ab1b8745621fb7/info/metadata/metadata.xml?format=default&output=html

6 McKay, L., Bondelid, T., Dewald, T., Johnston, J., Moore, R., and Rea, A., "NHDPlus Version 2: User Guide", 2012 https://s3.amazonaws.com/edap-nhdplus/NHDPlusV21/Documentation/NHDPlusV2_User_Guide.pdf

PART THREE:

RESULTS & POLICY OPTIONS

There is at least a 50-year history of protecting free-flowing rivers, water quality, and species habitat in the study area through tribal, federal, state, and local governance. At the federal level, the Wild and Scenic Rivers Act, the Endangered Species Act, and Clean Water Act all work to address some aspect of riverine ecosystem conservation needs. Administrative protections through instream flow allocations and land management regulations are employed across scales. Purchasing property or conservation easements on land of particular concern for biodiversity has also been used in these basins. Riparian restoration efforts have also been an effective strategy to enhance habitat. Emerging strategies such as Rights of Rivers and co-management agreements with Native Nations also show potential in this region.

SPECIES MANAGEMENT FOR BIODIVERSITY PROTECTION:

Protecting Wildlife through the Endangered Species Act and the National Wildlife Refuge System

Federal, state, and local land management plans can include practices that aim to conserve biodiversity. For example, the Endangered Species Act is the most powerful federal law that protects against species loss through both protection and restoration of critical habitat. Any one person or interest group can petition for the appropriate federal agency to list a species. A petition begins a process of determining whether indeed the species is threatened with extinction or at risk of becoming endangered. In the Colorado River and Rio Grande study area, the US Fish and Wildlife Service (FWS) has listed numerous riverine dependent species including but not limited to the Southwestern Willow Flycatcher, Narrow-headed Garter Snake, Humpback Chub, Razorback Sucker, and Silvery Minnow. Critical habitat for these species has been designated and recovery plans devised. Adaptive management within critical habitat can take place by coordinating with utility providers to ensure flows exist at critical stages of a species lifecycle or to support the restoration of habitat. On the Colorado River, this type of adaptive management is taking place at Glen Canyon Dam to mobilize sediment to restore beaches, support the breeding cycle of aquatic invertebrates and fishes, and maintain habitat for the southwestern willow flycatcher.[1,2] Another method for enhancing endangered and threatened species is to remove invasive species from critical habitat.[3] Supporting incentive programs such as bounties on invasive plant and animal species may be effective in bringing balance back to these systems.[4]

The National Wildlife Refuge System, created in 1903 by President Theodore Roosevelt, is another key conservation tool that river conservationists can employ towards protecting habitat for fish and wildlife species. These refuges provide access for activities such as hunting, fishing, and other recreation activities. The Bosque del Apache National Wildlife Refuge on the Rio Grande is one example of riverine protections that aims to provide critical habitat for migratory waterfowl.[5] Through Comprehensive Conservation Plans (CCP), the National Fish and Wildlife Service manages the refuges to optimize the habitat conditions for species of concern as well as stakeholder needs. Creating or expanding existing refuges on free-flowing rivers and their riparian wetlands could prove effective in achieving conservation goals for more wildlife in the region.

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1 Benson, M. (2012). Intelligent tinkering: the Endangered Species Act and resilience. Ecology and Society, 17(4), 28. https://doi.org/10.5751/ES-05116-170428

2 Bair, L. S., Yackulic, C. B., Springborn, M. R., Reimer, M. N., Bond, C. A., & Coggins, L. G. (2018). Identifying cost-effective invasive species control to enhance endangered species populations in the Grand Canyon, USA. Biological Conservation, 220(July 2017), 12–20. https://doi.org/10.1016/j.biocon.2018.01.032

3 Bair, L. S., Yackulic, C. B., Springborn, M. R., Reimer, M. N., Bond, C. A., & Coggins, L. G. (2018). Identifying cost-effective invasive species control to enhance endangered species populations in the Grand Canyon, USA. Biological Conservation, 220(July 2017), 12–20. https://doi.org/10.1016/j.biocon.2018.01.032

4 Pasko, S., & Goldberg, J. (2014). Review of harvest incentives to control invasive species. Management of Biological Invasions, 5, 263–277. https://doi.org/10.3391/mbi.2014.5.3.10

5 About the Refuge - Bosque del Apache - U.S. Fish and Wildlife Service. (n.d.). Retrieved January 19, 2022, from https://www.fws.gov/refuge/Bosque_del_Apache/about.html

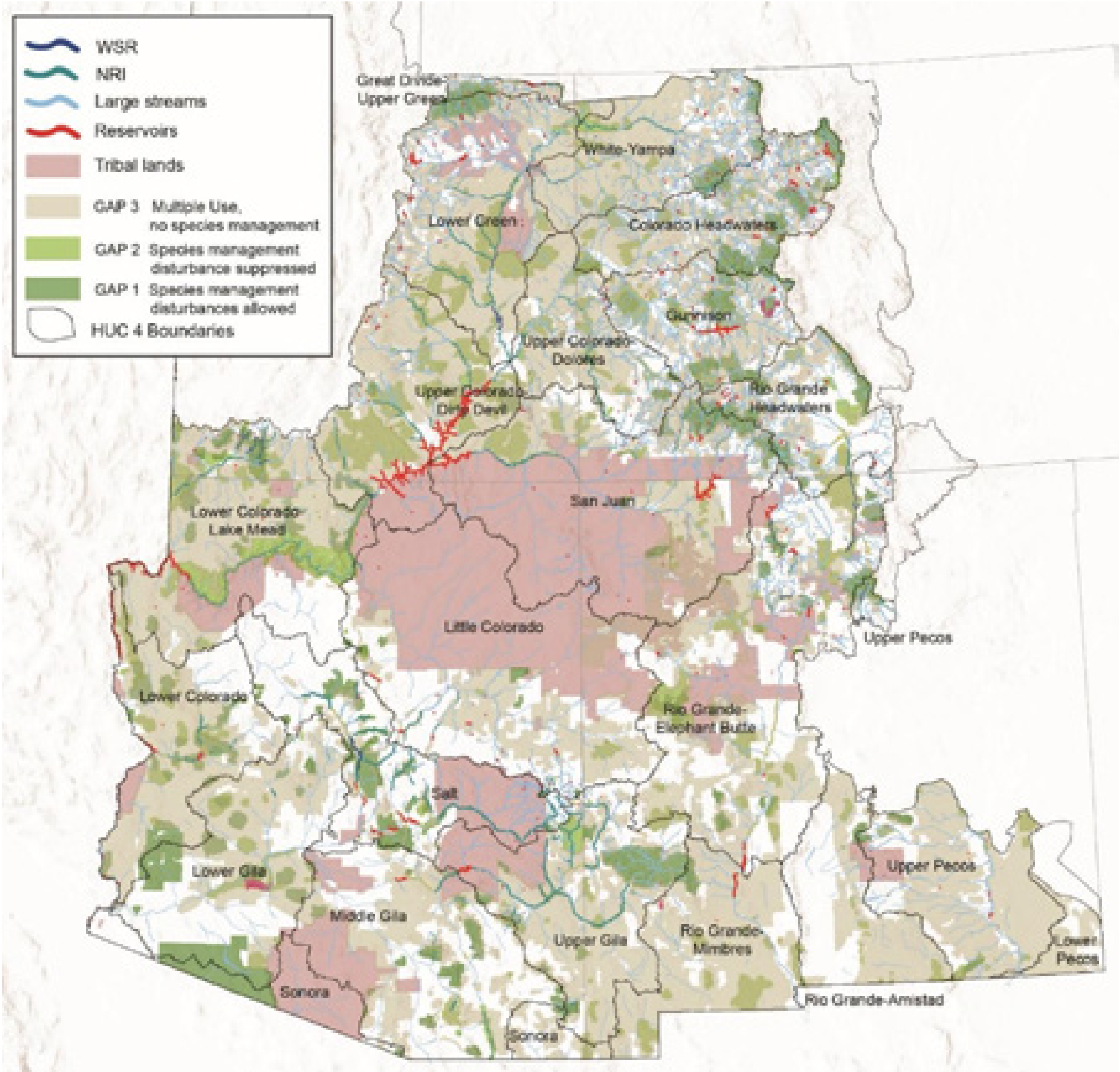

Figure 10. Upgrading GAP status from a 3 to a 2 can allow for low-cost management strategies that address particular conservation concerns for wildlife.

Changing GAP Status through increased Protections for Rivers and Landscapes

The USGS GAP Status Code measures the level of protections assigned under each land and water unit designation. GAP 1 and 2 areas are managed explicitly for biodiversity while GAP 3 are managed for multiple uses including both conservation and extractive activities. GAP 4 areas have no known mandate for biodiversity protection. Using the Protected Areas Database of the United States (PADUS) to identify areas in GAP 3 and 4 units that have species of conservation concern can then inform efforts to upgrade management practices to achieve either GAP 1 or 2 status. For example, ensuring native riparian vegetation persists within river corridors where forestry or agricultural activities are taking place can help support biodiversity, ecosystem function, and resilience in these productive landscapes.[1] Riparian areas naturally provide a buffer between upland activities and the river, thus protecting existing and restoring degraded riparian areas to support species can be an adaptive management strategy to achieve the GAP status upgrade. Establishing riparian management zones can help mitigate forestry impacts on private lands. The overall lack of explicit biodiversity management in the study area is evident in **Figure 10**.

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[1] Fischer Lindenmayer D. B. e Manning A. D., J. (2006). Biodiversity, ecosystem function, and resilience: ten guiding principles for comodity production landscapes. Frontiers in Ecology and the Environment, 4(2), 80–86. https://doi.org/10.1890/1540-9295(2006)004[0080:BEFART]2.0.CO;2

Managing Riparian Areas for Livestock Grazing

Riparian areas are sensitive and should be managed separately from upland areas. Restricting livestock from key riparian areas by installing cattle exclosures such as fences is one way to maintain biological integrity and allow sensitive vegetation to recover, thus restoring habitat for riparian species. In GAP 3 areas where grazing is permitted on public lands and in GAP 4 areas on private property, cattle exclosures can be installed to limit access to sensitive riparian areas.[1] Working with federal land management agencies to remove nuisance cattle that trespass in areas of high conservation concern is important in this region where cattle roam freely on expansive public lands. Arizona's Verde River provides a case in which agreements between the Forest Service and conservation groups were made, but enforcement did not occur until a lawsuit was brought against the agency for non-compliance.[2] Thus, monitoring progress on such agreements will be necessary for ensuring proper livestock management practices are in fact being implemented. In other words, proper adherence to best management practices for public lands grazing is vitally important to the health of riparian ecosystems and the wildlife that depend on them. Each river corridor should be assessed to determine the carrying capacity of cattle, taking into consideration the need for restoring and protecting ecosystem function and native vegetation.[3]

Restoring and Protecting Beaver Populations

Restoring or increasing beaver populations so that they may in turn restore riparian areas, may serve as a viable, low-cost solution to efficiently improve degraded ecosystem function, provide habitat, and sequester carbon. Beaver restoration in headwater streams in the Southwest is known to counteract the impacts of overgrazing by livestock.[4] In the Price and San Rafael rivers, both of which flow through some of eastern Utah's driest areas, a beaver reintroduction program is underway in an effort to help restore water resources related to rivers – both quantity and quality. The aim is for beavers to help restore connectivity and mitigate the overall degradation of these rivers brought by irrigation, pollution, and general mismanagement.[5] Expanding such beaver reintroductions to areas where they have been extirpated **(see Figure 11)** could help restore connectivity for improved ecosystem function and wildlife habitat, increase the production of imperiled fish populations, expand wetland areas, and reduce the risk of catastrophic wildfire. Reestablishing beaver in some locations, such as National Forest lands with grazing allotments, will require managing livestock to ensure the proper vegetation is available and abundant enough for the beaver to thrive.[6] Once established, beaver populations can persist in their habitat for thousands of years, making them a long-term, low-cost climate adaptation strategy.[7,8] **Protecting rivers where beavers are present can ensure these keystone species can continue to provide and enhance ecosystem services and wildlife habitat. The Upper Gila, San Juan, Dolores, Rio Grande headwaters, and the Upper Green and its tributaries all exhibit high rates of connectivity and flow within the current range of beavers.**

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1 National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. Washington, DC: The National Academies Press. https://doi.org/10.17226/10327.

2 Agreement Reached to Protect Endangered Species From Livestock on Arizona's Verde River - Center for Biological Diversity. (n.d.). Retrieved October 13, 2021, from https://biologicaldiversity.org/w/news/press-releases/agreement-reached-to-protect-endangered-species-from-livestock-on-arizonas-verde-river-2021-10-13/?fbclid=IwAR3J6e_iG_6BoDgHAPAAkN5i3TyWh2ZJ0eQmfWWuYFrOu0eXfIZe7FmRhpg#.YWg0qB6NAmg.facebook

3 National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. Washington, DC: The National Academies Press. https://doi.org/10.17226/10327.

4 National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. Washington, DC: The National Academies Press. https://doi.org/10.17226/10327.

5 The beavers returning to the desert - BBC Future. (n.d.). Retrieved August 20, 2021, from https://www.bbc.com/future/article/20210713-the-beavers-returning-to-the-desert

6 Small, B. A., Frey, J. K., & Gard, C. C. (2016). Livestock grazing limits beaver restoration in northern New Mexico. https://doi.org/10.1111/rec.12364

7 Hyde, J. L., Bohlman, S. A., & Valle, D. (2018). Transmission lines are an under-acknowledged conservation threat to the Brazilian Amazon. Biological Conservation, 228, 343–356. https://doi.org/10.1016/J.BIOCON.2018.10.027

8 Polvi, L. E., & Wohl, E. (2012). The beaver meadow complex revisited: The role of beavers in post-glacial floodplain development. Earth Surface Processes and Landformes, 37, 332–346. https://doi.org/10.1002/esp.2261

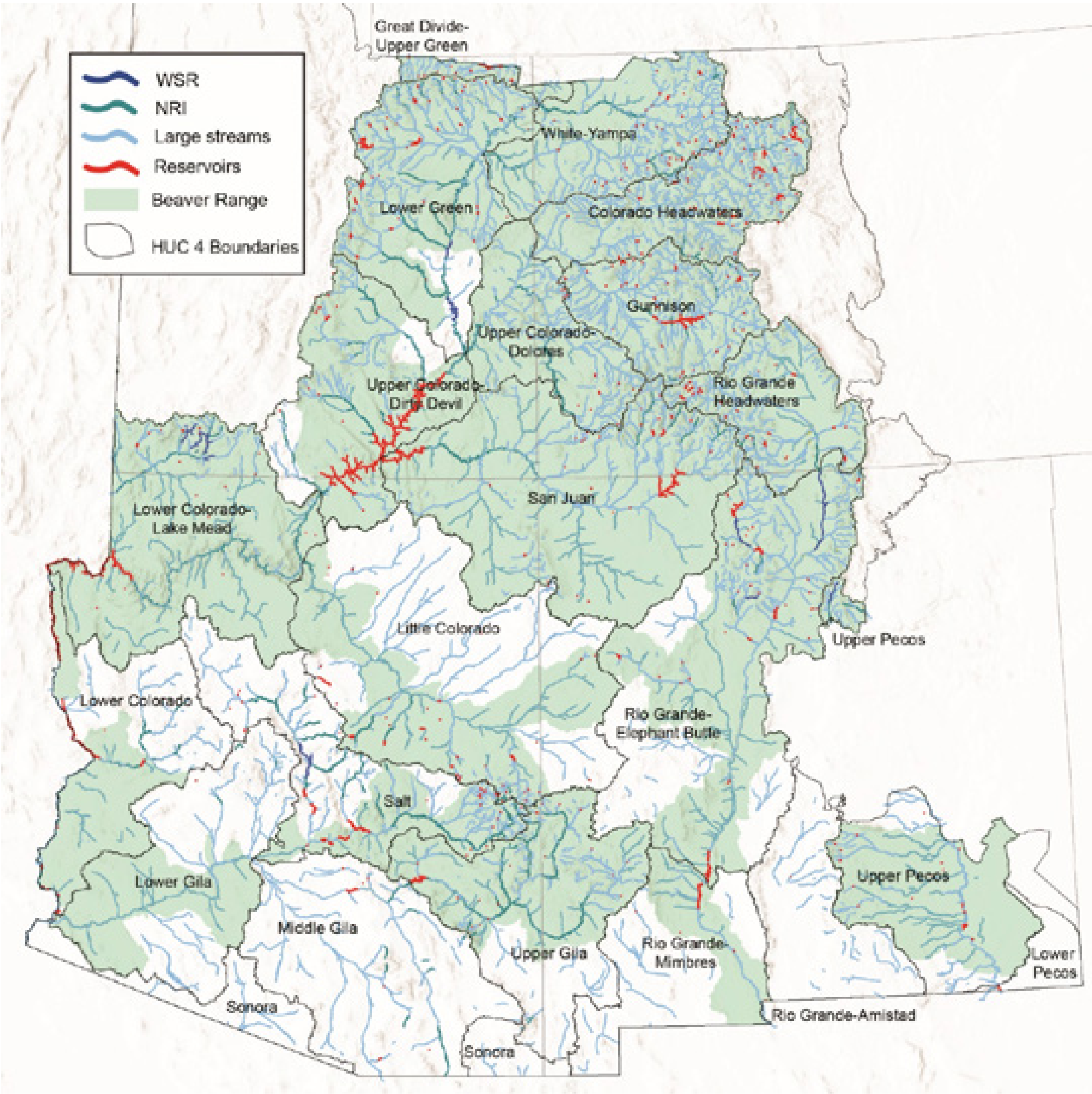

Figure 11. Beaver were once prolific throughout the entire study region. Extant beaver range (green) across the Colorado River and Rio Grande Basins reveals locations where beaver were extirpated from trapping and river alteration (white). Restoring or increasing beaver populations can be a low-cost strategy to improve riverine conditions. Protecting rivers where beavers are present can ensure their persistence in the ecosystem and the continued delivery of their beneficial ecosystem engineering.

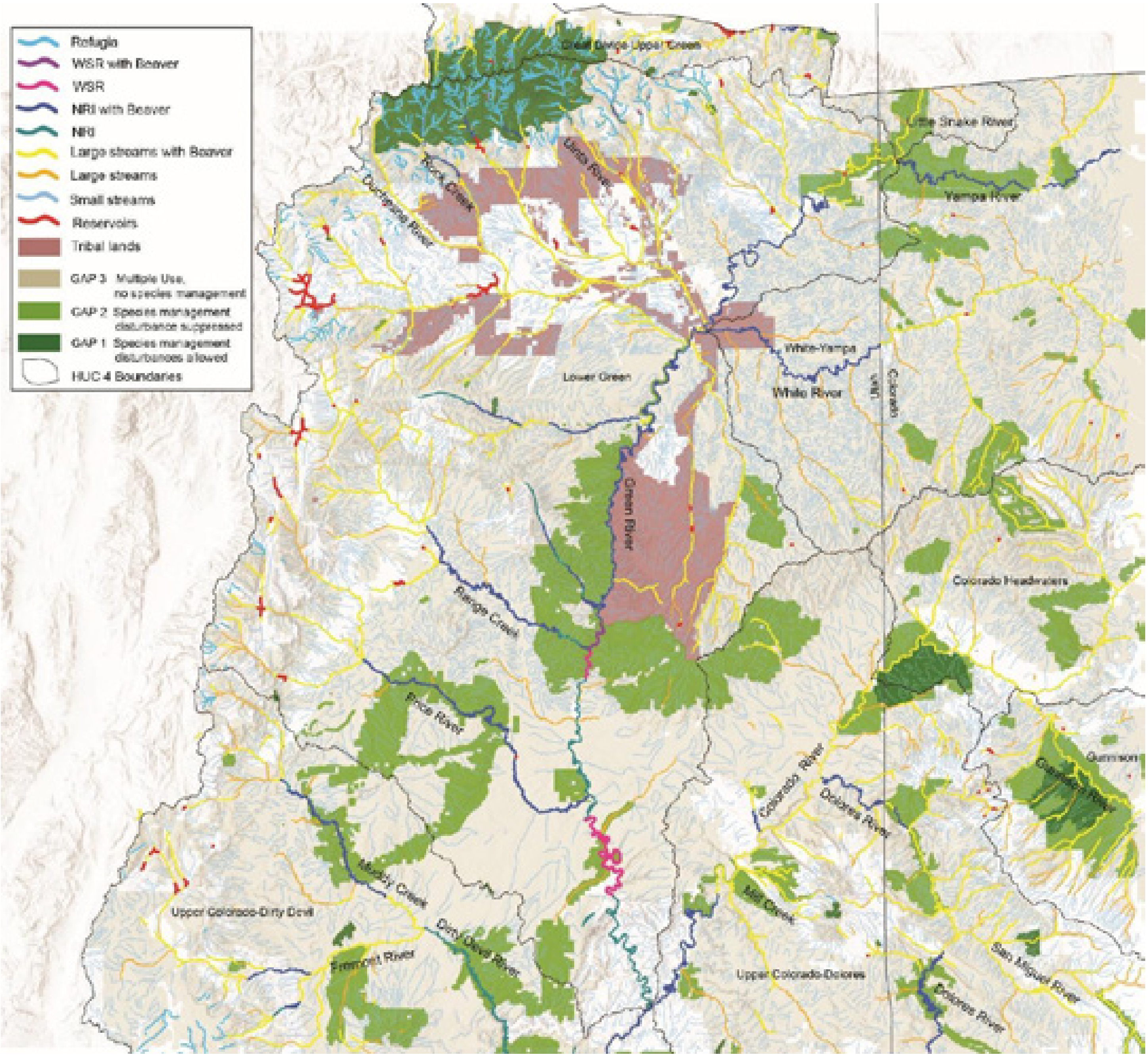

Figure 12. In the Uinta Basin, beaver are reported on numerous large streams that flow from highly connected headwater networks. Protecting the mainstream and headwaters reaches of these rivers can ensure rich riparian vegetation and help maintain refugia characteristics.

COLLABORATING WITH NATIVE NATIONS

Native Nations have land and water management practices grounded in millennia of scientific assessment and adaptation.[12] Indigenous ecological knowledge (IEK) passed down generationally contains knowledge, practices, and beliefs about relationships between all living things, including humans, that facilitate abundant and resilient plant, fish, and wildlife populations.[3] It is not surprising then that Indigenous territories are known to be some of the most biodiverse.[4] In the Colorado and Rio Grande basins, nearly 10% (~ 50,000 sq miles) is sovereign Indigenous territory **(See Figure 13)**. These lands contain some of the last free-flowing rivers in the region.

Many Native Nations have long considered beaver a sacred animal due to their ability to shape the landscape and create perennial water features. These ponds and meadows support vegetation that in turn attracts wildlife to an area. Beaver engineering has brought water and food closer to Indigenous communities, reducing the travel time to search for sustenance while increasing food and water security for the people.[5] Recognizing this relationship, the Zuni Pueblo in New Mexico considers beavers as partners in their riparian area restoration efforts.[6]

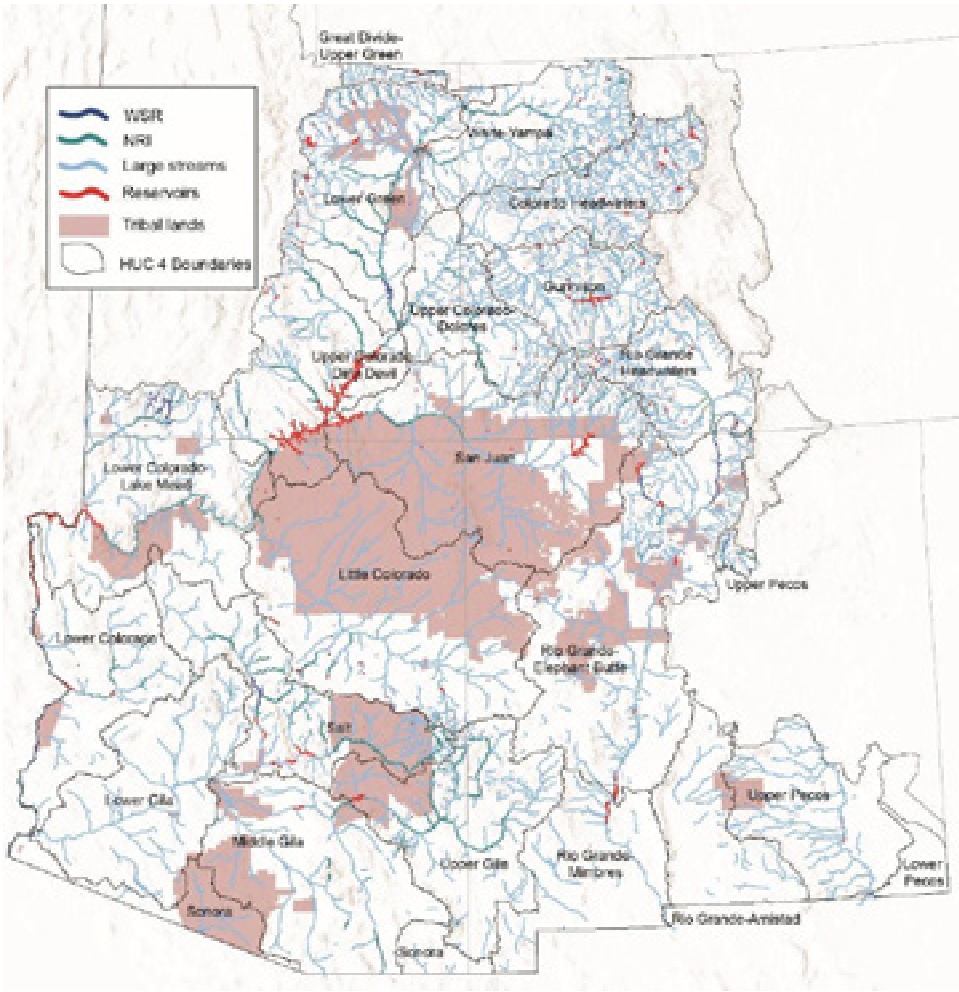

Figure 13 . Tribal lands of Native nations span 10% or nearly 50,000 sq miles of the over 550,000 sq miles of the study area.

1 Williams, T., & Hardison, P. (2013). Culture, law, risk and governance: Contexts of traditional knowledge in climate change adaptation. Climatic Change, 120(3), 531–544. https://doi.org/10.1007/s10584-013-0850-0

2 Whyte, K. (2018). Critical Investigations of Resilience: A Brief Introduction to Indigenous Environmental Studies & Sciences. https://doi.org/10.1162/DAED_a_00497_

3 Jackson, S. E., Douglas, M. M., Kennard, M. J., Pusey, B. J., Huddleston, J., Harney, B., ... Allsop, Q. (2014). We like to listen to stories about fish: Integrating indigenous ecological and scientific knowledge to inform environmental flow assessments. Ecology and Society, 19(1). https://doi.org/10.5751/ES-05874-190143

4 A global spatial analysis - Territories of Life. (n.d.). Retrieved October 16, 2021, from https://report.territoriesoflife.org/global-analysis/

5 LaPier, R. (2017). For Native Americans, a river is more than a “person,” it is also a sacred place. The Conversation. Retrieved from https://theconversation.com/for-native-americans-a-river-is-more-than-a-person-it-is-also-a-sacred-place-85302

6 Albert, S. and T. Trimble. 2000. “Beavers are Partners Restoration 18(2): 87-92. in Riparian Restoration on the Zuni Indian Reservation”. Ecological Restoration 18(2):87-92 Bowling.

Also in New Mexico, otters were reintroduced to the Rio Grande basin via the Rio Pueblo that originates on Taos Pueblo lands. These playful, charismatic creatures were extirpated from most of the basin due to trapping, degraded water quality, and river alterations.[1] Since reintroduction, rapid repopulation of the species has occurred in the Wild and Scenic Rio Grande and Rio Chama. Otters are apex predators that keep a balance in freshwater ecosystems and sentinels for water quality issues. With this combination of characteristics one can interpret the presence of otter in a river as a sign of a healthy watershed with good water quality and an abundance of life.[23] Working with Native Nations in other areas of the study region where otter have been extirpated may prove useful in reintroducing this species to those watersheds **(Figure 14)**.

Taking into consideration that rivers and the species that depend on them do not recognize political boundaries, collaborating with Native Nations is critical for creating culturally appropriate conservation policies and management strategies that respect their sovereignty. Such an approach can enable the conservation of entire ecosystems of high biodiversity concern. To facilitate such strategies, governments and conservation advocates must ensure shared governance, or co-management, of any newly established protected areas adjacent to tribal lands, and tribal governance or shared governance (as desired by the Tribe) on tribal lands.[4]

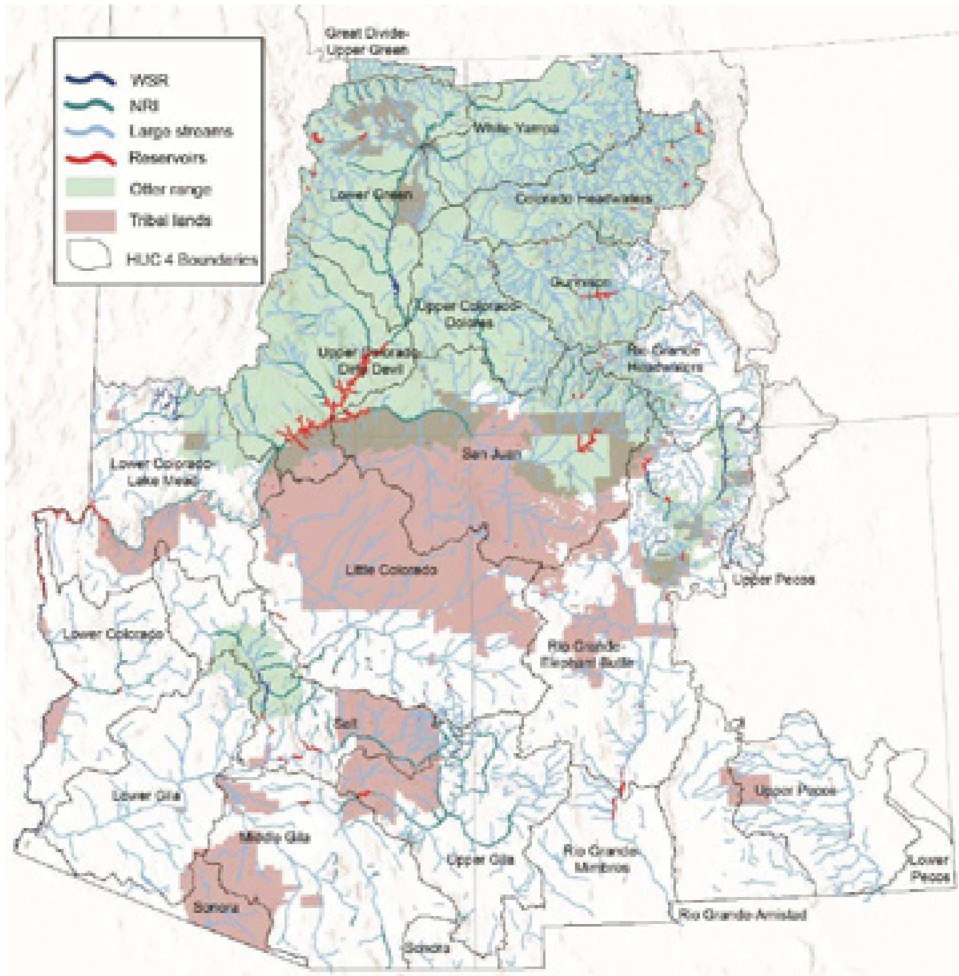

Figure 14. Otter often use the same den and lodge structures that beaver build for shelter. Due to trapping, water quality degradation, and habitat alteration, otters were largely extirpated leaving a current range (green) less than half that of its former range (white). Reintroductions In the Rio Grande basin by Taos Pueblo have led to rapid repopulation in the Wild and Scenic River Rio Grande and Chama reaches of the upper Rio Grande.

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[1] Polechla, P.J. Jr. and Carrillo-Rubio, E. (2009). Historic and Current Distributions of River Otters (Lontra canadensis) and (Lontra longicaudis) in the Río Grande or Río Bravo del Norte Drainage of Colorado and New Mexico, USA and of Chihuahua, Mexico and Adjacent Areas. IUCN Otter Spec. Group Bull. 26 (2): 82 – 96. (n.d.). Retrieved July 6, 2021, from https://www.iucnosgbull.org/Volume26/Polechla_Carrillo-Rubio_2009.html

[2] Savage, M., & Klingel, J. (n.d.). The Case for River Otter Restoration in New Mexico.

[3] Erb, J., Roberts, N., & Dwyer, C. (2018). An Otterly Successful Restoration. Wildlife Society, 45–49. Retrieved from https://www.fishwildlife.org/application/files/2515/2720/4550/TWP__River_Otter_Reintroduction_May_Jun_2018.pdf

[4] Cosens, B., & Chaffin, B. C. (2016). Adaptive governance of water resources shared with indigenous peoples: The role of law. Water (Switzerland), 8(3). https://doi.org/10.3390/w8030097

RIGHTS OF RIVERS

The Rights of Rivers is a swiftly evolving policy option for bestowing human rights to riverine ecosystems. This policy is a powerful tool for recognizing that rivers and watersheds are living entities with rights, not mere property to be exploited for economic development purposes. To date, adoptions of this policy have been led more frequently by Indigenous communities. First and foremost, the policy is designed to provide an avenue to pursue court action against degrading activities. Second, it can serve to provide layered protections on rivers of particular significance to Native nations. As a policy applied at the basin scale, it can work towards maintaining ecosystem integrity. Moreover, Rights of Rivers recognizes Indigenous cultural plurality in legal systems, and in the cases where it has been used, provides an avenue for bringing transformative change to the protection of rivers. Because Native American law has greater standing over local ordinances on tribal lands due to sovereignty, Rights of Rivers implemented by Native governments may be more effective at withstanding degrading developments in their rivers, such as dams.[1] In the United States, Rights of Rivers have been bestowed on the Klamath and Snake Rivers of the Pacific Northwest and the Wekiva and Econlockhatchee Rivers in Florida. Current campaigns exist to apply this policy to other rivers in the country.

SECURING INSTREAM FLOWS FOR FISH AND WILDLIFE

Instream flows, when placed as foci for ecosystem security and water policy, can have significant social, environmental, and economic outcomes. For example, securing instream flows while restoring, diversifying, and replicating habitat is essential for biodiversity protection and species resilience. Moreover, instream flows can protect natural capital, ecosystem service provision, and lead to water security at the basin scale.[2] Evoking the public trust responsibility of the government to protect riverine resources for current and future generations may serve to develop, apply, and/or expand instream flow policies for future allocations while reconsidering past allocations to achieve biodiversity conservation goals.[3]

Securing a quantity of water for instream flows acts as a type of water right for the river. This allocation can serve to halt further allocations of rights that could be used to extract more water from a system. While most rivers in the study region are already overallocated, securing the remaining water rights on river systems of conservation concern can facilitate ecosystem resilience. Colorado has a robust instream flow program that appropriates water to maintain flows. Meanwhile in Arizona, purchasing of lands where groundwater is being pumped and retiring wells is another way to ensure instream flows.[4] As Native Nations adjudicate water rights, they may allocate some of their rights to instream flows. In other cases, the purchase of water rights can convert a consumptive use of the water from activities such as irrigated agriculture to an instream flow, retaining that portion of water in the river. In a changing climate, reservoir drawdown due to water stress may preclude agreements for environmental flows as senior water rights holders are prioritized. Given this limiting reality, instream flows should be pursued as one option in a suite of policy and law options for biodiversity protections.

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[1] Rivers, T. C. R. V. C. for I. J. E. L. C. I. (2020). Rights of Rivers: A global survey of the rapidly developing Rights of Nature jurisprudence pertaining to rivers. Oakland. Retrieved July 6, 2021, from https://www.earthlawcenter.org/river-rights

[2] Tickner, D., & Acreman, M. (2013). Water security for ecosystems, ecosystems for water security. Water Security: Principles, Perspectives, and Practices. https://doi.org/10.4324/9780203113202

[3] National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. Washington, DC: The National Academies Press. https://doi.org/10.17226/10327

[4] National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. Washington, DC: The National Academies Press. https://doi.org/10.17226/10327

EXPAND WILD AND SCENIC RIVERS ACT DESIGNATIONS AND ANALOGUES

The National Wild and Scenic River System was created to meet the current and future conservation needs of the United States. The Wild and Scenic Rivers Act of 1968 (WSRA) protects and enhances the water quality and certain Outstandingly Remarkable Values (ORVs) of the nation's free-flowing rivers. These ORVs can be considered synonymous with riverine ecosystem services that provide myriad benefits to society at local, regional, and national scales **(see Figure 15)**.[1,2] Since the creation of the WSRA, in the study area just 1/10 of 1%, or 363.73 miles out of 348,962.90 miles, have been designated Wild and Scenic Rivers (WSR). The WSRA permanently protects the free-flow and the OVRs of regional and/or national interest in perpetuity. In the study areas, an additional 6,533 river miles have been identified as being eligible or suitable for Wild and Scenic River designation. Of these, roughly 3,000 miles are on the official Nationwide Rivers Inventory (NRI) while 3,500 miles are on the updated Eligible & Suitable list but are not listed on the Congressionally approved NRI. These numbers are significant as there is already a substantial array of rivers that have been identified as having significant conservation importance in the region. However, it is important to keep in mind that protected rivers together with the eligible and suitable rivers total less than 1% of the river miles in this region. There are numerous opportunities to expand Wild and Scenic designations.

By expanding designations in the study area, the system could better protect the unique riverine ecosystem services and biodiversity in each of the subbasins. WSR designation falls within the GAP 2 status. Moving rivers and their riparian areas from GAP status 4 (no species management) and 3 (multiple use) to Gap 2 would allow for the explicit management of aquatic species and riparian-dependent wildlife through a comprehensive river management plan.

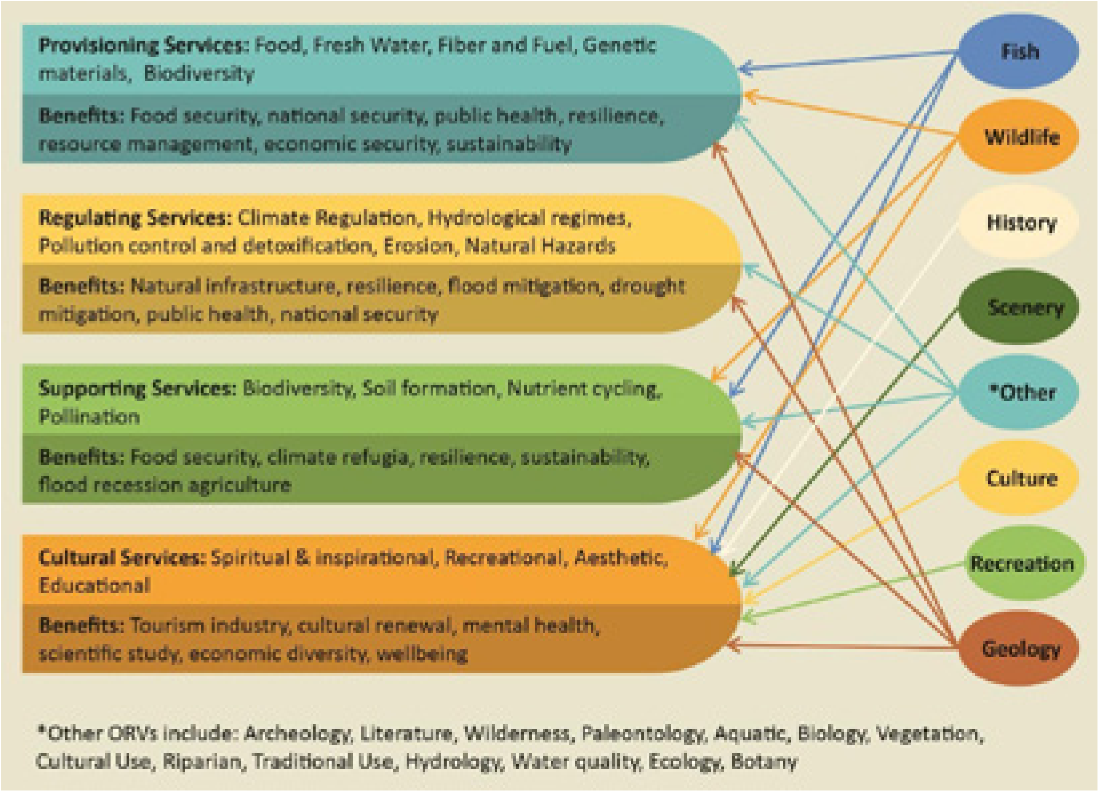

Figure 15. Outstandingly Remarkable Values correlate to riverine ecosystem services. Management actions that protect and enhance these vital ecosystem services lend to the continued purveyance of benefits to society including food security, water security, natural infrastructure, resilience, and wellbeing.

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[1] Perry, D.M. (2017). [Re]framing the Wild and Scenic Rivers Act for Ecosystem Based Resilience and Adaptation.", International Journal of Wilderness, 18(2): 41-48. https://www.researchgate.net/publication/322234684_Reframing_the_Wild_and_Scenic_Rivers_Act_for_Ecosystem_Based_Resilience_and_Adaptation

[2] Perry, D. (2021). Legible Rivers, Resilient Rivers: Lessons for Climate Adaptation Policy from the Wild and Scenic Rivers Act. In J. Cassin, J. Dalton, E. Lopez Gunn, & J. Matthews, Nature-based Solutions and Water Security: An Agenda for the 21st Century. Elsevier. https://www.elsevier.com/books/nature-based-solutions-and-water-security/cassin/978-0-12-819871-1

Just taking into consideration that the range of endemic species in these basins has declined as much as 70% gives rise to reason for protecting their remaining habitat (**Table 2**).

FISH SPECIES	BASIN	HISTORIC RANGE	EXTINCT RANGE	EXTANT RANGE	PERCENT DECLINE	WSR IN RANGE	NRI IN RANGE
BONYTAIL CHUB	CR & RG	7504.66	5238.61	2266.04	70%	58.13	694.57
COLORADO PIKEMINNOW	CR & RG	10958.70	3282.13	7676.57	30%	58.13	1246.92
GILA TROUT	CR & RG	2502.04	633.70	1868.34	25%	0	547.82
HUMPBACK CHUB	CR	2502.04	261.87	4477.66	.5%	58.13	1050.24
RAZORBACK SUCKER	CR	10486.80	3143.59	7343.21	30%	104.95	1820.53
SILVERY MINNOW	RG	2628.52	1878.67	749.85	71%	14.70	28.94

Table 2. The miles of extant range for endemic fishes in the Rio Grande (RG) and Colorado River (CR) basins has declined across species, though the Silvery Minnow and Bonytail Chub have seen the greatest declines at ~70% or more.

Meanwhile, protecting cold water refugia is also of critical importance in these basins. Climate Shield projections show that under the current scenario, only the highest mountain streams at higher latitudes will maintain their refugia characteristics. Of that remaining refugia, over 1700 m are eligible or suitable for WSR designation (**Figure 16**). Protecting these refugia, as well as the downstream tributary corridors, well help to ensure that these headwaters streams maintain their refugia characteristics.

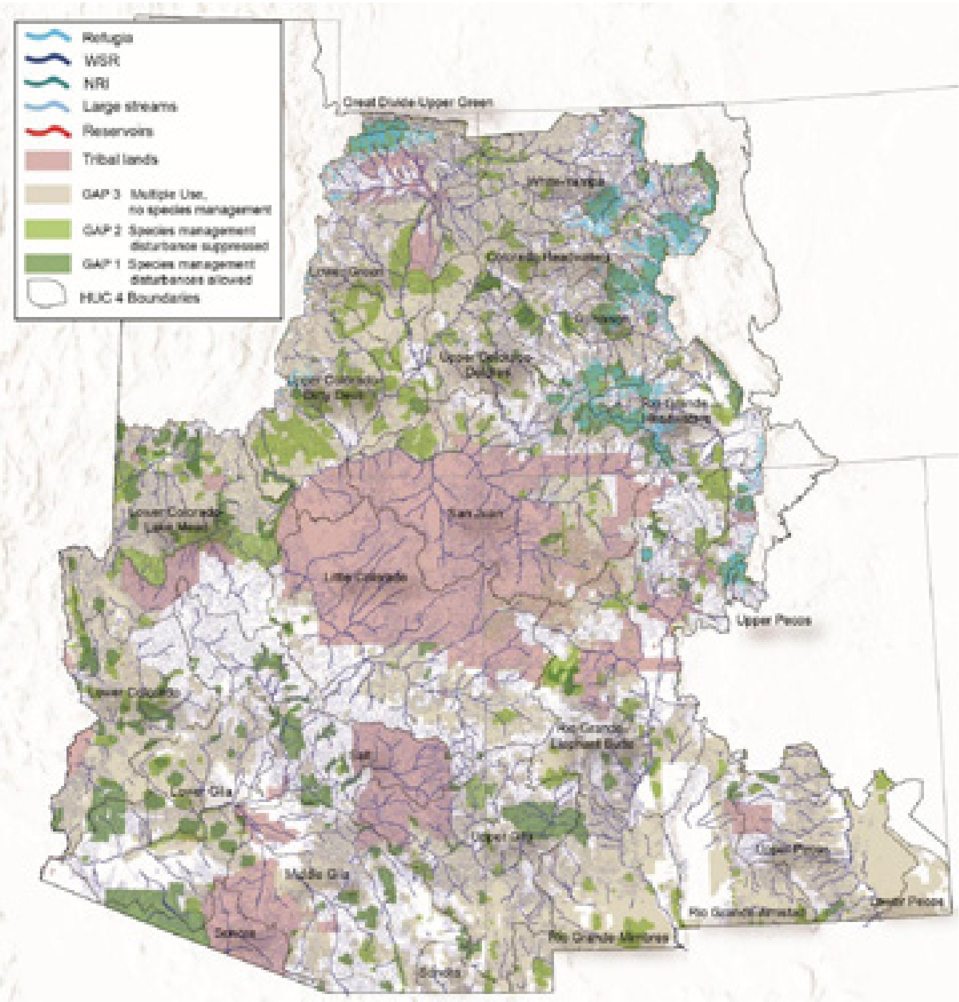

Figure 16. Climate Shield projections suggest that without deliberate action, by 2080 cold-water refugia will be limited to the highest mountain streams. Protecting not only the refugia, but also the downstream river corridors is critical for maintaining the refugia characteristics.

In seeking effective conservation policies and practices for biodiversity, focusing conservation efforts on tributaries to the Colorado and Rio Grande can be beneficial for maintaining habitat and ecosystem function. Unlike the highly altered, homogenized hydrology of main-stem rivers, unaltered tributaries provide hydrologic variability that are key for sending spawning signals as well as supplying energy and organic matter. Tributary conservation, therefore, may serve to support and /or restore imperiled species. Moreover, the focus on tributaries may reduce issues of jurisdictional complexity for project management. In cases where there are networks of free-flowing tributaries and main-stem channels, creating or expanding protections will offer the best chance for species and ecosystem service resilience.[1]

The identification of appropriate conservation areas suitable for the maintenance of multiple species (species richness) can be a challenging endeavor as the range of one species may not align with that of other species intended for protection. Ideally the range patterns of species richness will correlate, facilitating a smoother selection process. **It is important to keep in mind, however, that when considering conservation policy applications, functional diversity, not necessarily species richness, is thought to be the most critical for resilience. Functional diversity influences the productivity, stability, and nutrient balance within an ecosystem, among other aspects.** Therefore, conservation policy for biodiversity as an ecosystem service, may or may not preclude the conservation of some key species, depending on how important they are to ecosystem function. To that end, this study considers beaver as a key species of conservation concern due to its numerous contributions to riverine ecosystem function.

The proposed designation of the upper Gila River in New Mexico is a case where both species richness and functional diversity overlap, maximizing the potential conservation benefits **(see Figure 17)**. The proposed designation is also a model for advancing holistic and comprehensive protections on the last remaining major free-flowing river system in the Southwest. Recognizing that in this rural area, there is reluctance about increased federal regulations, the language of the proposed legislation includes safeguards for private property owners to address any concerns.

The San Juan watershed contains spectacular scenery and wildlife with beaver, otter, and Southwestern Willow Flycatcher habitat all overlapping. This watershed also shows promise for maintaining refugia characteristics into the future.

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1 Pracheil, McIntyre, and Lyons. 2013. Enhancing conservation of large-river biodiversity by accounting for tributaries. Frontiers in Ecology and the Environment 11: 124- 128.

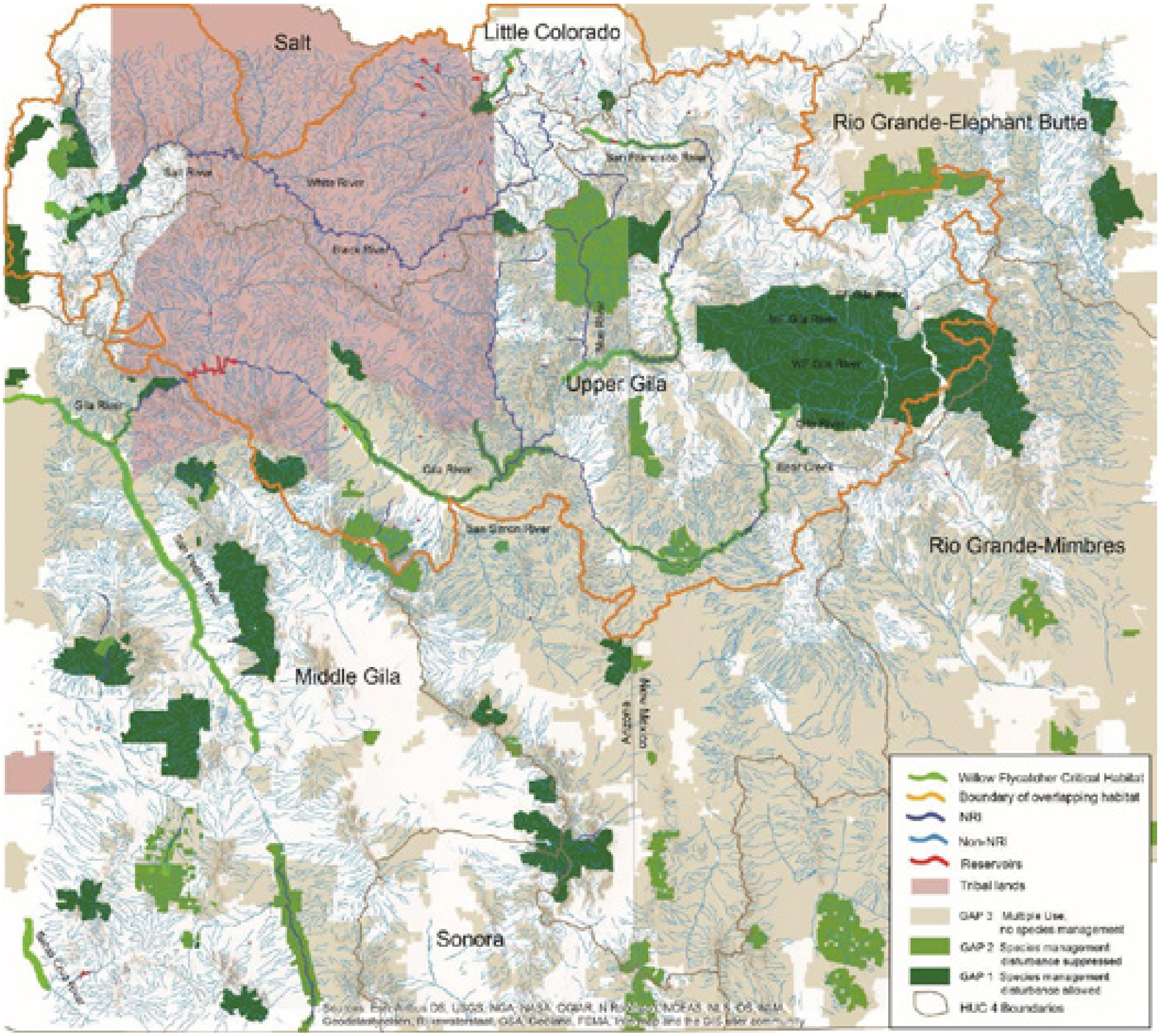

Figure 17. In the Upper Gila watershed, habitat for beaver, the federally threatened Narrow-headed Garter Snake, and the endangered Southwestern Willow Flycatcher overlap within the orange border providing a prime case of where species richness and functional diversity converge.

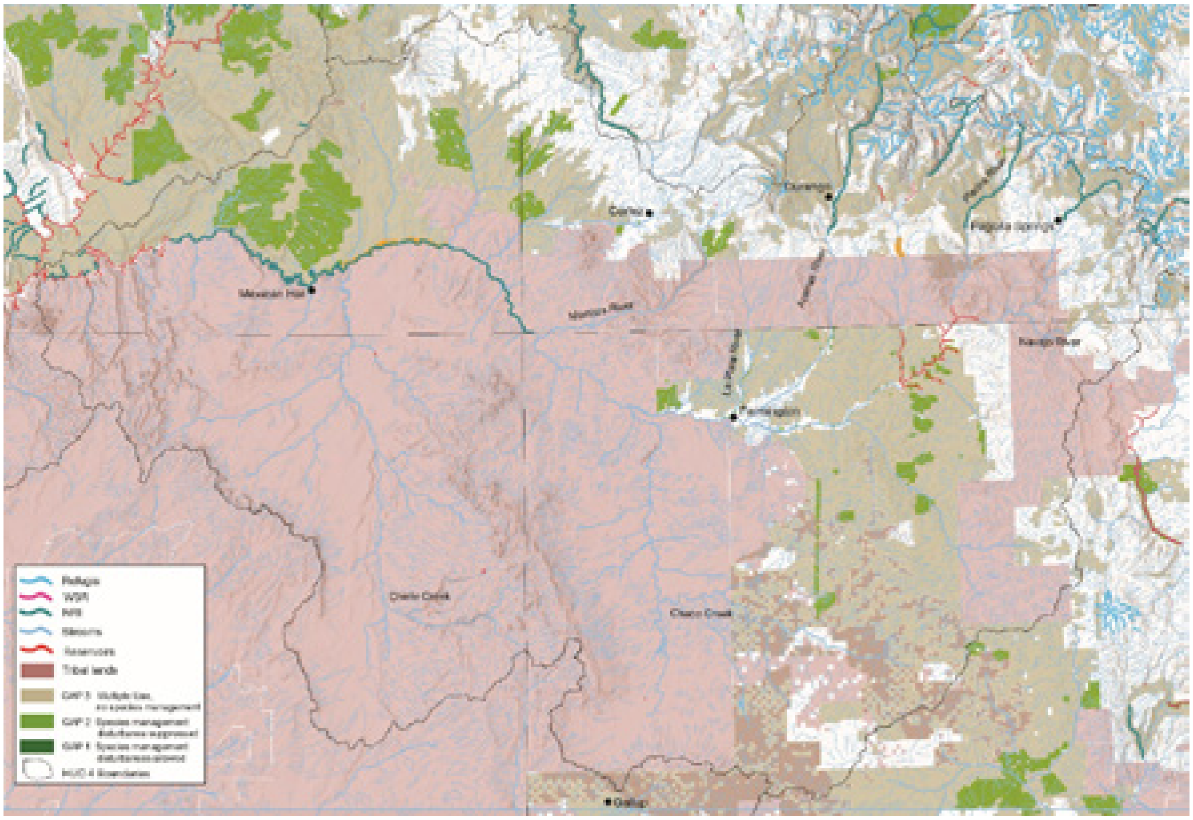

Figure 18. In the San Juan watershed, beaver, otter, and Southwestern Willow Flycatcher habitat overlap in many river corridors. Climate refugia is prevalent in parts of this and the adjacent subbasins, and the mainstem of the San Juan and its major tributaries exhibit high levels of connectivity. Working with the Navajo Nation to secure appropriate protections of the headwaters and mainstem could ensure wildlife habitat protection, especially in the areas with GAP 3 status.

DAM RETROFITTING, DECOMMISSIONING, AND REMOVAL

Of the 1,769 dams in the study area all but about 300 are on stream order 1 or are located on an intermittent or ephemeral reach of any order. Those 300 are located on perennial reaches stream order 2+. These reaches were once free-flowing, perennial reaches providing native fish habitat along with narrow-headed garter snake, willow flycatcher, and other terrestrial animal habitat, which is now lost due to the replacement of riparian zones with reservoir shorelines. Reservoirs often have unstable water levels and therefore do not support the same amount of riparian vegetation, or they fill a canyon and leave no room for a riparian zone.

In the case of Federal Power Act relicensing of non-federal dams in the U.S., dam operations must comply with the ESA and provide wetland and wildlife mitigation plans.[1] In some cases, retrofitting to provide fish passage to reconnect main-stem rivers with tributaries can aid in species recovery. These passage openings may prove especially useful when connections are once again opened to mountain streams through future dam removal and restoration efforts. Decommissioning and removing outdated dams can restore fragmented or degraded natural areas enhancing critical ecosystem services such as the flow of water, genes, sediment, and nutrients. Dam removal on Arizona's Fossil Creek, for example, restored this desert river corridor to an oasis teeming with wildlife activity. By removing invasive aquatic species and repopulating native fishes, the biodiversity in the river stands to be more resilient. The river was subsequently designated as Wild and Scenic to permanently protect its restored free-flow and ecosystem services. In this UN Decade of Restorations, this scenario could be repeated across the Colorado River and Rio Grande basins. **Prioritizing dams for removal based on their potential restoration benefits will be crucial for selecting dams in watersheds with existing biodiversity conservation priorities.**[2]

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[1] National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. Washington, DC: The National Academies Press. https://doi.org/10.17226/10327

[2] Guetz, K., Joyal, T., Dickson, B., Perry, D. (2021) Dam Removal Prioritization in the West: An Optimization Approach for River Restoration and Conservation. Restoration Ecology. https://doi.org/10.1111/rec.13583

PART FOUR:

RECOMMENDATIONS

Today an exciting opportunity exists to build on national and global initiatives to increase protections and address critical fish and wildlife conservation needs. Given the complex patchwork of land ownership as well as water rights and uses in the Rio Grande and Colorado River basins, we recommend a multipronged approach to protecting wildlife habitat through riverine ecosystem conservation. Due to the unique socio-political and ecological landscapes of each subbasin, specific conservation strategies must be considered on a case-by-case basis. A conservation strategy that incorporates layers of policy is arguably the best way to achieve durable protections and effective conservation goals. For instance, for rivers that run through sovereign Indigenous territories, federal lands, and private lands, layered protection could include upgrading Gap status to manage for species, allocating Rights of Rivers, designating Wild and Scenic Rivers, and working with landowners through incentive programs to manage their lands for wildlife. Regardless of the unique combination of policies agreed upon for a given portion of the study area, the following guidelines should be followed:

- Highly connected networks of headwater streams that flow unimpeded to key tributaries and main stem rivers should be prioritized for durable and layered protections utilizing the best policy options available within those jurisdictions. Some effective tools include Wild and Scenic Rivers designations, Outstanding National Resource Waters determinations, protected area designations with robust river protection components, and instream flow provisions.

- In areas where climate refugia currently exists, conservation action should be focused on preserving the conditions that enable those characteristics from the headwaters to the downstream tributaries.

- Outdated dams that block otherwise important habitat should be prioritized for removal and river restoration. Such targeted removals can enhance connectivity in basins where conservation priorities have already been identified such as on streams with Wild and Scenic or eligibility status.

- Reconnection and restoration of floodplains and riparian areas have many benefits for wildlife and people alike. Beaver mimicry and beaver reintroduction can be important components of such work.

- Adaptive management practices grounded in frequent monitoring should be employed to ensure management strategies are achieving desired wildlife habitat conservation goals.

- An Integrated Water Resource Management approach that considers the ecological needs of the river on an equal scale as the economic and social needs should be the driving framework for balancing decision making between conservation and development. Coordination and collaboration across sectors is necessary to achieve such a strategy. Establishing partnerships, coalitions, or river basin commissions can help achieve these pursuits.

- Intact riparian corridors with healthy native vegetation assemblages should immediately be identified and managed for biodiversity and other ecosystem functions by land management agencies, conservation organizations, and landowners.

- Policymakers should not view biodiversity as a constraint, but instead as a key factor in seeking resilient systems that can foster the continued provisioning of ecosystem goods and services. Educating policymakers about the benefits their districts and the country receive freely from these ecosystem services is imperative. Targeted outreach to state and national Senators and House Representatives in the basins should be the first step for garnering support.

- Focus attention on educating politicians and constituents about the economic and social benefits of biodiversity and ecosystem service protection.

- Forming partnerships with other entities to address these needs is integral to ensuring progress is made on established conservation priorities. Build coalitions to strengthen the bargaining power of those concerned with advancing protections. A diverse coalition can speak to the array of constituents who may have opposing views.

- Establish collaborations and co-management strategies with Native Nations in the region.

TAKE AWAY MESSAGES

(bolded sentences in the text)

- Riparian areas are often referred to as 'ribbons of life.'
- In the arid southwest, where yearly evaporation rates exceed precipitation by at least 10 inches, riparian areas play a disproportionate role in supporting biodiversity.
- Diverse and productive vegetation provides both food and shelter for terrestrial animal species.
- Connectivity is a key component of healthy riverine ecosystems as rivers are the great integrators of the landscape. Highly connected free-flowing rivers and their riparian zones serve as buffers against disturbance events.
- Riparian floodplains support high levels of biodiversity, are critical areas for numerous species of conservation concern, and economic and cultural values.
- Despite the rarity of riparian landscape features upon which so much of the Southwest's biodiversity depends and the wide range of ecosystem services they provide, the legacy of nearly two centuries of dredging, mining, dam building, and poorly managed livestock grazing, as well as increasing population pressures have impaired the critical riparian areas of these basins.
- Aside from dams, unregulated livestock grazing is one of the most degrading activities in riparian areas.
- In Arizona alone, 90% of native fish species are now extinct, extirpated, or listed as endangered. In the Lower Colorado River Basin, 75% of fish species are listed under the US Endangered Species Act due to compounding impacts of hydrologic alteration, invasive species, and land modification.
- Connectivity is essential for healthy river systems!
- Beavers are biological integrators of rivers and riparian areas who support biodiversity through their advanced and creative engineering prowess.
- Expanding protections across the networks of remaining intact river systems with high rates of connectivity is integral to meeting both societal and wildlife needs in a changing climate.
- Protecting and managing rivers and riparian areas for biodiversity in turn has positive, reciprocal benefits for adjacent terrestrial lands.
- When considering management policies for vulnerable species, prioritizing protecting places that are also simultaneously considered climate refugia may require little management, freeing up scarce monetary and human resources to focus on more at-risk habitat.
- In seeking effective conservation policies and practices for biodiversity, focusing conservation efforts on tributaries to the Colorado and Rio Grande can be beneficial for maintaining habitat and ecosystem function.
- Protecting rivers where beavers are present can ensure these keystone species can continue to provide and enhance ecosystem services and wildlife habitat. The Upper Gila, San Juan, Dolores, Rio Grande headwaters, and the Upper Green and its tributaries all exhibit high rates of connectivity and flow within the current range of beavers.
- Prioritizing dams for removal based on their potential restoration benefits will be crucial for selecting dams in watersheds with existing biodiversity conservation priorities.

APPENDIX A: SPECIES STATISTICS

Note: All species stats are limited to the study area; Stream orders 0 & 1 not considered for this study.

Bonytail Chub (Gila elegans)

The historic range of the bonytail chub included 7,505 miles (12,078 km) of perennial rivers within the Colorado River system. It has been extirpated from 5,239 miles (8,431 km) of its former range, leaving only 2,226 river miles (3,647 km) where the fish is currently present. Of these river miles where the fish is still extant, 487 miles (784 km) are within reservoirs while only 58 miles (94 km) are classified as Wild and Scenic. However, a further 695 miles (1,118 km) are potentially eligible for designation because they are listed on the Nationwide Rivers Inventory.

Colorado Pikeminnow (Ptychocheilus Lucius)

The historic range of the Colorado pikeminnow included 10,959 miles (17,636 km) of perennial rivers within the Colorado River system. The Colorado pikeminnow was extirpated from 3,282 miles (5,282 km) of its former range, including the entire Lower Colorado region, leaving only 2,226 river miles (3,647 km) where the fish is currently present in the Upper Colorado region. Of these river miles where the fish is still extant 482 miles (776 km) are within reservoirs while only 58 miles (94 km) are classified as Wild and Scenic. However, a further 1,247 miles (2,007 km) are potentially eligible for designation because they are listed on the Nationwide Rivers Inventory.

Gila Trout (Oncorhynchus gilae)

The historic range of the Gila trout included 2,502 miles (4,027 km) of perennial rivers within the Gila sub-basin of the Colorado River system. The Gila trout has been extirpated from 634 miles (1,020 km) of its former range, leaving 1,868 river miles (3,007 km) where the fish is currently present in the Upper Colorado region. Of these river miles where the fish is still extant 22 miles (35 km) are within reservoirs while no river segments are classified as Wild and Scenic. However, 548 miles (882 km) are potentially eligible for designation because they are listed on the Nationwide Rivers Inventory.

Humpback Chub (Gila cypha)

The historic range of the humpback chub included 4,740 miles (7,628 km) of perennial rivers within the Colorado River system. The humpback chub has been extirpated from 262 miles (421 km) of its former range, leaving 4,478 river miles (7,206 km) where the fish is currently present. Of these river miles where the fish is still extant 699 miles (1,125 km) are within reservoirs while no river segments miles are classified as Wild and Scenic. However, 1,050 miles (1,690 km) are potentially eligible for designation because they are listed on the Nationwide Rivers Inventory.

Razorback Sucker (Xyrauchen texanus)

The historic range of the razorback sucker included 10,487 miles (16,877 km) of perennial rivers within the Colorado River system. The razorback sucker has been extirpated from 3,144 miles (5,059 km) of its former range, leaving 7,343 river miles (11,818 km) where the fish is currently present. Of these river miles where the fish is still extant 823 miles (1,324 km) are within reservoirs while no river segments miles are classified as Wild and Scenic. However, 1,821 miles (2,930 km) are potentially eligible for designation because they are listed on the Nationwide Rivers Inventory.

Rio Grande Silvery Minnow (Hybognathus amarus)

The historic range of the silvery minnow included 2,629 miles (4,230 km) of perennial rivers within the Rio Grande system. The silvery minnow has been extirpated from 1,879 miles (3,023 km) of its former range, leaving only 750 river miles (1,207 km) where the fish is currently present. Of these river miles where the fish is still extant 50 miles (80 km) are within reservoirs while 15 miles (24 km) are classified as Wild and Scenic. However, a further 29 miles (47 km) are potentially eligible for designation because they are listed on the Nationwide Rivers Inventory.

North American Beaver (Castor canadensis)

The USGS provided range for the beaver includes 184,822 square miles within the two basins. When adjusted to only include the maximum range the species uses, which is within approximately 330 feet of river segments with suitable forage habitat, the functional beaver range is reduced to 2,124 square miles. Within this functional range there are 17,574 perennial river miles, with most of these miles located in the Upper Colorado Region (11,998 miles, vs. 3,423 in the Rio Grande basin and 2,153 in the Lower Colorado Region). There are only 181 miles of Wild and Scenic River segments between the three sub-basins, compared to 1,738 miles of reservoir. There are however, 4,193 miles of potentially eligible rivers for Wild and Scenic designation due to their being listed on the National Rivers Inventory.

North American River Otter (Lontra canadensis)

There are 21,073 miles of perennial river segments in the North American river otter's range within the study area. Of these, 1,170 miles are impounded while the remaining 19,902 miles are free-flowing. The Colorado River and Rio Grande basins account for 15,624 of these miles. The vast majority of river miles in the otter's range are within the Upper Colorado Region (13,854 miles, yet only 58 miles are designated Wild and Scenic, though there are 1,866 miles listed in the NRI in this same region. The Lower Colorado Region has 576 miles of perennial river miles within the otter's range with 56 Wild and Scenic miles and 203 NRI miles. The Rio Grande Region has 1,195 perennial river miles with 90 W&S miles and 47 miles on the NRI.

Southwestern Willow Flycatcher (Empidonax traillii extimus)

Critical habitat for the endangered Southwestern willow flycatcher exists along 845 miles of river within the Rio Grande and Colorado River basins. Almost all this critical habitat is within riparian zones along free-flowing perennial rivers (830 miles), with only 15 miles present along reservoirs. However, only 30 miles are protected by a Wild and Scenic designation, although 351 more miles are eligible for designation as NRI rivers. Additionally, a further 449 miles of critical flycatcher habitat is along free-flowing perennial rivers that are not W&S or NRI which could be protected to ensure the survival of this subspecies of willow flycatcher.

Narrow-headed Gartersnake (Thamnophis rufipunctatus)

Suitable habitat for the federally threatened narrow-headed gartersnake exists along 1,381 miles of river segments in the Lower Colorado and Rio Grande Regions, though almost all these miles are within the Lower Colorado Region (1,379 miles). There are 45 miles of W&S designated segments within its range along with 645 miles of NRI reaches along with 691 miles of free-flowing river segments. Narrow-headed garter snakes do not typically use reservoir banks as habitat, so the 22 miles of habitat located along reservoirs within the Lower Colorado Region based on USGS habitat data is likely unused.

APPENDIX B: DATASETS

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U.S. Geological Survey (USGS) - GAP Analysis Project (GAP), 2021, Protected Areas Database of the United States (PAD-US) 2.1 - World Database on Protected Areas (WDPA) Submission (ver 1.1, April 2021): U.S. Geological Survey data release, https://doi.org/10.5066/P9IVLRSS.

LIST OF ACRONYMS

CBD – United Nations Convention on Biological Diversity

FWS – US Fish and Wildlife Service

GAP – Gap Analysis Project

IUCN – International Union for Conservation of Nature

NHGS – narrow-headed garter snake

NRI – Nationwide Rivers Inventory

NWSRS – National Wild and Scenic Rivers System

PAD-US – Protected Areas Database of the United States

SWWF – Southwestern Willow Flycatcher

USGS – United States Geological Survey

WSR – Wild and Scenic River

WSRA – Wild and Scenic Rivers Act of 1968

END NOTES

AMERICAN RIVERS

Life Depends on Rivers℠

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