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Theme: Creating Hope through Action: Advancing Solutions to Rapid Environmental Change

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Abstracts

Abstracts are ordered alphabetically by presenting author, whose name is indicated in bold type.

Mapping actual evapotranspiration over croplands using vegetation index methods

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ABSTRACT: Natural and anthropogenic changes have altered water availability of croplands along the Zayandehrud River Basin (ZRB) in Iran, similar to what is happening on the lower Colorado River in the US. Knowledge of crop water consumption is of importance to better manage agricultural water use, particularly in drylands. Advances in estimating actual evapotranspiration (ETa) with remote sensing (RS) have contributed to improving hydrological, agricultural, and climatological studies. In this study, we evaluated the applicability of Vegetation-Index (VI) -based ETa (ET-VI) for mapping crop water consumption in arid cropland systems where lack of ground data restricts the ETa estimation. Cloud computing platforms are providing a powerful tool to access, process, and visualize big geospatial data. We used the

Google Earth Engine platform to calculate ET-VIs. To map ETa (2000-2019), ET-VIs were translated using Landsat-derived 3- and 2-band Enhanced Vegetation Index (EVI and EVI2) over croplands in the ZRB. Since EVI and EVI2 were developed for MODerate Imaging Spectroradiometer (MODIS), calculating these VIs using Landsat sensors requires a cross-sensor transformation to apply them in the ET-VI algorithm. The before- and after- impact of these empirical translation methods on the ETa calculations was assessed and performance of ET-VIs was evaluated. Our results show that ET-VIs' estimates agreed with each other. Compared to crop ET values, ETa estimations from MODIS-based continuity-corrected Landsat-EVI (EVI2) (EVI_{MccL} and $EVI2_{MccL}$) performed slightly better across croplands than those of Landsat-EVI (EVI2) without a cross-sensor transformation. Our findings show the importance cross-sensor continuity corrections when using empirical algorithms designed for specific sensors. Our ETa estimation of agricultural water use at 30 m spatial resolution provides a monitoring tool for croplands and their water consumption. Future research could examine the performance of empirical RS-based ET-VIs in different arid and semi-arid regions such as lower Colorado River.

Adaptation of scenario planning and risk assessment approaches toward development of priorities and approaches to management at Chaco Culture National Historic Park - a case study

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ABSTRACT: In order to manage and preserve the nation's park lands, Congress passed the National Park Service Organic Act in 1916 (16 U.S.C.§1). The Organic Act established the National Park Service with the stated purpose to conserve park resources and provide for their use and enjoyment "in such a manner and by such means as will leave them unimpaired" for future generations. How does the National Park Service manage cultural resources unimpaired in the face of climate change? What does that mean for the parks we manage? Current approaches to managing vulnerability of resources to climate change have been static and not dynamic. Chaco Culture National Historical Park, a UNESCO World Heritage listed resource, encompasses 33,997 acres and has well over 3,000 archeological sites ranging from small artifact scatters up to massive "Great House Architecture" for which the park is renowned, along with sensitive and fragile resources including ancient roadways, petroglyphs, pictographs, and more. In an effort to find our best pathway for the protection of cultural resources, we have worked with the NPS Regional staff and multiple partners, including the University of Arizona, University of Pennsylvania, Boise State University, Scenario Insight, the Southwest Climate Conservation Center and more to better understand climate change and its effects on cultural resources. This presentation includes a case study highlighting the difficulties of managing cultural resources in this time of change along with the exploration of scenario planning specifically for cultural resources.

A macrosystems approach to managing southwestern riparian ecosystems facing climate change & exotic species invasion

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ABSTRACT: Riparian ecosystems in the southwestern US are facing unprecedented demise due to increased drought, rising temperatures, fluctuating water tables and the spread of invasive species. Consequently, land managers are faced with simultaneous challenges that require new insight into how species respond to multiple threats and how they might adapt to rapid environmental change. Here, we employ a wide range of tools to investigate how dominant riparian species respond to both individual and multiple threats at local to regional scales. This approach merges methods ranging from molecular genetics to field and greenhouse trials to remote sensing technology to understand: (1) broad patterns and processes that influence adaptive genetic potential; (2) symbiotic relationships that mediate individual species' responses; and (3) feedbacks that are important for community-level interactions that drive biodiversity and associated ecosystem processes. By integrating these methods and technologies we aim to develop strategies that are focused on long-term adaptive management. The ultimate goal of a macrosystems approach is to provide integrated solutions to the problem of rapid environmental change, thereby leading to improved conservation and restoration of riparian ecosystems both on and off the Colorado Plateau.

Food forests as a strategy for climate mitigation

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ABSTRACT: Food forests are multi-layered polycultures consisting of mostly perennial species. They may include seven or more layers, including overstory and midstory trees, shrubs, herbaceous species, ground cover plants, root crops, vines, an aquatic layer and fungi. They are multifunctional and may provide other desired goods and services besides food, such as medicinal plants, wood, soil fertility enhancement, biodiversity protection, and carbon sequestration. They are also a type of "multistrata agroforestry," a practice that was ranked #28 on Project Drawdown's list of the 100 top climate solutions (https://drawdown.org.solutions). A recent survey and subsequent site visits have documented the presence of food forests in the Southwest. They occur in a wide range of environments, including large cities such as Tucson and Phoenix, and in physical environments ranging from the Sonoran Desert to elevations above 7,000 feet. This presentation will include both an overview of the types of food forests found in this region and an assessment of their potential role as a climate mitigation strategy, particularly for addressing the urban heat island effect in cities and for carbon sequestration.

Advanced information management and technology assessment for science in the Colorado River Basin

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ABSTRACT: The Colorado River Basin Actionable and Strategic Integrated Science and Technology (ASIST, previously EarthMAP) pilot project was initiated to facilitate interdisciplinary science in the drought-stricken Colorado River Basin and apply advanced information management and technology (IMT) solutions that can be used to deliver actionable science efficiently and effectively. As such, an ongoing objective for the pilot is to leverage advanced technologies to improve observation systems, integrate predictive models, and accelerate science communication to deliver outcomes faster, more efficiently, and at an appropriate level of detail or accuracy to support management decisions. To help achieve this goal, an assessment of data management and advanced technologies available to US Geological Survey scientists was conducted which led to the establishment of an inventory of IMT resources. A multi-year approach to evaluate and leverage these resources in support of Colorado River Basin drought related research was developed. A working group was established to design, test, and implement a workflow that accesses drought-related data stored in multiple databases and centralizes such into a cloud-hosted database. The data can then be accessed through multiple platforms and querying tabular data can be optimized to accelerate the delivery of science results to stakeholders. This presentation provides an overview of available IMT resources and describes a workflow to leverage some of these resources to efficiently deliver science results to stakeholders.

Cooling capacity of urban trees exposed to thermal stress

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ABSTRACT: In arid regions where episodic heatwaves regularly occur, urban heat islands pose a major threat to human and environmental health. Urban vegetation is known for mitigating some of these threats by cooling the local surroundings through shade and evapotranspiration. However, choosing the appropriate tree species remains a challenge, as urban planners have little information on species' cooling capacities. Here, we investigated (1) how plant water use and shade projection differed across species; and (2) how these parameters changed from spring to mid-summer in Phoenix, AZ, USA when temperatures regularly exceed 40°C. We measured leaf

stomatal conductance (gsw), leaf and whole-plant transpiration (Et), coupled with measurements of canopy temperature, canopy volume, and microclimate. Measurements were taken from mid-Spring and extended through pre-Monsoon and Monsoon summer (March-July 2021). Contrary to popular belief, exotic tree species did not significantly transpire more than native species on average or across seasons. While gsw declined as VPD and leaf temperature increased with summer conditions, an exception was observed in June 2021 in which both gsw and Et substantially increased after a heatwave event. That response was not observed in July 2021 due to a subset of species suffering from leaf thermal damage and possible loss of xylem conductivity. Eleven of the 14 species increased midday Et, contributing to enhanced canopy cooling, while the remaining three species suppressed water loss in response to thermal stress. Importantly, species that were highly susceptible to thermal stress had reduced canopy cover which compromised their capability of projecting shade during the warmest and driest period of the year. Ultimately, *Pinus eldarica*, *Cupressus arizonica*, *Chilopsis linearis*, *Fraxinus velutina*, and *Searsia lancea* were proven to be the best tree options for Phoenix landscaping as these species provide intermediate-full shade across seasons, relative to water use under arid conditions.

A quarter-century perspective on the growth, demography, and decline of Nichol's Turk's head cactus (*Echinocactus horizonthalonius*)

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ABSTRACT: The endangered Nichol's Turk's head cactus (*Echinocactus horizonthalonius* Lemaire var. *nicholii* L. Benson) occurs only in four small, isolated populations in the Sonoran Desert. Since 1995, we have characterized growth, flowering, recruitment, and mortality of a population in the Waterman Mountains of southeastern Arizona (Pima County, Ironwood Forest National Monument). During that quarter century, we documented the loss of ca. 80% of individuals from study plots near Waterman Peak: only 25 plants were alive in 2022 relative to >130 alive in 1995, for an overall rate of change in abundance of -6% per year. Recruitment per capita has increased during the study period, such that the decrease in abundance reflects an increase in mortality over time. A sharp and persistent population decline began in 2008 following establishment of a watering station for bighorn sheep (*Ovis canadensis*) ca. 250 m from our study area. Since the water source was established, we have noted an increase in sheep scat and damage to plants consistent with pawing by sheep. To distinguish impacts from sheep from those due to changes in temperature and precipitation, we established two additional plots in 2016 in nearby areas where sheep are not present. In these areas, annual mortality is lower than in the areas with sheep but is higher than that observed under cooler and wetter conditions that predominated during early years of the study. Moreover, individual plants grow less rapidly and are less likely to flower when drought is more severe. Together, our data highlight potential impacts of climate change for this rare and endangered plant.

Investigating limitations to pollination in rare and endangered cacti: case studies of *Pediocactus* and *Coryphantha*

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ABSTRACT: The Southwest is a center of diversity for cacti, including a number of rare and endangered species. Cacti exhibit slow population growth and high sensitivity to habitat loss, but are also important interactors with vertebrates and invertebrates in arid ecosystems, and their loss can simplify interaction networks and impact ecosystem function. Among other threats, absence or decline of pollinators may threaten some cactus populations, particularly when they are already rare. Pollinator declines have been recorded across ecosystems and taxa, prompting concern for ecosystem services globally. Threats to pollinators include habitat loss and climate change, as well as pesticides, diseases, and biological invasions. Absence of pollinator services can disrupt gene flow, lessen reproductive output, and reduce adaptive capacity in populations of rare plants. I investigate pollination limitation in two threatened cactus genera in Arizona. For *Coryphantha scheeri* var. *robustispina*), flower visitation and fruit production were reduced in populations adjacent to expanding urban development in the southern Sonoran Desert of Arizona, suggesting that urbanization may fragment plant populations and impact the overall population trajectory of the species across the region. For *Pediocactus peeblesianus* var. *fickeiseniae* in northern Arizona, intensive pollination research has revealed exceedingly low rates of pollinator visitation. These observations led to current research examining the influence of habitat characteristics and disturbance on pollinator communities interacting with the closely related *Pediocactus paradenei*. I aim to understand whether conservation efforts can target pollination services to support threatened and endangered cacti across geographic areas and habitat types.

Relationships between management trajectories and ecological patterns in management mosaic landscapes

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ABSTRACT: As global environmental change progresses, species increasingly demonstrate range shifts, driven by altered disturbance regimes, climate change, and habitat loss. Ecological fragmentation can impede range shifts by disrupting dispersal routes. Across the US, undeveloped lands are divided among a diversity of management jurisdictions. Jurisdictional boundaries are partially driven by intrinsic heterogeneity across landscapes, which contributed to historical assignment of jurisdictions. However, such boundaries rarely track natural ecotones precisely, and adjacent management units may contain the same habitat types. Different land management entities—federal, state, local government, or private—make management decisions that emerge out of different management missions, mandates, resource availability, and

objectives. Management decisions in turn influence ecological conditions; for example, differing approaches to fuels management can result in different levels of fire frequency, severity, and size in neighboring jurisdictions. Landscapes comprising many jurisdictions may thereby become management mosaics, with patchwork habitat conditions, driven by diverse management trajectories, corresponding to patterns of jurisdictional boundaries across the region. In this way, distinct social histories can manifest in ecological shifts across boundaries, possibly driving ecological fragmentation at some scales. We set out to tease apart these coupled social and ecological drivers of environmental heterogeneity across landscapes, in order to understand how and when ecological and social fragmentation are predictive of one another. We found that differential management of fire, grazing, and forest pests, as well as differential responses to disturbances in general, are related to significant changes in ecological variables in neighboring jurisdictions, after controlling for contextual factors such as elevation and broad vegetation type. Our results suggest that enhanced cooperation and coordination in management activities across jurisdictional boundaries may promote ecological connectivity and facilitate conservation in the face of global change.

Seed traits mediate the effects of biocrusts on plant germination

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ABSTRACT: Biological soil crusts (biocrusts) mediate key ecosystem functions in dryland ecosystems including soil stability, hydrology, nutrient availability. As such, biocrusts can strongly affect the recruitment of vascular plants. Biocrusts often impede the germination of some plant species, yet these effects vary depending on plant functional group and biocrust community composition. However, we currently lack understanding of the specific mechanisms underlying the species-specific effects of biocrusts on plant germination. Morphological seed traits (e.g., seed mass, shape, presence of awns) may affect which seeds can physically overcome biocrust physical barriers to germination, but this has yet to be rigorously tested. To explore the possible role of seed traits in determining biocrust effects on germination, we conducted a global meta-analysis to examine relationships between seed traits (e.g., seed mass, seed shape, seed appendage [e.g., awns], and appendage hygroscopicity) and germination responses to biocrusts. Preliminary data analyses indicate that seed shape and mass are important predictors of biocrust effects on germination with large and linear seeds having lower germination rates on biocrust versus bare soil. These results increase our fundamental understanding of biocrust-plant interactions in dryland communities and have a variety of practical applications in dryland ecology and management. For example, restoration practitioners could use this knowledge when deciding which plant species to use in dryland restoration projects.

Providing context for advancements in *Arctomecon californica* conservation using biocrust: comprehensive literature review with case studies

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ABSTRACT: *Arctomecon californica* (Las Vegas Bearpoppy, Papaveraceae) is a rare and endemic forb in southern Nevada with a potential relationship to biological soil crusts (biocrusts) that has long been in decline. This species is a charismatic indicator of the biocrust occupied gypsum-rich soils of the Mojave Desert, which are its primary habitat, and faces many threats including urban sprawl, pollinator loss, habitat destruction for resource extraction and energy development, and illegal off-highway vehicle recreation. While *A. californica* has been the focus of several studies and conservation efforts since as early as 1969, much of the research on this plant has remained unpublished and inaccessible. To ensure all stakeholders have access to all the existing knowledge of this species, we have reviewed and summarized over 40 works including sources that have never been digitized and are at risk of being lost. We also fully document our own efforts at biocrust facilitated conservation and restoration of this plant species, including plant salvage, in situ seeding, and ex situ cultivation. We hope to support further research by providing a comprehensive summary of everything known about *A. californica* and setting a precedent for publication of studies about conservation and restoration techniques for this species whether they are perceived as successful or not.

Innovation and tradition at Grand Canyon National Park; they can co-exist

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ABSTRACT: Public understanding and support for science and resource management is a fundamental program need for the National Park Service. At Grand Canyon National Park (GCNP), we have been exploring a host of opportunities to bring our research and science information into a more accessible format to help create the next generation of park stewards. From podcasts and websites to personal delivery of programs, Park staff and partners continue to look for innovative ways to engage park visitors with the resources of Grand Canyon. This presentation will showcase the range of tools Park staff, tribal colleagues and partners have been using to bring science and resource management to a greater audience. As our digital presence changes, we are striving to expand our reach and the voices of the Grand Canyon so that we are representative of the past and present, with an eye on the future of outreach opportunities and park stewardship.

Tools for restoration feasibility planning at the Lower San Pedro Wildlife Area (LSPRWA): vegetation and soil Assessment, LiDAR data, groundwater-surface water model, habitat suitability models

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ABSTRACT: Arizona Game and Fish Department plans to restore approximately 670 acres of riparian gallery forest and enhance emergent wetlands within the Lower San Pedro River Wildlife Area (LSPRWA) located approximately 50 miles north of Tucson, Arizona in the Lower Colorado River Basin. The goal is to assist in countering wetland and riparian habitat loss throughout the State and create and enhance additional critical habitat for federally threatened and federally endangered avian species. We conducted a feasibility study to prioritize restoration areas and develop site-specific habitat restoration plans. Components of the feasibility study included a background data review; a baseline assessment of soil, groundwater and vegetation characteristics in the riparian corridor; two-dimensional hydraulic modeling, and development of a surface water-groundwater model. These tools were used to prescribe restoration activities (e.g., conservation, selective invasive tree removal, large-scale invasive species removal followed by re-vegetation), prioritize restoration areas, and provide planting palette recommendations based on site conditions (soil texture, soil salinity, depth to groundwater, inundation frequency, and long-term groundwater resilience). Leaf on LiDAR data was paired with the field vegetation characterization to produce vegetation maps of the study area and develop a site-specific habitat suitability model for the southwestern willow flycatcher (*Empidonax traillii extimus*) and yellow billed cuckoo (*Coccyzus americanus*). The surface water-groundwater model was used to evaluate long-term groundwater supply adequacy critical for riparian habitat. It included scenarios that examined the impact of climate change and reduced pumping of select wells near the project area. Several tools will be presented, which habitat restoration practitioners could use at other large-scale restoration projects to help determine restoration feasibility, prescriptions, and prioritization.

The influence of pinyon-juniper fuels reduction treatments on soil erosion rates

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ABSTRACT: Over the past decade, millions of acres of fuels reduction treatments have been implemented across a range of western US forest types, with the goal to reduce the risk of catastrophic fire while restoring forest and rangelands to their historical structure, function and diversity. While there are clear benefits associated with reducing hazardous fuel loads, risks such as soil surface disturbance and subsequent soil erosion is of concern, particularly for less resilient, lower elevation pinyon-juniper woodlands. In this study, we measured wind and water

erosion in one common mechanical treatment and two prescribed fire fuels reduction treatments across pinyon-juniper woodland sites in Southeastern Utah. Prescribed fire was shown to result in a 11-32-fold increase in wind borne sediment transport as compared to the untreated control and masticated sites the first two growing seasons after treatment. Transport of wind-borne material appeared to peak in the first growing season after treatment and declined thereafter. A similar pattern was observed in soils captured by silt fences. The prescribed fire treatments resulted in 20-40-fold higher sediment accumulation in silt fences relative to the control and masticated treatments after two growing seasons. Our results suggest that the use of prescribed fire may result in significant soil loss in the year immediately following treatment, whereas mastication strategies that provide a protective mulch layer and less overall soil surface disturbance had similar soil losses to the untreated control site. Increases in soil erosion were linked to declines in plant and biological soil crust cover and increases in bare soil. Taken together, our results suggest that mastication should be the preferred fuels reduction method when there are concerns related to soil and site stability.

A cloud based platform for exploring satellite time series data in support of the US Southwest riparian corridors vegetation health and ecohydrology

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ABSTRACT: Most rivers within the Colorado Plateau region are impaired by a series of challenges driven by climate change, overuse, dams, and diversions. Over the last three decades, there has been extensive interest in understanding and quantifying these changes. As a result, scientists and managers have framed plans to deal with these changes, ranging from the release of tamarisk defoliating beetles to establishing restoration plots that preserve native plants, to planned water releases. All are aimed at slowing and even reversing the impending demise of these unique and rich semi-arid riparian corridors that are home to myriad wildlife species. Repetitive, medium-resolution remote sensing imagery addresses these objectives. Satellite platforms have consistently imaged the Earth's surface for over four decades providing a wealth of observational data that is used as a proxy for plant health, productivity, change, and a variety of ecosystem parameters. The vegetation index (VI) time series is of immense value to the study of the land vegetation, and over time it can serve as a first-order proxy for assessing change, biomass, and ecohydrological processes such as actual evapotranspiration (ETa). Our Data Explorer (https://vip.arizona.edu/viplab_data_explorer.php) is a cloud-based platform aimed at augmenting and facilitating access and visualization of long-term medium remote sensing data over these critically impaired riparian corridors. The platform provides data such as: (1) preprocessed high fidelity spectral data, (2) value-added VI time series, (3) ETa, and (4) spatially explicit maps of anomalies, change, and trends. These data can be visualized, explored, and acquired from within this user-friendly online platform. Landsat 5, 7 and 8 are the foundation for this effort. Potential ET from AZMET and DAYMET were required, and in combination with Landsat VI data, we estimate greenness and ETa for riparian corridors along the Lower Colorado, Bill Williams, Santa Cruz, San Pedro, Salt, Gila, and the Virgin Rivers.

An overview of Bureau of Land Management (BLM) pinyon-juniper treatment: a BLM Colorado perspective

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ABSTRACT: The Bureau of Land Management (BLM) manages 245 million surface acres of public land on the principle of multiple use and sustained yield of resources. In Colorado, the BLM manages 8.3 million surface acres, many of which are non-forested and include interfaces between shrublands and pinyon-juniper woodlands (PJ). Since 2015 the BLM has increased levels of PJ treatment using methods such as mastication, chaining, lop and scatter, prescribed fire, and various thinning prescriptions. For PJ treatments BLM decisions encompass local considerations along with existing laws, regulations, and policies. These considerations have a strong influence on PJ treatment planning and are represented in the treatment drivers and objectives of the project. Drivers of PJ treatment actions include management for fuels levels and wildfire risk, wildlife habitat, grazing, and cultural resources. Specific treatment objectives may include increasing habitat quality and extent for greater sage-grouse and big game species, protection of pinyon jay colonies, minimizing risks of wildfire to the public and on infrastructure, reducing PJ expansion/densification to increase herbaceous productivity, and managing the health of PJ stands for climate resiliency. Recently, the Department of the Interior and BLM are working to incorporate concepts of climate change, environmental justice, treatment effectiveness, and Indigenous Traditional Ecological Knowledge in policies and decision making. Applying these concepts to PJ treatment planning will likely necessitate strengthening science-management partnerships and coproduction activities to develop and employ actionable science. Collaboration is needed to craft a framework that supports treatment planning and implementation for suites of desired outcomes e.g., climate resiliency and wildlife habitat enhancement – some of which is ongoing through existing partnerships.

The current state of managing fires for ecological benefit and resource objectives in the southwestern US

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ABSTRACT: In 1935, the federal government instituted a severe wildfire suppression policy which formalized what would become nearly a century of fire exclusion from most fire adapted ecosystems in the western US. As land managers work to restore forests and grasslands to a healthy and resilient state in the face of a changing climate, they are faced with a stark reality of limited resources. They don't have the monetary, material, and personnel resources needed to treat an enormous backlog of acres with mechanical thinning and prescribed fire alone. Managing naturally ignited wildfires is emerging as a potentially ecologically appropriate and economical way to restore the benefits ascribed to recurring moderate intensity fire and to meet resource objectives as laid out in federal and state agency planning documents. A number of papers published over the past five years explore in depth the ecological and social science behind this topic. By reviewing the recent literature, this presentation provides an overview of the current state of managed fire in California and the Southwest with a focus on federal and

other governmental fire management agencies. Through exploration of managed fire's history, obstacles to implementing this tool as a land restoration strategy, and the effects of managing wildfire for resource benefit, we may speculate on its future use and constraints.

Indigenous knowledge at Grand Staircase-Escalante: an interdisciplinary approach to public lands management

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ABSTRACT: Indigenous voices have been historically excluded from land management decisions, especially on public lands. Traditional Ecological Knowledge (TEK), however, is increasingly being acknowledged as a demonstrated and valuable scientific resource when making decisions regarding game management, fire mitigation, agriculture, and ecological restoration. Co-management models such as the Bears Ears Intertribal Coalition (BEITC) have allowed for the integration of Native perspectives, but that level of outreach did not occur with the establishment of Grand Staircase-Escalante National Monument (GSENM), where Indigenous peoples continue to be excluded from traditional lands and sacred cultural sites. Through Grand Staircase Escalante Partners, we have made tribal coordination a priority at GSENM over the past two years and are developing an interdisciplinary strategy that incorporates TEK for a more holistic approach to ecological preservation that could be used as a model for the management of other public lands. To advance this initiative we have developed a logic model based on lessons learned from BEITC to guide our advocacy for Indigenous inclusion in Bureau of Land Management policies at GSENM. We have hosted tribal listening sessions, visits with Tribes whose ancestral lands are in GSENM (including Diné, Kaibab Paiute, Southern Paiute, and Hopi), and conducted outreach to public audiences. We will be advocating within BLM for the allowance of cultural practices such as gathering of firewood, animal remains, and sacred plants. We view TEK as integral to meeting our broader conservation goals and plan to incorporate it into our work protecting threatened & endangered species and habitats, maintaining water quality, addressing invasive species, and creating climate change resilience.

Overview of past litigation related to Arizona Snowbowl ski resort

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ABSTRACT: The Arizona Snowbowl Ski Resort has been the subject of several lawsuits starting with *Wilson v. Block* in 1983. This presentation will walk through the various lawsuits and include a discussion of other significant laws and cases that impact religious freedom and sacred sites that have been subsequently decided.

Snowtography: a growing network of flexible, low-cost snow and soil moisture monitoring quantifies hydrologic impacts of forest management and disturbance

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ABSTRACT: Southwest watersheds are undergoing unprecedented changes due to wildfire and forest restorations designed to reduce fire risk, with unknown consequences for snowpack. Trees interact with snowfall, sun and wind to influence how much snow sublimates, the timing of snowmelt, and the water available for trees, groundwater and streams. Despite the important role of trees, snow is often assessed with data from treeless clearings (SNOTEL), 2-D satellite imagery, or infrequent lidar snapshots. Therefore, we are developing a network of low-cost, flexible stations where automated snow photography and soil moisture measurements are made continuously across gradients of forest structure. We present results from six Snowtography stations (n>200 points) in Arizona and Colorado spanning dry ponderosa forests to subalpine mixed conifer ecosystems and assessing effects of wildfire and mechanical thinning during the extreme climate variability of the past five years. We combine daily snow depth, biweekly manual measurements of snow density, airborne lidar, and SNOTEL records to assess how forest structural changes regulate the amount and timing of snowmelt and consequent soil moisture dynamics. We find that at mixed conifer sites, canopy has a greater radius of influence on snowfall interception (7 m) than at ponderosa sites (3 m). Combining Snowtography with a snowpack model predicted snowmelt events with >75% accuracy validated by soil moisture sensors. Reducing canopy decreases water inputs to soils up to 20% and prolongs snowpack duration by up to 40 days, with both effects stronger at higher elevations and during colder, wetter winters. In ongoing work, we use a soil moisture model to quantify root zone moisture stress and deep drainage. Finally, we are assessing spatial patterns of snowpack dynamics with respect to the 3-D forest structure to develop recommendations for forest management practices optimizing water balance.

RainManSR: an in-situ rainfall manipulation experiment linking above- and below-ground responses to temporal repackaging of precipitation in a semiarid grassland

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ABSTRACT: A key climate change characteristic is temporal repackaging of precipitation: larger rainfall events separated by extreme-duration drought. Relatively little is known about coupled mechanistic responses of plants, soil hydrology, and cycling of carbon and nutrients. Additionally, existing remote sensing tools have minimal skill to capture these responses. Here we present a three-year field experiment in a semiarid grassland wherein a constant growing season precipitation amount was repackaged into four treatments with dry intervals ranging from 3.5 – 21 days and inversely varying event magnitudes of 5 – 60 mm. Aboveground measurements include whole-ecosystem ET and CO2 exchanges, soil CO_2 efflux, plant cover, community composition, perennial bunchgrass structural and functional traits, and ANPP. Belowground, minirhizotron tubes in each plot (N=60) monitor root growth and quantify BNPP with local allometry. Soil C and N species are extracted monthly. Plot-level remote sensing includes visible-light greenness and infrared thermal imagery. Leaf-level gas exchange and spectral reflectance quantified a full rainfall pulse-response with near-daily temporal resolution. Key results presented here will include (1) edaphic, hydrologic and biogeochemical controls on plant community composition and structure; (2) translation of rainfall drought into hydraulic stress in the soil and leaf; (3) assessment root/shoot allocation and root depth profiles in response to frequent-shallow versus rare-deep soil wetting; (4) quantification of CO_2 exchanges, ET and water use efficiency; and (5) evaluation of visible and hyperspectral remote sensing tools as indicators of plant response to extreme-duration drought. Analyses to date show that repackaging rainfall into fewer, larger storms (1) delays peak photosynthesis by up to 30 days without changing its magnitude; (2) Reduces root density by 40% in the top 10 cm while increasing roots by 30% at 45 cm depth; (3) increases perennial bunchgrass biomass by 30%; (4) deeper-rooted perennial plants remain cooler than shallow-rooted annuals, confirming access to deeper moisture.

Potential insights from southern Africa for co-existence of livestock and wildlife rangelands on the Colorado Plateau

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ABSTRACT: The Colorado Plateau is marked by a range of diverse stakeholder groups with different, and sometimes competing, land use preferences. These competing preferences for land-use between grazing livestock, and a range of conservation land uses including the re-establishment of wildlife populations can lead to conflict. This conflict manifests in an already polarized broader society, with associated policy stagnation. Insights from other regions and parts of the world may offer insights on how to potentially move forward. Southern African countries including South Africa and Namibia have experienced a large-scale transition from livestock to wildlife and conservation-dominated land use over the past three decades. This transition has been characterized largely by collaboration between livestock farmers and the conservation sector, rather than conflict. My talk will explore potential insights and lessons from southern Africa for the Colorado Plateau.

Development and application of an Inductively Coupled Plasma Mass Spectrometer (ICPMS) method to quantify uranium and arsenic in grocery store frozen cow and calf liver

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ABSTRACT: The purpose of this study is to characterize uranium and arsenic concentrations in frozen cow and calf liver obtained from a grocery store (Safeway) in Flagstaff, AZ. Five packages of cow liver and five packages of calf liver was obtained (n=10), defrosted, blended with a standard kitchen blender, dried for 72 hours, and then blended into a powdery like substance with a standard kitchen blender. The Environmental Protection Agency (EPA) method 3051A, a partial microwave digestion was carried through with 0.5 g of dried liver sample and trace metal grade nitric acid (HNO_3) (Thermo). The microwave digested samples were filtered, brought to volume with nano-pure water (18.2), and diluted five-fold before analysis with an X-Series 2 Inductively Coupled Plasma Mass Spectrometer (ICPMS) (Thermo). The results suggest low concentrations of uranium and arsenic in both the cow and calf liver. The limitations of this study are the lack of a standard reference material (SRM) for uranium and arsenic in animal tissue, the grazing habits of the cattle and calves euthanized for liver extraction is unknown, and the ages of the cattle/calves are unknown as well. The methodology and instrumental analysis from this project will be used to determine uranium and arsenic concentrations in sheep livers from the Navajo Nation.

Tradeoffs between leaf cooling and hydraulic risk taking in the foundation tree species *Populus fremontii*

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ABSTRACT: *Populus fremontii* is recognized as the most iconic and ecologically important riparian tree species in the arid western US. Yet, intensifying heat waves and drought are causing episodic *P. fremontii* mortality surges, particularly at the warm of its distribution. Using an experimental common located near the mid-point of *P. fremontii's* distribution, we investigated the physiological mechanisms that underscore local adaptation to thermal stress. We hypothesized that warm-adapted genotypes maintain cooler leaves during mid-summer, but with the tradeoffs of operating with lower water potentials and hydraulic safety margins. Results yielded four overarching conclusions. First, warm-adapted genotypes – sourced from locations with mean maximum summer temperatures above 40 °C – had leaves that were on average 3.8 °C cooler than cool-adapted genotypes – sourced from locations with mean maximum summer temperatures below 40 °C. Second, the cooler leaf temperatures were matched with warm-

adapted genotypes having 38% higher mean maximum stomatal conductance values that likely yielded greater midday evaporative cooling compared to cool-adapted genotypes. Third, higher stomatal conductance values corresponded with warm-adapted genotypes expressing functional trait syndromes that portend greater leaf water use rates including higher stomatal densities, higher theoretical leaf stomatal conductance values, and higher conducting sapwood area to leaf area ratios compared to cool-adapted genotypes. And fourth, warm-adapted genotypes had minimum midday water potentials that by late summer were over 0.3 MPa lower that cool-adapted genotypes and fell below the threshold that has previously shown to induce near complete hydraulic failure in *P. fremontii*. These results demonstrate that warm-adapted *P. fremontii* genotypes are predisposed to tightly regulate leaf temperatures during heat waves, potentially at an increased risk of hydraulic failure. As a consequence, the distribution of *P. fremontii* in the low deserts of North America will likely be confined to riparian areas with extremely high water tables with limited diel and seasonal fluctuations.

Burn severity impacts on watershed health in warm-dry mixed conifer four years post-fire, southwestern Colorado

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ABSTRACT: Wildfires have varying ecological impacts on watershed health depending on fire severity, topography, vegetation type and pre- and post-fire weather. Wildfires directly impact watershed dynamics through changes to the geomorphology and hydrologic properties of soil. Warm-dry mixed conifer forests of the southwest, prior to livestock grazing and fire suppression in the 20th century, experienced predominately frequent, low intensity surface fires every 3-14 years. Many of these forests have experienced no fire in over 100 years, resulting in dense forest stands prone to wildfire. In 2018, the Hermosa Creek Watershed experienced a wildfire (known as the 416 fire) that burned a total of 54,130 acres of varying severity. The 416 Fire had various ecological impacts on the Hermosa Creek watershed. Using ArcGIS, we randomly selected 10 points from each severity (no burn, low, moderate, and high) to quantify watershed dynamics and soil properties during the summer of 2022 (N=40). Our research objectives are: (1) to quantify 4 years post-fire differences in soil organic matter, soil texture, soil water infiltration rates, and litter and duff accumulation among four burn severities; and (2) to correlate how these soil properties relate to watershed health. Soil texture, soil infiltration rate, and soil organics above and below the surface are all key factors used to determine the impact of the fire on watershed health. We hypothesize that soil organic matter, litter, and duff will be lowest in high severity burn areas. Soil texture and infiltration rates will correlate with soil organic matter and litter and duff depths among the severities with low severity burn areas being more closely related to unburned areas than moderate and high severities. Our study will help direct future watershed management decisions of Hermosa Creek and contribute to the body of knowledge of post-fire watershed dynamics in warm-dry mixed conifer forests.

Familiar soil biota can help southwestern plant species cope with changing climates

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ABSTRACT: Most locations on Earth are becoming warmer, presenting major challenges for ecological restoration. In ecological restoration, it is a common practice to source plant materials such as seeds as close as possible to the restoration site. Yet, when we introduce these plant materials into the field, it is very possible that now or during the plant's lifespan, the climate does not or soon will no longer resemble the source population's evolutionary environment. Thus, even locally-sourced plant materials may be subjected to novel environments when deployed in the field. Environmental novelty is not constrained only to climate; another important element of the plant niche is defined by the soil that the plants grow in. Plant populations may be locally adapted to their soil environments, or soil biota that reside there, including root symbionts. We posed the question: can we induce superior performance of plants, either in their home climates or in warmed ones, by constraining the biotic and abiotic novelty of their soil environments? We studied three dominant and broad-ranging species: *Bouteloua gracilis*, *Pleuraphis jamesii* (both C4 grasses, associating with arbuscular mycorrhizal fungi), and *Pinus ponderosa* (tree, associating with ectomycorrhizal fungi). More often than not, we found that after three years in the field, plants tended to grow better when either growing in home soil or with home soil biota, or both; plants generally performed worst when both soil and soil biota were sourced from the transplant site, and thus were novel to the plant. We distill the following lessons from our work: (1) Introduction of plants and home soil biota together is feasible and is commonly beneficial. (2) We need ways to minimize novelty of the soil environment for our plant materials. (3) Novelty of soil can be just as influential as novelty of climate, we must stop ignoring it.

Ecological drought metrics to understand dryland ecosystem dynamics

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ABSTRACT: In drylands, water-limited regions that cover ~40% of the global land surface, terrestrial ecosystems are primarily controlled by access to soil moisture and exposure to simultaneously hot and dry conditions. However, quantifying ecologically relevant environmental metrics is difficult in drylands because the response of vegetation to moisture and temperature conditions is not easily explained solely by climate-based metrics. We developed and examined 27 climate and ecological drought metrics across dryland areas of the western US.

These metrics include a suite of 19 largely new "ecological drought metrics" designed to quantify multiple aspects of environmental limitation in drylands, including overall growing conditions, seasonal fluctuations, seasonal moisture timing, exposure to extreme drought, and recruitment potential for perennial plants. We found that these metrics provide substantial novel information beyond climate conditions alone, offering new perspectives on broad regional gradients of aridity and water limitation in the west. For example, seasonal fluctuation in soil water availability (SWA) was greatest in the southwest (Mojave Desert) while fluctuation in climatic water deficit (CWD) was largest in the northwest (northern Great Basin and Columbia Plateau). Seasonal timing of moisture also differed among metrics: the timing of wet degree days (WDD), SWA and CWD were only weakly related to seasonal timing of precipitation. Plant recruitment metrics varied strongly across western drylands. In the Great Plains, recruitment events occurred more frequently and lasted longer than in the intermountain regions, where recruitment events were comparatively rare and short. In addition to spatial patterns, these ecological drought metrics enable quantification of temporal fluctuations in ecologically-relevant soil moisture and temperature conditions that drive dryland ecosystem dynamics. The metrics are being used to assess the potential impact of climate change on drylands and to develop adaptive resource management strategies to sustain dryland ecosystem services in a changing world.

Monitoring *Tamarix* changes using satellite imagery in Grand Canyon National Park, Arizona

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ABSTRACT: Tamarisk (*Tamarix* spp.) is an invasive woody plant species that impacts biodiversity and water availability in riparian corridors throughout the Southwest USA. Remote sensing methods are commonly used to monitor tamarisk and its response to the northern tamarisk beetle (*Diorhabda carinulata*), a specialized herbivore introduced in 2001 in the SW USA as a biocontrol agent for tamarisk. We used a Spectral Angle Mapper (SAM) supervised classification method with WorldView-2 (2 m spatial resolution) multispectral images from May and August of 2019 to map healthy tamarisk, canopy dieback, and defoliated tamarisk over a 48 km segment of the Colorado River in the topographically complex Grand Canyon National Park, where coarse-resolution satellite images, such as 30-meter spatial resolution Landsat images, are of limited use. The classifications in May and August produced overall accuracies of 80.0% and 83.1%, respectively. Seasonal change detection between May and August 2019 indicated that 47.5% of the healthy tamarisk detected in May 2019 had been defoliated by August 2019 within the WorldView-2 image extent. When compared to a previously published series of tamarisk maps from 2009 and 2013, derived from multispectral aerial imagery, we found that 29.5% of healthy tamarisk canopy declined between 2009 and 2019, and 30.7% of healthy tamarisk canopy declined between 2013 and 2019. These changes imply that tamarisk beetle impacts continued to accumulate after land managers first noted the presence of the beetles in this reach of the river in 2012.

Potential impacts of climate change on narrowly distributed endemic *Pediocactus* (Cactaceae) species in northwestern Arizona

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ABSTRACT: Northwestern Arizona is home to four species of federally listed, endangered *Pediocactus* (Cactaceae) species: *Pediocactus peeblesianus* subsp. *fickeisenii* (Hochstätter) Lüthy; *Pediocactus bradyi* L.D. Benson; *Pediocactus paradinei* B.W. Benson; and *Pediocactus sileri* (Engelm. ex J.M. Coult.) L.D. Benson. With the exception of *Pediocactus peeblesianus* subsp. *fickeisenii*, these species occupy distinct habitats, are of limited distribution, and are strong, narrowly distributed endemics. Yet, the level of speciation across a relatively small spatial extent is remarkable, with all four species occurring within a linear distance of about 100 km. Using species occurrence data from SEInet and GBIF, supplemented by data from direct observation in the field, this preliminary study employs correlative species distribution modeling to explore the potential impacts of climate change on each of these narrowly restricted endemic species, as well as the potential range shifts over the extent of their distribution from Marble Canyon to Fredonia.

The utility of GIS for identifying areas of recreation conflict for targeted interpretive messaging

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ABSTRACT: Past research has extensively studied interpretive messaging and visitor conflict within parks and protected areas. However, comprehensive understanding of how to identify trailside interpretive sign locations is lacking. The purpose of this study was to introduce an approach using geographic information systems (GIS) that supplements decision-making regarding sign placement. The study site was Grand Canyon National Park's Rim to Rim (R2R) corridor. To identify sign placement locations, two analytical phases were conducted. First, GPS data loggers were distributed to visitors and their travel patterns were analyzed for spatial behaviors and spatial interactions that are known to influence the likelihood of recreation conflict. Specifically, locations with a high variance of visitor travel speeds and locations with concentrated visitor use were identified. Second, geographic data were analyzed to identify locations for a combination of features that together influence the likelihood of recreation conflict. Specifically, popular bidirectional trail segments with significant elevation change were identified. We reported these locations and areas using GPS coordinates for evaluation by future research. This research was a necessary step towards comprehensively understanding how to identify locations for interpretive signs.

Practitioners' perceptions and use of emerging techniques for restoration of arid and semiarid ecosystems

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ABSTRACT: Restoring native plant communities in arid and semiarid ecosystems is hampered by the extent of transformation and harshness of desert environments. Various techniques are proposed to improve germination, overcome establishment bottlenecks, and increase native plant survival. For practitioners, decisions about which technique to test and apply are affected by perceptions of a practice's effectiveness and operational feasibility, moderated by the restoration context, personal knowledge, and prior experience. To better understand adoption decisions and guide outreach about restoration options, we studied practitioners' perceptions of practices designed for the desert regions of the western USA: using locally adapted seeds; guiding species choices using provisional seed zones; applying chemical seed coatings; outplanting seedlings into "at-risk" sites before disturbance; and where appropriate, planting sagebrush seedlings after wildfire. We interviewed employees of federal and state agencies to learn about perceived barriers to adoption, then administered an online survey to Bureau of Land Management (BLM) employees and Society for Ecological Restoration (SER) members identified as working in arid and semiarid ecosystems of North America. Interviews revealed not only concerns about funding, labor, and time costs, but barriers stemming from deep-seated beliefs about when and how restoration should be done. Survey responses from 138 practitioners found that locally adapted seed and provisional seed zones were most frequently used, while seed coatings were least often used. All practices were perceived as effective by most respondents but using locally adapted seed was most likely to be considered "very effective." Conversely, respondents were more likely to say using locally adapted seed and seed coatings is difficult or very difficult, while outplanting techniques were seen as easier to apply. These results point to the need to identify ways to enhance the ability to apply seed-based restoration techniques.

Resident mitigation for post-fire flooding: lessons learned for collective action from the 2010 Schultz Fire

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ABSTRACT: Post-fire flooding is of particular concern in the US Southwest, where burned areas can drastically alter local hydrology to increase the risk of floods, debris flows and mudslides. Monsoonal precipitation brings heavy rainfall to the region during months of high wildfire activity and immediately following the peak of wildfire season, posing new and dynamic flood risk to communities downslope that necessitate coordinated response across property lines. However, there is little research to understand how residents in these communities respond to post-fire flooding and how they mitigate post-fire flood risk, both individually and collectively. We address these gaps by exploring potential indicators and influences on household participation in post-fire flood mitigation after the 2010 Schultz Fire that could lead to collective action across boundaries for addressing immediate and prolonged post-fire flooding. We mailed

a survey to 1,804 households in Flagstaff, Arizona, within the 100-year modeled post-fire flood risk area created by the Schultz Fire [407 completed questionnaires were returned for a 22.6% response rate]. Questions in the survey focused on mitigation actions, addressing community flood risk, and responsibility for post-fire management among other topics. We present findings from this survey with an emphasis on understanding what mitigation actions residents engaged in, what factors may influence mitigation behavior, and investigating if there are differences between individual and collective mitigation. Our results show that residents primarily engage in a narrow set of both individual and collective mitigation actions, and that these tend to be actions that require lower investments of time, money, and effort compared to other mitigation options such as waterproofing utilities or coordinating with neighbors. Furthermore, results indicate that resident mitigation behavior may be primarily influenced by their personal flood experience and risk perceptions. We provide implications for post-fire research and management, with a focus on capacity building and cultivating shared responsibility for post-fire flood risk to facilitate collective action.

Native bees in Buenos Aires National Wildlife Refuge: a first survey in a diverse but vulnerable desert grassland

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ABSTRACT: The Buenos Aires National Wildlife Refuge (BANWR), along the Mexican border in southern Arizona, is host to a rich community of bird and mammal species, many of which rely on seed-bearing plants for sustenance. Native bees (Anthophila) provide pollination services vital to the reproduction of such plants, and some of Earth's highest bee diversity has been documented within the broader Sonoran Desert region. Native bees are historically under-monitored, especially in remote, unpopulated, and inaccessible regions. As the climate warms, global declines in native bee populations have underscored the importance of bee monitoring projects. Without baseline occurrence data, tracking the changing status of bee populations is nearly impossible. Despite the diversity of the region and urgent need for monitoring bee populations, the bee fauna of BANWR has not been methodically sampled. We conducted a survey of the BANWR bee fauna at least once a month from May 2019 to March 2020, using blue vane traps at each of eight sites within the refuge. Our sites varied in elevation, precipitation, associated plants, and fire treatment. We found differences in the bee genera represented at each site, with individual sites averaging from six to nine genera, and a total of 35 distinct bee genera across all sites. In this poster, we present an overview of the native bees of BANWR and much-needed documentation of the occurrence and phenology of bee genera in a diverse semi-desert grassland. This study provides a starting point for assessing the status of bees in this vulnerable wildlife refuge.

Native and non-native riparian tree species of the western US show different seasonal variation in stomatal sensitivity to atmospheric vapor pressure deficit

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ABSTRACT: Riparian forests are among the most productive and biodiverse ecosystems of the arid western US, yet their future community structure and function is uncertain given past and ongoing introduction of non-native species as well as increasing aridity with climate change. Because plant stomata dynamically regulate carbon uptake with water supply, quantifying species-specific stomatal sensitivity to atmospheric aridity (atmospheric vapor pressure deficit, *D*) is a necessary component for predicting possible future changes in groundwater dependent ecosystems across the western US landscape. Using sap-flux data for nine dominant riparian species from four sites spanning an elevation gradient in northern Utah, we fit a time-varying empirical model of stomatal conductance to *D*. Species included seven native species with diffuse-porous wood anatomy (*Acer grandidentatum*, *Populus angustifolia*, *Betula occidentalis*, *Acer negundo*, *Salix* hybrid, *Populus* hybrid, *Populus fremontii*) and two non-native species with ring-porous wood anatomy (*Tamarix ramosissima*, *Elaeagnus angustifolia*). Our results showed three patterns of standardized stomatal sensitivity (*S*) with cumulative *D* over time. All native, diffuse-porous species showed either a positive correlation between *S* and cumulative *D* or no change in *S* with cumulative *D* over time. In contrast, the two ring-porous, invasive species showed a negative correlation between *S* and cumulative *D* over time. These results are among the first to demonstrate that stomatal sensitivity to *D* can vary significantly over the course of a single growing season and may have important implications for future tree community structure in western riparian forests. Given that the two ring-porous, non-native species were the only species to show decreasing *S* with cumulative *D* over time indicates that a progressive increase in aridity across the western US could amplify the competitiveness of these two highly invasive tree species relative to native tree taxa.

The hydroclimatic niche: a tool for predicting and managing riparian plant community responses to streamflow seasonality

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ABSTRACT: Habitat suitability is a consequence of multiple interacting environmental factors. In riparian ecosystems, plants are influenced by the interaction between stream hydrology and climate, hereafter referred to as “hydroclimate”. Here, we focus on the climate conditions (temperature, precipitation and vapor pressure deficit) during the months of lowest and highest streamflow as integrative metrics of resource and stress levels. We tested the hypothesis that hydroclimate variables would improve the fit of ecological niche models for a suite of riparian species using occurrence data from the western USA. We then projected those models onto the

regulated segment of the Colorado River below Glen Canyon Dam to assess the potential impacts of streamflow seasonality on vegetation objectives and species composition. We found that the inclusion of hydroclimate variables improved model fit for all species. Under different simulated hydrographs for the Colorado River, overall species richness was predicted to be greatest with late summer high streamflow, and native-to-non-native species ratios would be greatest with low winter streamflow. Species frequency recorded from survey data was also positively related to predicted habitat suitability, especially under the current regime of spring low flows and late summer high flows. Summer high flows were particularly associated with higher predicted habitat suitability for species that have increased in cover over recent decades (e.g. *Pluchea sericea*, *Baccharis* species, *Cynodon dactylon*). These findings suggest that hydroclimatic niches of plant species could be useful tools for managing, or predicting changes to, riparian vegetation through the seasonal timing of low and high streamflows.

Identification of variables affecting oneseed juniper dieback using structural equation modeling (SEM)

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ABSTRACT: Pinyon-juniper woodlands are widespread throughout the Southwest and provide important ecological and cultural services. In recent decades, pinyon-juniper woodlands have experienced extensive mortality due to drought and bark beetles. In 2021, widespread juniper dieback was noted in Northern Arizona throughout the Prescott, Coconino, and Kaibab National Forests, while pinyon was relatively unaffected. Oneseed juniper (*Juniperus monosperma*) was the primary juniper species affected in the Flagstaff area and experienced extensive but patchy dieback. Even within patches of severe dieback, individual juniper dieback was highly variable. Drivers of spatial variation in juniper dieback are unclear and represent a knowledge gap in our understanding of pinyon-juniper woodland dynamics. The objective of this project was to use a structural equation model (SEM) to identify the plot and individual-level variables associated with juniper dieback north of Flagstaff. Field data was collected at 25 plots during the summer of 2021 on the Coconino National Forest near Sunset Crater and Wupatki National Monuments. Plots were stratified across dieback severities and geographic area with the goal of capturing variation in dieback severity and stand characteristics. At each plot, elevation, slope, aspect, curvature, and tree canopy area were measured or calculated. For each tree (n=382), species, canopy size, nearest adult neighbor species and distance, microsite status were recorded. A structural equation model (SEM) was used to analyze the data and determine which variables had the strongest effect on tree dieback. Preliminary results show that microsite status, or whether or not a tree is located underneath another tree, had a significant negative effect on canopy dieback, indicating that nursed plants have lower dieback. The final results from this project will elucidate which abiotic and biotic variables have the greatest impact on juniper canopy dieback, which will improve predictions of future juniper dieback events in the Southwest.

Ephemeral and permanent stream hydrology alter adaptive trait syndromes in a riparian tree species native to the Southwestern US

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ABSTRACT: Riparian habitats of the Southwest are at risk due to the negative impacts of climate change and anthropogenic activities. This is largely due to water: reliance on the regularity of the North American Monsoon, winter precipitation, and vulnerability to the effects of damming, diversion, and ground water usage. As the timing and magnitude of these factors become more uncertain, hydrological limitations to net primary productivity will likely increase. Thus, understanding how dominant vegetation respond to changes in groundwater resources will be critical for conserving riparian habitat in the face of climate change. To address this, we assessed genotypes from populations of Fremont cottonwood (*Populus fremontii*) that occur across two levels of water availability: perennial and ephemeral stream types. We made *in-situ* measurements to assess "native" states and transplanted individuals to common environments that vary in temperature and water availability. *In-situ* measurements included assessment of water status, rates of transpiration and photosynthesis, and enzyme activity. Experimental designs included variation in rates of water table decline, distance to water source and temperature. *In-situ* assessment of these populations resulted in differences in the community phenotype of these populations, where perennial trees were generally larger with fewer gaps in the canopy, less water stressed, and had higher rates of transpiration than their ephemeral counterparts. Experimental results indicated that ephemeral trees were generally more fit for harsher environments as they invested more into roots and had higher rates of carbon assimilation and higher photosynthetic capacity when stressed than their perennial counterparts. These results suggest local adaptations to stream hydrology that could be important to match in restoration efforts in which streams that shift from permanent to ephemeral would benefit from restoration with stocks from ephemeral streams that are already adapted to this hydrology type.

Evaluating the US Forest Service Risk Management Assistance program and use during the 2021 wildfire season

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ABSTRACT: Wildland fire management in the western US is increasingly complex. Climate change-driven increases in fire activity and fire season length, continued development in the wildland-urban interface, and interactions between fire and other large disturbances combine to exacerbate risks to human lives and property. These challenges have increased need for, and emphasis on risk management principles and decision support tools during that provide a framework and structure for collaborative, proactive spatial fire planning and wildfire incident

management. To address this need, the US Forest Service developed Risk Management Assistance (RMA) to provide additional access to a suite of spatial fire analytical tools and specialized personnel trained in risk management, fire operations, and analytics to enhance fire management decisions. RMA is intended to help minimize firefighter exposure, protect values and assets of concern, and achieve incident, land, and resource management objectives. While these tools were initially designed for use in incident management, managers are also readily adopting their use in non-incident management contexts. Although RMA products are still relatively new applications their use has increased rapidly since 2018. Herein we present findings from our evaluation of the RMA program in which we focused on practitioner perspectives from the 2021 wildfire season. We surveyed over 50 practitioners, fire managers, agency administrators, and members of incident management team who helped manage 69 wildfire incidents, and collected information related to How RMA is being used to inform decision making, factors that facilitate or frustrate its use, and how RMA is also being used in non-incident planning contexts. We conclude with a series of recommendation on how RMA can be improved to better support incident response in the future.

Engaging Tribal perspectives in post-fire restoration and response

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ABSTRACT: Wildfires in the American Southwest affect the environmental, cultural and social functions of important landscapes for Tribal Nations. Historically, conservation on Tribal lands is undervalued by non-tribal communities and is therefore inherently under-resourced and underfunded. This omission leads to unhealthy relationships and divided interests between Tribes and conservation groups. The 2011 Las Conchas Wildfire in the Jemez Mountains of New Mexico decimated over 150,000 acres of land, crossing multiple jurisdictions and land management agencies. The fire impacted portions of Tribal-trust lands, which are critical for providing important resources for the cultural and social lifeways of the Pueblo Peoples. This catastrophic event also led to the direct inclusion and involvement of Tribes in post-fire restoration. The Tri-Pueblo Coalition between Cochiti, Jemez, and Santo Domingo Pueblos was developed as a result of the post-fire restoration work and intent to establish working relationships with the goal of enhancing inter-Tribal engagement opportunities for large landscape restoration projects. Trees, Water and People, a Colorado-based not-for-profit organization, works to address conservation and equity through meaningful engagement with Tribal Nations, adhering to Tribes' unique ecological knowledge systems and lived experiences in co-existence with fire. Most importantly, honest and transparent conversations are key to establishing working collaborations with Tribes focused on conservation or post-fire response. This presentation delves into our engagement model to demonstrate the appropriate approach to engaging with Tribes while respecting their sovereignty, honoring their decision-making processes, and acknowledging the balance of western science with Traditional Ecological Knowledge.

The USDA saltcedar biological control program, the saltcedar lawsuit, and the Endangered Species Act section 7(a)1 conservation program

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ABSTRACT: In 1986 the US Department of Agricultural (USDA) began research into biological control of saltcedar (*Tamarix* spp.), leading to open field releases of tamarisk leaf beetles (*Diorhabda* spp.) from 2000 to 2003. In 2005, the USDA Animal and Plant Health Inspection Service (APHIS) began a saltcedar control program after the US Fish and Wildlife Service concurred that release of a northern-adapted strain of tamarisk leaf beetles was not likely to adversely affect federally listed species. Unfortunately, greater than anticipated natural and human-assisted movement of the beetle resulted in its establishment in southwestern willow flycatcher (*Empidonax traillii extimus*) habitat, where defoliation apparently reduced the bird's nesting success. In 2010, APHIS terminated the biological control program and cancelled all tamarisk leaf beetle release permits because of the potential effects on flycatcher habitat. On September 30, 2013, the Center for Biological Diversity filed a lawsuit against USDA alleging that the saltcedar biological control program violated the National Environmental Policy Act and the Endangered Species Act. On May 3, 2016, the Court granted the plaintiff's second of five claims, finding that APHIS did not comply with section 7(a)(1) of the Endangered Species Act, which requires Federal agencies to utilize their authorities to carry out programs for the conservation of endangered and threatened species. On September 18, 2019, APHIS submitted a decision document to the court broadly describing the Agency's flycatcher conservation program. APHIS committed to help develop a publicly accessible geographic information systems (GIS) habitat model, implement flycatcher and tamarisk leaf beetle surveys, and create an educational campaign that included the development of an information repository of research on restoration. APHIS also committed to continue to solicit, develop, and implement projects that are feasible, within its authority and mission, and that have conservation benefits for the flycatcher.

Atmospheric radiocarbon for the period 1910 to 2021 recorded by annual plants on the Colorado Plateau: a local record for accurate dating of recent terrestrial organic matter

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ABSTRACT: We present a timeseries of tropospheric $^{14}CO_2$ for the period of 1910 to 2021 recorded by annual plants collected in the southwestern United States, centered near Flagstaff, Arizona. This timeseries is dominated by five commonly occurring annual plant species in the region, which is considered broadly representative of the southern Colorado Plateau. Most

samples (1910 to 2015) were previously archived herbarium specimens, with additional samples harvested from field experiments in 2015 to 2021. We used this novel timeseries to develop a smoothed, locally calibrated curve with uncertainties for 'bomb spike' ^{14}C dating of recent terrestrial organic matter. Our results highlight the importance of a locally-calibrated record for accurate bomb spike dating, especially during several critical periods when the local record deviates from the standard Northern Hemisphere record by 10‰ or more; we document, for example, a delayed arrival 1963-1964 bomb spike peak relative to the standard Northern Hemisphere Zone 2 record. Our data show that annual plants, as 'silent witnesses' to the atmospheric signature, are an alternative to traditional methods of establishing an atmospheric ^{14}C record using extracted tree-ring alpha-cellulose. Notably, annual plants are found in herbaria worldwide and can be sampled years or decades after collection. As the atmospheric bomb spike ^{14}C signal continues to flatten, accurate, precise, and locally calibrated records will be needed to distinguish current-year photosynthetic products from those of previous years. Our results are of broad scientific importance, particularly as the bomb spike is increasingly viewed as a near-universal marker of the beginning of the Anthropocene.

State agency perspective: PJ woodland thinning projects for grassland restoration in northern Arizona

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ABSTRACT: The invasion of Arizona grasslands by woody plants has been identified by numerous researchers and documented in numerous scientific papers. In northern Arizona the most common invading woody plants of concern are juniper and pinyon trees. The most commonly stated cause of this invasion is the removal of fire from the ecosystem. It is felt these fires killed small, and sometimes larger trees which allowed grass and forb species to flourish. Negative impacts as a result of this invasion identified include reduced forage production, reduced plant diversity, reduced ground cover resulting in increased soil erosion, reduced water availability and, of major concern to the Arizona Game and Fish Department, degradation of habitat for grassland dependent wildlife. As a result, woodland invasion into historic grasslands is identified as an item of high importance in the Arizona Game and Fish Department's State Wildlife Action Plan. Therefore, the Arizona Game and Fish Department is aggressively acting to remove invading juniper and pinyon trees from historic grasslands and savannas. The primary wildlife species benefited is the pronghorn, but other grassland dependent species benefit as well. Arizona Game and Fish Department's goal in its grassland restoration activities is not to convert woodlands into grasslands, but to merely restore historic grassland wildlife habitat. A variety of tools are utilized to identify what constitutes invaded grasslands including soil surveys, as well as historic maps and photography. Although several treatment methods are available for this grassland restoration, including reintroduction of fire, the most common method used is mulching, or mastication, of the trees as this provides the desired outcome relatively quickly with little negative aesthetic impact. To assess the success of the treatment, repeat photography plots are established to provide before and after treatment documentation. To assess impact to avian populations before and after bird surveys are conducted.

Culturally responsive teaching with/in indigenous contexts: lessons from the institute for native-serving educators

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ABSTRACT: The Institute for Native-serving Educators (INE) is a collaborative initiative to strengthen schools across Indian Country. We partner with Native Nations, Indigenous-serving schools, and public-school districts to develop professional development opportunities that meet community needs. By developing and supporting high quality, culturally responsive preK12 educators in Native-serving schools, we can address years of educational neglect and radically improve teaching and learning, thus preparing Indigenous students to thrive in higher education. INE began with the vision of Diné teachers, who approached NAU in 2016 to invite the university to develop a partnership that would provide culturally responsive professional learning to teachers on the Navajo Nation. We are now in our fifth year of working with Navajo teachers, and we have expanded to offer four additional programs to teachers and educators in other Indigenous communities around the southwestern US. This presentation will describe our approach to cultural responsiveness, which is grounded in both a robust body of research and the lived experiences of the teachers and leaders in INE. We will share a tool our research team developed that distills 23 core principles of cultural responsiveness with/in Indigenous communities and provide guidance on how others may use this tool (https://in.nau.edu/wp-content/uploads/sites/101/2021/10/CRAIS-Tool-Oct-2021.pdf). And finally, we will highlight three key takeaways from our work with and in Indigenous contexts: (1) that partnerships are never neutral, (2) that wellbeing always matters, and (3) that Native Nation building should always be the goal.

Effects of climate, biological soil crust disturbance, and recovery on lidar-derived soil surface roughness

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ABSTRACT: The southwestern US is home to a diversity of biocrusts that provide many key ecological functions, such as soil surface roughness. In this study, we evaluate the linkages between biocrust and surface roughness by monitoring their changes following disturbance and two years of recovery. We used mm-resolution terrestrial LiDAR to measure roughness at seven sub-meter, 3-dimensional kernels (spatial scales) for undisturbed and disturbed biocrusts within the cool Great Basin and the hot Chihuahuan Deserts. This multi-scalar approach allowed us to:

1) assess the relative importance of climate and disturbance on biocrust roughness, and 2) evaluate how soil surface roughness evolves with biocrust recovery. We found that undisturbed cool desert biocrust was up to three times rougher than hot desert biocrust. Much of the difference in roughness between the two desert biocrust communities appeared to be from climate or other regional factors. However, positive correlations between roughness and biocrust indicators, including soil chlorophyll-a, suggested that differences in roughness are also related to biocrust development. Mechanical disturbance aimed at removing biocrust resulted in significant reductions in soil structure and removed much of the observed differences in roughness between cool and hot desert soils. Two years after mechanical disturbance, disturbed soil plots increased in roughness up-to 300%. The increased surface roughness at spatial scales ≤ 10 cm were positively correlated with increased aggregate stability and indicators of biocrust reestablishment. Topographic change area was also an important contributor to roughness at all spatial scales, particularly at spatial scales ≥ 20 cm, where it was the most important factor evaluated. These results provide insight into how biocrust interacts with other biophysical processes to influence soil surface roughness and how soil surfaces evolve at time scales relevant to monitoring resource management efforts.

Perspectives on gender in wildlife biology

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ABSTRACT: What if biologists chose to study only one animal species in the world? Despite gaining tremendous understanding of the animal, this species would define our knowledge of all other species. Everything we identified about behavior, diet, disease, evolution, habitat use, physiology, and reproduction would be focused through the lens of a single species. As scientists, we recognize this is a ridiculous proposition. Why then, should we be any less concerned about representing the full range of human qualities and attributes in our profession? A variety of genders, ethnicities, sexual orientations, perspectives, areas of expertise, and cultures leads to better science. Increases in productivity, creativity, and quality rise when women and underrepresented groups participate. Problem solving and collaboration among people with diverse backgrounds and experiences leads to more innovative outcomes. Diverse groups of people raise different questions; questions drive science, and that moves science forward. Despite these and other examples, we struggle with equal representation. What challenges do women, LGBTQ+ individuals, and minorities face to entering and excelling in science? What are practical approaches to increase, recognize, and encourage contributions of diverse people into this profession? We must recognize our biases, create connections, take action, and be allies to underrepresented groups. Those in leadership roles can recruit and train women and minorities, foster an open work culture, mentor, encourage cross-job communication and nonhierarchical structures, make sure women and underrepresented minorities represent 15 to 30% of team members to gain critical mass. We drive science forward when “we” represents all of us.

Energy costs energy: a geospatial model of mule deer caloric expenditure in response to oil and gas development on the Colorado Plateau

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ABSTRACT: Mule deer are known to avoid human disturbances, including roads and associated oil and gas development. It is also well documented that the heart rate and oxygen uptake of large mammals varies by natural aspects of their habitat (terrain, climate, predators, etc.) as well as anthropogenic alterations (noise, light, fragmentation, etc.). But whereas physiological analyses can inform both development and conservation, management decisions have not considered the energy required of an animal specific to the locations of development. Using documented calculations of energy expenditure of mule deer by weight, in relation to slope and slope direction, plus avoidance factors for anthropogenic disturbance, we developed a spatiotemporal model of the minimum energy required for mule deer to traverse a landscape with increasing levels of oil and gas development in our study area, on the northern Colorado Plateau in Utah. Our bioenergetic cost-distance provides a way of delineating impediment to movement and therefore efficiency and survival. We confirmed, with spatial precision, that energy expenditure can be significantly increased by travel distance to avoid development, regardless of terrain. As the energy costs of locomotion correlates across multiple species of large mammals, our analysis of change can serve as quantitative representative of the impacts of oil and gas development for not only mule deer but multiple species—including those listed as threatened or endangered.

Place-based research and co-creating science to engage Navajo students

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ABSTRACT: Place-based research and teaching has great power to engage individuals from different institutions, cultures, and backgrounds in the common endeavor of maintaining valued components of the environment that are threatened by human activities. While research and teaching collaborations across institutions and cultures can further inform and improve practices across institutions. Furthermore, learning hands-on research in the outdoors creates and opportunity for all learners to bring something from their experiences to the collaborative leaning endeavor. Culturally responsive and inclusive teaching have important benefits that will (1)

strengthen students' identity and sense of the value of their existing knowledge, (2) promote equity and inclusivity in research, (3) engage students in conversing with Elders/Medicine Men/Women, and (4) support students' critical thinking while conducting research and incorporating Navajo knowledge ways of knowing. One example of culturally responsive and inclusive teaching is creating a place-based environment where students learn about Navajo cultural concepts. One place, in particular, is the Navajo Sweat House setting that holds spiritual significance where cultural concepts like identity, oral stories, songs, prayers, ceremonies, spirituality, respect for the life of all things, history, clan, language acquisition, ecological sustainability, philosophy, roles and responsibilities as men and women, and pedagogy that are learned and essential to the survival of self, culture, and traditions.

Climate impacts and resilience efforts by Tribal/Indigenous communities in the Southwest

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ABSTRACT: As the number of devastating climate events such as flooding, wildfires, and tornadoes occur across the country, many communities find themselves facing the consequences that are life-changing. In addition to BIPOC and low-income communities, Tribal and Indigenous people are disproportionately affected, especially those who live in areas far from services such as hospitals, grocery stores, and water wells. This presentation will provide various examples of southwestern Tribal communities impacted by climate change and showcase resilience efforts to address the need to prepare and care for the most vulnerable members of the community. In addition, Ms. Cooley will talk about how Traditional/Indigenous Knowledge plays a role in these resilience efforts.

Post-fire futures in southwestern forests: trajectories of recovery vs. conversion and management options for an era of rapid change

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ABSTRACT: Southwestern ponderosa pine forests are vulnerable to fire-driven conversion in a warming and drying climate, yet little is known about what kinds of ecological communities may replace them. To characterize post-fire vegetation trajectories and their environmental determinants, plant assemblages (361 sample plots including 229 vascular plant species, surveyed in 2017) were sampled within eight burns that occurred between 2000 and 2003. Non-metric multidimensional scaling, k-means clustering, principal component analysis, and random forest models were used to assess relationships between vegetation patterns, topographic and landscape factors, and gridded climate data. Seven post-fire community types were identified, including regenerating forests of ponderosa pine, aspen, and mixed conifers, shrub-dominated communities of Gambel oak and mixed species, and herb-dominated communities of native bunchgrasses and mixtures of ruderal, native and non-native species. Forest recovery was found

to generally be associated with cooler, mesic sites in proximity to forested refugia; shifts toward scrub and grassland types are most common in warmer, dryer locations distant from forested refugia. Under future climate scenarios, models project decreases in post-fire forest recovery and increases in non-forest vegetation. However, forest to non-forest conversion can be partially offset under a scenario of reduced burn severity and increased retention of forested refugia, highlighting important management opportunities. Burning trends in the Southwest suggest that post-fire vegetation will occupy a growing landscape fraction, compelling renewed management focus on these areas and paradigm shifts that accommodate ecological change. This presentation will illustrate how management decisions around resisting, accepting, or directing (RAD) change could be informed by an understanding of processes and patterns of post-fire community variation and likely future trajectories.

Genetic variation and ecological consequences of phenotypic plasticity in a widespread riparian species

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ABSTRACT: The ability to predict trait responses under altered environments is becoming increasingly important for the management of critical ecosystems, especially in the American Southwest where hot, prolonged drought conditions have already led to widespread forest dieback. Phenotypic responses include both shifts in mean trait values and trait plasticity, which together may cascade to affect numerous dependent species in complex ecological communities. Here, we investigated the combined impact of abiotic and biotic stressors on the foundation riparian tree species, *Populus fremontii*, by utilizing three replicated common gardens spanning a large climatic gradient and a simulated leaf herbivory treatment. This design allowed for evaluation of genetic (G), environmental (E), and GxE effects of climate transfer and leaf damage on 16 populations of Fremont cottonwoods collected throughout Arizona. We found strong genetic effects for morphological, phenological, and phytochemical traits as well as for the phenotypic plasticity of these traits. Furthermore, trait differences were correlated with survival and growth, consistent with patterns of local adaptation to population home provenance. The magnitude of phenotypic plasticity was trait- and population-dependent. Trees from hot provenances exhibited high plasticity in some traits, while the opposite pattern of high plasticity in cold-adapted populations was observed for other traits. Finally, we found evidence of climate-driven selection for traits and trait plasticities using Q_{ST}-F_{ST} analysis and phenotype-climate regressions, suggesting the evolution of traits and trait plasticity across the heterogeneous Arizona landscape. Overall, this study demonstrated large genetic effects and some predictive

power into the changing trait means and plasticities across steep climatic gradients and herbivory pressure.

The Southwest Bat Hub: implementing the North American Bat Monitoring Program to support conservation in Arizona and New Mexico

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ABSTRACT: We established the Southwest Bat Hub in 2021 to unite attempts by state and federal agencies to coordinate data collection to inform population-level understanding of the region's bats. The Southwest Hub serves Arizona and New Mexico (www.southwestbats.org). In the Southwest, there is an urgent need to understand the impacts of threats on bat populations, such as drought, fire and disease. Prior to the establishment of the Hub, the region had low participation in the North American Bat Monitoring Program (NABat) despite being a hot spot for bat diversity. Monitoring in the first year of the Hub being established has more than doubled prior years efforts, to a total of 65 cells submitting data in 2021 and substantially more being monitored in 2022. Partners for this project include the USFWS, US Forest Service (USFS), Bureau of Land Management (BLM), Tribal agencies, National Park Service (NPS), and local conservation groups. The Hub aims to facilitate the collection of consistent data and provide data products back to these partners to inform management. The Hub's services reduce the barriers to participation faced by partners, and include equipment sharing, data processing and management, training, and survey coordination and planning. We work with this extensive network of regional partners to ensure NABat's existing standardized data collection protocols are followed in the region. We facilitate the standardized processing of data collected and communicate the results to data contributors and stakeholders. The network of partners cultivated by the Hub are key in continuing to increase and enable survey efforts in the two states to generate sufficient data to provide both spatial and temporal coverage. Ultimately, this collaborative approach is necessary to develop robust status and trend modeling outputs to inform the management and conservation of bat populations.

Leaf hyperspectral reflectance reveals genetic relationships across an environmental gradient: implications for restoration and ecological monitoring

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ABSTRACT: Leaf hyperspectral reflectance can predict tree identity at multiple genetic scales across an environmental gradient. As climatic conditions continue to rapidly shift in the

southwestern United States, understanding how tree phenotype changes in response to novel extremes is imperative. We explore the variation of leaf spectral phenotype at the genotype and population scales and between wild and transplanted trees. We hypothesized that leaf spectral phenotype would reveal genetic, environmental and GxE interactions. In this experiment, we compared ground-based hyperspectral leaf reflectance data (500-2400 nm) from wild populations of Fremont cottonwood (*Populus fremontii*) and transplanted clones in three common gardens across this species' climatic distribution. We used partial least squares regression discriminant analysis (PLS-DA) to train and test predictive models and to identify wavelengths of importance for each model. Our study revealed four major patterns. (1) Leaf spectra are predictable with high accuracy at the genotype, population and environmental scales. (2) Gene-by-environment interactions are detectable using leaf spectra. (3) Spectral phenotype shifts in response to novel climates. (4) Leaf spectra in the red edge region (690:735 nm) show that tree stress increases as temperature transfer distance increases. Leaf reflectance is an efficient, non-destructive tool for assessing tree genetics as well as phenotypic shifts at the landscape scale. We discuss the potential of using leaf reflectance to assess cottonwood genetics as a means to improve restoration outcomes and ecological monitoring.

The effects of water erosion on archeological sites at Wupatki National Monument

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ABSTRACT: The effects of environmental changes can be seen through changes in archaeological site conditions. Over the past four years, archeological sites at Wupatki National Monument have been significantly affected by water erosion. Water erosion, mainly from summer monsoons, is affecting the integrity and condition of these archeological sites. The identification of archeological sites being affected by water erosion can constitute a need for National Park Service Archeologists to implement preventative measures and develop risk mitigation strategies to protect and preserve these archeological sites. WUPA01109, an archeological site consisting of a multi-room structure and four cists, is a prime example of how water erosion can affect an archeological site over time. Over the past four years, water has significantly eroded this archeological site causing new features and artifacts to be exposed as well as previously recorded features to be covered by shifting cinders. Mitigation measures were implemented in order to preserve and protect this archeological site.

Oystershell scale: an invasive insect threatening aspen in the Southwest

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ABSTRACT: Quaking aspen (*Populus tremuloides*) is a foundation species in the southwestern US because it provides critical habitat for an array of plants, animals, and invertebrates and makes a disproportionately large contribution to biodiversity. Aspen ecosystem resilience and the

services that aspen ecosystems provide are threatened by ongoing outbreaks of an invasive insect, oystershell scale (*Lepidosaphes ulmi*). Oystershell scale has been present in North America since the 1700s and is a common pest of many deciduous shrub and tree species, including aspen, in urban settings. Historically, oystershell scale has not been a major pest outside of urban areas. However, in 2016 forest managers in northern Arizona observed outbreaks of oystershell scale causing dieback and mortality in natural aspen stands. Since then, oystershell scale has been observed in lower elevation (< 2550 m) aspen forests throughout Arizona and has recently been documented affecting aspen in other western states, including Nevada and Utah. Oystershell scale also affects numerous other native plant species, including many riparian trees and shrubs. Oystershell scale's invasion pattern is consistent with that of a sleeper species, which is a non-native species whose populations remain at slow growth rates until abiotic or biotic conditions change, causing the sleeper species to awaken and experience rapid population growth. We hypothesize that oystershell scale is a sleeper species that awoke and is now in the spread phase of its invasion in the Southwest, likely triggered by a warming climate. This presentation will provide an overview of our knowledge on oystershell scale, including where the species is known to occur, how it is impacting aspen forests in Arizona, and which strategies are being explored for managing the insect. We conclude that oystershell scale poses an imminent threat to native plant species and ecosystem services and represents an immediate research and monitoring priority to better understand the extent of the problem and develop proactive solutions.

RestoreNet: a restoration field trial network to bridge science and land management

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ABSTRACT: The degradation of dryland ecosystems presents a complex challenge for restoration practitioners due to low and variable water availability, slow vegetation recovery rates, soil degradation, and a high level of environmental heterogeneity. Further, restoration treatments are often conducted at a single site, over a limited period of time, and results can be poorly communicated to stakeholders. RestoreNet is a restoration field trial network co-produced by scientists, land managers, and landowners in the southwestern US that provides a standardized cross-site experiment to test a set of ecological restoration strategies across a broad gradient of environmental conditions. RestoreNet began in 2018 and has grown to include 25 sites throughout the southwestern US (AZ, NM, CO, UT, CA). Our goal as a network is to provide guidance for improving restoration and seeding techniques, and to increase

communication of effective restoration strategies. At each RestoreNet site, we tracked the emergence, growth, and survival of seedlings that were recruited from different native seed mixes in combination with different restoration techniques. At some sites, we also outplanted native plant seedlings that were started in the greenhouse to understand whether this improved plant survival and tracked what species performed best under different environmental conditions. As the network advances, we are co-developing new research directions with stakeholders through site visits, workshops and stakeholder meetings, and outreach materials to communicate results and elicit feedback. The future of RestoreNet continues to evolve based on the interests and feedback from our stakeholders and we invite additional participants to contribute to the network.

Using Remote sensing for juniper management on the Kaibab National Forest

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ABSTRACT: Grassland restoration is a priority on the south zone (Williams and Tusayan Ranger Districts) of the Kaibab National Forest. The NEPA process was completed for the South Zone Grassland Restoration Project in 2017, allowing for implementation of thinning, prescribed burning, and other activities to restore the structure and function of across 550,000 acres of the forest. While restoration activities have occurred under this project a lack of resources to complete the work has slowed progress. In 2022 more resources became available to implement work on large landscapes A main challenge to achieve this goal has been identifying and prioritizing treatments areas across the forest. To meet this challenge, the forest is exploring use of remote sensing technology to identify various stages of tree encroachment on a forest wide scale. Scientists from the Rocky Mountain Research Station (RMRS) is working with the Forest to develop an encroachment model combining Lidar data and historic aerial photography with woody cover trend data sourced from the Rangeland Analysis Platform (RAP). When developed, this model will help identify the extent and magnitude of pinyon juniper encroachment across the forest and these data will subsequently enable prioritization of resources for restoration.

A new framework for convergent research: Actionable and Strategic Integrated Science and Technology (ASIST)

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ABSTRACT: In 2020, the USGS initiated a new scientific approach to integrated science focused on building cross-disciplinary connections conduct science investigations related to complex challenges cascading from the long-term drought in the Colorado River Basin. The USGS has released more than 840 publications, 575 data releases in ScienceBase, and 330 project webpages relevant to climate change effects across the CRB landscape. The current volume of USGS science is overwhelming for partners and collaborators to interpret without a structured framework to collect and interpret interdisciplinary results. To analyze such complex challenges the USGS scientific community has implemented regional scale approaches to science to leverage knowledge across science disciplines. Landscape approaches require working in partnership with many stakeholders to co-design, co-develop, and co-produce science across the landscape, enabling connections between of single-discipline science projects to gain a more holistic this complex, interconnected. As questions from our partners become more complex, the USGS needs to share ideas and capabilities with interested stakeholders. In addition to working together to share scientific knowledge, there is a significant opportunity to optimize use of advanced information management technology to bring together knowledge, data, models, and information. Advanced technology allows us to combine smaller projects into more holistic larger projects which will benefit society and deliver needed science and decision-support tools to decision makers in a timely manner. This presentation will provide a high-level overview of the USGS Actionable and Strategic Integrated Science and Technology (ASIST) approach as well as challenges, successes, and opportunities faced when working as an interdisciplinary team across large regions.

A belowground story: a soils perspective on the effects and reclamation options for oil and gas well pads in the western US

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ABSTRACT: Oil and gas energy development has increased rapidly in the western US. There are approximately 100,000 abandoned and active oil and gas wells on the Colorado Plateau. This extensive land use has created a large ecological footprint and there is significant uncertainty about how to successfully reclaim these hard-to-restore, highly disturbed drylands. To inform reclamation options, we collected soils from more than 160 plugged and abandoned well pads and adjacent reference sites across three states (Utah, Colorado, and New Mexico). We assessed soils for pH, organic matter, electroconductivity, carbon, nitrogen, and the sodium adsorption ratio. We hypothesized that soil conditions affected by the energy development created

challenging environments for revegetation, including low organic carbon and high salinity. Our soil data paired with remote sensing data explored the degree of plant recovery for each well pad. We found differences in soil between reclaimed well pads and their respective reference sites. Differences which help illuminate how soils and climate interact to dictate recovery. In particular, we found dramatic declines in carbon and nitrogen following well pad development compared with undisturbed adjacent soils. This is consistent with a less hospitable matrix for plant growth and helps to shape an important belowground perspective on edaphic controls over ecosystem recovery. Taken together, this large data set spans gradients in time since reclamation, climate, and soil type and provides new information that can be used to help inform a more successful reclamation of abandoned and marginal wells on the Colorado Plateau.

Burn severity in Mexican spotted Owl PACs and potential habitat across the American Southwest

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ABSTRACT: The Mexican Spotted Owl (*Strix occidentalis lucida*) is a species found in the American Southwest that is listed as threatened by the US Fish and Wildlife Service, with their primary threat being high-severity wildfire. Recent research has shown that over the last three decades, high-severity wildfire has increased in both frequency and area across the Southwest. The increases in fuel loadings and small tree densities from over 100 years of fire suppression together with selective logging for large diameter trees has created more areas at risk of high-severity fire. Because of this increased risk, maintaining the desired conditions for Mexican spotted owl habitat will become more difficult. To see if Mexican spotted owl habitat has experienced the same trends as other forested areas, we used Mexican spotted owl Protected Activity Centers (PACs) as a desired habitat indicator and looked at levels of burn severity within PACs across the American Southwest. We used Landsat imagery to obtain the relative differenced Normalized Burn Ratio (RdNBR) values for every wildfire on National Forest System Lands from 1985 to 2019. We were able to see what PACs had been affected by wildfire, how frequently, at what levels of burn severity, and the spatial extents. Another part of our research is using this burn severity data in conjunction with modeled potential Mexican spotted owl habitat provided by the USFWS and USFS. This map of potential habitat covers the same spatial and temporal extent as our fire severity data and will provide many insights on the interactions between fire and potential Mexican spotted owl habitat. This research will help land and wildlife managers in their decision-making process by allowing them to see what PACs have been affected by wildfire and to what extent. This knowledge can guide the locations of future forest restoration efforts, prescribed fire plans, and wildfire suppression efforts.

Opportunities in co-management of publicly-managed buffalo herds—three years of live transfers of Grand Canyon buffalo, and 30 years of restoring buffalo to tribal nations with InterTribal Buffalo Council

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ABSTRACT: Grand Canyon National Park and InterTribal Buffalo Council are entering our fourth year of partnership in working to manage the population of buffalo on the north rim of the Grand Canyon through live transfers to Tribal Nations with ITBC's Surplus Buffalo Program. ITBC has been restoring buffalo to Tribal Nations for 30 years. As we enter our 31st year of existence, and celebrate each new partnership developed, we share our experiences in these co-management activities, lessons learned, and opportunities going forward to engage Tribal Nations and individuals with buffalo management activities at Grand Canyon and beyond. This talk will also highlight the unique challenges and opportunities of working in a remote area, utilizing temporary capture facilities, and transporting never-captured buffalo from a field environment to highway-ready transport vehicles, safely to their new homes on Tribal lands.

Links between drought and river nutrition: phosphorus export from Glen Canyon Dam under declining reservoir elevations

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ABSTRACT: Rivers below dams often experience seasonal or persistent reductions in phosphorus (P) inputs due to phosphorus retention in reservoirs. Lake Powell retains the vast majority (95-99%) of the phosphorus that it receives, creating phosphorus limiting conditions downstream throughout the year. However, while we know phosphorus availability can be extremely low and that this could have cascading effects on aquatic ecosystems, our understanding of the controls over phosphorus cycling in these tailwater river remains notably poor. We used sediment incubations to estimate how shifts in the quality of dam releases (in terms of both dissolved oxygen and pH) may either stimulate or reduce downstream phosphorus availability and total protein production. We found that ecologically meaningful concentrations of phosphorus are released less from sediments when river pH increases by one unit (from 7 to 8). As reservoir levels go down, as is happening in the Southwest's current drought conditions, water is beginning to be withdrawn from Lake Powell's surface waters, where photosynthesis drives pH up. This, combined with empirical observations of the vertical distribution of soluble reactive phosphorus in the water column, suggests that phosphorus bioavailability downstream of the reservoir will decline as lake levels drop. Thus, declining reservoir water levels may further exacerbate food limitation in the Colorado River below Glen Canyon Dam, with critical implications for fish and invertebrate populations.

The Returning Rapids Project: how initial questions led to great collaborations

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ABSTRACT: During the early 2000's the level of Lake Powell receded exposing >30 km of previously inundated river corridor. For almost a decade, the river community of Cataract Canyon generated questions and informally tracked the changes they were observing. In 2018, increasingly dynamic conditions forged a group of citizen scientists to organize and better document these changes, culminating in several interdisciplinary research trips bridging several federal agencies. Field work and subsequent collaborations have been crucial in gathering baseline data and monitoring interannual conditions to help provide a better understanding of a rapidly changing Colorado River. The presentation will focus on the use of simple photo matching, time lapse cameras, and field observations as a means of effective science communication, eventually facilitating interdisciplinary research of both practical and academic interest. Also covered will be how the value of professional river guides, program managers, and passionate recreationists can help to get great minds to the right places – and then sit back and listen to what they have to say around the campfire at the end of the day's work.

Effects of ecological restoration treatments on understory plant diversity and productivity in Colorado dry conifer forests

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ABSTRACT: The dry conifer forests of the western United States have experienced considerable alterations in structure and composition since Euro-American settlement. Ecological restoration treatments aim to restore resilience to wildfire and other disturbances by creating more open, heterogeneous overstory conditions that emulate those of historical forests. While treatments appear to be effective at meeting this primary objective, it is less clear whether they also meet secondary objectives, such as restoring more diverse and productive understory plant communities. We assessed the effects of restoration thinning treatments on understory plants in dry conifer forests in the Colorado Front Range. We collected data pre-treatment and at 1-2 years and 4-6 years post-treatment, at 198 plots in treated and untreated areas. Preliminary results show elevated cover of both native and introduced understory plants in treated plots at 4-6 years post-treatment. On average, native cover was 25.5% in treatments versus 18.3% in controls, while introduced cover was 0.95% in treatments versus 0.19% in controls. Native species richness did not change strongly with treatment but introduced species richness was higher in treated plots: ~3 introduced species on average versus ~1 in control plots. These preliminary results suggest that ecological restoration treatments meet the goal of increasing native understory plant productivity at 4-6 years post treatment, but not the goal of increasing native richness. While introduced species did increase in cover and richness, they were still uncommon across the landscape. Further analyses will be conducted to determine how

environmental gradients interact with treatment to affect understory plant communities, which may help land managers refine treatment prescriptions.

Diné science and sacredness: from time immemorial to today

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ABSTRACT: For centuries, Western science and academics have assumed that Indigenous peoples lived on the basis of myth. However, it is becoming more apparent to these communities that indigenous ways of knowing are based in scientific knowledge and practice. This presentation will inform the audience of the Diné (Navajo) perspective of science, which is rooted in the culture, history, and philosophy of the people. The sacred knowledge of Diné is held within language, songs, and ceremonies, all of which hold power and can affect the environment at a molecular level. Ceremony, for example, has provided physical, emotional, and spiritual healing since the beginning of time. It has carried our people forward through many disasters, transformations, and evolutions. It is said that Diné ceremonies helped the Five-Fingered Earth Surface People (*Homo sapiens*) traverse through three worlds before emerging in this fourth world, the Glittering World. Sacred ceremony has guided and protected us since our emergence and continues to do so in contemporary times. Mountains, another example, are considered our Nataanii (Leaders). Each of which are sacred in nature, holding power for healing, restoration, and balance. In Diné bizaad (Language), the name for 'mountain', Dził, literally translates to "power'. The sacred nature of the elements that comprise the Earth, sky and ecosystems are held with much caution and care. They are considered sacred because they hold a force within, an energy that can either harm or heal, protect or kill. This perspective broadens the understanding of the interconnected nature of all things, and it differentiates how Diné interact with the world above, below, within and all around. Ahéhee.

Reducing human-caused wildfire: a survey of recreationists on two southwestern national forests

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ABSTRACT: Human-caused wildfire ignitions have become a prevalent issue across public lands in the southwestern United States, exacerbated by both a rise in recreation and rapid expansion of adjacent wildland-urban interface areas. This increased ignition risk, coupled with increasing wildfire severity across the western U.S, poses a significant challenge for prevention personnel and land managers alike. Research regarding the anthropogenic impact on wildfire has largely consisted of the documentation of spatial and temporal patterns, with little exploration of behaviors and attitudes of the public lands visitors who drive these patterns. Specifically, research focusing on recreationists' decisions while preparing for, and during, their trips to public lands has been fairly limited. Likewise, their perceptions of acceptability of various ignition sources and the effectiveness of prevention tactics have not been well documented. This information is critical in understanding the social aspects of human ignited wildfire, developing effective prevention practices, and allowing space for constructive discourse between

recreationists and public land managers. To address these gaps, we surveyed recreationists at two human-caused ignition "hotspots" -areas with significantly high densities of anthropogenic fire- on the Colorado Plateau: the Flagstaff Ranger District on the Coconino National Forest and the Jemez Ranger District on the Santa Fe National Forest. The survey consisted of questions regarding the participant's experience level with public lands, how they prepared for their current trip, and their perceptions of prevention strategies. We present preliminary data from these two locations, with a focus on exploring (1) preparation and information-seeking behaviors recreationists embark on before visiting public lands, (2) differences in preparation between local and non-local visitors, and (3) support or opposition for investment in various human-caused ignition prevention techniques. We make recommendations regarding how these findings may be used to develop effective human ignition prevention tactics while taking into account user opinions.

The Southwest Drought Learning Network

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ABSTRACT: Drought intensity and duration have increased over the southwest region, with impacts to wildfire potential, agricultural production, water management, the economy, and human well-being. Because of the region's significant exposure to drought, stakeholders needed a succinct method for documenting and communicating novel responses and lessons learned that could inform future drought scenarios. In response, the National Integrated Drought Information System (NIDIS), the National Drought Mitigation Center (NDMC), and the USDA Southwest Climate Hub (SWCH) initiated the development of the Southwest Drought Learning Network (DLN). The DLN serves to engage climate service providers, federal and state officials, scientists, and producers in a peer-to-peer learning environment to capture and share drought knowledge and experiences. The DLN operates through self-directed teams that emerge, continue, and dissolve based upon drought needs in the region. Success of these teams results from leveraging DLN members' own agency or organization resources and capacities to accomplish goals. The Sharing Management Practices team, one of the five current teams, aims to highlight transferable stories of drought adaptation, mitigation, and resilience happening on-the-ground, through actionable and accessible outlets. This work is made possible through partnership with the Collaborative Conservation and Adaptation Strategy Toolbox (CCAST), a multi-organization partnership directed by the US Fish and Wildlife Service, Bureau of Reclamation, and the University of Arizona. CCAST supports peer-to-peer knowledge sharing across landscapes through the development and dissemination of decision-support tools and case studies. CCAST provides the case study development process, development resources, and online dashboard, while the DLN identifies drought topics, provides additional writing capacity, and augments dissemination pathways. Through this partnership, the DLN has published ten case studies, with seven more in development, and mentored five interns to date.

Opportunities to improve out-planting performance of southwestern ponderosa pine by selection of arid adapted seed sources: insights from field and greenhouse common gardens

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ABSTRACT: Deforestation of Southwest ponderosa pines ecosystems due to a combination of abiotic and biotic stressors, such as wildfires and bark beetle attacks, has increased over the past century. Drought-related tree mortality is already a matter of concern and is expected to intensify over the next century as atmospheric temperature and drought severity increase. Recent wildfires have produced large openings on dry sites, leading to inadequate ponderosa pine regeneration. Slow regeneration may be attributed to a lack of seed trees and harsh abiotic conditions. Together, high tree mortality and meager regeneration exacerbated by a warming climate threaten southwestern ponderosa pine forests. Artificial regeneration using seedlings which are pre-adapted to future climate conditions can be used to compensate for these recent losses of ponderosa pine forests. To evaluate provenances for planting under increasingly arid conditions, we used seedlings from different provenances representing an elevational and temperature gradient across Arizona and New Mexico. Seedlings from 21 provenances were planted in three field common gardens across an elevational gradient. Seedlings from 10 provenances were planted in a greenhouse common garden at the NAU Research Greenhouse Facility. This presentation discusses evidence of differences in traits among provenances that may be helpful in future reforestation survivability. Results show adaptation of low elevation provenances, such as earlier budburst, lower specific leaf area, and less growth under dry conditions, to warm and dry conditions. Results also emphasize consideration of biotic stressors while planning large-scale reforestation and assisted migration of ponderosa pine.

Cultural difference vs. the cowardice of privilege: an analysis of the ongoing violence of the double bind residing within "The Master's House"

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ABSTRACT: The San Francisco Peaks, *Sunha: K'yaba:chu Yalanne* to the Zuni, is an important ancestral place in the *A:shiwi* migration narrative. It is associated with the Big Fire Medicine Society and is understood to be a sacred and sentient entity. Past efforts to protect this sacred place by Tribes from federal agency and capitalistic enterprises utilizing AIRFA, NEPA, and NHPA have proven unsuccessful. To sincerely begin to understand the inequitable ecology of (non)compliance in which Tribes are forced to engage through federal consultation is to confront bravely the limits of Western cosmologies and worldviews and the cartographic constellations of value and assumption that are deeply entangled in conceptual errors of colonial privilege and control. Working through Zuni Tribe experiences, this paper demonstrates how those guiding Western environmental bureaucracies and organizations often willfully ignore their

own religious foundations and perpetuate and re-entrench a worldview and value system that perpetuates predetermined outcomes in favor of colonial legacies of neoliberal capital, value, and control. Through such enduring processes, the Zuni people are continually placed in a "double bind," or an inescapable constraint through which Zuni knowledge and insight are both uncritically and ironically refuted by dominant scientific and environmental agents through *un*scientific and impositional means. Advocated here as a way out of this double bind is a pathway towards cultural understanding as *irreducible* difference—a *difference as difference* that must be fully implemented in theory *and* practice for sincere Indigenous conceptual consideration and inclusion to even begin to be approached. Underscored here is that the enduring epistemic *injustices* of ultracrepidarian interpretation, filtering, and gatekeeping of Indigenous concepts by Western governmental and non-governmental agents and actors are precisely what are *not* needed, "For the master's tools will never dismantle the master's house" (Lorde 1984).

Using aircraft hyperspectral, drone, and leaf spectral data to predict susceptibility of cottonwoods (*Populus fremontii*) to future climate change scenarios

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ABSTRACT: We lack a comprehensive spatially explicit understanding of how native foundation plant species like cottonwoods (*Populus fremontii*) in the southwest may adapt and survive under future climate change scenarios. Here we show preliminary results to create such a spatially explicit regional map where we combine leaf hyperspectral data (400-2500nm) and multispectral and thermal drone data collected at three cottonwood common gardens with NEON AOP aircraft hyperspectral and lidar flown over these common gardens as well as many river corridors in Arizona and Southern Utah. Preliminary leaf level results suggest that key traits such as Tcrit (the ratio of variable fluorescence yield to maximum fluorescence yield (Fv/Fm)) can be predicted (r^2>0.7) with spectroscopy as well as other traits such as crosstypes (i.e. Narrowleaf vs Fremont), droughted vs not droughted, and soil type (i.e. tamarisk legacy). In addition, thermal drone data for ~300 trees in two blocks and have found some significant temperature differences between populations. These preliminary results give us confidence that we can now use the landscape NEON hyperspectral data to predict susceptibility of individual cottonwood trees to future climate change.

Bartram's stonecrop (*Graptopetalum bartramii*) population status and habitat needs of a tiny succulent of the Sky Islands

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ABSTRACT: Bartram's Stonecrop (*Graptopetalum bartramii*) is a small, rosette-forming, perennial member of the family Crassulaceae that occurs in generally small, isolated populations in the canyons of the mountains of southeastern Arizona and northern Mexico. The species received Federal protection under the Endangered Species Act as a Threatened species in 2021. We report on population trends at 17 sites in five of the mountain ranges in the heart of the species' range in Arizona. Available population information on Bartram's stonecrop at these different sites spans from as much as 70 years to as little as 4 years as reported from monitoring by botanists, agency biologists and contracted surveyors, and our most recent investigations in 2021. Populations at five of the 17 sites appear to have been extirpated over the duration of monitoring. Populations at two other sites appear to be declining, but other sites are evidently maintaining their numbers. No populations show clear increases. The last several years of monitoring have been during the severe southwestern drought, and sites where populations have been extirpated are characterized by drying, loss of adjacent surface water, and in at least one case, extensive wildfire. We also collected intensive microsite-related data at a subset of the sites to evaluate local microhabitat conditions affecting population trends. At these intensively sampled sites we measured plant vigor and recruitment monthly during the 2021 growing season to investigate patterns of habitat quality related to shading, temperature, humidity, substrate type, and distance to perennial or seasonal surface water. In this presentation we summarize known habitat characteristics supporting Bartram's stonecrop.

What determines the effectiveness of pinyon-juniper clearing treatments? Evidence from the remote sensing archive and counter-factual scenarios

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ABSTRACT: In the intermountain western US, expansion of Pinyon (*Pinus edulis*) and Juniper (*Juniperus* spp.) woodlands (PJ) into grasslands and shrublands is a pervasive phenomenon, and an example of the global trend towards enhanced woody growth in drylands. Due to the perceived impacts of these expansions on ecosystem services related to biodiversity, hydrology, soil conservation, fuels, and forage, mechanical and chemical PJ reduction treatments have been a long-standing practice in the region. More recently, PJ reduction practices have come under enhanced public scrutiny, due to potential impacts on PJ-dependent wildlife, risk of erosion due to soil disturbance, and cost effectiveness due to variable rates of long-term success. Moreover, there is growing interest in understanding the biotic, abiotic, and management conditions under which PJ reduction treatments are effective. Here, we evaluated PJ reduction treatment outcomes leveraging large, curated databases of land treatments, new remotely sensed fractional cover time-series products, gridded climate and soils data, and analytical approaches adopted from the econometric literature. From 302 treatment events and 1569 distinct treatment polygons we found evidence that treatments reduced tree and largely increased shrub and perennial herbaceous cover for 10 or more years. However, treatments were also associated with increases

in annual, likely non-native, herbaceous cover. Importantly, we noted outcomes varied by landscape context, with some soil and geomorphic settings exhibiting consistent returns to pre-treatment conditions within 10-15 years, and others exhibiting more persistent changes in functional type composition. Despite the overall trends, there was considerable unexplained variability in outcomes from treatment to treatment, highlighting the need for attention to local geomorphic and biological context in planning future treatments. We conclude by describing a new research project aimed at integrating these soil-based decision support tools into PJ wildfire and fuel management using a framework that is repeatable, scalable, and built on federal monitoring data.

Wildlife monitoring in the Sonoran Desert using regional and global protocols

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ABSTRACT: Anthropogenic (i.e., human) stressors, such as urban development, human recreation, and climate change are major threats to biodiversity globally. Long-term monitoring of wildlife populations is essential for understanding how populations are impacted by anthropogenic factors over time. Further, using standardized protocols enables researchers to compare data within and across regions to better evaluate and predict regional population trends as the climate changes. The McDowell Sonoran Conservancy conducts multiple long-term ecological research projects on key species groups in order to monitor and maintain biodiversity in the McDowell Sonoran Preserve and beyond. For all of our research projects, we use past results and standardized protocols to develop rigorous study designs and ensure the data we collect can be added to regional databases. For example, we survey bat populations annually in the Preserve using acoustic bat monitors. We used results from a pilot study in the Preserve and protocols from the North American Bat Monitoring Program (NABat) to inform the study design for this project. We also share our data with NABat, contributing to a collaborative effort to monitor bat populations across North America. In addition, we survey ground-dwelling vertebrate populations semiannually in the Preserve using heat-and-motion censored trail cameras. We used past phases of the camera project and a modified protocol from the Tropical Ecology Assessment and Monitoring (TEAM) Network to develop the study design for this project. We also participate in Snapshot USA, adding our data to the collective effort to monitor mammal populations across the United States. With a focus on the Conservancy's bat project and wildlife camera project, we aim to demonstrate the importance of long-term monitoring, using past results and standardized protocols to develop a rigorous study design, and data sharing with regional partners when conducting ecological research to maintain biodiversity.

Effects of flow, sediment, and non-native fishes on age-0 population dynamics of humpback chub in the lower Little Colorado River

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ABSTRACT: Numerous theories postulate that the life histories of fishes are linked to natural flow regimes; however, how specific hydrologic features (e.g., max flow, flow timing) affect individual life history attributes (e.g., survival, growth, movement) remains unknown for many fishes. Here we combine catch data and mark-recapture data to reconstruct population dynamics of age-0 humpback chub (*Gila cypha*) in the Little Colorado River, in an environment which experiences large floods and high levels of suspended sediment. We use our reconstructed dataset to determine drivers of age-0 abundance (i.e., the number of age-0 present in the LCR in July) and age-0 outmigration (i.e., the probability that fish move from the LCR to the Colorado River between July and October). For patterns in abundance, we reinforce previous findings that suggest that lack of winter floods leads to lower age-0 abundances but emphasize the flow-abundance relationship is nonlinear so that even small floods can lead to high abundances. We also document a negative relationship between spring catch of channel catfish and age-0 humpback chub abundance, but caution more evidence is needed to better establish/refute this relationship. For outmigration patterns, results suggest that age-0 humpback chub outmigration is density-dependent and that survival of age-0 humpback chub is lower when monsoons are present. Given the high variability in age-0 humpback chub abundances and the link between age-0 abundance and adult recruitment, a better understanding of age-0 humpback chub population drivers will help predict population response to climate change and potentially help identify and evaluate management actions for conservation.

Surprising resilience of old forest in drought: 100 years of data from the Pearson Natural Area, Arizona

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ABSTRACT: Long-term forest demography studies provide irreplaceable data about forest dynamics, especially growth, mortality, and sensitivity to climate. However, due to the foresight and resources required to establish long-term studies of permanently marked trees, there are few such sites. The G.A. Pearson Natural Area (GPNA), Arizona, was set aside in 1920 as the first long-term untreated "natural" research tract of ponderosa pine (*Pinus ponderosa*) on Forest Service lands. It has been repeatedly measured, from 1920-2020, for 100 years of ponderosa pine growth and mortality. In the absence of fire or management activity, the forest became extraordinarily dense with a "doghair thicket" of regenerating trees due to prolific seed mast in 1918 and ideal germination conditions in 1919. Growth and mortality have been tracked for 100 years; live tree stems were mapped in the past decade. We expected to see increasing mortality in the older and larger trees, due to high levels of drought and competition. However, despite ≈ 40 years of steady climate warming and high stand density, mortality remains relatively limited and

lower than that observed in most other western long-term inventory sites. But the forest resilience may be temporary as the forest remains vulnerable to fire and drought. The GPNA represents an extraordinary research legacy of high value to the Southwest and an important contributor to the small set of forest sites around the world with such a long data set.

Recovering from wildfire in Arizona: Insights and opportunities from social science research after six wildfires

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ABSTRACT: Community impacts associated with wildfire continue to diversify and expand across the Colorado Plateau, necessitating innovative and responsive recovery strategies at the local, state, and federal levels. Social science research that examines community experiences with wildfire is limited but rapidly growing; however, little of that work to date has focused on populations in the Southwest. Building a foundational understanding of community recovery in Arizona and New Mexico is particularly important given the unique contexts that wildfires occur in here, ranging from damage to non-fire-adapted ecosystems to post-fire flooding exacerbated by monsoonal precipitation. This presentation summarizes common themes across recent social science studies of communities affected by several Arizona wildfires, including the 2010 Schultz Fire, 2017 Goodwin Fire, 2018 Tinder Fire, 2019 Museum Fire, 2020 Bighorn Fire, and the 2021 Rafael Fire. Together, these studies encompass completed questionnaires from more than 1,800 households and semi-structured interviews with 182 residents and professionals, all conducted between 2019 and 2022. Themes from these studies will be compared with the broader literature on community wildfire recovery to determine gaps and opportunities for research in the Southwest. The presentation will conclude by outlining a potential roadmap for future social science recovery research in the region, focusing on better characterizing and documenting region-specific contexts and drivers that require special consideration by organizations and agencies engaged in post-fire recovery.

Rapid risk assessment approach at Fort Union National Monument

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ABSTRACT: In response to a significant wall collapse in 2014, Fort Union National Monument recognized the need for a rapid and easily employable risk assessment protocol for its remaining adobe walls and partnered with the Center for Architectural Conservation of the University of Pennsylvania to develop and deploy one. Situated at the confluence of the Mountain and Cimmaron branches of the Santa Fe Trail on the boundary between plains and mountains in northeastern New Mexico, Fort Union witnessed three construction phases between 1851 and 1891 that resulted in the largest collection of 19th century adobe ruins in the United States. These ruins have been preserved by the National Park Service as they were found in 1954, when the fort became a National Monument. However, longer, hotter periods punctuation by heavier precipitation episodes in the last twenty years threaten both the fort's historic structures and the

park's ability to continue maintaining them. As the result of collaboration between the Center for Architectural Conservation and park employees, a weighted, eight-factor Rapid Assessment Survey (RAS) was developed to provide quantitative data of walls' risk for material loss or collapse. The initial survey in 2019 provided proof of concept and information to reconsider preservation work priorities. A second survey in 2022 provided comparative data to monitor wall degradation and fresh information to shape and recast work priorities, concentrating attention on the walls most at risk for immediate intervention and for longer term projects. Data from both surveys and from future surveys will inform treatment recommendations in an Historic Preservation Guide under development and continue to provide information for park management to make data-driven preservation decisions.

Prioritizing IUCN Threatened Sonoran Desert cactus species for *ex situ* conservation at the Desert Botanical Garden, Phoenix, Arizona

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ABSTRACT: Species prioritizations are a tool from decision science that can help inform how limited conservation resources such as funding can be allocated to optimize conservation objectives for threatened species. As a premier conservation-oriented organization of the Sonoran Desert, the Desert Botanical Garden (DBG) in Phoenix, Arizona, faces complex species conservation decisions with consequences that could include the irreversible extinction of regional species. A special focus of the DBG is the Cactus Family, the fifth most threatened group of living organisms worldwide. Nearly one-third of cacti are threatened with extinction due to poaching or habitat loss. *In situ* conservation actions are not feasible for many cactus species which occur in small, scattered populations in areas that can be dangerous for conservationists to access. We explored *ex situ* conservation actions available to the DBG, which hold promise in safeguarding cactus populations from difficult-to-control, *in situ* threats. Large numbers of living collections are often required for good genetic diversity. However, garden space at the DBG is limited. We therefore examined the benefits of a threatened cactus adoption program for citizens as an option for *ex situ* actions. With an adoption program, citizens could help protect threatened plants in their backyards, and the DBG could improve the genetic reserves available to conservation. Using data collected during the 2015 IUCN Cactus Assessment, we calculated evidence-rooted, transparent, and reproducible metrics to answer the question: Which species should the DBG enroll in *ex situ* conservation actions to minimize the mean percent population decline across all IUCN Threatened Sonoran Desert cactus species? We applied our metrics to 40 threatened cactus species throughout the Sonoran Desert and aim to use the results to inform the upcoming 2023 DBG Strategic Plan, which guides conservation at the DBG.

The influence of underlying factors on treatment effectiveness of piñon-juniper removal in restoring sagebrush habitat in northwest Colorado

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ABSTRACT: Due to numerous anthropogenic factors, piñon-juniper woodlands in the western US are expanding into adjacent ecosystems, increasing fuel loads, decreasing wildlife habitat, and reducing native plant cover. Across the western US, natural resource managers are completing land treatments to remove piñon-juniper trees encroaching into adjacent ecosystems. We assessed land treatments that have been completed across northwest Colorado with the goals of improving wildlife habitat, restoring ecosystem services, and reducing fuels. Our aim was to evaluate the influence of underlying ecological and management factors on treatment effectiveness. Using a combination of traditional monitoring methods (line-point intercept, species inventory), as well as vegetation cover data collected via remote sensing, we collected functional group composition and plot recovery data. Percent perennial forb and grass cover and percent annual forb and grass cover were collected to assess plant community recovery. Collecting perennial and annual herbaceous cover data allowed us to quantify changes in native perennial cover and in invasive annual cover from pre- to post-treatment. The underlying factors we considered in plant community responses to a range of tree removal strategies (e.g., mastication, prescribed burning, hand removal) were treatment method, elevation and aspect. We found that elevation and aspect had the greatest impact on treatment effectiveness. Sites at elevations between 2100-2400 meters and northern aspects were associated with cooler, wetter climates which supported a higher percent cover of native perennial forbs and grasses. Invasive annual species cover was found to be higher at slightly lower elevations and specifically on northeast aspects. Treatment type had no significant effects on either perennial or annual herbaceous plant cover. With these data, recommendations can be made to support land managers in the planning process for future piñon-juniper treatments to enhance treatment effectiveness and efficiency.

Forecasting the potential of smallmouth bass invasion in the Grand Canyon and designing responses

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ABSTRACT: Invasive fishes are a primary cause of declines in native fish species throughout the United States including the Colorado River Basin. Although dams and reservoirs have dramatically altered the natural ecosystems of regulated rivers, they also serve as barriers to the movement of invasive fishes. Warmwater invasive species, such as the smallmouth bass (*Micropterus dolomieu*), have invaded much of the Upper Colorado River Basin and are

abundant in Lake Powell. Historically, Glen Canyon Dam limited propagule pressure of smallmouth bass from the Upper Basin and created thermally unfavorable conditions downriver. Currently, use and management of the Colorado River is facing a paradigm shift due to long-term drought that has decreased storage in the river's reservoirs creating great uncertainty about critical water supply and limiting efforts to manage the river's natural resources. Lower elevations in Lake Powell are expected to increase rates of fish passage through the dam and create thermally suitable conditions in Lees Ferry for smallmouth bass. To quantify the risk of smallmouth bass establishment downstream from Glen Canyon Dam, we developed predictive entrainment and thermal suitability models. These models are relatively simple tools based primarily on Lake Powell elevation, which pairs the depth of dam intakes with fish depth distributions and thermal profiles. Our model results show that risk of establishment increases with decreasing elevation, and downriver risk increases over time as individuals accumulate at rates that outpace annual mortality. Our models also illustrate that under current and projected elevations, temperatures in Lees Ferry are and will be suitable for smallmouth bass reproduction. Water storage decisions that maintain or increase Lake Powell elevation reduce the potential for smallmouth bass establishment in the Grand Canyon in the short term. Potential responses to an invasion also include deep water, selective withdrawal dam operations to cool the river.

Creating and increasing STEM capacity and partnerships through cultural sustaining perspectives to environmental changes

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ABSTRACT: SCAC is a newly emerging tribal college which is currently building STEM capacity in response to environmental changes within its own, and surrounding, tribal communities. In this presentation/discussion, Dr. Lisa Eutsey and Mark Clytus with San Carlos Apache College (SCAC) will provide insights and best practices from Tribal College and Universities (TCU) for promoting student success, especially in STEM fields. We will address opportunities and challenges tribal colleges face when offering natural resources courses and programs. The importance of university partnerships will be emphasized, including SCAC's long-standing, strong partnership with NAU. Faculty use of culturally sustaining pedagogy will be emphasized. In addition, the importance of faculty and student engagement with the local community, as well as building relationships with tribal, state, and federal agencies will be discussed.

Assessing 50 years of change in riparian condition along the Colorado River in Grand Canyon

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ABSTRACT: Vegetation encroachment and channel stabilization are widely observed but inconsistently quantified responses to flow regulation below dams. We evaluated 116 precisely matched photos of near channel locations throughout Grand Canyon, spanning 50 years of the post-Glen Canyon Dam period, to quantitatively and qualitatively assess geomorphic and vegetation change in the riparian zone downstream of Glen Canyon Dam. Factors evaluated include: 1) change in pre-dam, high-flow sand deposits; 2) presence of recent (post-2012) High Flow Experiment (HFE) sand deposits; 3) encroachment of vegetation and soil crusts on formerly active channel deposits; 4) change in extent of active sand surfaces; 5) categorial changes in vegetation cover; 6) relative percentages of native versus non-native plant species; and 7) dominant species contributing to vegetation expansion and channel stabilization. In general, extensive, pre-dam sand deposits have been substantially deflated, and in many instances, replaced by lower and smaller HFE deposits. Virtually all formerly active surfaces have been stabilized by biological soil crust and vegetation. In western Grand Canyon, such vegetation often forms dense, nearly impenetrable stands. Non-native species such as Tamarisk (*Tamarix ramosissima*, *T. chinensis* and hybrids), Brome species (*Bromus* spp.), Camelthorn (*Alhagi maurorum*) and Giant fescue (*Schedonorus arundinaceus*), along with natives such as Arrowweed (*Pluchea sericea*), Seep Willows (*Baccharis* spp.), Common Reed (*Phragmites australis*), and in places, Honey mesquite (*Prosopis glandulosa*) dominate encroaching vegetation assemblages. Giant fescue and Common Reed are now prevalent in formerly sparsely vegetated zones along the river's edge. Elsewhere in the Colorado River drainage, perennial, non-native grasses along the highly flow-controlled Gunnison River are persistent despite occasional high magnitude flows, suggesting such encroachment is resistant to control by flows alone. Riparian vegetation along the Colorado River in Grand Canyon continues to respond to modest changes in the flow regime, indicating future flow changes will likely initiate additional vegetation adjustments.

Can whole topsoil inoculation improve seedling establishment on degraded rangelands in the southwestern US?

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ABSTRACT: Restoration and rangeland improvement projects are often focused on seeding, without addressing the underlying soil biological and physical barriers that can limit vegetation recovery. Soil that has undergone degradation may no longer be conducive for seedling establishment due to reduced soil water holding capacity, increased susceptibility to erosion, depletion in the soil seed bank, and alterations in beneficial microbes that plants rely on. In this two-part project, we seek to address underlying soil barriers to seedling establishment and survival on degraded arid and semi-arid rangelands. First, in a greenhouse experiment we tested whether incorporating live healthy soils that contain beneficial microbial symbionts support the survivorship and growth of common grasses used in restoration. We found that root colonization by fungal symbionts appears to promote seedling survival, but that the type of fungal symbionts varied among grass species. Further, we found evidence that inoculating seedlings with topsoil harvested from undisturbed sites with high native plant cover resulted in greater root

colonization of fungal symbionts than topsoil harvested from highly degraded sites that were denuded of vegetation. Second, we deployed a large-scale field experiment at 14 degraded rangeland sites across the southwestern US that combines the potential positive effects of topsoil inoculation from a nearby undisturbed "reference" area with seeding and other treatments designed to increase soil moisture and provide developing seedling with microsite protection (seedballs and soil pits). We hypothesize that the biological effects of adding beneficial microbes from undisturbed whole topsoil will be most effective when there is high water availability at the restoration site. Testing novel combinations of soil-based treatments across a range of environmental conditions will help guide the development of strategies to improve dryland restoration outcomes.

RestoreNet strategies for revegetation: Lessons learned from a restoration field-trial network spanning the southwestern US

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ABSTRACT: Ecological restoration often has poor success in dryland ecosystems. Further, restoration treatments typically occur at a single site and are implemented within a single season, limiting our understanding of treatment applicability across broader environmental gradients and over time. Forecasts of increased frequency and duration of drought in the southwestern US highlight the need to understand how well restoration strategies work across a range of climatic conditions. To address the limitations of dryland restoration, we implemented and monitored a standardized set of seeding and soil surface treatments across RestoreNet, a growing dryland restoration network of 21 sites in the southwestern US, from 2018 to 2021. We found that the timing of precipitation relative to seeding and type of restoration treatment used was generally more important in determining seedling emergence and survival than site-specific characteristics. Soil surface treatments aimed at increasing soil moisture retention (e.g., soil pits and mulch) improved seedling emergence, and this positive effect became more prominent with increased cumulative precipitation since seeding. Surprisingly, using seed mixes with species from warmer, drier conditions expected to perform well under climate change did not enhance overall seedling densities, even in extremely dry seasons. We also found lasting effects on seeded plant survival from the year and season seeded. Our findings suggest that seeded species recruitment across drylands can generally be promoted, regardless of location, through: (1) incorporation of soil surface treatments in addition to seeding, (2) employment of near-term seasonal climate forecasts, (3) hedging bets by seeding in multiple seasons, and (4) seeding with species adapted

for the current climate conditions in the region. These results inform strategies to ameliorate harsh environmental conditions for improved restoration success in drylands, both now and under expected aridification.

Snake snack: eDNA qPCR and DNA metabarcoding assays detect predation on and diet of threatened northern Mexican gartersnakes (*Thamnophis eques megalops*)

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ABSTRACT: The northern Mexican gartersnake (*Thamnophis eques megalops*) is a semi-aquatic snake that inhabits bodies of water such as rivers, ponds, and lakes, of parts of Arizona, Mexico, and New Mexico. It is currently a federally listed threatened species that has experienced significant population declines due to non-native predatory species (e.g., fish) and habitat loss/degradation. Our aims were to determine whether: 1) eDNA can be an effective tool for detecting (via qPCR) predation of the northern Mexican gartersnake by non-native sportfish, and 2) diet of the species can be identified by fecal DNA metabarcoding. We collected and tested largemouth bass (*Micropterus salmoides*) (n=61) and yellow bullhead (*Ameiurus natalis*) (n=1) feces and water samples (n=18) from Lake Roosevelt and lower Tonto Creek. We also collected 23 feces from northern Mexican gartersnakes in this area. We found that using eDNA to detect sportfish predation is a promising method, and that northern Mexican gartersnakes have a diverse diet of amphibians, fish, and reptiles. We also identified 15 arthropod genera, which were either diet items of the snake or their prey. This work demonstrates the utility of an eDNA approach for addressing diverse questions.

Legacy effects of decadal-long drought on biocrust microbes: could microbial legacies slow plant recovery from drought?

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ABSTRACT: Climate projections for many regions include increased frequencies of decadal-long drought. These climate disruptions commonly alter the composition of microbial assemblages, leaving a legacy of persistent changes that may drive the pace of ecosystem recovery. Previous evidence shows that biocrusts can decline with drought, which could have legacy effects on ecosystem recovery through several pathways. We quantified the contributions of microbes and their drought history to ecological recovery from drought for dominant plant species. After ending a seven-year chronic drought experiment in two dry grassland sites in New Mexico, USA, we reciprocally transplanted biocrusts between drought and control plots and

added seeds of the dominant grass species onto the surface of the soil. Sites included the Plains grassland, dominated by blue grama grass and light cyanobacterial biocrusts, and Chihuahuan Desert grassland, dominated by black grama grass with dark cyanobacterial biocrusts. We tracked biocrust community composition and biomass with 16S rRNA sequencing and chlorophyll *a* concentration to monitor success of the microbial transplants. To measure ecosystem recovery, we assessed seedling recovery. In Plains grassland, microbial transplants of biocrusts were successful, as shown by sequencing results. Here, restoration of control microbes increased blue grama recruitment post-drought by 34% relative to microbes with a drought history ($P = 0.0021$), indicating that microbial drought legacies slow recovery. However, when biocrusts were sterilized, blue grama had the lowest recruitment. In Desert grassland, microbes were highly disrupted by transplantation. Surprisingly, cyanobacteria were more abundant in previously droughted plots after transplantation, and plant recruitment was most successful in previously droughted plots with a microbial drought legacy. Our findings demonstrate that successful transplantation of biocrusts after drought can aid in ecosystem recovery and could be a management strategy for recovery from drought in drylands.

Preliminary analysis assessing the applicability of the Managed Fire Decision Framework within the post-2009 policy context

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ABSTRACT: During the wildfire season of 2021, we conducted 48 time-of-fire interviews with Forest Service line officers, fire managers, firefighters, and members of the public. We spoke with people within the context of ongoing wildfires that ranged along the spectrum of available response strategies including managing for resource benefit, confine & contain, and full suppression. The purpose of our research was several fold. First, we wished to explore the current presence and relative magnitude of the decision factors we elucidated from previous research that was only applicable to the pre-2009 wildfire policy context (Fillmore et al, 2021). We also looked for new themes that had emerged in the current fire climate, as well as find those that had faded in relevancy. Other research questions are designed to explore a hypothesis that had arisen out of our earlier investigations, as well as the operational experience of authors, where we observed inherent sociopolitical aversity to managing wildfires for any objective other than full suppression. We aim to update the "Managed Fire Decision Framework" presented in Fillmore et al (2021) to represent the modern fire context. We also hope to investigate our hypothesis that decision makers have a harder time making the decision to manage a wildfire, have a harder time discussing it openly, and feel disincentivized to adopt a strategy that is not attempting to fully suppress the wildfire. Although this may seem like a simple observation to those engaged in wildfire, it has yet to be formalized within a theoretical framework, which our research seeks to do. Although our analysis of the interview data is currently ongoing, we expect to have the preliminary analysis and results available to share by the time of the conference.

Varied long-term responses to climate change among steady states in a historical grazing gradient in southeast Utah

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ABSTRACT: Climate change, grazing history, and invasive plants are commonly noted stressors that contribute to dryland degradation. Previous research suggests that intense historical grazing practices often severely alter the structure and function of semiarid ecosystems due to soil biocrust degradation, decreases in perennial grass cover, and increases in non-native species abundance and distribution. Additionally, recent research across the Colorado Plateau suggests that climate change can also negatively impact soils, biocrust, and vegetation, therefore drawing into question the resilience of currently protected, yet historically grazed semiarid grassland ecosystems. We present findings from a 20+ year study in Canyonlands National Park, Utah, investigating variations in biocrust and vegetation cover across a historical grazing gradient that has created three distinct alternative steady states: a degraded annualized-bare system (previously heavily grazed), a grass-bare system (previous grazed only in winter), and a high biocrust and grass system (never grazed). Within the annualized-bare system, there has been a decline in C_3 grasses after 2001, both for native bunchgrasses and the non-native annual grass *Bromus tectorum*. Conversely, in the grass-bare system and the high biocrust system, native perennial grass cover for both C_3 and C_4 grasses has remained consistent. Late-successional biocrust components (lichens and mosses) are the most abundant in the high biocrust system, yet that ecosystem has observed recent declines in heat-sensitive biocrust species bringing biocrust cover closer to that of the grass-bare system. The grass-bare system consistently has the highest cover of non-native plant species including both *B. tectorum* and *Salsola tragus* (prickly Russian thistle). Future work will continue to build on this analysis by comparing the plot-level data across our gradient to larger landscape patterns to estimate the total landscape area in the three alternative steady states.

Old growth piñon-juniper: projections for the future and variation among trailing edge woodlands

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ABSTRACT: Old-growth piñon-juniper woodlands have endured centuries and may serve as a model for upcoming changes to this vegetation type in future dry/warm climates. Our research suggests varying severe challenges to old-growth woodlands on the southern edges, in the center, and on the northern edges of its distribution. In the Mogollon Highlands of central Arizona, mature *Pinus edulis var. fallax/Juniperus deppeana* stands occur with diverse shrub understory of sprouting chaparral species e.g., *Quercus, Cercocarpus, Purshia, Ceanothus, Artctostaphylos, Garrya*. Post fire trends in the Doce Fire 2013 favor the sprouting shrubs, and soil nitrogen increases due to contributions from actinorhizal species, yet thin-barked piñon is removed from

the system, likely for centuries. Even in unburned stands, the juniper species are experiencing extreme mortality, while piñons appear to be tolerating hot/dry conditions and recruitment is visible. In contrast, old-growth *Pinus edulis –Juniperus osteosperma* stands on drier sites of Mesa Verde National Park lack a vigorous sprouting understory; instead, cheatgrass has invaded recent burns, and little or no conifer re-establishment has been recorded after fires. *Quercus gambelii* sprouts vigorously after fires in shrub-rich wetter woodlands, creating shrublands. Even in unburned stands, piñon has suffered widespread mortality from *Ips confusus* beetles from 2003 into the present, and widespread death of junipers has been occurring recently. At the northern edge of piñon-juniper distribution, old growth woodlands of Dinosaur National Monument have not experienced widespread insect infestations, but where fires have occurred, cheatgrass has become dominant. The northern edge appears, at least at present, to be tolerating current climatic conditions, but is threatened by fire. We predicted a loss of about a third of the old-growth piñon juniper woodlands with type conversion to stable shrub-dominated ecosystems or unstable systems dominated by annual grasses and other non-native species. These trends underscore the value of the remaining old-growth stands.

Mapping and modeling agricultural evapotranspiration and crop water productivity with remote sensing: implications for water savings applicable to the southwest US in rapid environmental change

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ABSTRACT: As the global population grows exponentially, demand for food and water are increasing whereas supply of arable land and accessible fresh water are decreasing. This has become more apparent in the Southwest in recent years especially for irrigation dependent on the Colorado River watershed. A way to mitigate this looming problem is by increasing agricultural Crop water productivity (CWP). CWP is a ratio of crop output over water input for a given area used to measure how productive an agricultural growing site is relative to water used to produce food. To produce more crops with less water, a better understanding of CWP of various crops from field to regional scales is needed. However, methods to map and model CWP at high spatial and temporal resolution while differentiating individual crop types specific to growing season are lacking. Therefore, the objective of this study was to provide a new approach to map and model CWP at high spatial resolutions with remote sensing. In this study Actual Evapotranspiration (ET_a) was calculated to derive crop water use using remote sensing, meteorological data, and cloud computing. This was determined for almonds, cotton, wheat, pistachios, grapes, barley, rice, corn, and walnuts in the Central Valley of California. ET_a was determined using 30m resolution Landsat 8 images implementing novel Evaporative Fraction and Reference Evapotranspiration methods. Water use results allowed for estimating CWP (kg/m^3) with agricultural yield data for selected crops per growing season. From this, the amount of water that can potentially be saved by increasing CWP was determined showing that with only modest increases in CWP significant amounts of water can be saved. The methodology used in this study can be expanded to croplands in other areas such as in the Southwest and Colorado Plateau region to mitigate food and water insecurity in the 21st century.

Climate sensitivity and memory of *Populus tremuloides* differ between trees that survive and trees that die during drought

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ABSTRACT: Increases in drought frequency and severity are causing large-scale forest dieback. Repetitive drought stress could mean climatic conditions of past months or years may be just as important as current conditions for tree growth. Therefore, understanding how current climate affects tree growth (climate sensitivity) as well as past climate's continued effect on tree growth (climate memory) could reveal early warning signs of drought-related mortality. Leveraging a dataset of quaking aspen (*Populus tremuloides*) ring-width measurements from northern Arizona, we compared climate sensitivity and memory, focusing on temperature and precipitation, of drought-surviving trees with those that died. Using a Bayesian framework, we assessed differences in climate sensitivity, as well as the temporal pattern of climate memory using 407 trees across four sites. Across all sites and all trees, wider rings were associated with greater winter precipitation (previous October to current year March), but summer precipitation (April-September) only significantly enhanced growth at two of the four sites. At these same sites, ring widths of living trees were positively affected by higher winter/spring average temperatures; however, trees that succumbed to drought were negatively affected. Furthermore, ring widths from surviving trees were negatively affected by hotter summer temperatures, whereas dead trees were positively affected. This suggests that drought-surviving trees were better able to utilize warmer winter/spring temperatures to jumpstart photosynthesis and mitigate the impacts of hotter summer temperatures. Additionally, spring/winter temperature was most important three years prior to ring formation for living trees, demonstrating longer memory compared with dead trees. Yet, all trees showed a relatively short memory with respect to winter precipitation such that precipitation received during the winter immediately prior to ring formation was most important. Detecting changes in climate sensitivity and memory of tree rings could help illuminate how trees respond to future droughts, leading to better predictions of tree mortality.

A century of vegetation change in sagebrush landscapes of the Rio Grande del Norte National Monument, New Mexico, USA

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ABSTRACT: Sagebrush ecosystems across the western United States have experienced many changes in vegetation cover and composition over the last century. Drivers of change include livestock grazing, energy development, treatments targeted at sagebrush removal, non-native species, changing fire regimes, and climate change. The Rio Grande del Norte National Monument (RGDN), located on the Taos Plateau in northern New Mexico, contains some of the largest sagebrush landscapes in the southwestern United States. Dramatic changes in non-sagebrush vegetation in the region driven by human land use raises questions regarding historical

vegetation composition, changes, and implications for management in the RGDN. Was it always a sagebrush dominated landscape, or was grass historically more common? We combined General Land Office (GLO) surveys from 1881 with sagebrush ages, field vegetation surveys, and modern vegetation maps to test for changes in sagebrush in the RGDN over the last 140 years. We transcribed more than 1,300 GLO surveys that mentioned vegetation for the mile-long section lines in nine townships. We conducted field vegetation surveys at 339 points along 11 section lines and collected tree ring samples from 120 sagebrush along seven section lines. Sagebrush presence across the study area increased from 15.8% in 1881 to 79.2% in 2019 (a 64.3% increase), ranging from increases of 39.9% to 93.1% among the townships. Only two out of 653 section lines lost sagebrush between 1881 and 2019. Tree-ring dates from 115 sagebrush indicate a maximum age of around 87 years, synchronous regeneration among sections, and sagebrush regeneration in every decade since the 1930's.

Eras of wildfire policy: the history of federal and interagency management of wildfires for restoration

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ABSTRACT: Federal wildland fire policy has undergone many transformations in the last century, from total fire suppression through the first half of the 20th century to allowing fire, where feasible, to play its natural role in the ecosystem in the 21st. This is reflected in recent upgrades to fire managers' toolboxes, first with prescribed fires and later with managing natural ignitions for restoration. The latter of these has gone by many names; policies have used "resource objective fires," "managed fire," and "wildland fire use," while professionals and the public have sometimes (mistakenly) called it a "let burn" strategy. Inconsistency in terminology and implementation of this tool has created a need to characterize the current policy landscape in order to better understand how it drives decision-making in fire management. Previous research documented and categorized these transformations into the "Eras of Wildland Fire Use." We extend this concept to the present day by compiling relevant documents, including federal laws, interagency policies, individual agency guidance, handbooks, manuals, standards, and director's orders and letters from 2001 to 2022. We organized them chronologically and found that two new Eras emerged: the Discrete Fire Classification Years (2001-2009) and the Operational Flexibility Years (2009-today). With an increasing focus on regional/local planning/decision-making, today's policies give a wider array of options and individual discretion for managers and agency administrators. These, combined with orders from fire agency chiefs, can create opposing forces that limit how often these tools are used with each passing fire season.

No deficits here: strategizing for successful science communication in an age of information overload

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ABSTRACT: Ample research has shown that the so-called "deficit model" of science communication—in which audience members basically act as vessels waiting to be filled with information—does not hold. Today's science communication landscape is a complex one in which information is produced and disseminated by numerous actors and received in many different ways by diverse audiences; in this system, the transmission of particular messages is readily subject to miscommunication. This introductory symposium session will provide a brief overview of the contemporary science communication landscape, with a focus on how scientists and science communicators can shape their work by focusing on equity and inclusion. It will lay the groundwork for the remainder of the symposium by providing an overview of what is currently known about how members of various publics receive science information, and how the challenges of "translation" can result in miscommunication. The presentation will include brief examples of how innovative science or health communication efforts have attempted to address challenges through culturally appropriate messaging and inoculation against misinformation.

An innovative strategy to assess Colorado River Basin stakeholder science needs related to drought

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ABSTRACT: The Colorado River Basin (CRB) is experiencing widespread drought conditions. As part of the United States Geological Survey (USGS) Actionable and Strategic Integrated Science and Technology pilot project in the CRB, the USGS developed an innovative strategy, based on an engagement framework, to identify stakeholder science needs and better co-produce science. For this framework, a stakeholder includes any agency, organization, group, or individual that addresses issues related to drought science, is interested in the CRB Earth-system, or both. To identify stakeholder science needs, we conducted a systematic review of more than 200 stakeholder's public content. From this review, we compiled more than 480 stakeholder science needs, and associated these needs to relevant drought-focused Earth-system themes and topics and identified integrated-science opportunities and science priorities. Each science need was linked to an average of 3 unique Earth-system science themes. The theme most frequently linked was surface and groundwater, appearing in 288 entries, followed by the themes human, flora, fauna, and atmospheric, which appeared in 241, 189, 174, and 154 entries, respectively. In addition, each science need was associated with an average of 6 unique science topics, with a total of 73 unique science topics identified. Frequently used science topics included climate and weather processes, effects of changing land-use patterns on ecological systems, streamflow, habitats and wildlife, hazards including wildfire, and water quality and water use. These stakeholder analyses allow the USGS to prioritize stakeholder science needs by identifying common science themes and topics that are shared by multiple stakeholders. The high degree of overlap in Earth-science themes and topics indicates that an integrated science research approach representing interactions among processes and potential unknown linkages would benefit stakeholders. Additionally, identifying shared science needs among stakeholders would

encourage co-produced activities where shared data and resources can be integrated towards a common goal.

Transforming statewide data on woody biomass resources into utilization through scientific support and funding opportunities in Colorado

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ABSTRACT: Forests across the Southwest are subject to intensifying impacts from the interaction of drought, pathogens, and wildfires. Simultaneously, the rising costs of management activities continues to constrain implementation of stewardship and management plans, especially for projects comprised of small diameter trees. In light of the challenges and opportunities of managing areas with abundant low value woody material, the Colorado State Forest Service is developing a Statewide Assessment of Forest Biomass observed through convergent lenses of wildland fuels, wood resources, and carbon storage. An anticipated outcome of the assessment includes recommendations connecting data to increased opportunities for biomass utilization and the intertwined outcomes of reducing fuel loading, bolstering the wood products industry, and bettering forest health. To catalyze action, the information gathered by the Assessment is coupled with on-going work through the CSFS Forest Business Loan Fund via small Biomass Utilization Grants. Investing in the wood products industry as an outlet for woody material generated by management actions may change the cost per acre for completion of projects and could therefore enable further management actions. This support is extended to conventional wood products and newer utilization avenues. It also encompasses utilization of typical feedstocks while seeking options for non-timber woody species such as Juniper and Scrub Oak. Ultimately, connecting data, to science-based forest management practices and outlets for biomass utilization is an important part of sustaining healthy forests in Colorado.

The effect of various rates of compost addition on aggregate stability and infiltration rate

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ABSTRACT: Some dry rangelands have been degraded due to past management practices and face challenges in restoration in light of changing climate. Active restoration may be required to build productivity and resilience of grasslands in order to support the people, livestock, and wildlife that rely on these regions. Compost applications have shown promise on rangelands in California, but little is known about the effectiveness of compost for improving soil health and water relationship in dry, monsoon-driven environments such as the Chihuahuan Desert and southern Great Plains grasslands. Additionally, for compost to be used at larger scales, we must optimize applications to meet the producers' goals and constraints. Thus, we measured and compared aggregate stability using a dip test and infiltration rate of the second inch across three

different compost applications of 0.25", 0.5" and 1" (n=3) at Sol Ranch in Wagon Mound, NM and Polk's Folly Farm in Cedar Crest, NM. Each application rate was spread onto two replicate plots and a no-compost control was included in the comparisons. At Sol Ranch, as compost amount increased from control to 1", aggregate stability increased by 30%; At Polk's, there was not a change in aggregate stability with compost addition (interaction compost x site $P < 0.05$). Infiltration rate decreased at both sites by at least 5 minutes from control to 1" addition (compost $P < 0.05$). Our results show that compost addition can increase soil health and reduce water runoff and soil surface evaporation with the largest amount of compost application having the biggest effect. This research offers reproducible methods to improve upon the rangeland outcomes of past land management practices and help adapt these rangelands to a changing climate.

Impacts of climate change and Grand Canyon National Park vegetative ecosystems: a case study using phenology and citizen science

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ABSTRACT: In 2013, the inaugural George Melendez Wright Climate Change Intern initiated the project: Local Touchstones: Phenology and Climate Change to gather information on how climate change is impacting ecological indicator tree species at Grand Canyon National Park. Since the establishment of this project, the vegetation and interpretation programs at the park have monitored and collected data on the phenology of Gambel oak (*Quercus gambelii*) to determine if and how climate change is influencing shifts in life stages of trees at the South Rim of the canyon. Using historical climate data collected at 6 weather stations at the South Rim, we designed and implemented a three-step approach to determine that there is a relationship between temperature accumulation and the emergence of different phenophases (life stages such as breaking leaf buds, fruiting, dropping leaves, etc.). This analysis leads us to predict that with warmer temperatures and other compounded impacts from climate change, such as drought and decreased snowpack, we can expect to see phenophases emerging earlier in the season for Gambel oak. Using this hypothesis, we also revisited riparian ecosystems in the inner canyon to revitalize monitoring for Fremont cottonwood (*Populus fremontii*) to set park staff up for future analyses in water-rich ecosystems in a drought-prone climate, utilizing the same three-step approach that was used in this stage of the Local Touchstones project. An important component of the Local Touchstones project and other phenology projects involve citizen science, so we have also created a framework to encourage more citizen science at the rim as well as in the inner canyon. Finally, using the knowledge we learned from this study and a literature review from other National Parks' phenology studies, we have established management suggestions for park staff moving forward for ecological management decisions.

Influence of drought, warming and fire on the mycorrhizal fungi associated with pinyon-juniper woodlands

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ABSTRACT: Climate change has significantly altered pinyon-juniper woodlands by increasing drought frequency and intensity and creating conditions that promote stand-replacing fires and subsequent establishment of non-native grasses. The beneficial mycorrhizal fungi that associate with pinyons and junipers can improve the resilience of their host plants to these changes by improving access to limiting soil resources, but they are also affected by them. In this talk, I synthesize the results of more than two decades of study examining how the mycorrhizal fungi of pinyon-juniper woodlands respond to drought, warming temperatures and fire. The warming, drying conditions of the past two decades are associated with a sharp decline in the diversity of the ectomycorrhizal fungi associated with pinyon pine, with a shift in community composition towards poorly studied ascomycete fungi that may differentially benefit certain plant genotypes. While mycorrhizal fungi can survive in the soil for many years following drought-related tree mortality, their species composition and diversity are altered, with negative consequences for tree growth. Similarly, fire has only short-term effects on the abundance of the arbuscular mycorrhizal fungi associated with junipers and native grasses, but alters their species composition in the longer-term. These changes in species composition can negatively affect native plant growth and reproduction, while having no effect on the performance of cheatgrass, a particularly problematic non-native grass. Taken together, these studies show consistent effects of climate change on mycorrhizal fungal diversity and species composition, many of which have negative consequences for host plants. Management and restoration strategies that consider both plants and their fungal partners may improve the resilience of the above- and belowground components of pinyon-juniper woodlands.

Soil biota responses to forest thinning and prescribed fire in Valles Caldera National Preserve, New Mexico: lessons from three studies.

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ABSTRACT: Soil biota are key to maintaining healthy and productive forests, but are often overlooked when planning restoration of frequent-fire-adapted forests in the Southwest. We summarize findings from three studies examining effects of thinning and prescribed fire on microinvertebrates, fungi, and soil physical properties in Valles Caldera National Preserve, New Mexico. In the first study, we measured microarthropod and nematode abundances across untreated, thinned only, or thinned/burned ponderosa pine forest management units. We found

that mites, but not nematodes or collembolans, were reduced ~60% in a thinned/burned management unit relative to adjacent untreated and thinned only management units. Abundances were correlated with easily-measured indicators of habitat and resource availability, which may assist land managers in evaluating treatment implications for soil fauna. In the second study, we subjected volcanic loamy soils in a xeric mixed conifer forest to one, three, or nine passes from a feller buncher (a common type of tree harvester) to assess how disturbance from heavy logging machinery affects soil physical properties and nematode communities, with the aim of determining thresholds for negative impacts. Eight months after treatment, we found that nematode communities were less impacted than soil physical properties by harvester passes. Finally, in the third study, a field mesocosm experiment, we investigated the functional ramifications of faunal and fungal community differences in restored and untreated ponderosa pine forests. Our manipulation of soil mesofauna communities (comprised mainly of mites and collembolans) indicated that mesofauna can influence decomposition indirectly by affecting the functional composition of fungal communities (the ratio of ectomycorrhizal to saprotrophic fungi), but that this phenomenon may be dependent on ecological context: we detected an effect of mesofauna on fungal communities, and of fungal functional group ratios on decomposition, only in the thinned/burned management unit. We will present management recommendations informed by our findings.

Functional diversity of native seed mixes increases native plant competition with *Bromus tectorum* (cheatgrass)

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ABSTRACT: Winter annual grass *Bromus tectorum* ('cheatgrass') has invaded over 54 million acres of western United States drylands, decreasing ecosystem functioning by reducing native plant diversity and increasing wildfire risk. Native seeding efforts are commonly used to increase native plant cover in cheatgrass-infested areas yet are often unsuccessful. As such, new strategies are needed. Trait-based approaches may be used to inform design of native seed mixes with greater competitive traits and potential biotic resistance. Yet, we have limited understanding of how native seed mix functional diversity and traits affect restoration outcomes. Using a full-factorial greenhouse experiment, we evaluated the effects of increasing native seed mix functional diversity on the recruitment and growth of native plant species and cheatgrass. We employed three native seeding treatments: perennial grasses (G), forbs (F), perennial grasses and forbs (G+F) with and without cheatgrass (-E, +E). We also measured plant traits for all species in our study (i.e., root: shoot ratio (RSR), specific leaf area (SLA), specific root length (SRL), and above and belowground biomass) and analyzed how trait community weighted means (CWMs) related to observed competitive outcomes between the native plant community and cheatgrass across treatments. We asked: (1) does increasing native functional diversity increase native plant recruitment and decrease cheatgrass recruitment and growth? And (2) do native plant functional traits mediate these outcomes? Our results indicate the seed mix with the highest functional diversity (G +F) had the highest native plant diversity and lowest cheatgrass biomass. However, traits values such as SRL had the highest similarity with cheatgrass, while as communities SLA and RSR increased, cheatgrass biomass decreased among all treatments. Our results suggest

functional and trait-based approaches to seed mix design could be important to improving weed management and restoration outcomes in drylands.

Invasive *Tamarix ramosissima* reduces seedling recruitment in the native foundation tree *Populus fremontii*

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ABSTRACT: We investigate how interactions between a widespread invasive species, *Tamarix ramosissima* (tamarisk), and a native foundation tree species, *Populus fremontii* (Fremont cottonwood), alter the establishment and survival of Fremont cottonwood seedlings, a critical life history stage for recruitment. Fremont cottonwood is a foundation tree species of southwest riparian communities and is quickly being displaced by invasive tamarisk. Few studies have examined if there is a potential for rapid evolution in long-lived native foundation tree species' response to exotic species invasion. To examine how Fremont cottonwood responds to exotic invasion by tamarisk, we measured differential recruitment and survivability in successive seed germination stages of half-sib families originating from paired "native" (without tamarisk) and "invaded" (with tamarisk) sites along three rivers reciprocally transplanted in local native and invaded soil. Three patterns emerged. One, overall recruitment, performance and survivability of cottonwood seedlings is significantly reduced when they are exposed to invaded soil types. Two, maternal-half sib families originating from invaded sites experienced significant reduction in recruitment and survival when compared to families originating from native sites. Third, seedlings from maternal half-sib families originating in invaded sites performed significantly better on invaded soil than seedlings from maternal half-sib families originating from native sites. These results lead us to conclude that tamarisk invasion reduces Fremont cottonwood recruitment and fitness. Additionally, given that invaded families perform better than native site families on invaded soil, we also conclude that there is a potential for rapid evolution of Fremont cottonwood in response to invasive tamarisk.

Classifying pinyon-juniper communities using ecological sites

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ABSTRACT: Pinyon-juniper communities occur throughout the west, transitioning from grasslands or shrublands at lower elevations, and to ponderosa pine forest at higher elevations. Over the past 300 years there have been changes to the ecological dynamics of pinyon-juniper communities. The most obvious change across the landscape is the increase of pinyon and juniper densities and expansion across the west. Understanding where species of juniper and pinyon have invaded grasslands or increased within existing woodlands or forestlands is essential

to managing the land within its capabilities and limitations. The Natural Resources Conservation Service (NRCS) uses ecological sites as a site-based classification system to describe ecological potential and ecosystem dynamics of the land area. These ecological sites provide a framework for classifying and describing a distinctive kind of land with specific abiotic and biotic characteristics that differ from other kinds of land in its ability to produce specific types of plant communities and respond to management or disturbance processes. Decades of juniper and pinyon expansion from historic distribution and densities has made classifying present plant communities a challenge. Because of this, present plant communities rarely have a high degree of similarity to the historic plant community. Thus, ecological sites are delineated where land units share recurring soil, landforms, geological, and climatic characteristics. Using these physical attributes and local soil site information the ecological site can be identified without vegetation on the site. Using the NRCS ecological site approach can aid in classifying and evaluating pinyon-juniper communities.

How far can NEPA requirements bend before they're broken? The questionable case of Arizona Snowbowl capacity, consultation, and cumulative effects

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ABSTRACT: Arizona Snowbowl is located within the San Francisco Peaks Traditional Cultural Property, which is part of the cosmology of at least 14 Tribes. Operation of the resort, including artificial snowmaking with 100% reclaimed water, is extremely controversial and offensive to many Tribal members and also many non-Indigenous Flagstaff residents. Since the publication of its 2005 Environmental Impact Statement (EIS) and Record of Decision (ROD) for Arizona Snowbowl Facilities Improvements, the Coconino National Forest (CNF) has made several piecemeal decisions that allowed Snowbowl's daily visitation to increase with no environmental or safety analysis, nor public notification or Tribal consultation. These decisions potentially violate the resort's Special Use Permit (SUP), the National Environmental Policy Act (NEPA), and National Historic Preservation Act (NHPA). The resort's SUP requires that "The overall development shall not exceed that capacity without further environmental analysis and documentation through the appropriate NEPA process," and the 2005 EIS stated at least 11 times that parking and lack of a shuttle would limit skier capacity. Instead, a combination of factors including a shuttle and new parking lot likely massively increased capacity during the 2020 COVID-19 pandemic. The Forest Service claims cumulative effects were analyzed in a document that actually said, "the project… does not change use or capacity in any way and thus would not realistically result in cumulative effects."

The role of conservation organizations in science and information sharing

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ABSTRACT: Non-governmental organizations (NGOs) hold a unique role in science and information dissemination. As special interest groups, we are trusted by those whose interests we

are trying to protect, and we have a strong obligation to the facts. To be effective as environmental advocates, we must: relay relatable and accurate information to the public so that they can take action to protect their values at risk; share concise, referenced information with elected officials so they can communicate with their colleagues and create beneficial policies; and convey relevant science to land managers and agency officials to support agency actions and regulatory permitting. NGOs employ an array of techniques to disseminate information that go beyond typical science communication and invite the voices of those affected by agency decisions. These can include interpreting scientific jargon into layperson terms and sharing information at events, through media outreach, on social media, in film and infographics, sending action alerts, writing official comments on agency actions, issuing sign-on letters, and other methods that make important information easier to access, relate to, and use.

Recovery of a native riparian tree following removal of an invasive competitor

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ABSTRACT: Invasive plants, by definition, displace native species, however this does not necessarily mean that their removal leads to competitive release and thus recovery. The lack of such recovery can have cascading effects through ecosystems. In riparian areas of the American Southwest, removal of invasive *Tamarix* spp. trees has had deleterious impacts on habitat availability for the endangered Southwestern willow flycatcher (*Empidonax extimus trailii*, abbr. SWFL), which nests readily in *Tamarix* when native *Salix* spp. (willow) canopy is not present. However, previous research has found conflicting results regarding recovery of native plants when *Tamarix* is removed, and none have specifically focused on *Salix*. Using a multi-state dataset of *Tamarix* removal sites in three different watersheds, we asked the following questions: (1) Does removal of *Tamarix* lead to the establishment of *Salix*? (2) Which *Tamarix* removal methods have the best outcomes in terms of *Salix* cover? (3) What environmental conditions are required to implement a successful *Salix* restoration effort? We compiled data on vegetation response to *Tamarix* removal consisting of plant cover, soils, and geographic conditions in 243 sites where *Tamarix* had been subject to active removal and/or biocontrol and 172 reference sites. We examined the response variables of total cover of all *Salix* species as well as *S. exigua* (narrowleaf willow) specifically, which is the most dominant *Salix* species in the study extent. We used linear mixed models with backward stepwise selection to predict response of Salix cover, both final-year outcomes and change over time. We found that (1) while decreased *Tamarix* cover is associated with an increase in *Salix*, the increase does not compensate for the overall losses in canopy cover. (2) We did not find a significant difference in *Salix* cover among *Tamarix* removal methods or relative to negative reference sites; however, sites where herbicide was applied at any point had higher *Salix* cover. (3) We found that *Salix* cover was greater when soils were sandier and less saline, and under cooler and wetter climate conditions. Our data reflect the fact that *Salix* and *Tamarix* occupy distinct environmental niches. Our findings suggest that *Tamarix* removal does not necessarily lead to favorable outcomes for SWFL conservation but that outcomes can be improved by focusing on sites more likely to promote *Salix* growth based on environmental characteristics.

Effects of the 2021 federal flows on riparian plant vegetation index and actual evapotranspiration in the Colorado River Delta, Mexico.

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ABSTRACT: Minute 323 is a Binational Agreement between the US and Mexico which resulted in the delivery of a federal flow in 2021. The US-Mexico border at Morelos Dam is considered to be "km 0" of the Colorado River delta. A total of 28,641 acre-feet (35.3 mcm) were delivered in Mexico at the top of Reach 4 at km 63 to Reach 7 at km 106 for a period of 164 days. The goals of these flows were to create ecological and social benefits to restored and unrestored areas. Using two remote sensing metrics, the Landsat Enhanced Vegetation Index (EVI2) and actual evapotranspiration (ETa) (estimated using Landsat EVI2 and ground-based weather station data to determine ET(EVI2)), we analyzed the vegetation response of greenness and water use to the water deliveries. We used two sources to estimate ETa: point data from weather stations and DAYMET (gridded, 1km). We found ETa calculated using point data was higher than when using DAYMET but the relative differences among sites were the same. In Reaches 4-7 only, EVI2 increased 3.5% and ETa decreased 4.3%. In Reach 4 (restoration sites) EVI2 increased but varied from 0- 7%. They also showed spatial variation in EVI2. In the summer of 2021, more pixels had high EVI2 values (>0.28) than in 2020. In restoration sites, ETa decreased 5% and 3% in two sites (Chausse, Cori) between 2020 - 2021 and increased 5% at site CILA. For Reaches 4-7 only, the Federal Flow did not contribute to greenness as much as the Pulse Flow in 2014 (3.5% vs. 5.5%) and has no effect on ETa. The lack of effects on ETa in 2021 could result from lower ETa values driven by weather parameters and a lower effect on greenness could be related to differences in the inundation patterns between both flows.

Riparian seedling establishment following an environmental flow release combined with active revegetation

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ABSTRACT: Conservation of cottonwood-willow forests is a priority for many land managers along the Colorado River. Since the early 1990's, environmental flows have helped stimulate recruitment of cottonwoods and willows along the Bill Williams River (BWR), a tributary to the lower Colorado R. in western Arizona, regulated by Alamo Dam. We conducted a field experiment to assess effects of an environmental flow release combined with planting *Populus fremontii* rooted seedlings on riparian seedling establishment along the BWR. A high flow peak, followed by a gradual flow recession, was released from Alamo Dam in March 2018. This release was expected to produce nursery sites with conditions suitable for cottonwood germination and establishment. We selected four ~1 km-long reaches with different hydrogeomorphic properties that could lead to different seedling responses. Within each reach,

we established 12-30 experimental sites, each of which included a pair of 10 m^2 plots located on a distinctive fluvial landform. In one of the plots, we planted 20 rooted seedlings during the flood recession, while the other plot ("control") was unplanted. Survival of planted seedlings six months after planting was ~55-85% in three of the reaches, but only ~10% in the driest reach. Volunteer *P. fremontii* established in all but the driest of the reaches, with higher density along two of the reaches that had perennial low flow channels. Planted plots had 2-13 times greater percent foliar cover of *P. fremontii* than control plots in the three reaches with volunteer seedlings. Planting *P. fremontii* immediately after an e-flow release resulted in greater density and growth relative to control plots. Because significant volunteer seedling establishment occurred along low flow channels, future planting could focus on selected high flow channels, where e-flow releases are less likely to be effective on their own, but where soil moisture is sufficient to permit establishment.

Convergence of riparian successional trajectories 11 years after a large flood and *Tamarix* biocontrol

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ABSTRACT: The interplay of disturbance and environmental stability can drive vegetation dynamics. Disturbance reduces vegetation abundance and stability favors vegetation development. However, depending on the nature and regime of the disturbance agents involved, the successional trajectories of each system can vary greatly. In riparian systems, natural disturbance is largely manifested through flood-driven fluvial processes, but other disturbance forces potentially influencing vegetation dynamics, such as fire and herbivory, have the potential to significantly influence vegetation dynamics. We studied the successional trajectories of plant communities during a period of relatively low fluvial disturbance: an 11-year period after a 40-yr flood event that in 2010 caused significant disturbance to the floodplain vegetation along the lower Virgin River in Nevada and Arizona. Shortly (0-2 years) after the large flood, a second large disturbance event of a different nature began: extensive defoliation of the dominant non-native shrub, *Tamarix,* by a defoliating biocontrol agent, *Diorhabda*. In 2021, we resampled vegetation and topography in 450 plots that we previously monitored in 2010, 2012, 2015 and 2017, along 24 field transects distributed across five river reaches. We found that the successional trajectories of riparian vegetation on landforms that experienced either sediment erosion, deposition, or no change in elevation with the 2010 flood tended to converge to plant communities dominated by the native shrub *Pluchea sericea* (arrowweed). Cover of *Tamarix* recovered slightly, while desirable *Populus* and *Salix* spp. (cottonwoods and willows) remained at relatively low abundance in the system. The riparian plant community also seemed to be highly sensitive to precipitation patterns, with species richness, diversity and cover of herbaceous species, particularly annual species, peaking in wetter years. The converging plant composition described here will determine important ecological functions of riparian vegetation, for example the use by wildlife, including bird species of conservation concern.

Resist-Accept-Direct (RAD): a framework for the 21st century natural resource manager

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ABSTRACT: An assumption of stationarity—i.e., "the idea that natural systems fluctuate within an unchanging envelope of variability" (Milly et al. 2008)—underlies traditional conservation and natural resource management, as evidenced by widespread reliance on ecological baselines to guide protection, restoration, and other management. Although ecological change certainly occurred under the relatively stable conditions of the recent past, the nature of change under intensifying global change is different; it is unidirectional, and rapidly pushing beyond the bounds of historical variability. In the past, a manager could plausibly work to reverse or mitigate many stressors or their impacts to approximate pre-disturbance ecological conditions, but now accelerated warming, changing disturbance regimes, and extreme events associated with climate change reduce that potential. Indeed, even 'holding the line' in the face of inexorable human-caused change is ever more difficult and costly. Thus, the convention of using baseline conditions to define goals for today's resource management is increasingly untenable, presenting practical and philosophical challenges for managers. As formerly familiar ecological conditions continue to change, bringing novelty, surprise, and uncertainty, natural resource managers require a new, shared approach to make conservation decisions. How, for example, should a manager respond to projections of loss of the Joshua tree from much of its current range, or to the emergence of new and different vegetation communities after a large fire event? The RAD (Resist-Accept-Direct) decision framework has emerged over the past decade as a simple tool that captures the entire decision space for responding to ecosystems facing the potential for rapid, irreversible ecological change. It assists managers in making informed, purposeful choices about how to respond to the trajectory of change, and moreover, provides a straightforward approach to support resource managers in collaborating at larger scales across jurisdictions, which today is more urgent than ever.

Can rocks solve all of our problems?

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ABSTRACT: Grasslands are essential natural and agricultural ecosystems that encompass over one-third of global lands. However, land conversion and poor management have caused losses of these systems which contributed to a 10% reduction of net primary production, a 4% increase in carbon emissions, and a potential loss of US $42 billion a year. It is, therefore, important to restore, enhance and conserve these grasslands to sustain natural plant communities and the livelihoods of those that rely on them. We installed low cost rock structures (media lunas) to assess their ability to restore grasslands by slowing water flow, reducing erosion and improving plant establishment. Our treatments included sites with small and large rock structures that were

seeded with a native seed mix as well as sites with no seed or rock and sites with only seed addition. We collected summer percent cover for plants, litter, and rock and spring seedling count data. We also collected soil for nutrient, moisture, and microbial analysis. Within the first year, we found no change in plant cover between rock structures of two rock sizes. We did find, however, an increase in soil moisture, litter, fungal richness, and spring seedling germination within the rock structures, despite a historic drought. This work demonstrates that rock structures can positively impact plants and soils of grasslands even within the first year. Our results suggest that managers should seriously consider employing these low-cost structures to increase short-term plant establishment and possibly, soil health, in grasslands.

Hedging bets in an erratic aquatic environment: how do branchiopod crustaceans in potholes deal with unpredictable timing and volume of precipitation?

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ABSTRACT: Potholes (bedrock basins) capture precipitation, forming ephemeral aquatic ecosystems that may support invertebrates, including branchiopod crustaceans (e.g., fairy shrimp and clam shrimp). After a rain event, pothole organisms quickly activate, having only the time the pothole holds water to mature and reproduce before the aquatic environment vanishes. Branchiopods survive dry periods as desiccation-tolerant eggs in the sediment. Timing and amount of precipitation are highly variable. Rain collected in a pothole triggers hatching but may not last long enough to complete life cycles. This situation provides selection pressure for "bet hedging" adaptations, where not all eggs hatch under the same conditions. We reared *Branchinecta packardi* (fairy shrimp) and *Leptestheria compleximanus* (clam shrimp) from pothole sediment and isolated female and male pairs in jars. When we could see eggs on the bottom of jars, we removed the adults, counted eggs in each clutch, then allowed the water to evaporate. Seven days after the last water was visible, we added 100 mL of distilled water to each jar. We counted the number of hatchlings 24, 48, and 72 hours after water was added, then poured off almost all water and allowed the remaining eggs to dry. Eggs were again held for 7 days after all water was gone, then distilled water (100 mL) added; the cycle was repeated 10 times. Seven clutches of *B. packardi* eggs and 17 clutches of *L. compleximanus* were produced. Numbers of eggs and hatchlings per clutch varied considerably for both species. Most hatching occurred in the first 24 hrs of the first wet cycle for both species, but no eggs of either species hatched after the fifth wet cycle. Other studies also found most hatching occurred in the first few wet cycles but hatching continued through eight to sixteen wet/dry cycles. Implications of extended hatching delays for population maintenance in unpredictable environments will be discussed.

Delta dynamics: reestablishment of river channels in the deltas of reservoirs

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ABSTRACT: Recent drought has resulted in the dramatic lowering of the two largest water-storage reservoirs in the western United States: Lake Powell and Lake Mead. These drops in reservoir elevations have resulted in the re-emergence of over 100 km of the Colorado and San Juan rivers at the upstream end of Lake Powell and over 80 km of the Colorado River in Grand Canyon at the upstream end of Lake Mead. Upon reservoir lowering, the rivers have incised into lake and delta sediments. In places, this incision causes the river to establish a course different than the path of the pre-reservoir channel and has resulted in the formation of two well-known waterfalls: Paiute Falls on the San Juan arm of Lake Powell and Pearce Ferry Rapid on the Colorado River at the upstream end of Lake Mead. We describe recent observations of the bed and water surface profile of the Colorado River near the mouth of the Dirty Devil River where a knickpoint has developed and a future waterfall may be imminent if water levels continue to drop. These reservoir-waterfalls have important implications for river and reservoir management. As knickpoints, they control the upstream energy gradient and affect the rate and pattern of evacuation of exposed reservoir delta sediments, thus affecting river dynamics and river ecosystems far upstream. They also have immediate impacts in the vicinity of the knickpoint on navigation, which affects decisions regarding expensive infrastructure such as boat ramps. They also create ecological barriers that impact the migration of native and nonnative fish.

Defending the sacred: uniting and living under natural law

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ABSTRACT: The Dine' Be' Nanagha' Yee' Da'Aho'ta' (Dine' Medicine Men Association, Inc.) is an established non-profit organization incorporated with the Navajo Nation since the early 1970s. We are an established and recognized organization of the Navajo Nation, we neither function with remuneration, nor as an established operation with specific sites. We are a membership of traditional apologists, spiritual Dine' hataalii (healers), prophets, cultural educators, wisdom keepers, medicine people, elders and traditionalists who have come together willingly to maintain, protect and promote the Dine' way of life, intellectual knowledge, right to self-determination and the fundamental right to worship the Great Spirit according to our sacred (holy) protocols. The extreme need for humans to reunite under the immutable Laws of Creation is evident in the extraordinary destructive strength and frequency of natural disasters we see today. How are we, five finger ones, going to accomplish this? Thoughts of co-management and what that means have been introduced. Discussions of what free, prior and informed consent would look like for the Original Nations and Peoples of this land. As we seek solutions what can the Dine' way of life offers towards achieving peace?

Variations in hydrology and vertical transport of metals in the unsaturated zone across the mine life cycle at breccia-pipe uranium mines, Arizona, USA

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ABSTRACT: There is a critical information gap about the processes that control transport of mixed-metals in shallow soils. This study characterizes fluxes of water and metals to identify the primary mechanisms of transport in soils in the Arizona strip, north of the Grand Canyon. Study sites include four breccia-pipe uranium deposits with mining histories of no extraction (EZ2), recent production (Arizona 1), reclamation (Pinenut), and post-reclamation (Kanab North). Sediment cores were collected around the perimeter of the mine yards for analysis of bulk metals concentrations and soil physical and hydrologic properties. Dissolution experiments were conducted to characterize solubility of metals in surface soils including As, Cd, Co, Cu, Mo, Ni, Pb, Sb, Tl, U, and Zn. To distinguish transport of solid versus dissolved phases, an end member mixing analysis was applied to profiles from undisturbed locations. The majority of transport occurred in solid particles in the upper 30 cm. A Fickian-diffusion model of mechanical mixing with historical inputs predicted similar rates of vertical mixing among the sites. Mixing rates were at or above those previously estimated in other studies. Numerical models of soil-matrix flow using decadal weather records and calibrated to profiles of moisture content, matric pressure, and Cl concentration predicted water losses to deeper layers that were minor (~1% of precipitation) and sporadic (e.g., three deep percolation events in 40 years), indicating limited potential for downward transport of dissolved uranium and other soluble metals. Implications of this study include: (1) soil mixing of airborne dust from mine operations sequesters metals in soil and retards further aeolian transport, (2) further study is needed to compare biotic and abiotic processes affecting soil mixing and migration of metals, (3) downward movement of dissolved metals in soil-matrix water is sporadic (e.g., at intervals of decades), posing challenges to characterizing long-term losses to deeper zones.

Soil measurements show greater compaction on reclaimed or abandoned oil pads compared to unimpacted sites

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ABSTRACT: The Colorado Plateau is a significant region for energy development, with over 100,000 active, abandoned, or reclaimed oil and gas wells. While oil and gas development in the region is economically important, the reclamation of impacted lands is also critical and uniquely challenging given the dry climate and variable soils of the Plateau. Here, we report results of a survey of 134 reclaimed or abandoned well pads across Utah, Colorado, and New Mexico. Pads were sampled in the summer of 2020 and 2021; sampling was designed to assess the ecological recovery of lands utilized for energy development, as well as the degree to which reclamation practices can improve outcomes. One particularly challenging legacy of oil and gas development is the use of heavy machinery, which we hypothesized could lead to increased soil compaction and thus alter hydrologic processes and contribute to low plant and ecosystem recovery rates. We

assessed soil compaction on pads by measuring soil bulk density, penetrometer resistance, and hydraulic conductivity (as assessed with mini-disk infiltrometers). We collected data both on and off-pads to compare impacted and non-impacted conditions. Preliminary results indicate that on-pad sites are compacted relative to off-pad sites: penetrometer resistance and bulk density was significantly greater ($p < 0.05$) at both 0-5 cm and 0-10 cm depth on pad. Hydraulic conductivity is generally reduced on-pad, although the difference is not statistically significant. These results are consistent regardless of pads' status as reclaimed or abandoned, suggesting that many oil and gas pads remain compacted even after reclamation. Given the potential impact of compaction on revegetation, erosion control, and ecological recovery, more research on strategies for mitigating compaction on oil and gas pads is needed, as well as study on the relationship between compaction and hydraulic conductivity.

Modernizing data telemetry efforts for important riparian resources in the Grand Canyon

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ABSTRACT: The Grand Canyon Monitoring and Research Center (GCMRC), as the science provider to the Glen Canyon Dam Adaptive Management Program (GCDAMP), monitors the status and trends of resources downstream of Glen Canyon Dam in support of ongoing adaptive management experimentation. Similar to GCMRC's role in providing long-term monitoring for the Colorado River ecosystem, the Center often responds to more immediate needs of GCDAMP stakeholders with regard to current status of important resources. The remote environment and extreme terrain of the Grand Canyon region presents many challenges for collecting information about Colorado River resources, both in tradition methods and in acquiring data through remote access. GCMRC's Geospatial Science and Technology project has taken the lead in modernizing existing data telemetry efforts in order to address the growing need from stakeholders while aligning our efforts with emerging trends in information technology. To this end, project staff have explored new technologies that are now available for improving access to data in near real-time. In this presentation we introduce advances in data telemetry that have been achieved recently for the Science Center, highlight new tools for exploring data online, and address future possible directions that can be pursued.

Assessing climate change challenges at Grand Canyon National Park - what to do...and not do?

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ABSTRACT: Grand Canyon National Park is an iconic landmark and World Heritage Site, visited by millions of people each year. The park is also a large and complex place, with an elevational range from 720 m at Phantom Ranch to 2,400 m at the North Rim. The diversity of natural resources within Grand Canyon reflects the elevational range and variety of vegetation

communities of the park. Cultural resources are also extensive and varied, representing thousands of years of occupation and continue to hold strong connections with associated tribes in the region. Assessing climate change impacts and management options to address those challenges will need to be placed within the context of the complexity of the park's resources using the Resist-Accept-Direct framework for priority resources at high risk. Identifying which resources will receive priority is an ongoing process and will require collaborative partnerships to provide the best available information, including incorporation of Traditional Ecological Knowledge/Indigenous Science into decision-making. Preliminary information from a Climate Change Assessment report, in collaboration with the NPS Climate Change Response Program, are presented, including future climate predictions and categories of resources at risk. Additional examples of Grand Canyon projects informing climate change planning will be highlighted, including springs/hydrology monitoring, cave mapping, and water-source development (*e.g.*, the Transcanyon Waterline Project) and how these projects are helping to inform management decisions for the park. Capacity limitations and other challenges are identified that will inform what conservation activities are feasible and which actions may not be appropriate or implementable, as the park moves into new climate realities defined by aridification, reduced snowpack, and increased temperatures.

Accounting for warming climate and future fire: a decision-making framework for complex postfire landscape-scale management

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ABSTRACT: Across the Southwest, hotter drought is fueling larger more severe wildfires and driving ecological transitions. In the eastern Jemez Mountains of New Mexico, nearly 30% of the 153,000-acre 2011 Las Conchas Fire burned at high-severity levels across a landscape which had seen 95% mortality rates of mature ponderosa pine in the mid-2000s. Las Conchas reinforced the transition of conifer forests to shrublands and grasslands in the severely burned areas by killing both regenerating conifers and their adjacent seed sources. In addition, resulting post-fire floods scoured the bottoms of canyons, altering hydrogeomorphic patterns and threatening human communities, cultural resources, and drinking water supplies. These factors have challenged ecosystem resilience and are, in some areas, resulting in permanent vegetation community shifts. It is becoming increasingly common for restoration and conservation actions to focus on preparing for anticipated future conditions that differ from the past. To steward ecosystems undergoing unidirectional change and to incorporate socially and culturally acceptable solutions, the 'Resist-Accept-Direct' framework provides a way of addressing altered landscapes and those that are in transition. The RAD framework can be applied to diverse situations where managers must decide whether or not to intervene and whether intervention, if chosen, should seek to prevent change or steer it. This presentation focuses on the East Jemez Landscape Futures Collaborative's landscape-scale development of a broad set of guidelines for sequenced action based on past research and management work. As we see fires increasing in size and intensity across the West, the lessons learned in the eastern Jemez and the development of the R-A-D

based strategy have broad applicability to other communities and landscapes who, once past the initial emergency response, are left to grapple with transformed landscapes.

Conservation of Pima Pineapple Cactus (*Coryphantha scheeri* var. *robustispina*) in Pima County: an updated model and monitoring with distance sampling

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ABSTRACT: The Pima pineapple cactus, *Coryphantha scheeri* var. *robustispina* (PPC) is a federally endangered cactus subspecies. Its distribution is almost entirely in southern Arizona. Due to the PPC's listed status and ongoing threats to the cactus, it is covered by Pima County's Multi-species Conservation Plan (MSCP). Surveys over the last decade have documented locations of over 800 PPC, improving our knowledge of its distribution across County lands. To fulfill the County's monitoring obligations under the MSCP, we needed to develop a narrower sampling frame that systematically represented its distribution on our lands. A recent USFWS range model provided an envelope, but the two existing habitat models were about two decades old. We were able to use our geo-referenced PPC observations and more recent GIS/remote sensing data to develop an updated, higher resolution, PPC habitat model based on soil, vegetation, and topography. Model results were robust, with an AUC of 0.89. Our sample frame included model values ≥ 0.29. We used a spatially balanced approach to randomly select 35 plot locations consisting of four parallel 250m transects 40m apart. We will monitor the plots every three years using a distance sampling approach. Our protocol includes collection of environmental covariates on each transect, as well as at locations where PPC are observed. All PPC detected are geo-referenced and scored using a quantitative condition assessment that includes measurements and reproductive condition. During the spring of 2022, we completed 26 plots (25.25 km) and detected 48 PPC (1.9 PPC/km, 1-14 PPC/plot); on 52% of the plots we did not detect any cactus, and the minimum model value where PPC were detected was 0.42 (mean = 0.85).

Expanding your audience: collaborating with the arts to communicate science to children

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ABSTRACT: The use of storytelling as a means for education has been a fundamental human trait since time immemorial. Because the first years of life are extremely important for the development of lifelong behaviors and attitudes toward the environment, introducing positive and interesting conservation and nature themes into lessons for children is vital for creating a new generation of environmental advocates. For children, the ability to combine story with imagination and imagery is vital for their understanding of complex topics. Pictures and art can help clarify stories and bring context to complicated ideas. The use of art as a tool for science communication, via visual arts, theater, music, and other avenues, can be instrumental in

communicating science themes that are traditional or novel. Because picture books rely on visual content, they are very successful tools to develop a child's perception and learning of the topics included within the story. Story books and other media can allow children to explore the world around them through imagination, even when it is not feasible to actually visit the setting of the story in real life. In this talk, I will demonstrate support for the benefits in communication that come from increasing collaboration between science and the arts that exists in the literature, and provide examples to the audience about specific avenues they can take to improve communication of their own science to interested youth.

Exploring regional patterns in predicted Southwestern Willow Flycatcher breeding habitat with a Landsat model

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ABSTRACT: A rangewide assessment of Southwestern willow flycatcher (SWFL) breeding habitat was completed in 2016 with a Landsat model between 2013 and 2015. The regional assessment mosaicked 57 scenes and revealed patterns in habitat range associated with drought patterns, fire dynamics, flooding, and insect infestations. This presentation broadens the rangewide habitat assessment by examining patterns and drivers of predicted SWFL habitat between 2013 and 2022. Several basins are focused upon to increase our understanding of basin and regional drivers of predicted SWFL habitat, with special emphasis on management issues of concern.

Vulnerability of arid grasslands to future climate change in the western US

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ABSTRACT: Grasslands cover a third of Earth's landmass and provide a range of critical ecosystem services. Anticipating how perennial C_3 (cool-season) and C_4 (warm-season) grasses will respond to climate change will be key to predicting future composition and functioning of grasslands. Here, using integrated species distribution models (SDMs), we (1) identified historical environmental drivers of C_3 and C_4 perennial grass distributions, (2) assessed how C_3 and C_4 grass distributions may shift in response to future climate change, and (3) evaluated when and where projected shifts were robust across climate scenarios in the western United States. We found C_3 grasses historically occupied areas with lower temperature and more variable precipitation regimes, while C_4 grasses occupied areas of higher temperature, greater temperature variability, and greater warm-season precipitation within narrower soil texture niches. In response to future climate change, C_3 grass abundance declined across 74% of the western US region while C_4 abundance increased across 66% of the region. C_3 grasses expanded in mid- to higher-latitude areas with increasing temperature and decreasing seasonality of precipitation. In contrast, C_4 grasses increased in higher-latitude regions, but declined in lower-latitude, dryer

regions. Results were surprisingly robust across future climate scenarios, suggesting high confidence in the direction of these future changes. Findings imply C_3 and C_4 perennial grasses will have highly divergent responses to climate change that may result in grassland functional compositional changes in the 21st Century. Increasing temperatures and precipitation variability may favor some C_4 grasses, but overall C_4 habitat expansion may be constrained by soil conditions. Our findings support actionable insights for anticipating the impacts of climate change on grass-dominated and co-dominated ecosystems and improving large-scale conservation and restoration efforts.

Transgenerational plasticity and genetic variation contribute to varied climate response in black cottonwood

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ABSTRACT: Seasonal patterns affecting plant phenology vary dramatically across the landscape, and climate change is acting as a transforming force on plant traits and the phenological timing of plant growth activity. The capacity for tree populations to cope with climate change depends upon the amount of evolutionary potential and plasticity a species has in natural populations. *P. trichocarpa*, black cottonwood, have adapted to an expansive climatic range which brings variation in tree morphology, phenology, and responses to abiotic and biotic stresses. By expanding on the development of black cottonwood as a model system, we can potentially distinguish transgenerational plasticity and genetic-based phenotypic responses to climate and add valuable insights to a variable system (Nicotra et al. 2010). First, trees were propagated from genetically variable source sites across the species range. Then, epigenetic environment-treatments were initiated by planting clones at two first-generation garden sites in Corvallis (variable temperature environment) and Clatskanie (stable temperature environment), Oregon. After maturation, trees were then propagated from these two sites and planted in two common garden sites in Arizona: the WCCER site (warmer), and the Arboretum site (cooler). Tree source is our genetic effect while the first-generation gardens allows us to test for transgenerational plasticity effects passed down through clonal reproduction. Genetic variation and transgenerational effects of growing environment had similar magnitude of influence on height, diameter, and leaf number. The trees propagated from clones grown in the more variable (Corvallis, OR) first-generation garden were larger for all measures. Re-sprouting dates were also affected by both genetic source populations and first-generation garden growing condition. The clones from the less variable first-generation garden (Clatskanie, OR) re-sprouted earlier. Our data suggest that clonally propagated cottonwoods have traits determined by both genetics and transgenerational environmental effects.

Managing bison in Utah

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ABSTRACT: The Utah Division of Wildlife Resources (UDWR) manages two completely wild, free-roaming, disease-free bison herds in Utah. The first herd is located in southeastern Utah on the Henry Mountains and was initiated in 1941. The second herd is located on the Book Cliffs in eastern Utah and was started in 2008. Land ownership of both herds is primarily public with BLM and state lands comprising a large amount of both units. In addition to federal and state owned lands, Ute tribal lands comprise a large percentage of the Book Cliffs Unit. UDWR manages both herds to a post hunting season population objective with hunting permits set annually to achieve the objective. Population abundance is estimated annually using a combination of aerial surveys from helicopters and population models. Annual calf production and sex ratios are determined using summer ground classification surveys, whereas adult survival rates are determined by maintaining a sample of satellite GPS-collared animals in each population. GPS-collared bison also provide information on habitat use and selection, as well as real-time data on overlap with cattle and cattle allotments, which can create conflict. Management challenges for the two herds include competition with cattle, horses, and other wildlife species, forage allocation, population viability and genetic concerns, and potential disease issues.

Woodland recovery may be related to microclimate more than tree size

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ABSTRACT: In pinyon-juniper woodlands of the southwestern US, severe drought in the past two decades has resulted in widespread mortality of large canopy pine trees. Woodland recovery appears to be dependent on the growth and survival of juveniles that established prior to the mortality event. Juveniles may benefit from resource release after mortality of canopy trees, or conversely may suffer from increased abiotic stress following loss of sheltering canopy trees. In this study, we investigated how variation in these responses may be mediated by microclimates and juvenile tree size, a proxy for resource access and stress tolerance. We created 135 dead canopy plot environments and paired them with live canopy plot environments. We used a subset of plots to intensively sample air temperature, humidity, and soil moisture (microclimates). We recorded all juvenile trees and used a subset encompassing a wide range of tree sizes to take photosynthesis measurements. Broadly, we anticipated that larger juveniles and those in dead canopy environments would show the highest rates of photosynthesis. Preliminary results showed no significant vigor differences across juvenile tree sizes, but that juveniles in dead canopy environments on average had higher rates of photosynthesis. While there was not robust evidence of microclimates driving differences in physiological responses, overall trends suggested that juveniles benefitted most from dead canopy environments where some live trees remained (e.g., other large juveniles or live juniper trees). Additionally, dead canopy environments were cooler, more humid, and had greater soil moisture availability on average as compared to live canopy environments. While these preliminary results suggest a potentially

strong role of microclimate drivers for juvenile vigor responses in dead canopy environments, additional sampling is underway to clarify these results across juvenile sizes, with additional physiological and growth parameters also being sampled.

Using NASA Earth observations to monitor and model juniper woodland mortality in Grand Canyon National Park

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ABSTRACT: Significant die-off of the drought-tolerant species Utah juniper (*Juniperus osteosperma*) and one-seeded juniper (*Juniperus monosperma*) have been observed in Grand Canyon National Park (GCNP) and throughout central and northern Arizona. As climate models project rising temperatures and continuous drought, land managers are concerned for the future of juniper in and around Grand Canyon National Park. This project incorporated data from Landsat 8 Operational Land Imager (OLI), the Shuttle Radar Topography Mission (SRTM), and ocular samples of the National Agriculture Imagery Program (NAIP) in a random forest model in an effort to identify patterns between environmental characteristics and locations of juniper woodland mortality and to model areas subject to vulnerability. This study found no significant correlation between ocularly sampled juniper tree mortality and remotely sensed environmental variables used and thus, accurately modeling mortality vulnerability in the future was not feasible. The ocular sampling, however, allows our partners at the National Park Service to better understand areas of juniper tree woodland mortality and the relative amount of mortality in the park. Additionally, the areas of juniper tree mortality found in this project provide our partners with guidance for future field sampling.

Agaves, Yuccas, and Hesperoyucca – Oh, My!

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ABSTRACT: We share insights gained from recent treatments of the Agavoideae genera *Agave, Yucca* and *Hesperoyucca* for the International Union for Conservation of Nature (IUCN) Red List assessments. There are 21 taxa (including subspecies and varieties) of *Agave* in Arizona and at least six of these are ancient domesticated species not protected under the Endangered Species Act nor assessed for the IUCN Red List, which does not assess domesticated species. Conservation of these domesticated species will require collaboration from Native American and non-government institutions. We discuss the need for more high-quality herbarium specimens and data in order to clarify the taxonomy and distributions for species of *Yucca*. We then present a brief overview of our recent fieldwork documenting *Hesperoyucca newberryi* in Sonora, Mexico, previously only known from western Grand Canyon, and note how this new distribution information contributes to our understanding of paleobotanical plant communities.

A multipronged approach to assessing impacts of climate change on precontact masonry structures at Tuzigoot National Monument – a case study

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ABSTRACT: The National Park Service manages Tuzigoot Pueblo, one of the most well-known Southern Sinagua villages in the Verde Valley of Arizona. Constructed between AD 1000-1400, Southern Sinagua architecture utilizes simple stone masonry and mud plaster to form complex, multi-room, multi-story pueblos. These ancient buildings were the homes of ancestral Native American people and continue to be important to descendant communities throughout Arizona. Over the past 85 years, National Park Service resource managers have continually grappled with the most effective and efficient methods for preserving these fragile structures. Current patterns of climate change have further impacted resource managers' understanding of the natural weathering cycle of these structures, forcing the NPS to develop new approaches to assessing site vulnerability. This case study at Tuzigoot National Monument will demonstrate a multipronged approach to assessing these dynamic structures in an increasingly unpredictable climate through new assessment methodologies, increased monitoring, correlative weather data, and experimental archeology.

Grazing management may moderate the effects of climate change on big sagebrush plant communities

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ABSTRACT: Livestock grazing is one of the most widespread land uses in drylands. In the future, grazing may interact with rising temperatures and altered precipitation regimes to influence plant communities in unexpected ways, especially in drylands. Within sagebrush ecosystems, which are widespread across the western US, increases in temperature are projected to decrease water availability with more profound effects for currently moisture-limited areas. Understanding the direction and regional patterns of grazing and climate change impacts is critical for informing sustainable ecosystem management. We used an individual plant based simulation model (STEPWAT2) to study the combined effects of grazing intensity and climate change (including the effects of changes in both precipitation regime and temperature) across the sagebrush biome. Overall, grazing had only small impacts on big sagebrush (Artemisia tridentata), and climate change effects tended to be negative, but with positive responses to climate change in some cooler and wetter areas. Perennial cool-season grasses and forbs, which provide important habitat and ecosystem structure in sagebrush ecosystems, were more sensitive to the effects of both climate change and grazing. The magnitude of the impact of grazing on

biomass of these herbaceous plants was larger than the impact of climate change. As a result, we found that reducing grazing from heavy to moderate intensity was, in most cases, able to counteract the negative effects of climate change. Overall, our simulations show that with climate change there may be less forage availability in sagebrush ecosystems, and that management that reduces grazing pressure may be able to compensate for this change.

Wood for Life program—a best practices model to provide resources and a sustainable source of firewood to local tribes through forest restoration efforts; to reduce forest-wide fuels; and to foster and strengthen partner relationships

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ABSTRACT: Much of northern Arizona's forests are in degraded health. They are overly dense and prone to disturbances like catastrophic fire, drought, and disease and insect outbreaks. Forest restoration activities that involve the removal of hazardous fuels through mechanical thinning operations reduce the risk of severe fire and post-fire flooding. However, the small-diameter trees and biomass thinned from the forests have little to no market value, and there is limited forest products industry capacity in the region. Leaving piled wood on a project site for more than a few months increases the risk of fire and insect infestation. The lack of industry and forest product markets in the region has delayed large-scale forest restoration efforts. At the same time, many homes on the Navajo Nation and Hopi Reservation in northern Arizona are not connected to the power grid and rely on coal and wood for home heating. The closure of the Navajo Generating Station and the coal mine in Kayenta in 2019 left many tribal members vulnerable to energy uncertainty. A diverse set of stakeholders, including federal, Tribal, and local governments, nonprofit organizations, corporations and more, joined forces in 2020 to create innovative solutions that spur forest restoration and improve community health and well-being. The Wood for Life Partnership (WFL) facilitates the delivery of a sustainable and substantial amount of firewood to tribal partners from forest restoration projects on National Forest Service lands (NFS). WFL connects wood from forest restoration projects with local tribal communities in need of firewood for heating, cooking, and traditional uses. The project seeks to address two very different—but both critically important—needs. It facilitates the removal of small trees and biomass from NFS lands while simultaneously providing tribal neighbors with firewood. WFL recognizes the strong and direct ancestral connections of local Tribal Nations to the lands that are now administered by national forests in northern Arizona and supports the strengthening of those connections through forest product agreements.

Science-informed decision-making: Coconino County addresses catastrophic wildfire risk and post-wildfire flooding

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ABSTRACT: Coconino County draws upon scientific information and data to guide policymaking, planning, decision making, and project implementation. Subsequently, the County shares essential scientific knowledge and perspectives with partners and constituents to advance understanding and communicate the impact of their efforts. Two examples of the science/policy/program nexus are the county's forest restoration and drought mitigation efforts. The Coconino County Forest Restoration Initiative commenced in 2017 when supervisors identified catastrophic wildfires and post wildfire flooding as the number one public safety risk for citizens in the County. This resulted in the County developing a science-based, county-wide Forest restoration initiative aimed at reducing wildfire risk and creating flood management infrastructure. These efforts included partnerships with the Kaibab and Coconino National Forests and other partners. Coconino County's Forest Restoration Initiative and strategies and partnerships significantly reduces the threat to Coconino County and serves as a model for other counties across Arizona and the western United States. In response the 2019 Museum Fire in Flagstaff, Arizona, Coconino County partnered with the Forest Service, and local hydraulic consultants to undertake flood control and mitigation activities in the burn area. The US Forest Service Museum Fire Sediment Reduction Project broke ground in late April and is expected to be completed this fall. Funded by the US Forest Service, the $3.5 million project includes grade stabilization and watershed restoration work to slow the flow of runoff and reduce sediment production and reduce the impacts of sediment and floodwater in downstream neighborhoods.

Shifting paradigms in ecological restoration of southwestern pinyon-juniper ecosystems: past, present, and future

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ABSTRACT: Paradigms and associated approaches for ecological restoration of southwestern pinyon-juniper ecosystems have shifted over the last three decades. Restoration efforts of the mid-1990s primarily focused on tree removal and seeding of perennial grasses to address concerns over tree density increases and expansion of trees in grassland and shrubland habitats. Later, recognition of the importance and prevalence of persistent woodlands raised new questions concerning restoration needs in infrequent-fire structural types where overstory conditions were generally intact. More recently, widespread tree mortality resulting from drought and insect outbreaks and the spread of invasive species after wildfire have spurred managers and researchers to consider novel treatment approaches aimed at conserving old trees and ecological integrity and restoring landscape patterns. In this presentation, we will provide examples from our long-term and current research in pinyon-juniper systems of the Colorado Plateau to highlight changes in restoration paradigms and provide context to explore options for future management.

Tradeoffs between leaf cooling and hydraulic risk in hot environments

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ABSTRACT: For many plants, especially those occurring on the warm edge of a species distribution, temperature buffering is critical for maintaining leaf carbon balance. One way to evaluate plants that are best suited to cope with future heat waves is to quantify leaf thermal safety margins: the difference between leaf temperature and the temperature at which leaf photosynthetic capacity is inhibited. Here we define photosynthetic inhibition as the temperature at which electron transport capacity of Photosystem II drops to 50% of its maximum (T_{50}). We evaluated T_{50} in one of the most iconic and ecologically important tree species in the southwestern US, *Populus fremontii* in a common garden setting along the Colorado River near Yuma, AZ. The common garden comprised of eight *P. fremontii* populations sourced across an elevation gradient from 50 m to 1230 m. Mean population T_{50} ranged from 51.1 °C to 52.5 °C. However, contrasts among populations were not correlated with elevation, indicating that low-elevation populations potentially operate with a much narrower thermal safety margin compared to high-elevation populations. However, genotypes sourced near the warm edge of *P. Fremontii's* distribution had mean midday leaf temperatures that were 3 °C cooler than genotypes sourced from cooler locations, reflecting a 50% higher mean midday stomatal conductance compared to cool-adapted genotypes. These results indicate that warm-adapted genotypes operate with a relatively narrow thermal safety margin and as a consequence are adapted to take "hydraulic risks" so that evaporative leaf cooling is maximized during heat waves. Identifying genotypes that maintain leaf thermal safety while minimizing hydraulic risk will likely be a necessary feature of future *P. fremontii* restoration efforts along the lower Colorado River and other warm-desert riparian ecosystems.

Tracking snow accumulation and ablation from forest into a 20-year old burn scar in the Sierra Ancha Experimental Forest using snowtography

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ABSTRACT: The Colorado Basin States are facing water shortages amidst an increased demand for water, rising temperatures and ongoing drought and are projected to continue experiencing these conditions. The frequency and severity of wildfires further threatens critical water sources. Climate change and natural disasters have led to an increasing need to better understand the long-term impacts wildfire disturbance has on watersheds and the hydrologic cycle in the highly diverse climates of the Southwest. Water supply in the Southwest United States is heavily dependent upon winter snowpack. The variability of runoff from intermittent snowmelt in Arizona as well as the many variables affecting snowfall accumulation creates challenges for water managers to predict and administer water resources. The ability of watershed managers to more accurately predict snowmelt-generated streamflow is directly correlated to their access to

timely field data and understanding of the impact of forest disturbance, terrain and forest structure on snowpack accumulation, ablation and soil moisture conditions. We use snowtography in conjunction with soil moisture sensors to measure and correlate snow accumulation, ablation and soil water content with vegetation in a wildfire affected area of the Sierra Ancha Experimental Forest, Arizona. Snowtography uses repeat photography to track snow accumulation and ablation. Results show how variability of snowfall accumulation and ablation is affected by forest structure and terrain. The study includes two 85m-long snowtography transects extending from a forested area into a 20-year burn scar. This research, in conjunction with other snowtography sites in the Southwest, will improve our understanding of how significant forest disturbances of varying age affect snow accumulation, ablation and the duration of seasonal snow cover. Better understanding these variables can increase the ability for watershed managers to more accurately predict spring runoff yields.

Lake Powell as a sentinel for sediment flux in the Upper Colorado River Basin: past, present, and future

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ABSTRACT: Lake Powell has effectively trapped all sediment in the Upper Colorado River Basin (UCRB) since the closing of Glen Canyon Dam, but our ability to track sediment sources and fluxes is limited. From 1963–2018 Lake Powell accumulated >2 km^3 of sediment; more than half of this volume is in Colorado River and San Juan River deltaic deposits. Suspended sediment loads calculated from USGS stream gage records between 1963 and the early 1980s, when sediment sampling ceased, cannot account for sediment accumulated to that point in time. Recent sediment records from the Colorado, Green, and San Juan Rivers using continuous acoustic data as a surrogate for suspended sediment concentration yield even lower sediment flux than the historic record. Our inability to balance the volume of sediment in the UCRB over a >50 year period highlights major knowledge gaps. As a result of extreme fluctuations in reservoir level, thick accumulations of deltaic sediment are present over nearly 100 river miles of the Colorado and San Juan Rivers. At low reservoir levels the fate of this sediment is two-fold: 1) in canyons it is connected to the river channel and actively eroded and redistributed downstream, and 2) in embayments, where it is not well-connected to the river channel, the sediment forms extensive terraces. In order to understand the fate of remobilized sediment a volumetric framework must be paired with approaches to monitoring deposition in the reservoir. The evacuation of sediment from river corridors in the upper reaches of Lake Powell can be similarly monitored, permitting enhanced understanding of sediment budgets from the landscape scale to that of Lake Powell. Such efforts have the potential to enhance understanding of sediment flux at the scale of the UCRB, but will not reconcile the difference between gaged records and total volume.

Comparing geography and severity of managed wildfires in California and the Southwest USA before and after the implementation of the 2009 policy guidance

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ABSTRACT: Managed wildfires, naturally ignited wildfires that are managed for resource benefit, have the potential to reduce fuel loads, minimize the effects of future wildfires, and restore critical natural processes across many forest landscapes. The 2009 federal wildland fire policy guidance in the United States was designed to provide greater flexibility for the use of managed wildfires, but the effects of the policy on wildfires in the western US is not fully understood. Our goal was to compare managed and full suppression wildfires and also analyze differences between managed wildfires across space (Arizona/New Mexico and California) and time (before and after 2009) using four metrics: (1) distance to wilderness, (2) distance to the wildland urban interface (WUI), (3) percent of area burned with high-severity, and (4) number of land management agencies for each wildfire. Across the study area, we found that managed wildfires were significantly closer to wilderness areas, farther from WUI, had less percent area burned with high-severity and fewer agencies managing the fire compared to full suppression wildfires. In California, managed wildfires occurred closer to wilderness, and had a larger percent of high burn severity area compared to the Southwest (Arizona and New Mexico) managed wildfires. Within each region however, there were no significant geographic differences in managed wildfires before and after implementation of the 2009 policy guidance. Despite the greater flexibility of the 2009 policy guidance, the basic geographic properties of managed wildfires in these two regions have not changed. As the climate warms and droughts intensify, the use of managed wildfires will need to expand during favorable weather conditions to address the threat of large, uncharacteristic wildfires to people and ecosystems.

Bison for tribal spiritual and food connections

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ABSTRACT: Using bison as food to reconnect to self and find healing within indigenous communities. When we work with bison through guided bison butcherings our goal is to provide a safe space that allows for self- and cultural exploration, experimentation and discovery while being encouraged and supported. This method allows for personal understanding, forgiveness, competence, awareness, creativity, critical thinking, while understanding how to work together. Breaking down bison through the traditional butchering process provides individuals not only

with understanding of the bison on a biological and physiological level but also allows for the opportunity to understand similarities between us and them, pre-contact and post contact. Through these connections, Individuals are able to empathize and associate themselves to the bison as relatives. A practice our ancestors were able to comprehend, pre-contact. Feedback received from guided butcherings were very positive in that individuals expressed how they were calm through the whole butchering process and they were able to enjoy themselves while learning and sharing experiences regarding bison. With these discoveries we wish to redefine and re-structure what self-healing, food security and cultural understanding looks like in Indigenous communities through the understanding of the bison.

High spatiotemporal resolution thermography reveals novel insights into the plant hydraulic strategy of key dryland functional groups

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ABSTRACT: Dryland regions of the southwestern United States are rapidly warming, and rainfall is becoming less frequent and more intense, with major yet poorly understood implications for ecosystem structure/function. Thermography-based estimates of canopy temperature can be used to infer changes in gross primary productivity (GPP), and evapotranspiration (ET). Here, we utilize a novel application of high spatiotemporal thermography implemented at the plot level to evaluate its potential to track key hydraulic traits. We leveraged two long-term experiments: (1) The Rainfall Manipulation experiment at the Santa Rita Experimental Range (RainManSR), which includes treatments designed to test the impacts of temporal repackaging of a fixed total seasonal precipitation amount on key plant function groups of the Sonoran Desert; and (2) A long-term climate manipulation experiment designed to evaluate the sensitivity of key plant and soil functional groups of the Colorado Plateau, including biocrusts. At RainManSR, we found temporal repackaging of precipitation profoundly influenced canopy temperature dynamics, and these changes could be used to infer changes in hydraulic traits and predict GPP and ET at the individual plant level. Few/large precipitation events led to cooler plant temperatures (1.4 °C) compared to many/small precipitation events. Notably, perennial plants were 2.5 °C cooler than annual plants in few/large precipitation events due to higher accessibility to deeper zone water, resulting insignificant increases in the aboveground biomass of the perennial. However, annual plants were 1.8 °C cooler than perennial plants in many/small precipitation events due to higher moisture in the shallow root zone. For the Colorado Plateau experiment, we present preliminary results regarding warming and altered precipitation treatment effects on biocrusts and their role in regulating overall ecosystem temperature/energy exchange. Overall, our cross-site findings imply shifts in climate, including a change in the timing of precipitation, will have major implications for dryland community composition and function.

Biocrust inoculum survival in restoration depends on source material, cultivation practices and inoculation technique

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ABSTRACT: Biological soil crusts occur across global drylands and influence ecosystem functions like soil stability, fertility, and hydrology. Declines in biocrust communities due to soil surface disturbances like agriculture, development, and recreation often result in soil destabilization and erosion. Because of this, there have been many efforts to restore biocrusts by cultivating organisms in the laboratory, greenhouse or field and then inoculating disturbed soil surfaces, coupled with methods to relieve abiotic stress (e.g., shade cloths). These inoculation methods have had mixed results, with high mortality and lack of growth likely due to the harsh environmental conditions. In this study, we developed an approach to grow biocrusts "sods" where biocrusts from the Colorado Plateau, Mojave and Sonoran Deserts, plus their cultivation substrates and shade cloths were applied to degraded sites on the Colorado Plateau. One-year post-inoculation, we assessed 1) moss and lichen cover, 2) cyanobacteria abundance through molecular methods, and 3) soil stability (Slake method) for all deserts, substrates, and shade treatments. For cultivation, we found that biocrust organisms sourced from different deserts respond similarly; the cyanobacteria relative abundance was about 7% when grown without substrate or shade, 11% if grown on paper substrate, and 28-34% if grown on jute with a shade cloth, which is improved compared to control plots. In addition, soil stability increased only for shaded cultivation treatments. One year following inoculation, the Colorado Plateau mosses and Mojave lichens maintained highest cover with shading. Cyanobacteria relative abundances in shaded sods dropped from 30% to 20% in the first year while soil stability decreased on the Slake scale from 5 to 3 (max stability is 6), with only shaded sods significantly greater than controls. In conclusion, we recommend sod-style biocrust inoculation as a targeted restoration strategy with shading during cultivation and inoculation of multiple biocrust types.

Machine Learning algorithms for land cover classification using Landsat imagery over the Colorado Plateau, performance and training considerations

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ABSTRACT: Accurate land cover (LC) maps are essential for the study of changes in the environment, especially to assess the trends of ecological variables, urban development, wildlife habitat, or agriculture planning. Generating land cover maps involves the interpretation of imagery taken from airplanes or satellites, along with field verification. Datasets with high spatial resolution result in the most detailed land cover maps, hence high-resolution satellite imagery is one of the most valuable inputs. The availability of multi-temporal satellite imagery

together with the recent advancements in machine learning (ML) techniques can support the generation of very detailed land cover maps relatively quickly. In this work, we prototyped a ML classifier algorithm over the San Juan River watershed in the Colorado Plateau. Random forest and artificial neural networks were applied to a time series of Landsat 8 OLI satellite imagery. Existing LC maps, like the 2011 GAP, and high-resolution Google Earth imagery were used to train, validate, and assess the algorithm performance. The predictors used for the algorithms are the Landsat spectral bands, and vegetation indices, such as NDVI and EVI, augmented with landscape phenology metrics. The algorithm was first tested in a different study over the US-Mexico transboundary region and modified and evaluated afterwards in the San Juan River watershed by using a variety of in situ parameters, open access data, and historic LC maps. The resulting maps have enough detail and accuracy to help update the 2011 GAP, support change studies, and inform ecohydrological research in the region by having more certainty in the location and extent of classes of interest, such as riparian areas.

Pathogenic boundaries in language and law

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ABSTRACT: Members of Indigenous nations who revere the sacred beings who live within or upon the San Francisco Peaks have been forced into difficult choices. For three generations their efforts to reduce harm and increase respect and reverence around this place have drawn them into negotiations that have proven barren. The interests of settler-descendants in leisure and profit are consistently privileged and expanded, while Indigenous interests in respect and reverence are diminished. Dominant conceptual frameworks have proven toxic and pathogenic not only for Indigenous people, but for everyone—for all our relations. Tangible harm has resulted. Yet a more hopeful, affirmative approach to this conflict is conceivable.

Language engages dialectically and creatively with core axioms held and carried by human communities. Key terms such as Traditional Cultural Property, sacred sites, religious freedom, resource management, co-stewardship, and trust responsibility, empower decision-making based on property ownership and the fiction of a neutrally administrative balance between competing rights and privileges. Processes attached to these terms purport to be historically progressive, yet their epistemological roots end within the bounds of the United States Constitution, with a few quaint carryovers from English common law. From an Indigenous perspective these processes are as parochial as the world within the bounds of a medieval European town.

US Forest Service officials initiating tribal consultation on Snowbowl development have referenced Joint Secretarial Order 3403 which promotes Federal stewardship and co-stewardship of “federal lands and waters, including wildlife and its habitat.” Its goals of collaboration and consultation will only succeed if Indigenous people are equal participants—better yet, senior participants, based on their seniority in knowledge and relationship with these lands. This will require privileging and incorporating Indigenous frameworks based on relationships and responsibilities, rather than competing privileges of property and leaseholds.

Is the endangered Southwestern Willow Flycatcher population growing and expanding its distribution, or declining, and shrinking? (Is it time for a SWFL blitz?)

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ABSTRACT: The southwestern willow flycatcher (*Empidonax traillii extimus*, SWFL) was listed as endangered in 1995 under the Endangered Species Act of 1973. Since listing, ecological studies and surveys to determine the abundance and distribution of SWFLs have been conducted over much of its range and these data have been compiled into a rangewide database. This database has provided agencies concerned with the protection and recovery of SWFLs and SWFL habitat with key information to track their status, primarily in the US Fish and Wildlife Service 5-year reviews. Landscape-level habitat and occupancy models, used to further recovery plan goals, have been developed using these data. But the rangewide database was last updated using data collected through 2012. Since then, SWFL survey data have not been compiled into a rangewide database, and a comprehensive view of the extent (spatial and temporal) of surveys across the range is lacking. At the same time, threats to the flycatcher and its habitat, including tamarisk leaf beetle, diminishing water availability, and climate change, continue. We argue that it is time for a SWFL blitz, a multi-state rangewide survey and sampling effort, concurrent with the development of a comprehensive rangewide database, which can inform effective efficient recovery efforts.

Outreach in Puerto Rico: surface water, groundwater, and precipitation gage infographics

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ABSTRACT: Puerto Rico was heavily impacted by Hurricane Maria, a Category Four storm, in 2017. Large-scale flooding and heavy winds caused damage to more than 94 surface water, groundwater, and rainfall monitoring stations across the island. As a result, the US Geological Survey (USGS) secured supplemental funds that enabled local staff to repair and upgrade the island's hydrologic monitoring network. As part of this initiative, infographic signs to be placed on monitoring sites are being created in both English and Spanish to increase public awareness of the gages. The infographics explain what the surface water, groundwater, or precipitation gage is, what it does, and its importance in relation to Puerto Rico's water resources. We hope this product engages with the local community in a meaningful way, increases awareness of the USGS hydrologic monitoring network, and promotes access to water information and USGS staff. Expansion of this outreach initiative to other monitoring sites within the US is planned in order to engage with local communities and stakeholders, with a specific focus on under-served communities.

USGS Colorado River Basin Science and Technology Collaboration Meeting Series: insights and next step

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ABSTRACT: The USGS has thousands of publications, datasets, and resources freely available to the public, resource managers, and the science community, but accessing and interacting with this large, diverse body of information can be challenging. The Colorado River Basin Actionable and Strategic Integrated Science and Technology (ASIST) Project hosted the Colorado River Basin Science & Technology Collaboration Meeting series, bringing together USGS staff to discuss a range of topics, from integrated science to use of advance technology to address complex stakeholder-driven science questions in the Colorado River Basin (CRB). For each topic, meeting attendees provided input on existing USGS expertise and capabilities, knowledge gaps, science and technology needs, applications, strategies, and next steps to further the understanding of complex drought effects on human and natural systems in the CRB. Summarized attendee responses from these meetings include identifying common themes across meeting topics for producing integrated science that better meets stakeholder needs and builds science connections and capacities. For example, we identified science topics often mentioned by meeting attendees (e.g., atmospheric and climatic processes, groundwater) as well as science topics mentioned more frequently by USGS staff (e.g., computational methods). We also categorized attendee responses with USGS data lifecycle terms. For example, data lifecycle terms were mentioned more often as a challenge in the "Drought predictions" session than the "Human systems" session. An important outcome of these summaries will be the ability to match agency science expertise and capacities with stakeholder needs. Products from these meetings also will identify science and technology gaps, inform priorities for future research and support, and direct development of Information Management and Technology resources to serve stakeholder priorities. This information is being used to build an approach in the CRB focused on bringing together expertise from across the organization to address complex Earth science challenges with partners.

Reevaluating the Southern Colorado Plateau Network's bird monitoring program: accounting for ecological change in the Anthropocene

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ABSTRACT: Southwestern bird populations face a plethora of threats, even on protected lands. These range from invasive plants along riparian corridors, to drought-associated die-back of pinyon pines, to large-scale wildfires in high-elevation mixed-conifer forest. The need for effective monitoring programs that can inform management to help counter these threats is therefore urgent, yet monitoring programs must also be 'futureproofed' against changes to the distributions of both birds and their habitats. We use an evaluation of SCPN's bird monitoring program protocol (2007-2018) as a case study to highlight lessons learned about the design of monitoring programs for the Anthropocene. Specific points of emphasis include: (1) the importance of space-based over habitat-based monitoring designs in the face of wildfire and shifting habitat distributions. In particular, habitat-based designs are at risk to loss of habitat, forcing a choice between changing either the spatial frame of the study or the habitat type being monitored. (2) Maximizing the number of species and habitats being monitored. Future species of conservation concern are unknown, while maximizing ecological variation in habitats and habitat quality allows for better inference about species-habitat relationships. (3) Integrating monitoring protocols at scales relevant to the management of local populations and management units. This will require park-wide scales of inference, but also efforts to standardize protocols across networks where possible. (4) Accounting for shifting phenology when timing surveys. Monitoring surveys with single visits are particularly sensitive to phenology-driven shifts in species detectability (e.g., singing rates in birds); establishing baselines and tracking phenology is key to ensuring accurate sampling data. (5) Integrating predictive modelling into monitoring programs. Even long timeseries are only an ecological 'snapshot' of populations; relating population densities to climatic and habitat structure covariates allows us to predict how future changes, especially those with no historical analog, will affect populations.

Assessing native ungulate wildlife habitat four years post-fire in the 416 burn area, southwest Colorado and its implications on wolf management

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ABSTRACT: The severity of fire regimes in mixed-conifer forests impacts stand structure and biodiversity, which ultimately affects wildlife habitat. It is important to understand how wildlife responds to post-fire vegetation changes to implement conservation and management actions. Rocky Mountain elk (*Cervus elaphus nelsoni*) and mule deer (*Odocoileus hemionus*) are commonly found in coniferous forests in Western North America and are often preyed on by the grey wolf (*Canis lupus*). Determining what forest habitats ungulates favor post-fire is necessary to understand how predators respond to fire. In 2018, the 416 fire was started via an unplanned ignition resulting in a total of 54,130 acres in southwest Colorado. We generated random points using ArcGIS and selected 10 points for each burn severity (no burn, low, moderate, high) to quantify ungulate habitat selection using trail game cameras and collecting scat at each plot in the summer of 2022. Our objectives are to: (1) quantify Rocky Mountain elk and mule deer habitat usage across the day (morning, midday, evening) and seasonally (early, mid, late) in four burn severities 4-years post-fire; and (2) determine how density patterns may influence wolves utilizing the various post-fire habitats in the 416 burn area. We hypothesize that elk and mule deer will be more prevalent in high severity burn areas in the early season compared to low/moderate burn areas because low tree canopy cover will allow sunlight to reach the forest

floor earlier in the season promoting forage plant growth. As the growing season progresses, we hypothesize that mule deer and elk will be more prevalent in low and moderate burn severities compared to high burn severities because there will be more cover protection. Our data will be beneficial to land managers wanting to understand how fire impacts predator-prey relationships through food resource availability and cover in post-fire landscapes.

On the move: how mobile location data can help public land managers tackle complex problems

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ABSTRACT: Recreation has received a wave of interest. Visitation increases, changing demographics, and an overall need to track use patterns more accurately has placed an emphasis on searching for answers quickly. Mobile location data, collected passively from samples of cellular devices, provides new insights to public land managers on a scale not before possible. Data from hundreds of thousands of mobile applications passively collects location data from users, whether they are in or out of connection. Since 2018, mobile location data has skyrocketed in use across the tourism industry with destinations using it to track ad campaigns, visitor origins, and areas of high use. However, the public land and outdoor recreation industry is still building steam using such data compared to their urban destination management counterparts. This research presents preliminary results from mobile location data analysis at a variety of public land areas and displays use cases for how the data could be used in the future. From exploring relative use in Alaska's state parks to helping solve wildlife issues at seashores, these studies use innovative methods to address challenging questions in the park and recreation industry.

Population health assessments for bison conservation

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ABSTRACT: The American bison (*Bison bison*) once numbered in the millions. Due to market hunting, interbreeding with domestic cattle, disease, and habitat fragmentation, the population nationwide diminished to 1000 individuals. The first efforts in conservation began in the early 1900s. In 2020 the Department of Interior and partnering conservation organizations released published a new Bison Conservation Initiative. The initiative recommends a wholistic approach that addresses genetic and health objectives in the conservation and restoration of bison populations. As has been done with restoration of other wildlife species (e. g. bighorn sheep), this is best accomplished by establishing robust surveillance programs in source and recipient populations, mitigating disease risks through the use of vaccinations and control programs in captive populations, and utilizing best management practices for translocation events. Several diseases have been recognized as causing population level impacts in and impacting conservation of bison: *Mycoplasma bovis*, *Mycobacterium bovis*, *Mycobacterium pseudotuberculosis*, *Bacillus anthracis*, *Brucella abortus*, *Clostridia* spp. This presentation will review suggested herd management practices for bison health and protocols for introducing new animals into a herd.

Population based differences in cold tolerance affected by drought and temperature acclimation in *Pinus strobiformis*

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ABSTRACT: Drought and cold stress invoke similar responses in conifers (Pardos et al. 2014), indicating drought and cold tolerance may act via the same biological pathways (Sung *et al.* 2003, Atkin *et al.* 2005, Beck *et al.* 2007, Costa *et al.* 2008). *Pinus strobiformis* (SWWP) experiences drought and cold stress in its natural habitat that varies by population. We set up two experiments using seedlings germinated from northern and southern populations. The cold tolerance and its interaction with drought exposure were our focus in order to examine how these stressors may be linked and how it varies among populations. We determined trees from warmer populations were significantly more likely to survive and have less cellular damage upon exposure to freezing temperatures when put through a cold acclimation treatment, simulating fall hardening, than when left in a warm environment. Trees from colder populations performed better in the freezing treatments overall from both warm and cold acclimation environments, showing they remain fairly cold tolerant even through the summer. In another experiment we used rainout shelters to simulate drought and control conditions at two common garden sites, one cold and one warm, to examine the interaction between cold and drought stress. We found that coming out of winter and into spring, trees in a wetter, colder environment maintained higher leaf mass area (a trait indicating greater resources per needle) and greater cold tolerance than trees in a warmer, drier environment. Our experiments concluded that SWWP cold tolerance can be influenced by an acclimation treatment before winter stress to increase survival through winter and by avoiding drought to maintain hardiness through spring. Our research indicates there are differences between how northern and southern populations tolerate cold stress when experiencing resource depletion as a result of drought stress.

Experimental 'Bug Flows' increased algae production and insect diversity in the Colorado River, Grand Canyon

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ABSTRACT: Aquatic insects are the cornerstone of river food webs and fuel growth of fish, bats, and other wildlife. Yet aquatic insect assemblages in the Colorado River downstream of Glen Canyon Dam are neither diverse nor productive, and therefore unhealthy, leading to food limitation for native fish and simplified food webs that are inherently unstable. Prior research by our group showed that hourly changes in flow associated with hydropower production were a significant constraint on aquatic insect assemblages. To mitigate adverse effects of hydropower production on ecosystem processes, dam managers tested experimental Bug Flows in 2018-2020. These entailed steady-low flows every weekend from May-August with routine fluctuating

releases for hydropower production on weekdays. Here we describe response of lower trophic levels to the experiment. Bug Flows increased gross primary production on weekends by 41%, resulting in an additional 100 metric tons of algae-carbon to sustain food webs in the 400-km long Grand Canyon segment. More adult midges emerged from the Colorado River during steady-low weekend Bug Flows compared to weekday fluctuating releases, suggesting that steady-low flows improve conditions for adult insects. Notably, the abundance of adult caddisflies captured in community science light trap monitoring increased by 400% riverwide in two of three Bug Flow years compared to the pre-Bug Flow baseline from 2012-2017. Bug Flows likely benefitted native fishes in Grand Canyon through increases in production and diversity of lower trophic levels, although continued experimentation, research, and monitoring would be needed to definitively establish this link.

Promoting diversity, equity, inclusion, and justice in forest resource programs in the US: a survey of NAUFRP member institutions

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ABSTRACT: The National Association of University Forest Resources Programs (NAUFRP) conducted a survey of its member institutions to assess current efforts to promote Diversity, Equity, Inclusion, and Justice (DEIJ) in forestry resource programs in the US. In this presentation, we will share description of various DEIJ efforts at the forestry program unit level, in terms of composition of DEIJ committees, their focus and sources of supports, as well as specific practices. Most of the unit-level committees are consisted of faculty and staff with varying degree of involvement of undergraduate and graduate students and alumni representatives. A few programs reported having a dedicated administrative position or a separate student group, in addition to the committee. While the DEIJ goals are similar among different institutions, activities of DEIJ group vary from offering free events for voluntary participation to providing recommendations to institutionalize DEIJ related work in faculty& staff workload. We will also share some examples of DEIJ practices for students, faculty and staff, and also for promoting institutional change. This presentation will provide an opportunity for participants to reflect on their own experiences and share best practices for promoting DEIJ in forestry education.

Understanding drivers of abiotic and biotic treatment success in dryland soil restoration: a meta-analysis

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ABSTRACT: Soil degradation is one of the greatest environmental issues our planet faces today, with over 33% of Earth's soils degraded. Drylands are especially vulnerable to degradation given their history of intensive use and desertification. Active soil restoration is considered a leading strategy in combating soil degradation. However, soil-based dryland restoration techniques have shown varying success, potentially due to insufficient understanding

of the ecological contexts in which soil-based treatments are most beneficial. To improve our understanding of how to best use active soil restoration, we conducted a global meta-analysis of soil treatment effectiveness across environmental gradients in drylands. We aimed to answer the questions of how soil restoration affects soil health, how this effect varies across environmental gradients of aridity and soil texture, and how intervention factors of treatment type, seeding, and time, impact effectiveness. To answer these questions, we compiled a database of 155 publications containing 1,403 unique records and conducted meta-analyses to test the effects of soil restoration on soil health. Overall, dryland soil restoration improved all measures of soil health: soil aggregate stability (+14%), bulk density (-10%), soil moisture (+13%), soil organic carbon (+59%), soil nitrogen (+69%), mycorrhizal colonization (+5,964%), and basal respiration (+360%). Effects of soil-based restoration varied across environmental gradients with aridity and soil texture influencing restoration effectiveness for aggregate stability, soil moisture, soil organic carbon, and soil nitrogen. For soil carbon and nitrogen, effects of restoration were greatest in more arid systems with fine-textured soils and mesic systems with coarse-textured soils. We also found that abiotic treatments were more effective at increasing soil nitrogen, while biotic treatments were more effective at increasing mycorrhizal colonization. These findings indicate soil restoration is an effective tool for increasing soil health across drylands and improve our understanding of the ecological contexts in which treatments are most successful.

Impacts of extreme seasonal drought on Colorado Plateau grassland plant communities

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ABSTRACT: Climate change is causing an increase in drought frequency and duration in the American Southwest due to long-term warming trends and changes to the seasonal timing and intensity of precipitation. Studies suggest that drought has negative impacts on grassland plant communities by decreasing plant productivity and survival, often with greater effects on herbaceous than woody species. Differences in plant water use efficiency based on photosynthetic pathways may also mediate responses to seasonal drought. We tested the resistance and resilience of Colorado Plateau grassland plant communities to extreme seasonal drought with and without a dominant shrub (*Ephedra viridis*) present. Our treatments included cool-season drought (66% less than ambient precipitation, Nov. – May), warm-season drought (66% less than ambient precipitation, May – Nov.), and an ambient precipitation control. Treatments were applied over four years, followed by three years when all plots received ambient precipitation. We measured productivity and species composition twice annually throughout the seven-year experiment. Our results indicate that drought timing and plant community composition have differential effects on grassland community resistance and resilience. Perennial grasses had reduced biomass with little post-drought recovery across all treatments, but cool-season grasses showed larger and more persistent declines than warm-season grasses. Warm-season grasses recovered more quickly from cool-season than warm-season drought. *E. viridis* had high resistance and resilience to both drought treatments and

negatively impacted perennial grass recovery. These results indicate that semi-arid grassland communities on the Colorado Plateau may have differing resilience to climate change, including losing cool-season perennial grasses and becoming more shrub dominated.

Abiotic variables associated with conifer regeneration in warm-dry mixed conifer in the 416 Fire, southwestern Colorado

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ABSTRACT: Climate change induced drought is a large driver for increased wildfire activity and severity and has been linked to a reduction in successful conifer regeneration. Conifer regeneration and seedling establishment is one of the most critical post-fire processes for the sustainability of any forest ecosystem. As climatic drivers continue to increase drought conditions, and thus altering forest stand dynamics, an understanding of what biotic and abiotic variables influence post-fire conifer regeneration is essential for forest health management. On June 1, 2018, the 416 Fire was ignited by an unplanned, artificial ignition that burned 54,130 acres in southwest Colorado during an exceptional drought. We generated random points using ArcGIS and randomly selected 15 points for each burn severity (no burn, low, moderate, high) to quantify forest overstory, shrub, and conifer regeneration (N=60). We found no significant differences for total pre-fire surviving conifer regeneration (>10 cm to <2.64 m height) or post-fire conifer regeneration (< 10 cm height) among burn severities due to high regeneration site variability despite over six times the average seedlings/ha in low compared to high severity areas. *Pinus ponderosa* dominated seedling regeneration across all burn severities. We quantified that Climatic Water Deficit (CWD) and elevation had an inverse relationship with conifer regeneration using a General Linear Model and that low and moderate burn severities had a positive correlation with conifer regeneration. We found no statistical significance difference in shrub cover three years post-fire suggesting that shrub cover had returned to pre-fire conditions. Our findings highlight that elevation and climatic stress are important predictors of conifer regeneration in the 416 burn area, and these variables may help further refine post-fire locations that will have a high likelihood for natural regeneration success and where planting seedlings will have the highest chance for establishment and survival.

Applying the adaptation workbook process to the Southwest

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ABSTRACT: Land management agencies and organizations are under increasing pressure to integrate climate change considerations into planning and implementation activities. The USDA Southwest Climate Hub, Northern Institute of Applied Climate Science (NIACS), and our partners have been working to tailor climate adaptation tools to meet the diverse needs of

resource managers working collaboratively across multiple spatial scales through the Climate Change Response Framework (CCRF). This framework provides usable information and resources regarding climate change science and adaptation and facilitates application of this information through on-the-ground management to achieve local goals and objectives. The CCRF combines a multi-step process known as the Adaptation Workbook and is paired with "menus" of adaptation strategies and approaches to help land managers design and implement site-specific climate change adaptation actions. Initially the tool focused on forested ecosystems; however, collaborators quickly became interested in developing topic-specific menus for their systems of interest. Starting with forests in 2012, these tools are now being used by natural resource professionals who manage an array of ecosystems and approach management with varied goals and values, focusing on forested watersheds, urban forests, wetlands, wildlife habitat, recreation areas, coastal ecosystems, carbon stewardship, fire adaptation, arid grasslands, agriculture and tribal perspectives. These menus can be modified to fit different sector-specific planning needs, while using a common decision-support process. This presentation will cover the components of the Adaptation Workbook and highlight an example of the how the Adaptation Workbook Process has been applied in the southwest.

Engaging with federal agencies—best practices from the tribal perspective—case study of a Bureau of Reclamation project, Hopi ethnographic study for the Navajo-Gallup Water Supply Project

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ABSTRACT: The Hopi Cultural Preservation Office (HCPO) is charged with the responsibility of representing the Hopi peoples' cultural interests both within and outside the Hopi reservation. The responsibility requires the involvement and the input of the Hopi tribal government, Hopi villages, clans, and religious societies, as well as coordination with Federal agencies who manage Hopi ancestral lands and sacred spaces. The Hopi Cultural Preservation Office is the central tribal clearing house for the culturally-related issues coming to the attention of the Hopi Tribe. For over three decades, the Hopi Cultural Preservation Office has worked with Federal agencies to protect and preserve cultural resources within Hopi Tutskwa (Hopi Aboriginal Lands) in the greater Southwest. Much of this work has been accomplished by sharing Hopi knowledge to inform and influence federal activities and decisions.

Evaluating rock pool hydroperiod fluctuation using climate variables to inform habitat monitoring and protection in the western Sonoran Desert

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ABSTRACT: The western Sonoran Desert is one of the driest areas in North America and seasonal freshwater rock pool habitats, known as tinajas, are threatened by continued warming and drying climate trends. Tinajas are recharged by rainfall and provide intermittent habitat for aquatic invertebrates and critical drinking water for a variety of wildlife species. However,

changes in water persistence between rains, known as a hydroperiod, may affect future insect biodiversity and dependent predator populations. Partnering with the National Park Service and the University of Arizona, this project evaluated historic climate variables that influence tinaja hydroperiods and analyzed historical water fluctuations over the last 40 years. Observations from Aqua and Terra Moderate Resolution Imaging Spectroradiometer (MODIS), OpenET, and the Gridded Surface Meteorological dataset (gridMET) were used to calculate climate variable normals and variability for evapotranspiration, land surface temperature, wind, solar radiation, and precipitation in a climatological time series analyses. A hydroperiod trend analysis was then applied to a case study of 10 known tinajas with *in situ* observations to quantify historical trends of wet and dry periods. Climate maps and time series showed increases in temperature and solar radiation ($p<0.05$), while analyses of *in situ* data showed correlations of hydroperiods with precipitation and evapotranspiration. End products identified high-risk tinajas and demonstrated that Earth observations can successfully be correlated with *in situ* hydroperiod observations and used to prioritize water resource management and inform protocols driving the conservation of tinajas.

Are foliar stripes part of a pollinator syndrome in monkeyflowers?

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ABSTRACT: In monkeyflowers, genus *Mimulus*, anthocyanin pigmentations and patterns have been explored rigorously in flowers, yet few studies have explored the function and genetic framework of foliar anthocyanins. Anthocyanins can contribute to plant-animal interactions, including attracting pollinators and frugivores, as well as repelling herbivores and parasites. *Mimulus verbenaceus* has a lateral purple stripe across the green leaf due to anthocyanin pigments, a relatively recently evolved trait that has risen to a high frequency in natural populations. *M. verbenaceus* is an herbaceous perennial found in riparian habitats in the southwest. The evolutionary processes through which the striping phenotype rose in frequency in natural populations is unknown. We hypothesize striped *M. verbenaceus* plants have a fitness advantage over non-striped plants in natural populations. We posit that plants with the purple lateral pigmentation pattern are being selected for through hummingbird pollination; with the stripe acting as a visual cue to recruit pollinators. Hummingbird pollination may lead to higher reproductive fitness, as there is a potential for increased heterozygosity through outcrossing. Additional traits associated with leaf striping may contribute to pollinator recruitment and indirectly contribute to this potential fitness advantage. We test this hypothesis through a series of greenhouse grow-ups and complementary field studies using two parental genotypes with and without the striping phenotype and an F_2 family derived from a cross between the two parental genotypes. If our results show a fitness advantage for striped over non-striped plants, we can conclude natural selection is acting on these populations. If striped plants are significantly more likely to have negative stigma-anther separation and larger floral diameters, our results would be consistent with a cross-fertilization syndrome. Such results would suggest an effect on fitness related traits based on striped *M. verbenaceus* plants, leading us to conclude outcrossing by hummingbirds promotes high reproductive fitness and impacts population persistence.

Evaluating management options for addressing the cumulative effects of a changing climate and decades of increasingly departed fire regimes

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ABSTRACT: The Tonto National Forest encompasses almost 3 million acres that include Sonoran Desert as low as 1,300 feet, and wet mixed conifer at almost 8,000 feet. Management choices made decades ago on, and far from, the Tonto National Forest have significant influences on the potential ecological trajectories for most of these ecosystems. *Bromus rubens,* planted a century ago in southern Arizona has been the primary driver for about 411,056 acres of fire in the Sonoran Desert since 1970. At higher elevations, interrupted fire regimes have changed the nature of ecotones between forested areas and shrublands, allowing fire to whittle away at forest edges and, with increasing frequency, burning large portions of the remaining forests with uncharacteristically high severity. Between 1990 and 2021, about 23% of the forested areas on the Tonto National Forest burned with uncharacteristically high severity fire in areas that are unlikely to recover to a forested condition. Management actions over the last century have set up sociopolitical expectations that further complicate and limit management options. In the face of climate change, the management of landscapes with highly departed ecological functions presents enormous challenges for managers needing to identify management actions that can support the ecological future of the landscapes on the Tonto National Forest.

Effects of fire on biological soil crust in pinyon-juniper woodlands

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ABSTRACT: Climate change and exotic grass invasion are increasing wildfire frequency and severity, threatening Pinyon-Juniper woodlands (PJ) across the Western US. In addition, PJ woodlands have been affected by fuel-reduction treatments (i.e., thinning or mastication). Many species and communities are highly dependent on PJ woodlands, including one of the Colorado Plateau's most fundamental organisms, biological soil crusts (biocrusts) – assemblages of cyanobacteria, lichens, and mosses that live atop dryland soils. Biocrusts adhere and stabilize soil surfaces and have large effects on soil fertility and water availability, however, biocrusts are highly sensitive to disturbances. Here, we used a burned, unburned, and thinned or masticated experimental design to examine fire effects and fuel-reduction treatments on biocrust communities and soil biogeochemistry. Biocrust community composition and total cover was significantly influenced by wildfire, with many biocrust species showing no signs of regeneration decades after fire. Burned areas had significantly higher cover of bare ground, early successional cyanobacteria, and short-ruderal mosses compared to unburned areas. In contrast, unburned areas (i.e., intact PJ woodlands) hosted an abundance of late successional mosses,

lichens, and darkly-pigmented cyanobacteria. Notably, the tall moss *Syntrichia ruralis* was found exclusively underneath the canopies of *Pinus edulis* and *Juniperus osteosperma* – suggesting PJ as an important habitat for this species. Fuel-reduction had variable effects on biocrust. At sites where trees were thinned, the biocrust community was similar to unburned areas, but when trees were masticated (mulched and spread across the soil surface), biocrust cover was reduced, similar to burned areas. At these masticated sites, soil nutrients were higher than burned areas – suggesting mastication can have a significant effect on nutrient cycling. Overall, our results suggest that wildfire reduces diversity and abundance of biocrust for decades, whereas fuel-reduction treatments have variable affects on biocrust and soil biogeochemistry, which depend on the fate of the thinned woody debris.

Who started, stopped, and continued participating in outdoor recreation during the COVID-19 pandemic in the United States? Results from a national panel study

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ABSTRACT: The COVID-19 pandemic has been proposed as a catalyst for many US residents to re-engage in outdoor recreation or engage in outdoor recreation for the first time. This research describes the results of a representative US national panel study aimed at better understanding the socio-demographic profile (gender, ethnicity, community type, income, and age) of those participants new to outdoor recreation since the start of the COVID-19 pandemic. This research addresses how these new outdoor recreationists differ from (1) those who frequently participated in outdoor recreation prior to the pandemic and continue to participate in outdoor recreation, (2) those who did not frequently participate in outdoor recreation prior to the pandemic and remain un-engaged, and (3) those who frequently participated in outdoor recreation prior to the pandemic but stopped their frequent participation following the onset of the pandemic. More than 20% of the sample indicated that they were new outdoor recreationists. The majority of respondents in all categories, including those that were new to outdoor recreation amidst the pandemic, identified as being white, however these new outdoor recreationists were also the least ethnically diverse. The previously but no longer outdoor recreationist respondents were significantly more ethnically diverse than the other three groups, and they tended to live in more urbanized settings. Discussion of these results includes implications for outdoor recreation managers and researchers who seek to better understand who the COVID-19 pandemic has influenced with regard to outdoor recreation participation. Implications regarding social justice, access and equity to public places that facilitate outdoor recreation, and health-related policies, will be addressed.

Informing visitor use management with statistical and simulation modeling: Examples from the field

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ABSTRACT: There has been unprecedented growth in visitation in national park units and other public land recreation areas throughout the United States in recent years. Consequently, management decisions about how best to protect natural and cultural resources while providing high-quality visitor experiences are more challenging than ever. There is momentum across the National Park System and elsewhere to develop and apply visitor use management strategies to balance visitation with desired conditions for park resources and visitor experiences. Among the more notable developments in visitor use management is the piloting and implementation of reservation and timed-entry systems. These and other visitor use management strategies are potentially contentious and are often challenging to develop and implement for complex social-ecological systems. Statistical and simulation modeling are powerful tools for informed visitor use management and decision-making across public land recreation areas. Models provide a data-driven basis to establish existing park conditions and to evaluate relationships among amounts and types of visitor use and indicators of park conditions. Furthermore, statistical and simulation models provide a space to experiment with and evaluate potential management scenarios to help inform pilot applications and long-term implementation. This presentation will use examples from the field to illustrate the role of statistical and simulation modeling to inform visitor use management decisions.

Creating opportunities for knowledge exchange to inform fire and climate adaptation planning

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ABSTRACT: Decades of fire suppression that includes the exclusion of the Indigenous use of fire, combined with increased warming and drying from climate change, have contributed to larger and more severe wildfires across the Southwest. Land managers and communities thus require additional approaches to face the consequences of these for natural resource management. To address such urgent issues, the Southwest Climate Adaptation Science Center (SWCASC) collaborates with multiple partners to provide opportunities for co-produced, actionable research and knowledge-sharing. Much of this work supports collaborations with Indigenous Peoples and communities, who are leading the way in implementing climate adaptation strategies with both traditional and western-based science approaches. This includes the use of cultural burning to increase the resiliency of ecosystems and cultural health. For example, the SWCASC is collaborating with the North Fork Mono Tribe in the southern Sierra Nevada in a series of hands-on traditional burning efforts that are accompanied by pre- and post-vegetation monitoring. This work directly contributes to targeted decision-making processes and supports the application of Indigenous-led stewardship. To further facilitate knowledge exchange, the SWCASC and the Southwest Fire Science Consortium, along with other partners,

initiated the Southwest Fire and Climate Adaptation Partnership (SWFireCAP) — a network of partners working together to advance fire and climate adaptation in the Southwest. SWFireCAP is a space for knowledge exchange through roundtables focused on cultural burning and fire-focused on-the-ground adaptation planning. The partnership has leveraged existing opportunities through conference and forum sessions, including a day-long participatory session focused on the use of "good" fire during the 2021 Southwest Adaptation Forum and a keynote session at the 2022 International Association of Wildland Fire Conference, featuring a panel of Indigenous early career researchers. The SWCASC, along with its SWFireCAP partners, seeks to continue to broaden this important work throughout the Southwest region and beyond.

Collaborative development of CREVAT, a GIS-based tool to assess NPS cultural resources vulnerabilities to climate change in the Intermountain Region

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ABSTRACT: Current planning for the stewardship and conservation of cultural resources in the national parks has been based on historical patterns in weather and material response. Because of climate change, these norms may no longer be applicable. As conditions and material responses change for natural and cultural resources, it will be more difficult to fulfill the National Park Service (NPS) mission to 'preserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations.' To prepare for potential future changes, the NPS Vanishing Treasures Program partnered with the University of Arizona to develop a framework to address climate change impacts on cultural resources in the NPS Intermountain Region. Project partners developed an interactive online vulnerability assessment tool that incorporates the degree to which environmental factors impact an area (*exposure*) and the degree to which a cultural resource is impacted by exposure (*sensitivity)*. The tool incorporates environmental factors such as extreme precipitation and soil erosion and calculates sensitivity using a novel approach for cultural resources building systems that includes factors such as predominant system material and complexity of construction. Using the Cultural Resources Environmental Vulnerability Assessment Tool (CREVAT), park managers can access the project's vulnerability assessment through two geospatial tools; one summarizes cultural resource vulnerability at the park level and the other summarizes vulnerability at a regional scale, allowing managers to evaluate and compare vulnerability and risk across parks. NPS cultural resources managers and university researchers collaboratively developed CREVAT to meet the needs of park managers for preliminary cultural resources climate risk assessments and reports to supplement field-based

evaluations. CREVAT climate risk information was incorporated into a year-long initiative to generate Intermountain Region adaptation strategies, through a multi-scenario planning process tailored to address cultural resource challenges.

Mixed-severity wildfire shapes habitat use of ungulates and large carnivores

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ABSTRACT: Wildfire is a widespread form of ecological disturbance and can have both positive and negative effects on animals. Further work is necessary to understand how large mammalian herbivore and carnivore populations respond to the gradient of fire severity. The overall objective of this research was to understand the relative roles of bottom-up and top-down factors across the gradient of fire severity on populations of ungulates (i.e., elk and mule deer) and large carnivores (i.e., black bear, mountain lion, and gray wolf) seven years post fire. Remote wildlife (RW) cameras sampled the gradient of fire severity seven years post a large mixed-severity wildfire (Wallow Fire, year 2011, 2,177 km^2) in the White Mountains of Arizona, USA. We evaluated RW camera data using single-species occupancy and Royle-Nichols (relative habitat use) models. As predicted, large mammals (black bear, elk, mountain lion, mule deer, and wolves) exhibited high occupancy and/or habitat use in relation to higher levels of fire severity and/or fire heterogeneity, which was likely related to increased food resources, 7 years post fire, and cover. Some species (black bear and elk) also exhibited relatively high use of unburned forest. If high occupancy and/or habitat use by wildlife in areas experiencing higher fire severity and heterogeneity translates into increased populations of animals, wildfire might be beneficial to humans, focal wildlife populations, and fire-adapted ecosystems.

Future of Piñon-Juniper Woodlands in response to extreme drought in the Southwest

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ABSTRACT: Although the increased drought-driven mortality events in Southwestern US woodlands in the last two decades is well documented, we know less about how these mortality events impact organismal and ecosystem-scale processes as the ecosystem recovers. We synthesize empirical responses in two large-scale girdling experiments in New Mexico pinon-juniper woodlands (PJ) that differed in elevation and ecosystem structural characteristics to understand the impact mortality events have on the mechanisms that amplify climate change, and the trajectory of these woodlands as they recover. We asked three questions: (1) What impact does piñon vs juniper mortality have on soil temperature and moisture patterns? (2) What impact does piñon vs juniper mortality have on remaining sapling and adult physiological and growth

processes? And (3) What impact do coniferous mortality events have on carbon sequestration, albedo, moisture and heat exchange processes? The two girdling experiments led to different outcomes in soil moisture and temperature suggesting both prevailing climate and factors such as canopy density and soil type are important determinants of this response. Both piñon and juniper saplings are quite tolerant of higher radiation and heat levels associated with overstory mortality, regardless of which species dies. Juniper saplings have higher photosynthetic and growth rates than piñon saplings under dead trees, particularly when water availability is low, however, unlike piñon, they do not recruit every year. Ecosystem scale processes rebound ~3-5 years following mortality and we see no evidence so far that these mortality events are triggering conversion of PJ to savanna. Given that PJ woodlands are not only susceptible to drought-related disturbances but dominated by two tree species with distinct hydrological niches and trait spectra, we suggest it is a model system to help predict the future trajectory of a variety of dryland woodlands under a regime of increased drought disturbance.

Native American cultural connections with pinyon-juniper woodlands

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ABSTRACT: The movements of the Ute people were based on the availability of resources and season. During the warmer seasons such as spring and summer, Utes would occupy higher elevations. The springtime was the New Year for the Utes, time to celebrate with the Bear Dance and the awakening of all that went dormant during the colder months. Fall and winter started the move down low, harvesting berries, nuts, and game. There are specific times when harvesting Pinyon Juniper (PJ) for the lodges of the Bear Dance. The blessings of the trees will provide strength and wisdom of the times. Trees are people and possess their own spirits. Each is taken with a prayer. Fire is an important element to the Ute people. I remember my grandmother's home was wood heated. It always felt like the best warmth, nothing like a good wood fire at grandma's house. Fire is a very integral part of prayer and ceremony. Fire is one of the four elements necessary within our sacred space. PJ woodlands are on a 400+ fire regime, meaning they have large stand-replacing fires every 400-500 years. Except now it's much more frequent, and they're not returning to PJ woodlands – instead PJ is being invaded by non-native grasses that take over. This means resources we utilized for our daily and ceremonial uses diminish. A part of our cultural identity disappears and leaves us to try to teach our young people about Ute ways from memories of what used to be. We see this as a loss of a family member. We have over harvested in some locations because we utilize what is in our reservation boundaries. Would this mean we don't build the Bear Dance lodge? Does this mean we don't dance to celebrate a new year? We teach our children by dancing with them, and they can see us beside them. Prayers won't be said, and teas wouldn't be administered for healing purposed and cleansing. Life as a Ute person would be sad and so different.

Evaluating greenness and water requirement of urban greenery using Sentinel imagery in Google Earth Engine in a dryland city

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ABSTRACT: Advancements in remote sensing are expanded in a wide range of disciplines, and spatial scales, including urban planning. Greening and cooling cities are of priority to many municipalities and local governments. Accessibility to open-access satellite images and cloud platforms that optimally process a large amount of satellite imagery help urban planners to manage urban green spaces (UGS) more efficiently. In this study of UGS, we use higher resolution Sentinel imagery (10 m) in Google Earth Engine (GEE) to evaluate changes in greenness and the water requirement in Sanandaj, Iran. Sentinel-derived Normalized Difference Vegetation Index (NDVI) of urban greenery within the city limits is calculated and mapped to assess the changes in greenness for all the UGSs from 2019 to 2021. Evapotranspiration (ET) of UGS is then estimated using a vegetation-based RS-ET method to evaluate their water requirement. A total of 309 Sentinel 2 satellite images were processed in GEE. We compared UGSs in different months regarding their trends over the study period. UGS monthly mean NDVI in 2019, 2020, and 2021 are 0.575, 0.568, and 0.529, respectively; this shows that the extent or quality of urban greenery decreased in Sanandaj between 2019 and 2021. The results show that the city is the greenest in May. In contrast, in February, the city is the most non-green and thus the driest. In this month, we not that some green spaces dried out due to water scarcity or did not reach their potential greenness due to deficit irrigation. We conclude that the methods and results of UGS from this aridland city may be useful for evaluating trends in both greenness and water use (or requirement) in urban centers with similar dryland vegetation on the Colorado River Basin in the US; Moab, Phoenix, Las Vegas, Yuma & Tucson are cities undergoing pressures from drought.

Lessons learned from the Bears Ears Inter-Tribal Coalition

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ABSTRACT: The Bears Ears Inter-Tribal Coalition worked with the Obama administration, National Park Service, Bureau of Land Management, and other entities in a collaborative process to develop a comanagement model for the Bears Ears National Monument. Over the years, the US government established policies and procedures to work with Tribes as sovereign nations to care for Sacred Sites: the federal government would “accommodate” (Executive Order 13007), provide “consultation and coordination” (Executive Order 13175), and finally, recently committed to “collaborate in the co-stewardship of Federal lands and waters" (Joint Secretarial Order No. 3403). A historic cooperative agreement signed in June 2022, finally granted Tribes cooperative status on decision-making processes, protection, and management of Bears Ears National Monument. This talk will focus on the process of working for the collaboration and

comanagement of Bears Ears. It is important for government entities, state and local, to accept changes proposed by Tribal members. The Bears Ears Coalition always strove for a paradigm shift needed to carry out their initiative. The shift required significant education about how traditional governments differed from Western governments, and recognition of the cultural perspectives of each.

The ecological recovery of plugged and abandoned oil and gas well pads across the Colorado Plateau

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ABSTRACT: The Colorado Plateau contains approximately 100,000 abandoned and current oil and gas wells spanning 60+ years of activity. The physical and ecological footprint of these developments can be quite large and there is uncertainty on where, when, and how these highly disturbed lands can be successfully reclaimed. The overarching goals of this research effort are: 1) to understand how past and current energy developments are impacting ecological systems of the Colorado Plateau, and 2) to identify strategies to mitigate deleterious consequences of these activities. We collected data from 134 plugged and abandoned well pads over two years (2020 and 2021) and across three states (Utah, Colorado, and New Mexico). We sampled from a population of plugged wells provided by the Bureau of Land Management using a stratified random sample design. To understand the degree of ecological recovery each pad has achieved, we quantified a suite of plant, soil, and landscape measurements from a chronosequence of pads that broadly represent the soil and climate settings of the Colorado Plateau. We followed Assessment Inventory and Monitoring (AIM) protocols to facilitate comparison of pad condition to those in the broader landscape. We found trends in our plant and soil measurements on reclaimed well pads compared to AIM plots, with variation in outcomes among soil and climate settings. Cover of bare ground, noxious species, and large canopy gaps (>100 cm) were generally higher on well pads compared to AIM plots, while total foliar cover was lower. Taken together, this large data set, that spans gradients in time since reclamation, climate, and soil types, will be valuable for ascertaining possible reclamation outcomes and success rates. This new information can then be used to plan reclamation of abandoned and marginal wells and serve as reference data for agencies and landowners to evaluate outcomes across the region.

Traditional Ecological Knowledge and Land Management

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ABSTRACT: There is a large realm of land management actions that can be improved and benefit from the knowledge of tribal people who were the stewards of these places generations before public lands were established. Federal agencies like the Forest Service are led by science-based decision-making. Traditional Ecological Knowledge (TEK) is an understanding of the natural world acquired through generations of human interactions with particular landscapes. Tribal nations have the same goals as federal land managers, to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. Where appropriate, TEK can and should inform Federal decision-making alongside scientific inquiry. To integrate TEK into management effectively, actions must be co-produced with local and Indigenous communities, which requires cultural sensitivity, safe-guarding of information, and relationship-building among partners. In this session, case studies of Indigenous TEK-integrated management across the Southwest have been presented. Using these case studies, as well as perspectives from partners in a question and answer panel session, we will create a compilation of best practices and chart a path forward to increase Tribal perspectives in federal public land management.

Tamarisk biological control significantly alters bird community composition in the absence of cottonwood and willow vegetation

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ABSTRACT: We investigated how the initial stages of riparian recovery from tamarisk biocontrol and how tamarisk decline affected birds, their arthropod prey, and microclimate. We compared avian community diversity and composition, arthropod abundance, and humidity and temperature at sites along the Virgin River in Nevada and Arizona, USA characterized as either mixed native vegetation (50-75% of canopy native vegetation), tamarisk-dominated vegetation (70-90% tamarisk) or tamarisk-dominated vegetation where the majority died due to biocontrol. We compared avian communities sampled after biocontrol to counts at the same locations before biocontrol. Prior to biocontrol, community compositions of all but one site grouped together based on unbiased clustering algorithms. Following biocontrol, tamarisk-dominated sites grouped separately, and mixed sites grouped with the pre-biocontrol cluster. Comparison of pre- and post-biocontrol communities showed 7 common species declined by 30% or more in sites dominated by dead tamarisk, while one species did so at mixed sites and 3 at tamarisk-dominated sites. Individual census points in dead tamarisk had significantly lower Simpson diversity than the same points censused prior to biocontrol, unless native vegetation was present, supporting the hypothesis that death of tamarisk was the cause of changes in dominant species abundances. Following biocontrol, tamarisk sites were warmer and drier and supported fewer non-tamarisk-obligate arthropods. Our results indicated dieback and mortality of tamarisk from biocontrol was associated with decreases in several common bird species during this initial phase of riparian recovery, although this effect was ameliorated when native willow and cottonwood were present and are consistent with the hypothesis that reductions may be driven by changes in microclimate

and arthropod prey abundance. We recommend tamarisk management include native vegetation planting in areas impacted by tamarisk beetles.

Reclamation methods matter for long-term site stabilization on a dryland Arizona mine

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ABSTRACT: Reclamation on federal land entails a series of actions intended to create a self-sustaining plant and soil community that approximates and sets the stage for succession to the original, undisturbed native ecosystem. Conventional reclamation methods (such as drill seeding with non-native plants) are still frequently used by industry specialists, although novel approaches integrating ecological concepts which address biophysical barriers to ecosystem recovery are now being considered. Novel and traditional methods vary not only in cost and likelihood of establishing desired species, but also in how they contribute to or detract from short-term site stability (e.g., susceptibility to soil erosion). An understanding of these costs and benefits is particularly important in the context of mining, for which stabilization of potentially contaminated soil is critical. We tested reclamation methods at an abandoned uranium mine in northern Arizona as part of a broader effort to assess risks of uranium mining to ecosystems of the greater Grand Canyon region. We compared seeding methods, seed mixes, and inoculation with biological soil crust, to understand how reclamation choices can influence the resulting community and site susceptibility to soil erosion. We found that a novel seeding method using artificial shelters, although more costly, resulted in greater perennial plant cover, increased plant litter on the soil surface, and greater resistance to surface erosion. A seed mix using only native species also resulted in greater perennial plant cover and growth rate compared to a non-native seed mix. Although biocrust persisted throughout the post-treatment monitoring period, we detected no relationship between inoculation and soil resistance to erosion or plant community composition after four years. These results suggest that certain novel reclamation methods may aid in improving soil resistance to erosion and increasing perennial plant growth, critical factors in both re-establishing native ecosystems and the long-term stabilization of post-mining sites.

Indigenous woodland management and energy sovereignty on Cedar Mesa, Utah

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ABSTRACT: The well-being of people is intertwined with the health of woodlands and forest ecosystems across the world. Integral to many aspects of health like clean air and water, arboreal ecosystems directly provide fuel, food, and medicines. People participating in arboreal ecosystems mediate nutrient flows, fire ecology, and species distributions. Over millennia, both arboreal ecosystems and people local to those ecosystems have adapted to human-forest

interactions. The Pinyon-Juniper woodland on Cedar Mesa in southeastern Utah is one such system. Today, numerous Indigenous communities rely on this woodland for a variety of resources, especially firewood. In 2018, we began human ecological research to articulate how Indigenous Traditional Ecological Knowledge (ITEK) is at work on Cedar Mesa, how to best translate this ITEK into land management practices, and how this may be impacted by climate change. Interviews, focal follows and surveys about firewood harvesting, ecological monitoring, and modeling based on remotely sensed vegetation data emphasize the central role of these woodlands in Tribal energy sovereignty in the region. While larger regional energy transitions and infrastructure improvements hold promise for promoting energy access and sovereignty in the Four-Corners region, woodlands are likely to continue to play an important role in household energy budgets. As droughts threaten the region, tree mortality rates are likely to increase, which poses a long-term threat to the valuable relationship between people and the woodlands. Firewood harvest has the potential to mitigate some of the impacts of climate change on the woodlands, such as reducing fuel loads to limit fire. Although current carbon emissions have already committed the world to warming, and likely committed the Pinyon-Juniper woodlands on Cedar Mesa to substantial changes, the continuance of ITEK practices is integral to sustaining human and woodland health.

Pre-fire assessment of post-fire debris flow hazards in the Santa Fe Municipal Watershed.

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ABSTRACT: Forest fires are increasing in size and severity due to drought, a warmer climate, and overstocked forests. Not only do fires directly threaten communities, but post-fire flooding and debris flows pose significant threats to water supplies, life, and property. High- and moderate-severity forest fires increase the likelihood of post-fire debris-flows by forming water-repellent soils and removing forest canopies, plants, and litter, all of which decrease infiltration and increase runoff and erosion. Given different rain and fire scenarios, the probability of debris-flow occurrence and volume can be estimated using empirical models for locations in mountainous landscapes. Recent observations suggest that high-severity fires are increasingly likely and therefore planning for post-fire debris flows is increasingly important. This presentation addresses two fundamental modeling questions posed by the debris-flow hazard assessment for the Santa Fe Municipal Watershed (SFMW): where are debris flows most likely to occur and how much debris might they produce? We discuss the probability of post-fire debris flows in high, medium, and low fire and precipitation scenarios, how previous forest treatments and topography impact debris flow hazard and volume by impacting burn severity, and the impact of modeled debris flow volumes on water supply infrastructure and communities downstream. Results and implications from this work can help inform water and forest managers (e.g., targeting high-risk sub-basins for future treatments or post-fire mitigation), providing an

opportunity to prepare for and mitigate potential negative effects associated with fire and subsequent debris flows.

Utilizing translocation with symbiotic mycorrhizae to cope with multiple stressors

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ABSTRACT: During the UN Decade on Ecosystem Restoration, the need for regeneration, replanting, and restoration is expected to grow, while planting material shortages constrain efforts and climate change presents new challenges. We tested two strategies to address these challenges: translocation of tree ecotypes and of native mycorrhizal communities symbiotic with plant roots. In some studies, intraspecies translocations from warmer climates still show neutral to negative results compared to local provenances. Additionally, mycorrhizal inoculation, effective if well-matched to plants and site conditions, can have neutral to negative results with poor pairings, so methods for its use with translocation are not obvious. Few studies examine the interaction between these two strategies. We evaluated these two factors and their interaction with the soil legacies left by an invasive plant, under mega-drought conditions not experienced since 800 CE. We compared *Populus fremontii* (Fremont cottonwoods) from two ecoregions / adaptive trait syndromes (a confluence of traits adapted to either frost or heat). Trees were planted at a field site in soils with or without legacies of invasion by exotic *Tamarix* spp. (tamarisk). For half of the trees, we concurrently translocated native mycorrhizal fungi. Four main lessons emerged. (1) Tamarisk soil legacies reduced native cottonwood survival by 85%. (2) Active translocation of a diverse, native community of mycorrhizal fungi after tamarisk invasion doubled and then tripled cottonwood survival during the first and second field seasons. (3) By the second field season, translocated trees survived at twice the rate of trees from the local ecoregion, if inoculated. (4) However, inoculation sometimes had neutral to negative effects, interacting with timing, pairing between tree and inoculum sources, and soil conditions. Results emphasize the efficacy of utilizing symbiotic relationships in translocation, the need to thoughtfully optimize mycorrhizal pairings and inoculation timing, and the detrimental effects of an invasive plant's soil afterlife.

The gap between mycorrhizal science and application: existence, origins, and relevance during the United Nation's Decade on Ecosystem Restoration

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ABSTRACT: During the United Nation's Decade on Ecosystem Restoration, planting material shortages are expected to constrain restoration. Climate change is expected to reduce recruitment and exacerbate the need for restoration and natural regeneration. Concurrently, research shows that native mycorrhizal fungi optimized to plant provenance and site conditions significantly and meaningfully accelerate restoration, support crucial ecosystem services, and provide natural climate solutions (sequestering carbon), and nature-based solutions for climate change (providing climate adaptation). We reviewed 130 systematically available management plans for natural areas in the United States to evaluate whether the science-based innovation of restoring native mycorrhizal communities has translated into implementation. Results are notable: management plans frequently discussed the ecosystem services mycorrhizal fungi provide, but nearly one half (46%) viewed fungi solely as pathogens or ignored them altogether. Only 8% of plans mentioned mycorrhizae. Only one plan mentioned that mycorrhizae were potentially helpful to natural regeneration, and one mentioned utilizing soil as a restoration tool. Our examination of publicly available data and case studies suggests that relatively meager protections and research funding, research difficulty and data paucity, and limited access to mycology experts and training characterize this gap between science and implementation. A database of literature showcasing mycorrhizal ecosystem services and benefits is provided to highlight when and why mycorrhizae should be considered in management, regeneration, and restoration. Three action items are recommended to safeguard native mycorrhizal communities and accelerate restoration and regeneration. Ten implementation tips based in scientific literature are provided to clarify the need and methods for mycorrhizal restoration.

Analyzing differences in endophytes in saguaros (*Carnegiea gigantea)* across different precipitation and solar radiation levels

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ABSTRACT: Deserts are often overlooked when discussing climate change and its effects, as hot, dry conditions become more common. However, as periods of prolonged drought and temperatures have increased, saguaro (*Carnegiea gigantea)* seedlings are failing to reach maturity. Bacterial and fungal endophytes can improve plant tolerance to stressors like heat and drought, but their importance to saguaros is poorly understood. We examined the endophytic microbial communities of eleven saguaro populations along a solar radiation gradient. We hypothesized that: 1) the endophytes found in the north-facing side of saguaros would be more abundant and diverse than the endophytes in the south-facing side of plants and 2) that the endophytes of the south side of plants would be more tolerant of heat and drought conditions. To test our hypotheses, we sampled tissue from the north and south side of five saguaros from each of the eleven populations, surface sterilized them, plated them on potato dextrose agar, and monitored them for fungal growth. The isolated endophytes will be identified using DNA analysis and tested for drought tolerance by using polyethylene glycol (PEG) at different concentrations which simulates drought conditions. Our preliminary results show two key

findings: (1) hypothesis 1 was not supported, there were higher rates of infection on the south-facing side of the plant ($p<0.001$); (2) fungi comprised a greater proportion of endophytes than bacteria ($p<0.001$). Hypothesis 2 testing the heat, drought tolerance of endophytes is currently underway. The functional roles of saguaro endophytes may be important in the adaptation of saguaro to heat and drought. As southwest deserts become hotter and drier due to climate change, saguaro endophytes may play an increasingly significant role in responses to that change. We hope to identify endophytes that promote heat and drought resistance as a means of improving saguaro seedling establishment.

Natural resource management professionals Tribal workforce development

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ABSTRACT: There is a recognized need for tribal workforce development to address anticipated losses in experienced and knowledgeable tribal forest practitioners. These losses are due primarily to an aging workforce in both federal and tribal programs. The Ecological Restoration Institute at Northern Arizona University has been leading efforts to address these anticipated losses. In this presentation, I will discuss various collaborative initiatives to promote: 1) Increasing opportunities and access to forestry education classes; 2) Increasing interest in natural resource management careers; 3) Working with a variety of agencies and partners to increase employment opportunities. One of such initiatives is the Tribal Forestry Student Summit being organized with the Intertribal Timber Council, other higher education institutions, and NGOs. The Summit will provide an opportunity for next generation of forestry and natural resources practitioners to interact with experienced professionals to maximize transfer of institutional knowledge. It also provides an essential pathway for the enthusiasm and innovative thinking of the next generation to be integrated to the resource management profession. However, tribal workforce development needs continuous long-term investment to sustain the efforts with iterative assessment and innovation.

Developing and using native plant materials for restoration across the Intermountain West

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ABSTRACT: Restoration in water-limited drylands is an inherently difficult task as a result of prevailing adverse weather conditions, notably hot and dry conditions, in combination with variable site characteristics and invasive species. Restoration complexities are further compounded by having to choose native plant materials that will be appropriate for a site, including from the pool available within a species as well as from what is available among species; in many instances, desired native plant materials may not even exist. Typical guidance suggests that native plant materials be “genetically appropriate” for restoration sites, which most often means that they are locally adapted to similar environmental conditions. A variety of tools

and data can be used to support these goals, and I will discuss ongoing work on the Colorado Plateau to increase the availability of regional materials and encourage their best use. In particular, the Bureau of Land Management Colorado Plateau Native Plant Program is supporting landscape genomic analyses to identify patterns of genetic diversity and adaptation in restoration species, as well as the elaboration of a workflow to prioritize the development of new plant materials. Such investments are critical to facilitate successful restoration outcomes across the Intermountain West.

Addressing redundancy and representation in rare species recovery frameworks using genetic and distributional data

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ABSTRACT: A primary concern of conservation efforts is delineating groups of individuals that may, under successful management, lead to species recovery without the loss of intraspecific diversity. In the United States (US), the US Fish and Wildlife Service implements the concepts of resiliency, redundancy, and representation when developing management guidelines to achieve recovery and protect diversity. Genetic data have proven useful for informing redundancy and representation, though few spatial methods are available to extrapolate site-based empirical patterns across a species' range. Herein, we demonstrate how ancestry probability surfaces developed using a new methodology (popmaps) may overcome the challenges inherent in creating spatially explicit guidance. Popmaps uses empirically derived population structure patterns to estimate populations over a species-specific landscape surface. First, we combined population structure analyses with pairwise, population-specific demographic modeling to investigate historical processes influencing Graham's beardtongue (*Penstemon grahamii*), a rare plant narrowly distributed across the Uinta Basin in Utah, a dryland region of the western US. This combination of analyses helped us reconcile conflicting genetic patterns – namely that an abrupt shift in ancestry near the center of the species' range illuminated by some analyses likely resulted from a history of recent admixture. With knowledge of genetic patterns in hand, we developed an ancestry probability surface that quantitatively depicts, with uncertainty, the distribution of the genetically defined populations. Furthermore, we investigated the environmental space represented within and between populations to understand if certain populations and/or sites are experiencing unique climates, which may be informative to management given future climate scenarios. Beyond providing a species-specific product to inform management options, our study highlights how understanding demographic history may be critical to guide conservation efforts when interpreting population genetic patterns.

Vital signs: condition survey and vulnerability assessment for built heritage

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ABSTRACT: This paper outlines the development of a framework for risk and vulnerability assessment for built heritage using new digital surveying methods coupled with spatial analytical tools. The Center for Architectural Conservation (CAC) has been developing and testing condition survey methodologies that seek to formalize and expedite the survey process as a cyclical monitoring tool for more effective site management in the face of changing climate. Many past and current site condition surveys tend to focus on the identification and remedial treatment of immediate conditions. While this serves an important and necessary function, most surveys do not collect essential data conducive for replication or in a manner that can be used to model future damage. Recently, the CAC and National Park Service have developed and tested a range of survey methods at several national parks including Fort Union, Pecos, Tuzigoot, and Wupatki. These parks are expected to experience increased temperature and drought over the coming years; however, intensive individual precipitation events during the summer have already challenged current methods and cycles of preservation leading to unprecedented wall failure and collapse at many sites. Site managers need a better way to help prioritize resource risk based on current and future conditions as a function of an entire set of factors including environmental context, original construction, past treatments, and micro weather data. Further analysis of the data relative to wall construction, past conditions and interventions (legacy data), and weather data including time sequence photography completes the picture to establish relative risk and vulnerability for individual features across the entire site. The expediency of real-time spatialization has the potential to influence the ways that site managers prioritize their work in real-time and, in the long term, monitoring or intervention of priority areas. The framework contributes to moving site management from remedial to preventive preservation.

NEON in the Colorado Plateau and Southwest region: expanding the scope of ecological science through long-term, open access ecological data

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ABSTRACT: The National Ecological Observatory Network (NEON) is a continental-scale observation facility that collects long-term, open access ecological data to better understand how ecosystems are changing across the United States. NEON will provide 30 years of data from 81 terrestrial and aquatic field sites, including four sites within the Colorado Plateau and Southwest. NEON data cover a range of subject areas within ecology, including organismal observations, biogeochemistry, hyperspectral imagery, and micrometeorology. All samples and data collected by NEON are publicly available and can be accessed digitally through the NEON website. By providing free and open standardized data - along with data analysis tools, tutorials, and educational resources - NEON is engaged in the global effort to expand the scope of science and make scientific data access easier for all. NEON's field sites within the Colorado Plateau and Southwest are essential to continuing the most extensive ecological data collection and monitoring program in the United States. A vast array of scientists from various disciplines within ecology have conducted research using NEON data and samples from NEON field sites in the Southwest and Colorado Plateau. Many of these studies use NEON data to investigate

questions that contribute to our understanding of climate change. This talk will introduce NEON's field sites in the Colorado Plateau and Southwest, resources for working with various NEON data for research or education and showcase research using NEON data from NEON field sites in the Colorado Plateau and Southwest. Specifically, it will highlight research using NEON data with implications for our understanding of climate change impacts. The talk will also highlight the Observatory's Assignable Assets program, which makes available components of NEON's infrastructure to outside researchers and community members to support their research or other activities.

Forest restoration can increase climate resilience in southwestern forests

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ABSTRACT: Forests in the southwestern USA have seen an increase in the frequency, size, and severity of wildfire in recent decades. A history of fire suppression has led to overly dense forests and a changing climate is increasing the risk of these forests to loss from fire and drought. Increasing the pace and scale of restoration is critical to the USFS 10-year Wildfire Crisis Strategy because restoration has been shown to reduce wildfire risk in a changing climate. We have completed a series of studies that show there are additional co-benefits to forest restoration that can make our forests more resilient to climate change. We have evaluated the effects of forest restoration on ponderosa pine forests under the Four Forests Restoration Initiative (4FRI), an ongoing large-scale forest restoration project in northern Arizona. Our studies have found that 4FRI thinning would decrease competition for water resources in mid-century climates, leading to a 31-35% decrease in tree drought mortality and a 20-27% increase in tree growth. We also found that the reduction in fire risk and increased tree growth would increase total ecosystem carbon 9-18% by the end of the century despite the initial loss of carbon removed through mechanical thinning. Lastly, we found that runoff in thinned forests was about 20% higher than un-thinned forests. With few tools available to mitigate climate effects, this research shows that forest restoration could buy time to retain forest cover, understand climate effects, and develop management strategies that reduce the loss of forest cover from climate-induced impacts.

Co-producing science to inform land management across the American Southwest – examples from the USGS Restoration Assessment and Monitoring Program for the Southwest (RAMPS)

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ABSTRACT: Ecosystem restoration in arid and semi-arid ecosystems of the Southwest is challenging because of unreliable precipitation, disturbances that are growing in intensity and

frequency, resource limitations, and a lack of information for making scientifically-informed decisions. Some of these challenges can be addressed via collaborative, innovative, and dynamic approaches whereby participants transmit and receive information on effective and resource-efficient approaches to enhance land condition. During this talk, we will share examples of how we are using a co-production model to communicating science and improve restoration outcomes. Examples include the creation of the RestoreNet restoration field trial network where we co-produce science with end-users, support for the Diné Native Plant Program where we weave indigenous knowledge with Western science, and climate adaptation planning with land managers across the Colorado Plateau. Through these efforts, RAMPS is matching cutting-edge science with some of the most pressing land management problems.

Climate adaptation strategies for semiarid grasslands

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ABSTRACT: Climate change is altering ecosystems and has rapidly become a significant challenge for natural resource managers and policy makers. In recent decades, perennial grasslands in arid and semiarid regions of the southwestern United States are declining coincident with substantial warming and drying, and future climate projections for the region suggest more frequent and severe droughts driven by growing seasons that are both longer and hotter. As a result, sustaining grasslands is an increasingly complex challenge for land managers and conventional management practices may not be sufficient to meet objectives. In addition, landscape scale ecosystem change caused by aridification appears to be occurring more rapidly than resource management agencies can adapt procedures and policies to enable effective field-based responses. To confront these evolving challenges, managers require not only access to the best available knowledge on climate impacts and adaptation options, but also tools that connect information to action in the context of local conditions and circumstances. Here, we present a structured list, or "menu," of adaptation strategies and approaches specific to arid grasslands, co-developed by a group of research ecologists, land managers, and adaptation specialists. This collection of diverse adaptation options is intended to facilitate implementation of climate adaptation actions that are connected to management goals, based on understanding of climate impacts, and tied to adaptation intent. The Semiarid Grasslands Menu presented is the culmination of long-standing partnerships between NPS and USGS, which engaged over 150 land managers, researchers, and climate adaptation experts over five years. The Semiarid Grassland Menu is a suite of traditional, unconventional, and nuanced management options that addresses novel ecological conditions and climate change impacts.

Southwestern Willow Flycatcher and tamarisk beetle status and habitat restoration efforts—Virgin and Lower Colorado Rivers

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ABSTRACT: Tamarisk leaf beetles (*Diorhabda* spp.), released in the western US as biocontrol for tamarisk (*Tamarix* spp.), began defoliating breeding areas of the federally endangered southwestern willow flycatcher (*Empidonax traillii extimus*) in 2008 along the Virgin River around St. George, Utah. Beetles then expanded their range downstream, affecting flycatcher breeding sites along the Virgin River in subsequent years and arriving at the Bill Williams River in 2017. Flycatchers consistently had poor reproductive success when they attempted to nest in stands with a significant component of defoliated tamarisk. Breeding sites varied in the prevalence of tamarisk, the timing and duration of defoliation, and the degree of subsequent tamarisk mortality, and the trajectories of the local flycatcher populations varied in accordance with the amount and quality of the remaining habitat. Active restoration of native riparian woodlands in watersheds where flycatchers nest primarily in tamarisk is urgently needed to provide flycatchers with alternate nesting sites. Restoration efforts along the Virgin River have shown that restored sites do not need to be large to support breeding flycatchers. Factors that may increase the chances of restoration areas being used by flycatchers include targeting formerly occupied sites that have been affected by beetles and placing restoration areas close to currently occupied flycatcher sites.

Climate and soils moderate land cover change following grazing retirement in Capitol Reef National Park

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ABSTRACT: Grazing by domestic livestock is a dominant land use across the Colorado Plateau. Grazing by sheep and cattle have been widespread since the mid-19th century, but changes to federal land management beginning in the 1930s and continuing through the 1970s have resulted in incremental reductions and removal of livestock from federal lands. Here, we use retirement of grazing permits within two allotments in Capitol Reef National Park to assess land cover trajectories following livestock removal. “Cathedral” (5,318 ha.) was retired in 1999 and “Rock Springs” (1,353 ha.) was retired in 1989. In this study, we utilized new advances in land cover mapping, soil type mapping, and novel analytical tools to assess the consequences of livestock removal on three aspects of land cover: bare ground cover, perennial herbaceous cover, and total spring foliar cover. Model results suggest that total spring and perennial herbaceous cover across the landscape has increased by *ca.* 0.25% year^{-1} post-removal, while bare ground has been reduced by *ca.* 0.35% year^{-1}. Increased mean yearly minimum temperatures were negatively associated with bare ground cover, while precipitation was positively associated with

perennial herbaceous cover. Bare ground cover was strongly dependent on soil type - especially on deep, rocky soils. Snow cover (an important moderator of livestock range) was not associated with landscape cover change, but cost-distance to water was important depending on soil class. These results suggest that while cattle removal may lead to increases in plant cover and reductions in bare ground on the Colorado Plateau, the magnitude of changes will be heavily moderated by the region's inherent soil complexity. However, a hotter, drier climate may slow these changes or prevent them entirely.

Assessing recent and future climate impacts on *Papilio* spp. and their host plants

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ABSTRACT: Changes in global temperature and increasing aridity profoundly impact many aspects of the biosphere. Many of these interactions are negative, yet some species and their ecological relationships may benefit from these new climatic circumstances. Species distribution models of western *Papilio* species and their associated hostplants were created using data from GBIF, which includes museum records as well as community science data from iNaturalist and eButterfly. Models were based on the standard 19 bioclimatic variables and used to estimate contemporary distributions of butterfly species and host plants. The same models were used to predict future distributions of butterfly and plant species, using the CMIP6 dataset of forecast environmental variables for 2070. Contemporary and forecast estimates were compared when the total area of butterfly species' ranges was predicted to overlap with at least one host plant species. We find western species are very likely to face reductions in area. All but one species occurring in arid regions are predicted to have a contracted geographic range in 2070, while non-arid species were less likely to have range contractions by 2070. Changes in individual species' ranges will further influence regional species richness across North America. Estimates of individual species' predicted ranges were also used to estimate species richness for the two time periods, contemporary and 2070. Contemporary estimates indicate western North America has slightly higher *Papilio* species richness than other parts of the continent. However, future climate conditions indicate a decline of species richness in the arid southwest and intermountain west. These findings have the potential to improve conservation and restoration efforts of these butterflies and their larval habitat across western North America.

Incorporating inclusive practices inside and outside the classroom

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ABSTRACT: The United States' population is becoming increasingly diverse. Between 2010 and 2020, the White adult population decreased from 74.7 percent to 64.1 percent, the Black or African American adult population remained at 12 percent, the Hispanic or Latino adult population increased from 14.2 percent to 16.8 percent, and the Multiracial adult population increased from 2.1 percent to 8.2 percent according to the US Census Bureau (2021, census.gov). In 2005, the Association of American Colleges and Universities (AACU) urged colleges and

universities to approach diversity through Inclusive Excellence, a comprehensive and innovative approach that is linked to teaching, the central goal of higher education. The strategy of the AACU was to challenge postsecondary institutions that have been dominated by white male students since their inception to consider how to involve the entire academic community to combine inclusivity and excellence (Milem, Chang, & Antonio, 2005). The importance of incorporating inclusive practices inside and outside the classroom is extremely important. It begins with faculty developing a diverse curriculum and student affairs professionals like myself and our department linking it to student support and student life experiences. In the Office of Inclusion: Multicultural and LGBTQIA+ Student Services our purpose is to serve all students focusing specifically on gender, sexual, and racially diverse populations that are underrepresented on this and other campuses across the nation. We aim to support students through holistic guidance that enables them to be the best version of themselves and reach their goals. Our goals consist of facilitating engagement opportunities to cultivate a sense of belonging and community through a cultural and/or identity inclusive environment.

Bats, bugs, and boaters: insectivorous bat foraging along the Colorado River in Grand Canyon is determined by the availability of aquatic flies

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ABSTRACT: Aquatic insects emerging from streams are resource subsidies that support riparian consumers such as birds, spiders, lizards, and bats. In this study, we collaborated with whitewater river runners and other community scientists in Grand Canyon, Arizona, USA to sample adult flying insects using light traps and to record acoustic data of bats foraging over the Colorado River from 2017-2020. We collected 1,428 paired samples on 611 sampling nights at 410 sampling sites throughout a 470 km segment of river. We predicted that sampling nights with high catch rates of insects would also have high rates of bats foraging activity. Additionally, we expected that aquatic insects would be better predictors of bats foraging in the riparian zone than terrestrial insects. We constructed Bayesian regression models that included variables to account for variation in bat foraging activity due to spatial and temporal relationships, landscape structure, riparian vegetation, air temperature, and lunar phase, as well as prey availability. We found that total bat foraging activity was greatest on sampling nights that had high catch rates of aquatic flies (Diptera). We also found that foraging activity of small Myotis (*Myotis californicus M. yumanensis*) was greatest when sampling occurred later relative to sunset and that canyon bats (*Parastrellus hesperus*), conversely, were more active earlier in the evening. Our results highlight the importance of aquatic insects as prey for terrestrial wildlife and demonstrate the power of community science as a tool for ecosystem monitoring.

Providing inclusive and accessible learning experiences to student scientists with disabilities

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ABSTRACT: In this presentation, Dr. Metzger and Dr. Jenson with the Institute of Human Development at Northern Arizona University will provide insights and best practices from their NSF funded research helping students in STEM fields achieve professional success. According to the National Center for Education Statistics, roughly 19% of all undergraduate students and 12% of graduate students reported having a disability between 2015–2016. And yet, students with disabilities are less likely than their peers to graduate and enter into the US labor force. Additionally, students with disabilities in STEM fields like Environmental Sciences and Natural Resource Management, face stigma from peers and instructors and barriers to accessibility regarding classroom design and fieldwork initiatives. During our presentation, we will discuss how instructors can combine universal design, trauma-informed, and adult learning theories to create innovative coursework which creates equitable learning spaces for all students. Additionally, we will offer insights from our TAPDINTO-STEM mentoring program for students with disabilities which can inform how Natural Resource Management/Environmental Sciences can connect with student scientists with disabilities.

Collaborative goal setting and strategy development: building foundations for effective science communication for the USGS Grand Canyon uranium mining project

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ABSTRACT: Increasingly, scientists are expected to communicate their findings to the general public in a way that is relevant, accessible, and interesting. While many scientists are receptive to these expectations and want to actively participate in science communication, they are often left without guidance on how to do so effectively, which can confuse stakeholders, or even create distrust (Longnecker 2014). Findings from the science and risk communication literature indicate that science communication is a complex undertaking that is often context specific and dependent on existing knowledge, values and interests of intended audiences (Bruine de Bruin and Bostrom 2013). This paper reports on the implementation of a science communication project designed to improve the communication of USGS science related to uranium mining in the Grand Canyon Watershed to a diverse set of stakeholders. We present a literature-informed model for the coproduction of a science communication strategy and science communication outputs that are specifically tied to stakeholder needs and interests. We then present a detailed description of the coproduction process that includes generating shared understanding of project context (e.g. communication product and stakeholder inventory), co-development of communication goals, co-design of approach to data collection and analysis, and early consideration of stakeholder-relevant communication products and initiatives. The paper

includes example activities, tools and instruments that can be applied in other contexts for developing a science communication plan.

Change in ciénegas in the Madrean Archipelago derived from 37 years of Landsat satellite imagery

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ABSTRACT: Ciénegas are freshwater to brackish wetlands in arid and semi-arid regions of North America. They are associated with groundwater or lotic components that may result in perennial waters on temporal scales of decades to centuries. Ciénegas are primarily found in the southwestern US and northwestern Mexico at elevations up to 2000 m. The extent of these wetland communities has greatly decreased from historic conditions and ciénegas are now considered imperiled, threatening the flora and fauna that rely on these water sources in arid and semi-arid environments. To estimate the change in ciénega condition over a 37-year period (1985-2021), the approximate boundaries of 40 ciénegas in the greater Madrean Archipelago ecoregion selected from a published dataset developed in collaboration with Dean Hendrickson and Thomas Minckley were digitized in Google Earth based on its collection of high spatial resolution aerial and satellite imagery. Visible agriculture fields and urban areas were omitted from the delineation of the polygons. We generated seasonal 37-year time series of normalized difference vegetation index (NDVI), normalized difference infrared index (NDII) and Tasseled Cap metrics (greenness, brightness, and wetness) for the ciénega polygons from Landsat satellite imagery using Google Earth Engine, R Software and ArcGIS. These time series were plotted and analyzed individually and collectively to characterize trends in the data that highlight changes in ciénega condition. In addition, control sites were generated from the digitized polygons to capture general trends in the outlying vegetation and quantify relative change. The results of this study will present a more nuanced view of recent change in these important wetland systems. Ciénega restoration efforts may be an important part of responding to a rapidly changing climate and water regime, while data describing trends in the condition of ciénegas are useful information for the restoration and land management communities.

Data integration and coupled modeling to guide water management decisions in the Colorado River Basin

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ABSTRACT: The Colorado River basin is a key water resource for 40 million people in the United States and Mexico and provides critical habitat for four federally listed endangered fish

species. To increase the reliability of water supply across the basin, more than 60 million acre-feet of reservoir storage has been developed. The dams constructed to provide this storage have also dramatically changed downstream hydrologic and thermal characteristics. The result has been a decline, and in some cases extirpation, of endemic fish species. As the basin continues to grapple with the on-going Millennium Drought (2000-present) and the reduction of flows due to a warming climate, reservoirs have fallen to unprecedented low levels. As reservoir elevations, thermal stratification patterns, and operational procedures change, the downstream river segments and ecosystems may once again be altered. Anticipating changes in aquatic ecosystems over large spatial scales requires understanding thermal responses to basin-scale management decisions. However, existing water management tools used for allocating water amongst users have lacked process-based heat flux representations needed to simulate and forecast extreme water temperature changes that occur at large scales in the western Furthermore, spatial and temporal resolution mismatches between system-operation models and river temperature models inhibits the ability to directly link these tools together. To evaluate climate and management related impacts on aquatic thermal regimes, we developed a modeling framework that integrates the Bureau of Reclamation's Colorado River Simulation System (CRSS) water management model, climate reanalysis and forecast datasets, and coupled process-based river and reservoir temperature models. This framework is applied to a large portion of the Colorado River basin spanning Flaming Gorge to Lake Mead, and illustrates methods to overcome data limitations, integrate models of varied temporal and spatial scales, and use of model coupling tools. While we use this framework to provide insight into the ecological implications of future climate and water management strategies in the Colorado River basin, these methods are adaptive and transferable to other rivers facing ecological concerns due to flow regulation and climate change.

Science to support resource management under uncertainty: lessons learned from a decade of participatory climate change scenario planning

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ABSTRACT: Resource managers are faced with stewarding natural and cultural resources under tremendous uncertainty about climate change (CC) and its impacts. Scenario planning (SP), a tool used to support decision making in the face of such uncontrollable uncertainty, has been adopted by scientists and adaptation specialists to address this challenge. It works by developing a small set of scenarios, or descriptions of plausible yet divergent future conditions, and using them to inform planning and decision making. Although SP has been applied widely and grown in popularity, a synthesis of detailed best practices for conducting CC SP to support resource management has been lacking. In this presentation, we describe how a decade of CC SP engagements with National Park Service (NPS) units has resulted in 1) a generalized approach for conducting participatory CC SP that is grounded in natural and cultural resource management priorities, 2) key management outcomes, and 3) broader lessons for applying CC SP, including insights for fostering participant engagement, considering non-climate stressors, incorporating quantitative approaches, and translating scenarios into strategic conservation action.

The Arizona Monarch Collaborative: promoting action and collaboration for the western monarchs of Arizona

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ABSTRACT: Effective management of the monarch butterfly (*Danaus plexippus*) and its habitat requires coordination among a broad variety of land ownership and stewardship entities across the Southwest. Recognizing the need for information sharing and collective action, lead agencies for monarch protection in Arizona initiated the Arizona Monarch Collaborative (AMC,) in June 2019. The Collaborative includes participants representing over 80 organizations across Arizona, including state and federal agencies, tribes, non-profits, consultants, museums, nurseries, botanical gardens, and universities. This statewide group works to further monarch and pollinator protection in Arizona by coordinating and promoting conservation and management actions. The AMC uses the Western Association of Fish and Wildlife Agency's (WAFWA) Western Monarch Conservation Plan to guide its priority actions. The Collaborative is led by a steering committee, and members can be involved in three subcommittees: Plants Materials, Management Practices & Outreach, and Research. During strategic planning in 2020-2021, each subcommittee identified a few priority actions to focus efforts. In addition to the subcommittees, the Collaborative issues a monthly news update on monarch related information and news and a website with information on the Collaborative and monarch resources, https://www.azmonarchcollaborative.org/home.

What is visitor use management? An overview of the history, science, and framework

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ABSTRACT: For nearly 5 decades, scientists, researchers, and practitioners developed unique, interdisciplinary approaches for managing public visitation to parks and protected areas in a way that protects resources while providing for high quality visitor experiences. This process is often referred to as visitor use management. This presentation reviews the history of visitor use management, including the science that informs current frameworks, to set the stage for understanding dynamic, uncertain change into the future.

Data integration to inform bird conservation and habitat management in the Southwest United States

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ABSTRACT: Many of the largest global drivers of bird species declines, including climate-change induced temperature and precipitation shifts, are particularly strong in the Southwest United States. Given the rapid pace and dire consequences of climate-induced impacts on bird biodiversity, it is increasingly necessary to generate robust predictions of species occurrence, population trends, and how human activity shapes bird species and communities. In this age of 'big data' - including decades-long species' monitoring data, global databases of bird observations, and remotely-sensed habitat data – we have a unique opportunity to integrate datasets to build better predictions of species trends across time and space. In this presentation, we showcase two examples of how data integration can increase understanding of bird populations, a goal that is relevant for understanding baseline populations and for monitoring how habitat restoration aimed at climate resilience and high-severity fire mitigation may impact bird species. First, we introduce an approach for combining multiple monitoring data types for focal bird populations to build integrated population models that inform population trends in response to landscape-scale habitat restoration efforts similar to several in the Southwest Region (e.g. Four Forest Restoration Initiative, Arizona; Southwest Jemez Mountains Landscape Restoration Project, New Mexico). Next, we demonstrate how combining systemic monitoring data (Integrated Monitoring in Bird Conservation Regions, IMBCR) with community science data (eBIRD observations) increases the spatial and temporal coverage of species occurrence data for species distribution models of Southwest focal bird species. Both approaches demonstrate how combining data sources increases our ability to make inferences about bird population trends and space use. Furthermore, while we highlighted two examples of data integration, we hope to spark creative thinking about how other data sources for Southwest birds (e.g. movement, diet, acoustic monitoring) could be integrated to provide novel and important insight into bird species' and community trends.

A community of practice to address non-native aquatic species in the West

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ABSTRACT: The Collaborative Conservation and Adaptation Strategy Toolbox (CCAST) is an online platform for peer-to-peer knowledge exchange and development of decision-support tools to address issue-based conservation challenges. In May of 2020, CCAST launched the Non-Native Aquatic Species Community of Practice (CoP). The CoP is a forum for information sharing and tool development on the treatment of non-native aquatic species where they are undesirable or incompatible with management objectives. Key examples include American bullfrogs, several species of non-native fishes, and several species of crayfish. Non-native aquatic species can affect native species both directly (through competition and predation) and indirectly (through ecosystem disturbance) and can cause considerable harm to our environment, economy, and health. The broad impacts of climate change - reduced water availability, increased prevalence of drought and flooding, and rising temperatures - further contribute to the

decline of native aquatic species. These conditions may also facilitate the distribution of non-native aquatic species and create competition for shrinking aquatic habitat. The CoP has identified key challenges to managing non-native aquatic species, including physical and ecological, jurisdictional, regulatory, funding, and human dimensions. The CoP attempts to address these challenges through collaborative action on the scale each challenge presents. Over the past two years, CCAST has published 27 Case Studies, hosted 22 webinars, and held three workshops on the research and control of non-native aquatic species. Current efforts underway related to control of invasive American bullfrogs include summarizing bullfrog impacts and the feasibility of their control, developing a guidance document of recommended control practices, and supporting workshops to demonstrate bullfrog control techniques. More broadly, CCAST continues to work with CoP members to identify common needs, co-produce case studies, and collaboratively develop decision-support tools.

New Mexico Highlands University FORT-CREST Project

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ABSTRACT: As our country has experienced the most destructive wildfires in history, it is , more important than ever to research and implement effective and efficient forest management and restoration strategies. With funding from the National Science Foundation (NSF), Centers for Research Excellence in Science and Technology (CREST) program, the Forest Restoration Triangle (FORT) Center housed at New Mexico Highlands University (NMHU) provides our students and the surrounding area with innovative research and learning opportunities to develop forest management and restoration strategies at three integrated levels: tree, stand, and landscape. The Center engages students in Science, Technology, Engineering, and Mathematics (STEM) coursework and research with ongoing mentoring and support provided by peers and faculty. Three core institutions comprise the FORT-CREST Center: (1) the New Mexico Forest and Watershed Restoration Institute at NMHU; (2) the John T. Harrington Forestry Research Center at New Mexico State University (NMSU); and (3) the Department of Forestry at NMHU. FORT-CREST has provided a unique opportunity for an integrated, comprehensive Center that combines the perspectives of these three organizations and covers every forest management issue in the Southwest. The FORT Center is currently implementing three Subprojects/research areas to address the shifts in forest structure and composition in Southwestern forests and create field-based STEM undergraduate and graduate education programs designed to produce students with the knowledge and expertise to manage these forests in the future. Considered together, the three Subprojects address the different aspects of the management and restoration of resilient forests in New Mexico and the Southwest in the context of climate change and fire. **Subproject 1** addresses post-fire restoration through the establishment of planted trees, **Subproject 2** addresses the restoration of overgrown ponderosa pine and mixed conifer forests, and **Subproject 3** addresses restoration-based approaches applied at larger scales using an adaptive management approach with linked education and outreach components.

Using hydrological modeling to validate benefits from green infrastructure at the United States-Mexico border

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ABSTRACT: Binational conurbation along the US-Mexico border face stormwater management challenges from increasing impervious surfaces and strained water conveyance infrastructure. High volumes of stormwater runoff compromise public health, water quality, and economic well-being. This study developed a binational network of urban green infrastructure (UGI) in Ambos Nogales (Nogales, Arizona, US and Nogales, Sonora, MX) as a nature-based solution to combat these challenges. The proposed UGI network, which includes loose rock detention structures, was qualitatively evaluated for its potential hydrological benefits using the KINEmatic Runoff and EROsion (KINEROS2) hydrological model within the Automated Geospatial Watershed Assessment (AGWA) tool. Working with binational planners, a system of 166 sites for UGI was suggested as suitable and capable in relation to the natural and built environments. Using these suggestions, pre- and post-UGI treatment scenarios were modeled using a 10-year 1-hour storm event with spatially uniform precipitation to examine the watershed processes the structures might influence. UGI sites were reclassified to wetland land-cover class to mimic how sites treated with green infrastructure take on wetland-like characteristics. Despite only 1.26% of the total area of the watershed being identified for UGI treatment, our model results show a percent decrease in runoff (-5.63%), peak flow (-4.71%), and most notably sediment yield (-11.66%) at a plane level (a model-defined element). Our watershed model results were comparable to peak-flow reduction estimates obtained through the Rational Method, validating our approach. The resulting cross-border UGI network is proposed as an integrated stormwater management approach that supports efforts to increase resiliency to natural hazards (e.g., high erosion and extreme temperatures) and systemic challenges (e.g., access to green spaces and limited resources) common to binational urban areas.

Drought tolerant and drought intolerant pinyons converge in fungal communities during drought but differ in leaf spectra

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ABSTRACT: The Southwest is experiencing a long-term drought due to climate change. The drought is leading to *Pinus edulis* (pinyon pine) mortality. Pinyon pine is a dominant tree in the Navajo Nation and is significant culturally and economically for subsistence, fuelwood, and building materials. Drought tolerance in pinyons is linked to root-associated ectomycorrhizal

fungi (EMF), which are beneficial to plants by providing them with nutrients and water in exchange for photosynthate. However, identifying drought tolerant (DT) and drought intolerant (DI) trees based on fungi is difficult in the field. Hyperspectral imaging can detect significant differences between DT and DI seedlings in water absorption. Measuring the spectral reflectance of tree needles could provide a quick way of determining if trees are DT or DI and if it relates to their associations with EMF. Previous work has demonstrated that EMF in the genus *Geopora* promote drought tolerance, particularly in DT pinyons. We hypothesized that DT and DI adult and seedlings would differ in both EMF colonization levels and in their leaf spectra. We collected root samples from 14 adult pinyon trees and 100 seedlings from the common garden near Sunset Crater National Monument. We used a dissecting scope to visually sort EMF root tips based on morphological differences, and quantified abundance and diversity of identifiable fungal genera. We also measured leaf spectra on the same population of trees. Results show that both DT and DI trees are dominated by *Geopora* EMF after more than 20 years of drought. DT and DI trees also differed in spectral reflectance. We intend to expand this work to a wider geographic range, and we are currently making mycorrhizal measurements and linking them with pinyon leaf spectra at another site near the Navajo Technical University campus in Crownpoint, New Mexico.

Rafael Fire case study

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ABSTRACT: The Rafael Fire burned on the Prescott, Kaibab and Coconino National Forests in June 2021. This fire demonstrated the importance of fuels treatments on the Coconino and Kaibab National Forests. Mechanical, prescribed fire, and wildfire treatments between the fire and numerous values at risk showed how forest treatments provide wildland fire management with stronger alternatives and higher probability of success. These altered ecosystems provide firefighters a safer work environment and allows tactics to be accomplished with less resource commitment. Even under critical fire weather, management of the was successful with no significant losses and the primary line locations all holding (without use of alternative, contingency or emergency lines).

Return of the beetles: a Museum Fire story

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ABSTRACT: Large scale post-fire restoration practices focus on protection of forest and cultural resources and flood prevention, but we know very little about impacts of these management efforts on the insect community. Through our earlier and ongoing efforts monitoring fire scars from slash pile burns, we found that several critical nutrient-cycling insect taxa are diminished in fire-disturbed areas. For this study, we investigated existing Burned Area Emergency Response (BAER) treatments in the Museum Fire footprint near Flagstaff, Arizona to identify ground-dwelling insect communities and determine if their community composition

could have a long-term effect on reestablishing vegetation. We hypothesized that altering habitat complexity will draw in diverse arthropods that are critical to soil nutrient cycling and stabilization and accelerate native plant recovery. We installed pitfall traps near established BAER transects to monitor pre- and post-monsoon ground-dwelling arthropods and recovering vegetation after mulch treatments across the area. We found multiple beetle taxa within the mulch treatments that are not present in our other study sites across northern Arizona, indicating some potential for additional habitat in post-fire mulch treated areas. Vegetation data indicate some combination of native, non-native, and invasive species that are expected after large-scale fire in this ecosystem. Second-year success of these plants may rely on community interactions between insect herbivores, fungivores, pollinators, and predators. This study answers fundamental questions of post-fire insect recolonization and habitat requirements and their effects on nutrient cycling and vegetation success. This will inform further BAER treatments to provide sustainable and long-term soil stability and vegetation recovery to better protect life, infrastructure, and natural and cultural resources in the aftermath of catastrophic fire.

Bison conservation genetics and metapopulation planning in the Department of the Interior

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ABSTRACT: The US Department of the Interior's Bison Working Group has been working since 2008 to advance conservation of American bison. With completion of an expansive population viability analysis (PVA) in 2020, the BWG is now developing a metapopulation management strategy that will guide the occasional movement of modest numbers of bison among federal conservation herds (and some designated partner herds) to minimize risk of inbreeding and loss of diversity due to genetic drift. This presentation discusses the findings of the 2020 PVA, status and current advances applied to the metapopulation management plan, and the eco-cultural restoration goals, principles, and actions of the 2020 Bison Conservation Initiative.

Primary production responses to extreme changes in North American Monsoon precipitation vary by elevation and plant functional composition through time

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ABSTRACT: Warm-season precipitation derived from the North American Monsoon contributes 40% of annual precipitation to dryland ecosystems in the southwestern US and is projected to become more variable. However, there is large uncertainty on whether this variability will be expressed as either extreme wet or dry years and how primary production of different plant functional types will respond across widespread elevation gradients in this region.

We experimentally imposed extreme drought and water addition treatments from 2016–2020, during which ambient warm-season precipitation declined to reach historic lows, to understand production sensitivity of dominant plant functional types along a 1,000 m elevation gradient in and adjacent to the San Francisco Peaks near Flagstaff, AZ. We found that the production responses of plant functional types to monsoon precipitation extremes were dependent on the number of treatment years that occurred across sites along the elevation gradient. C_4 perennial grasses were most responsive to precipitation manipulation treatments, followed by C_3 perennial grasses and annuals, while perennial forbs and shrubs had weak or no responses. C_4 perennial grass reductions due to extreme drought were generally stronger or occurred earlier at low elevation sites, while multi-year extreme drought extended negative effects to C_3 perennial grasses at high elevation, and all sites showed delayed responses to multi-year water addition. We found that the sensitivity of C_3 perennial grass production differed for extreme drought and water addition compared to ambient precipitation at one site, but other sites and plant functional types had similar sensitivities to the different treatment types. The upward advance of primary production responsiveness from single- to multi-year extreme changes in warm-season precipitation suggests more immediate shifts in functional composition and carbon cycling at low elevation, while high elevation ecosystems may become less resistant as the effects of extreme precipitation compound through time.

Effects of plains bison (*Bison bison bison*) herbivory on grassland structure and function on the North Rim of Grand Canyon National Park, Arizona

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ABSTRACT: The plains bison is a grassland keystone species that historically played a critical role in the structure and function of grasslands throughout North America. Plains bison have been found to affect primary productivity and soil quality; however, the effect of bison on the semi-arid, high elevation grasslands of the North Rim, Grand Canyon ecosystem have yet to be assessed. With expansion of plains bison into North Rim, Grand Canyon National Park, we sought to assess potential effects of bison on local grassland structure and function. We used a replicated herbivore exclusion experiment in meadow habitat using both long-term exclosures (1-acre) and temporary exclusion cages (1-meter^2) to evaluate ungulate consumption and herbaceous productivity in the presence and absence of bison grazing. We established six sites in Grand Canyon National Park (GRCA) in areas with high bison density, and six sites in similar meadow habitat in Kaibab National Forest (KNF) with low bison density. We sampled twice each year in 2021 and 2022, where sampling events occurred in summer and fall to capture peak production of both cool (C3) and warm (C4) season plants. During each sampling event, we collected information on percent ground cover and vegetation biomass using quadrat clipping rings. We took additional measurements to evaluate soil quality (erodibility and nutrient availability) using soil corers and in-situ soil probes. Additionally, we deployed temperature and rain gauges at 10 sites to collect local climate information and remote sensing wildlife cameras to assess grazer type (bison, deer, cattle, etc.) and frequency. Our initial results from 2021 showed that sites in GRCA showed higher total ungulate consumption. On average, these six

sites in GRCA also had lower total vegetation biomass, higher aboveground production, higher total belowground nitrogen concentration, and lower phosphorus concentration when compared to sites with low bison density (KNF). Soil erodibility was similar among sites regardless of bison density. We are currently completing data analysis using a linear mixed model to evaluate fixed effects (i.e., year, stratum, and treatment plot) and interaction effects, while accounting for random site effects (i.e., site and subplot) on aboveground primary productivity and soil quality.

Building a community for FAIR and integrated modeling using catchments in the Lower Colorado River Basin

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ABSTRACT: Our project focuses on making existing US Geological Survey (USGS) science products more Findable, Accessible, Interoperable, and Reusable (FAIR). USGS scientists face common questions when working on multidisciplinary teams to address complex science challenges, such as (1) what models are available?, (2) when is it appropriate to couple/integrate models?, and (3) how can we apply technology to do so? The long-running Artificial Intelligence for Environment & Sustainability (ARIES) project supports integration by giving semantic meaning to data and model content, enabling their coupling via artificial intelligence (AI). This capability can enable access to sophisticated data/models via a web browser, improving access to data for underserved groups. By design, the approach is multidisciplinary, navigates across spatiotemporal scales, and is scalable for broader USGS model coupling challenges. Our work more seamlessly links interdisciplinary data and models using the AI techniques of semantics and machine reasoning, focusing on hydrologic and ecological model integration in the Colorado River Basin to better address drought and climate change in the Basin. This method streamlines FAIR model and data integration, making it easier for scientists to identify available data and models and understand their appropriate (re)uses. Finally, the project aims to build a community around interoperability-focused modeling in the USGS, improving capacity to address complex scientific challenges. The project couples streamflow data using the SPARROW model with riparian vegetation greenness and water use data for the San Pedro and Virgin Rivers. Coupling these models will improve our understanding of how climate change affects riparian ecosystems that provide vital biodiversity and ecosystem services in the Southwestern US We aim to understand the effects of long-term drought on ecosystems, infrastructure, and socioeconomic systems. It also develops products and tools to help stakeholders adapt to long-term drought and climate change.

Uncultivated riparian plant evapotranspiration and consumptive use for selected areas of the Little Colorado River watershed on the Navajo Nation

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ABSTRACT: Select reaches of Little Colorado River tributaries on the Navajo Nation of northeastern Arizona, USA, were delineated on high-resolution National Agricultural Imagery Program (NAIP) imagery (1 m resolution) from one summer image and then rasterized using Landsat-8 OLI (30 m) to estimate plant greenness and actual evapotranspiration (ETa) for 2014-2020. The objectives were to estimate the riparian land cover area for trees and shrubs, calculate their corresponding ETa (mm/day and mm/year), and derive riparian consumptive use in acre-feet for select riparian areas of the Little Colorado River watershed. We used indirect remote sensing methods based on two sources of gridded weather data, Daymet (1 km) and PRISM (4 km), and Landsat measurements of vegetation activities using the two-band Enhanced Vegetation Index (EVI2). Estimates of potential ET (ETo, mm/year) were calculated using Blaney-Criddle. We then quantified riparian landcover ETa using the Nagler ET(EVI2) approach. Lastly, using both vector and raster estimates of tree, shrub and total riparian area, we produced the first direct measurements of consumptive use for this region. These findings refine literature-based estimates in the range of 25,387 – 46,397 acre-feet and are valuable to the Navajo Nation in the adjudication of water rights and other environmental policy decisions.

Synergistic land use and climate drivers of wind erosion on the Colorado Plateau: implications for management

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ABSTRACT: The southwestern USA is experiencing the worst drought since the beginning of the tree ring record back to 800 CE. This has spurred concerns about increased wind erosion and resultant dust emissions with negative impacts on ecological productivity, respiratory health, biogeochemical cycling, infrastructure damage, and snowpack runoff acceleration. Different avenues of investigation into primary drivers of dust have yielded mixed results depending on the spatial and temporal sensitivity of the evidence with modern monitoring networks showing sensitivity to land disturbance and related bare soil exposure as well as drought. However, high elevation lake sediment dust studies report more correspondence with both disturbance and periods with broad changes like more frequent flooding that increase erodible sediment supply. We use monitoring data from passive aeolian sediment traps near Moab, UT, field observations of land use, and scalable climate, soil, and vegetation raster data to better understand the modern influence of disturbing land uses (livestock, oil and gas well pads, and other anthropogenic surface disturbances) that drive both exposure of bare soil and increased erodible sediment supply. Disturbed areas were very active in dry years, but notably areas with little disturbance and low bare soil exposure had much less sediment transport. Cattle use had the largest

association with erosional activity with analysis suggesting that both trampling (creating loose erodible sediment) and herbivory (decreasing bare soil protection) from cattle playing large roles. Bare soil patterns from new sub-annual fractional cover remote sensing products proved very helpful in mapping these patterns. Empirically scaled maps show that many areas in drier parts of the Plateau, particularly those with less calcium carbonate in soils, are more susceptible to sediment mobilization when disturbed. Our results suggest that despite the magnitude of the current drought, minimizing disturbance can mitigate a majority of dust emissions.

Strategies for engaging native youth in community environmental issues; inviting native youth to consider environmental protection careers.

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ABSTRACT: Native American youth are often not aware of the variety of career opportunities in environmental protection. This presentation will share what the presenter has learned through 30 years of working with Native American youth in a variety of educational settings. Real-time connections that the student can understand and value will increase engagement of the students. These connections could include cultural connections or local environmental issues that impact them and their family. The Alaska Knowledge Network provides guidelines for culturally responsive schools and communities that make touchstones for considering culturally responsive education. The guidelines include incorporating community and elders into the educational program. Native American youth also enjoy using technology to gather local environmental data. The presenter uses a variety of sensors, including recently developed low-cost air sensors to increase awareness of air quality. The most popular sensor for the students is one that uses their smart phone to gather and display data.

Bison hide pictorial history of bison recovery and management in Arizona

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ABSTRACT: American bison were one of the first wildlife species to have been successfully recovered through modern wildlife conservation efforts. Bison are an important species to several Native Americans tribes, in which bison hides were used in an artistic fashion to depict important tribal events. The Arizona Game and Fish Department has incorporated this concept into an artistic rendering illustrating the history of American bison on a bison hide. This pictorial representation illustrates the iconic American bison story of near extirpation and recovery over the last 150 years in North America, while also highlighting the current management efforts of Arizona's bison herds managed by the Arizona Game and Fish Department.

Management challenges and success of Arizona's three bison herds

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ABSTRACT: The Arizona Game and Fish Department (Department) has been managing bison for the benefit of public trust within the state of Arizona for nearly 100 years. Bison represent a sustainable resource for hunting and public wildlife viewing, while providing intrinsic value to the public and economic benefit to northern Arizona communities. Currently, the Department manages three distinct bison herds; the Kaibab Plateau, House Rock, and Raymond bison herds. The Department has encountered challenges during our time managing these bison populations. One notable challenge is managing a species that roams and utilizes large geographic areas,

oftentimes leading to the possibility of crossing land jurisdictional boundaries and potentially creating land management conflicts with adjacent private landowners and governmental partners. Another challenge the Department has encountered is managing herd outcomes that occur when pressure is applied to these herds associated with various public recreation opportunities. Through time, the Department has applied adaptive management solutions on lessons we have learned through these challenges creating many short- and long-term management successes. This presentation will provide a brief history of Department management of each bison herd within Arizona, highlight these various challenges and successes involved with each herd's short- and long-term management, and highlight the Department's contribution to nationwide bison conservation efforts.

Investigating seedling success in assisted population migration of ponderosa pine

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ABSTRACT: Increased temperatures and changing precipitation conditions are altering the regeneration environment for trees across the western US. Several high severity fires in recent years have left many previously forested areas in need of reforestation. Conventionally, local seed sources have been used in reforestation to promote local adaptation within species populations. However, as climate warming accelerates, the local populations that previously existed may not be adapted to future climate conditions at the site. Therefore, assisted population migration, or the use of seeds from populations that will be better adapted to future climate conditions, may be warranted for tree species. In this study, we assessed seed and seedling characteristics of eight different populations of ponderosa pine in Colorado with a greenhouse experiment and field study. Seeds from populations with a range of climatic conditions were grown in a greenhouse experiment under drought and well-watered conditions. Seeds from the same populations were also sown at two field sites that burned in 2012, one within the current elevational range of ponderosa pine, and one just above the upper elevational limit. Seeds from hotter and drier populations tended to be larger and produce taller seedlings with more total biomass, regardless of greenhouse watering treatment. Significant variation in seedling growth was also found between different families within populations in the greenhouse. In the field, plot microsite played a much larger role in predicting survival than seedling family. However, seedlings from hotter and geographically closer populations tended to have increased survival in the first year after sowing across all sites. This study reveals significant variation in seedling growth and survival across populations of ponderosa pine and provides evidence for interactions with local climate conditions. Despite the highly drought tolerant nature of this species, seed selection will be important in future reforestation efforts to plan for forest resilience.

Risk of ecological transformation in pinyon-juniper woodlands across the US West

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ABSTRACT: Pinyon-juniper woodlands are an important component of dryland ecosystems across the US West and are potentially susceptible to ecological transformation if forest recruitment is unable to compensate for mortality losses under future climate conditions. Pinyon-juniper decline and transformation to other vegetation types may negatively impact ecosystems services in persistent woodlands, but simultaneously, could benefit areas where historic conifer encroachment threatens other biome types and taxa. However, predicting woodland futures is complicated by various factors: pinyon-juniper species possess unique strategies for persisting and reproducing under drought conditions, there is uncertainty around future climate conditions, and there are limitations on inferring demographic rates from large-scale forest inventories. Here, we quantify how climate change is expected to alter population demographics in five common pinyon-juniper woodland species in the US West and put our results in the context of a decision framework to give land managers options when faced with landscape change. Our results show that two of our five study species, *Pinus edulis* (PiEd) and *Juniperus monosperma* (JuMo), are projected to experience population declines, due to both changing mortality and recruitment rates. These declines are reasonably consistent across various climate futures, and the magnitude of uncertainty in our results due to climate is less than the uncertainty due to model specification. Interestingly, model uncertainty becomes larger for PiEd over time, while uncertainty for JuMo decreases over time. Declines in both species are projected to occur in the relatively warmer and drier locations of the US West. We found that a proportion of expected pinyon-juniper declines may be moderated by density reduction and our results inform where active woodland management is likely to be successful for resisting or directing ecological change in coming decades.

The dark side of the desert: dark biocrusts in the Mexican Chihuahua desert

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ABSTRACT: The "dark biocrust" is a diverse group of cyanobacteria, microfungi, and lichen that colonize open dryland soils. They all share light protecting pigments to resist the high exposure to solar radiation. In the heart of the Chihuahuan desert (Mexico), vast swathes of these dark biocrusts cover hundreds of hectares of open creosote desert scrub and halophytic grasslands in the Mapimi Biosphere Reserve (MBR). Although these black carpets appear homogenous, we asked, how contrasting microhabitats (beneath canopy, open interspace) associated with the most abundant shrub (*Larrea tridentata* and *Prosopis glandulosa*) and grass species (*Pleuraphis mutica* and *Sporobolus airoides*) may influence the diversity, composition, and ecological interaction networks of the microbial communities of dark biocrust? We collected a total of 32 biocrusts and associated soil samples. We examined the bacterial and fungal communities using amplicon-based metabarcoding. Thereafter, we applied an interaction network analysis based on the Lotka-Volterra approach to infer ecological interactions patterns (positive and negative interactions) assessing the combined microbial community profile. For bacteria, we identified a total of 15 phyla, with Cyanobacteria being the most abundant phylum. Bacterial composition was different only when comparing the microhabitats linked to *S. airoides* sites (PERMANOVA, P=0.041). There were 17 soil physicochemical properties that significantly influenced bacterial community composition. For fungal communities, Ascomycota was the overwhelmingly abundant phylum; fungal composition was different only between the microhabitats in the *P. mutica* sites (PERMANOVA, P=0.047). Nine soil variables were highly correlated with the fungal community composition. Fungal diversity showed significant differences across sites (ANOVA, $P \leq 0.001$) but not at the microsite level. The cross-domain (bacterial-fungal) network analysis identified six key taxa, mainly belonging to Cyanobacteria, with more than 200 interactions with other taxa. Despite the visual homogeneity of the dark biocrust at the MBR, different sites and microhabitats had unique key taxa and interaction networks, revealing an unaccounted diversity of dark biocrusts.

Building a park-based climate response using the tools and frameworks developed by the National Park Service and partners

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ABSTRACT: The NPS Climate Change Response Strategy encourages parks and programs to understand, adapt to, mitigate, and communicate about climate change. We overview tools and resources available to parks for each of these components, setting the foundation for later talks in the session that provide greater detail on specific topics. The NPS guidance *Planning for a Changing Climate* outlines the basic process for managers to make climate informed decisions by considering possible risks and impacts associated with climate change, thus better positioning parks for the increasing uncertainties posed by the future. Park managers can use the Planning for a Changing Climate process to understand climate exposure and resource vulnerability under plausible future climatic conditions; revisit their current goals and develop *forward-looking ones* that consider future conditions; and identify and prioritize management actions using the Resist-Accept-Direct framework. Park managers can understand their resource and/or facility climate vulnerabilities through use of in-house generated, park-specific *Climate Futures* – plausible,

divergent climate projections, or use regional scale resources such as the Fourth National Climate Assessment or other studies that address climate vulnerability at the scale of a park or specific habitats and species. The Cultural Resources Environmental Vulnerability Assessment Tool is available for a rapid, park-specific assessment of cultural resource vulnerability. Scenario planning can be used to develop adaptation strategies and tactics to address the identified vulnerabilities and account for the uncertainty in future climates and their impacts. NPS' Climate Change Response Program (CCRP) helps parks use all these tools to integrate climate change into plans such as the Resource Stewardship Strategy. The Green Parks Plan, and the Climate-Friendly Parks Program, provide guidance that helps parks build sustainable park operations. The National Climate Change Interpretation and Education Strategy guides parks when they reach out to the public with place-based climate stories. The CCRP has developed on-line, self-paced training and other formal training to help park mangers understand climate change concepts, science, and tools. Parks can access these tools and get assistance in using them and developing programs through Technical Assistance Requests.

Deriving fallow cropland maps across sections of the Western United States for 2010-2020 using decision-tree models on Google Earth Engine

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ABSTRACT: Fallow agriculture, the practice of choosing not to plant a crop during a season where a crop is normally planted, is an important component of many crop rotations. Knowing cropland fallow extent can help to assess crop productivity needed for food security assessments. It also can help to determine crop water use, water productivity, and water savings assessments. Several factors can influence a farmer's choice to leave fields fallow including lack of irrigation, rainfall, soil moisture, soil health, and cultural practices. The annual spatial extent of fallow agriculture is poorly understood relative to annual crop production within the United States. The US Department of Agriculture (USDA) Cropland Data Layer (CDL) does map fallow areas. While its cropland class is mapped with very high accuracy of about 90%, the CDL cropland fallow class is not as accurate. This study developed a methodology to map fallow croplands within the Northern Great Plains region of the United States, extending eastward from the upper Colorado Plateau, using an easily implementable decision tree algorithm. The algorithm applies training data from dry (2017), normal (2015), and wet (2019) precipitation years to encapsulate a wide variety of annual and climatic variability. Simple decision trees were created to run on MODIS 250 m time series imagery to identify fallow agricultural lands based on Enhanced Vegetation Index (EVI) time series data. The algorithm was run yearly from 2010 through 2020. Producer's accuracy ranged from 70 to 84% for the fallow category and 92 to 95% for overall accuracy. Fallow areas ranged from 10,000 ha for Minnesota to 1,300,000 ha for Montana. For Colorado, fallowland was highest in 2012 at 442,000 ha (a dry year) and lowest in 2019 at 164,000 ha (a wet year). Preliminary results covering the Colorado Plateau will also be presented.

Managing and restoring resilient river-riparian ecosystems in dryland regions

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ABSTRACT: River and riparian ecosystems in dryland regions are naturally dynamic systems subject to high spatial and temporal variability. These systems are generally predicted to become even more variable due to climate change coupled with other stressors related to human land and water management practices or the introduction of biological control agents to help manage invasive riparian plant species, such as tamarisk (*Tamarix* spp.), in the Western United States. This creates a lot of uncertainty in determining when and how natural resource managers should intervene to restore or enhance riparian ecosystems to maintain or recover desired ecosystem benefits. In the face of this uncertainty, which is exacerbated by rapidly changing conditions, the importance of ecological resilience has gained increased attention. In this talk, we will discuss practical approaches to incorporating ecological resiliency concepts into our strategies for prioritizing, designing, and implementing restoration actions. We will then use case studies to provide real-world examples of restoration strategies designed to maintain, enhance, or restore ecological resilience in riparian ecosystems. We will describe our experiences and lessons learned from restoration efforts that address site, reach, and broader riverscape riparian corridor scales, with a focus on recent and ongoing efforts in the arid and semi-arid west, and particular emphasis on our recent experiences in the Santa Clara River in Southern California.

Long-term simulated atmospheric nitrogen deposition has minimal impacts on biogeochemical and ecosystem properties in three semiarid grasslands on the Colorado Plateau.

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ABSTRACT: Drylands, which constitute >40% of Earth's land area, have naturally low nitrogen stocks and are predicted to be sensitive to modest increases in reactive nitrogen availability, but direct evidence that atmospheric nitrogen deposition will have sustained effects on dryland ecosystems is sparse and conflicting. We used data from three long-running nitrogen deposition simulation experiments and a complementary laboratory incubation experiment to address three fundamental questions about how nitrogen inputs affect dryland ecosystems: (1) What are the short- and long-term biogeochemical consequences of nitrogen inputs?; (2) Do these consequences depend on soil moisture availability?; and (3) Does soil texture modify the effects of nitrogen inputs and/or soil moisture availability? In 2011, we established three study sites along a soil texture gradient in Arches National Park, USA with plots receiving 0, 2, 5, or 8 kg N ha^{-1} annually (n = 5). A suite of soil biogeochemical metrics was assessed over the long- and short-term and we compared foliar chemistry, soil extracellular enzyme activities, heterotrophic respiration rates, and nitrogen trace gas fluxes in the fertilization plots at select intervals during the study period (2011-2019). Finally, we conducted a laboratory incubation to measure the effects of soil moisture on heterotrophic respiration rates. We identified some short-

term effects *in situ*, but no lasting consequences of added nitrogen for any of the metrics measured. In the incubation experiment, soil moisture treatments had independent effects on heterotrophic respiration rates but did not modify the short-term effects of added nitrogen. Our results oppose the common prediction that coupled dryland biogeochemical cycles are highly sensitive to nitrogen. Instead, they suggest that available nitrogen inputs are lost from some drylands before they can be immobilized or physically bound to soil.

Interdisciplinary approaches to vulnerability analysis of National Park Service cultural resources to climate change

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ABSTRACT: Shifting climatic baselines across the American Southwest have presented significant preservation and management challenges for cultural resource stewards of the National Park Service (NPS) and beyond. For decades, the focus in most park units has been on fortifying critical and fragile resources for slow and anticipated change and loss. Presently, because of the unanticipated and unpredictable environmental conditions that are becoming emblematic of the Anthropocene, we are needing to investigate anew the rates at which resource degradation occurs and the thresholds of resources to respond to and accommodate those changing conditions. As extrinsic exposure conditions change, so too do the intrinsic responses of resources to these changes. From a systems-based perspective, this results in technical problems of ever-increasing complexity, where the interaction of evolving exposure conditions and aging resources, alongside their aging, and often hidden or undocumented repairs have necessitated cultural resource managers to question how cultural resource vulnerability is defined, monitored, and addressed. Over the last several years and at numerous parks in the Intermountain Region of the NPS, partnerships facilitated through the CESU between the Vanishing Treasures Program and university partners such as the University of Arizona and the University of Pennsylvania Center for Architectural Conservation have highlighted the success of interdisciplinary collaboration and the development, validation, and implementation of sustainable methodologies and tools to better understand climate change vulnerability and counteract its effects on cultural resources. Case studies presented during this session by representatives of both national parks and university partners will describe in detail some of these efforts, their preliminary results, and their resultant effect on both short- and long-term cultural resource planning decisions at those sites.

Detection of listed bat species under bridges through the use of fecal DNA

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ABSTRACT: Detection of listed bat species (i.e., designated endangered by national or international organizations such as the International Union for Conservation of Nature [IUCN]) using bridges is important for wildlife conservation and management. Species that roost under bridges include the Indiana bat (*Myotis sodalis*), a United States (US) federally listed species and the little brown bat (*Myotis lucifugus*), listed endangered by the IUCN and for >10 states and provinces. This roosting behavior puts these species at greater risk when bridges require maintenance or replacement. The ability to inexpensively and efficiently detect species will prove essential to bat conservation as infrastructure projects increase. We determined whether bridges could be used to detect listed bat species via assays that were developed and tested on the Colorado Plateau. We used guano collected at roosts of 118 bridges in the US and 106 bridges in Canada that were provided to our Species from Feces program. We employed DNA metabarcoding or Sanger sequencing to identify bat species. We detected 16 species or species pairs of which ≥3 species are listed in the US or Canada. We found that, like species accumulation curves and our previous samples from mines in the US southwest, the more bridges sampled, the more species detected. However, even a single bridge sample detected a listed species in 8 of 16 states or provinces. Because use of bridges by bats includes both day and night roosting, monitoring bridges using our non-invasive approach can successfully identify species. Our samples show that this approach is productive in identifying use by bat species, including those that are listed.

Riparian plant presence and abundance are differentially controlled by hydrology and temperature along a regulated, dryland river

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ABSTRACT: The distribution and abundance of riparian plants are impacted by riverine and climatic processes at regional and local scales. Across broad scales, air temperature differences can influence riparian plant species turnover. At local scales, flooding and depth to groundwater interact to shape plant species turnover along a lateral, hydrological gradient. Climate change and river regulation are simultaneously changing air temperature and the riverine environment, potentially resulting in unique environmental conditions and unanticipated riparian plant responses. Interactions between temperature and flow regime could impact recruitment and establishment differently since they can be linked to different factors. Using a large dataset that spans a 5.3 °C mean temperature gradient, we address two hypotheses: (1) higher temperatures alter species response to river hydrology, and (2) species occurrence and abundance will be controlled by different environmental variables. Data were collected along the Colorado River downstream of Glen Canyon Dam in Marble and Grand Canyons, Arizona, USA. Plant species presence and cover class were recorded at over 400 locations from 2016-2020, along with environmental covariates. Using ordinal, hurdle-at-zero Bayesian regression models, plant occurrence and abundance were modeled simultaneously with respect to temperature, hydrology, and their interactions. This model was designed for zero-inflated cover class data, which are common in vegetation monitoring studies. Results from several species were compared.

Regressions indicated that plant species have unique responses to temperature and hydrological variables and that presence and abundance can differ in their controlling environmental variables. In *Salix exigua* (coyote willow), increasing temperature and increasing distance from baseflows each decrease species presence (mean effect sizes of -1.36 and -1.87), while the interaction between temperature and distance from baseflows controls species abundance (mean effect size -0.34). As temperature and river hydrology change, impacts to riparian plants will likely differ across species and conditions controlling recruitment and establishment may be decoupled.

Conservation or livestock goals: managing bison for conservation and for income—a case study of The Nature Conservancy's Medano-Zapata Ranch in southern Colorado

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ABSTRACT: There are many challenges in managing bison that are unrelated to ecology. The Medano-Zapata Ranch bison population is a semi-private herd that is limited in size and migratory opportunity. It is a perimeter-fenced landscape of 48,000 acres adjacent to Great Sand Dunes National Park and located within a larger landscape of suitable habitat. Conservation outcomes for bison and its habitat are primary goals for the herd. And yet politics, cultural differences and financial drivers greatly affect management and decision making as federal stakeholders invest in establishing a new conservation population of bison in the San Luis Valley. To better financially support the Medano-Zapata bison population, The Nature Conservancy (TNC) established a private contractor to manage the ranch. But this requires giving up some control at the expense of full conservation management, so the contractor can maintain profitability. For example, a conservation goal of approximately a 50:50 sex ratio is desirable but challenging in the context of a for-profit management model. Additionally, genetic standards for DOI conservation bison have differed from some privately ranched herds. This sets up stakeholders and interested parties for conflicting goals and values that change based on federal policies and whomever is in the current Administration. TNC has worked with the United States Geological Survey (USGS), Texas A&M University, and the management contractor (Ranchlands/Zapata Partners) to decrease cattle mtDNA in Medano bison for the last 10 years, with successful results (decreased to < 1%). However, nuclear DNA is likely around 5-8% according to genetic markers evaluated by Texas A&M University (TAMU) in 2012. Carrying capacity goals for bison and other wildlife in the conservation area create challenges, especially where there may be different views of patchiness, disturbance and impacts. The path to the creation of conservation outcomes for bison in a landscape of many managers and drivers has proven challenging. We will highlight road bumps and successes of joint management that includes federal, state, NGO, and private ranch stakeholders as well as implications for determining when a herd achieves outcomes that warrant a status of "conservation herd".

Agent-based microsimulation for emergency evacuation in Rocky Mountain National Park

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ABSTRACT: The risk during emergencies in US national parks is exacerbated by the effects of global climate change and growing visitation. The increasing need for preparing national parks for future emergencies necessitates the use of predictive tools to proactively evaluate adaptive disaster management strategies. We examined the use of agent-based traffic microsimulations for emergency evacuation in national parks by simulating two of the busiest attractions in Rocky Mountain National Park – the Bear Lake Corridor and the Wild Basin area – using the Aimsun Next software. The Bear Lake Corridor was examined under 13 scenarios comparing different visitor volumes, exit strategies, and road conditions (i.e., traffic control, car crashes, and road constructions), while the Wild Basin area was studied under two scenarios with varying visitor volumes. The objectives were achieved by building and calibrating the traffic network, incorporating visitor behavior into the microsimulation model, simulating traffic patterns in the software, and estimating evacuation time. The process of developing these simulations is described. The simulation results estimate the total time of evacuation, reveal slight traffic congestion happens at certain intersections, and demonstrate that the time and rate of hikers returning to the trailheads determine the total time of evacuation. The benefits, limitations, and considerations for utilizing agent-based microsimulations for emergency evacuation are discussed.

It takes time: carbon starvation in *P. edulis* after a decade of experimental drought

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ABSTRACT: Forests are fundamental components of the global carbon cycle, but are experiencing more frequent drought stress, leading to long term reductions in tree growth in surviving trees. Understanding the physiological functioning of trees surviving long term drought stress may help to constrain future predictions of tree growth and mortality. Shifts in the age or turnover time of non-structural carbohydrates (NSC) may underlie changes in tree growth under

long-term increases in drought stress. But NSC responses to drought are challenging to quantify, due in part to large NSC stores in trees and subsequently long response times of NSC to climate variation. Using a decade-long severe drought manipulation (-45% ambient precipitation, 2010-2021) and an extreme short-term drought manipulation (-90%, 2020-2021) in Pinus edulis, we measured the $\Delta^{14}C$ of NSC, plus a suite of ecophysiological metrics. We tested the hypothesis that carbon starvation alters the age of the sapwood NSC pool. Long term drought halved the age of the sapwood NSC pool, coupled with reductions in starch (-75%), radial growth (-39%), and stem respiration (-28%). In contrast, one year of extreme drought (-90% precipitation) had no impact on NSC pool size or age, despite significant reductions in pre-dawn water potential, photosynthetic rates/capacity, and twig and needle growth. Trees are long lived organisms with large and old reserves of carbon that appear resilient to extreme disturbance in the short term. However, after a decade of drought, trees drew down their older stored carbohydrates to support metabolism, suggesting limits to resilience.

Tracking riparian vegetation change on the San Carlos Apache Reservation and Upper Gila River watershed to inform impacts of climate change and identify restoration priorities

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ABSTRACT: Riparian systems across the southwestern United States are extremely valuable for the human and ecological communities that engage with them. However, they have experienced substantial changes and stresses over the past century, including non-native vegetation expansion, vegetation die-offs, variations in flows, and increased fire activity. Vegetation management approaches, such as ecological restoration, can address some of these stressors as well as reduce the risk of future impacts. In collaboration with the San Carlos Apache Tribe and the Southwest Climate Adaptation Science Center, we describe an application of remote sensing to inform restoration priorities along the upper Gila River within the San Carlos Apache Reservation and Upper Gila River watershed draining from western New Mexico into eastern Arizona. First, we use historical black-and-white and current high-resolution multi-band aerial imagery to map long-term changes in the riparian vegetation (i.e., 1935–present) to identify historic vegetation and river channel properties. Second, we apply a spatially and temporally explicit trend analysis across three observed climate periods (i.e., 1985-1993, 1993-2014, 2014-2021) using the Normalized Difference Vegetation Index (NDVI) and the Tasseled Cap metrics derived from the Landsat satellite image archive to quantify more recent (i.e., 1985–present) changes in riparian vegetation conditions and identify areas potentially more at risk for degradation. Changes in riparian vegetation are analyzed within a climate framework to better understand trends and the potential effect of climate and land use change. Vegetation greenness has largely increased throughout the watershed despite intensifying drought conditions across our study period, though areas within the lower watershed have shown increased stress and higher rates of wildfire and other disturbances over the past 5-years. Nevertheless, small-scale restoration activities appear to show improved overall vegetation conditions, suggesting overall efficacy of these restoration activities. Results from this study will be integrated with traditional

ecological knowledge and restoration objectives of the San Carlos Apache Tribe to develop a restoration plan that will help riparian vegetation communities adapt to change.

Considerations for monitoring visitor use into the future

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ABSTRACT: Visitor use estimation and monitoring are fundamental practices for land management agencies. The NPS has collected visitor use data since 1904 and its data collection protocols have evolved over time based on inclusion of new types of parks into the NPS system, the changing nature of visitation, and technological developments. The National Park Service (NPS) is required to collect and report visitor use monthly with an annual report delivered to congress. New legislation, America's Outdoor Recreation Act 2022, is being considered that emphasizes the need for timely visitor use statistics reporting. Included in the legislative language is the requirement for a "Real Time Data Collection Program" that highlights the need for emerging technologies. In this presentation we provide a brief background about the NPS Visitor Use Statistics program and some of the challenges of estimating use in units across the national park system. We will discuss current technologies and count procedures used by the NPS Visitor Use Statistics Program along with contemporary studies that have examined emerging technologies, such as Location Based Services (LBS), that have garnered much interest for their potential to estimate visitor use on public lands. As new counting technology emerges an emphasis on data quality, reliability, continuity, and transparency needs to be maintained to support the myriad of applications of these data support such as visitor spending analyses, damage assessment, and infrastructure investment.

Biocrusts are dynamic in both compositional and functional responses to global change drivers

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ABSTRACT: Biological soil crusts (biocrusts) are photosynthetic soil communities found in drylands worldwide, that are central to the stability and resilience of dryland ecosystems, but vulnerable to global change. Biocrusts are the dominant ground cover on the Colorado Plateau, a region that is also experiencing rapid climate and land-use change, making it the ideal place to investigate how biocrusts will respond to global change. While we have a strong sense of the vulnerability of biocrusts to change, we know less about how biocrust successional states recover from disturbance and the impacts of successional state shifts on ecosystem functions. Here we synthesize data from multiple experiments to investigate the consequences of: climate change, land-use change, and atmospheric nitrogen (N) deposition on biocrust successional states and

ecosystem processes, such as soil stability and N cycling. In our climate manipulation and simulated land -use change experiments, we found biocrusts recovered rapidly under ambient temperatures but warming interacted with the precipitation disturbance to halt recovery. Further, warming alone caused losses of later successional mosses and lichens, as well as soil stability. In our experimental N addition experiment, we simulated N pulses using bare ground, early and late successional states to determine how successional state and multiple N cycling functions respond to elevated N. We found that biocrust successional states responded differentially to added N, with early successional crusts showing a faster peak in NO_x emissions and the smaller amount of remaining inorganic N after the pulse when compared to late successional crusts. Therefore, early successional crusts favor N losses via gaseous pathways relative to late successional crusts Taken together, these results illustrate how increasing temperatures may drive shifts of successional states, with subsequent changes to soil stability as well as changes to gaseous N losses with implications for air quality.

Feeling the burn: trajectories and tipping points of piñon-juniper woodlands after fire

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ABSTRACT: Piñon-juniper (PJ) woodlands are a dominant community type across the Intermountain West and are experiencing significant effects from increasing wildfire occurrence and severity due to climate change. Shifts in fire regime have myriad consequences for PJ woodlands that comprise over a million acres of public lands and that provide critical cultural, economic, and environmental benefits. Recent PJ mortality and failure to regenerate after catastrophic stand-replacing wildfire have elevated concerns about the long-term viability of PJ woodlands in the context of global change. Trends suggesting that PJ woodlands are unable to recover following more frequent stand-replacing fires is of great concern. Moreover, we have only a limited understanding of how fuel treatments and post-fire seeding affect future PJ recruitment and fundamental soil functions. Here, we describe a project co-developed by managers and scientists to explore the fate of Colorado Plateau PJ systems in the context of fire. In particular, we examined the trajectory of vegetation structure, soil biogeochemistry and PJ regeneration dynamics following fire and thinning treatments designed to reduce the risk of fire using paired burned (~20 yr ago), unburned, and thinned sites in Mesa Verde and on Ute Mountain Ute land. Overall, we found the legacy of fire created distinct plant communities that did not show any signs of returning to their previous state – intact PJ woodlands. This shift was characterized by a lack of *P. edulis* and *J. osteosperma* recruitment and increases in invasive cheatgrass, seeded western wheatgrass, and shrubs. Further, burned areas had smaller sizes of interspaces among plants, which are essential habitats for light sensitive organisms like biological soil crust and endangered and endemic plants. Overall, a lack of recovery of Piñon-

Juniper woodlands following fire was disconcerting but working together across the management-science boundary provides hope in maintaining habitat, culture, and ecosystem functioning of PJ ecosystems.

Morphological and genetic analyses of large datasets for taxonomic and conservation considerations of rare cacti from the southwestern deserts of the US

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ABSTRACT: Several recent projects at the Desert Botanical Garden have focused on the genetic relationships among endangered cacti and their closest relatives. For each project, population-level samples were collected from across the range of the rare species and from a subset of populations of close relatives. Population genetic and whole chloroplast sequence data were gathered and analyzed using clustering and phylogenetic approaches. Results indicate that genetic variation is geographically structured, sometimes supporting the rare cactus as a unique evolutionary lineage, but sometimes supporting stronger genetic affinity among geographically proximate populations. Current work at the California Botanic Garden is focused on the *Coryphantha* (*Escobaria*) *sneedii* complex, which is in a state of taxonomic confusion, making conservation efforts for these federally and state protected taxa conflicted and complicated. To explore genomic-scale measures of genetic connectivity and divergences, 500 individuals, including those of the outgroup species, were collected. All samples were genotyped using ddRAD-seq methodology, recovering a mean of 120,517 loci per individual. Results indicate very low levels of heterozygosity and isolation by distance. Divergences among populations are generally high and inconsistent with nearly all current taxonomic treatments. Detailed morphological studies conducted at Arizona State University for many of these same species have revealed that large sample sizes are critical for understanding the range of morphological variation within and among populations and are important for reducing sampling error and phenological effects from environmental factors. Not all genetic and morphological results from these studies are in alignment, which is not surprising given the recent and rapid radiation of these genera of cacti and the potential for convergent evolution of characters that are typically used to define cactus species.

Using PhenoCam data to model spring green-up across diverse North American grasslands

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ABSTRACT: Vegetation seasonality heavily influences many ecosystem and climate processes, such as carbon uptake and the energy and water cycles. Thus, understanding drivers of

vegetation phenology is crucial for predicting the current and future impacts of climate change on ecological systems. Using photoperiod and temperature, existing models can accurately predict the date of spring onset in temperate forests. However, these models tend to perform poorly in grassland systems because most do not incorporate a measure of water availability, a primary limiting factor for grassland plant growth. In this study, we used long-term datasets of digital imagery from the PhenoCam Network of 43 diverse North American grassland sites (195 site-years) to assess the performance of existing spring phenology models, as well as develop and test several new models that include precipitation or soil moisture as drivers (53 models total). The new models generally performed better, with the top models including both temperature and precipitation. The best model (RMSE = 16.0 days) was sequential, in which a site must first accumulate enough precipitation and then temperature to trigger spring onset. Importantly, it performed well across all grassland types using a single set of parameters, from the Great Plains to Southwest desert grasslands (> 250-day spread), although, model performance was improved when the parameters were independently optimized for four separate climate regions (RMSE = 10.4 days). Therefore, both sufficient precipitation and temperature are required for grassland plants to become active in the spring, but optimal thresholds vary by region. This new model improves our understanding of how climate variables interact to influence grassland phenology, and thus, our ability to predict how future climate change will impact diverse grassland systems.

Hopi way of life: having faith and belief in the Creator

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ABSTRACT: The Hopi continue to live by their sacred covenant with the Creator to live in a peaceful way. The Hopi way of life and relationship to the Sacred Mountain has sustained them since the beginning. It's this way of life that has given Bucky Preston the strength and stamina to run thousands of miles to protect water. Water is life. Understanding and respecting the natural flow of water is critical for Hopi crops. As traditional farmers who rely on natural rainfall the development at Snowbowl has been devastating. The newcomers to this land cannot understand the spiritual connection of recreating on reclaimed sewage water and the drought we are experiencing. It is critically important for them to begin to see the connection and consequences of living out of harmony with our Mother Earth and her natural life systems.

Arizona hedgehog cactus (*Echinocereus arizonicus* subsp. *arizonicus*): ongoing restoration efforts in Tonto National Forest

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ABSTRACT: *Echinocereus arizonicus* subsp. *arizonicus* (Arizona hedgehog cactus or AHC) is a US federally listed endangered subspecies under the Endangered Species Act since 1979 and is endemic to an approximately 25km2 known area in central Arizona growing largely within the Tonto National Forest. AHC prefers rocky microsites such as cliffs, bluffs, outcrops, and

boulders within a narrow range of Madrean woodlands and chaparral plant communities from approximately 1007-1740m in elevation. The US Fish and Wildlife Service estimated current population at 6,000-6,700 individuals in January 2021. Between 1979 and 2021, AHC abundance and habitat both continuously declined due to road construction projects, mining operations and recent fires. The Telegraph Fire of June 2021 burned more than 20% of the subspecies' known habitat and 56% of its estimated habitat. Approximately 1600 plants mapped by the US Forest Service prior to the fire fell within the fire's perimeter. Desert Botanical Garden has been involved in conservation of AHC by seed banking, monitoring, propagation, population genetics studies and salvaging. In March 2022 we transplanted 60 previously salvaged stems in the new Pinto Creek Bridge area, concluding a conservation project begun in 2017. In October 2021, we started a new project under Section 6 funding in which we are trying a newly developed technique: harvesting stems from wild AHC plants to root under controlled conditions for future transplant into native habitat. With this technique, we can produce mature, reproductive individuals in a short period of time (1 year) compared to propagation by seed (estimated 8-10 years), at a size that can survive and establish under field conditions. We will continue restoration of the target subspecies by transplanting and maintaining 300 asexually propagated individuals with the help of volunteers by February 2023. Our presentation will illustrate some of the conservation actions we are taking for the AHC.

Communicating environmental health science to Native communities through Native-themed and Native-created Art

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ABSTRACT: In December of 2016 the Community Environmental Health Program (CEHP) inaugurated its first ever Artist-in-Residence program by having Zuni Pueblo artist Mallery Quetawki begin the task of tailoring the program's scientific research communication to be more culturally inclusive and relatable. At the request of CEHP's partner communities to use more culturally appropriate visuals, Ms. Quetawki has since created acrylic paintings and digital artwork to portray the complexities of biochemical pathways and other health related information under the scope of an Indigenous lens. This "lens" is a product of not only the artist's Pueblo upbringing and college science education but the collaborations with both keepers of Indigenous knowledge and the investigators involved in CEHP projects such as Native Environmental Health Equity (Native EH Equity), Metals Exposure and Toxicity Assessment on Tribal Lands in the Southwest (METALS), Navajo Birth Cohort Study/ Environmental Influences on Child Health Outcomes (NBCS/ECHO) and the participant Engagement-Cancer Genomic Sequencing Center (PE-CGS) under the University of New Mexico Comprehensive Cancer Center (UNMCCC). The key goals for the artist-in-residence program are to translate the science, bridge bi-directional communication and create an inclusive environment effectively and appropriately

so that our collaborating Indigenous communities are well informed and represented throughout the processes of research from consent to collection and evaluation to remediation.

Utilizing aerial imagery and NASA Earth observations to assess pinyon-juniper tree mortality in Flagstaff, Arizona

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ABSTRACT: In 2021, amidst a decades-long drought, an extensive juniper mortality event occurred at Wupatki National Monument (WNM) in Arizona. Loss of pinyon-juniper woodlands (PJW) threatens the ecosystem and could lead to a potential loss of habitat, nutrients, and breeding areas for local wildlife. In partnership with the National Park Service (NPS), the NASA DEVELOP team used remotely sensed data to map PJW mortality and analyze the relationship between tree mortality and multiple factors, including soil moisture, precipitation, and temperature, that could be responsible for PJW decline in north-central Arizona between 2015 and 2021. To identify the extent of living PJW, the team performed an unsupervised classification using National Agricultural Imagery Program (NAIP) data in conjunction with NPS-created land cover maps, Landscape Fire and Resource Management Planning Tools (LANDFIRE), NPS and United States Forest Service (USFS) vegetation maps, and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) products. This method classified land cover on a pixel-by-pixel basis. Terra Moderate Resolution Imaging Spectroradiometer (MODIS), Global Precipitation Measurement (GPM) Integrated Multi-satellite Retrievals for GPM (IMERG), Soil Moisture Active Passive (SMAP), Shuttle Radar Topography Mission (SRTM), and Landsat 8-derived Land Surface Temperature, Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) were used to analyze environmental factors that could be contributing to pinyon-juniper mortality. Overall, 43% of the pixels classified as living pinyon-juniper throughout the study area, including portions of Coconino and Kaibab National Forests, Wapiti and Sunset Crater National Monuments, and the Southern Rim of the Grand Canyon, in 2015 showed mortality in 2021. Within WNM specifically, 47% of pixels previously classified as living pinyon-juniper in 2015 showed mortality in 2021. PJW mortality was weakly correlated to elevation, soil moisture, and land surface temperature within WNM, although significant relationships were not found in the broader study region. Results from this study can inform NPS vegetation management that best protects natural and cultural resources. Furthermore, this work highlights how remote sensing approaches can be used to monitor PJW, which are an important component of the landscape.

The relationship between *Coccidioides posadasii* and biological soil crusts in Arizona desert ecosystems.

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ABSTRACT: Valley fever is caused by an endemic pathogen of the southwestern United States, Mexico, Central, and South America driven by the soil-inhabiting fungal genus, *Coccidioides*. Humans contract the disease through the inhalation of infectious spores, and 40% of individuals develop symptoms that could lead to death. To date, no one has attempted to address Valley fever through environmental remediation and restoration of natural soil communities. Biological soil crusts (biocrusts), communities of cyanobacteria, lichens, and mosses that live in and bind the top mineral soil layer, provide ecosystem functions including C and N fixation, soil stability, hydrological cycling, and thermo-tolerance. Restoration of biocrusts in areas of high *Coccidioides* endemism could reduce Valley fever incidence via several pathways: (1) stabilizing the soil surface with biocrusts should reduce the potential of *Coccidioides* spores to aerosolize, and (2) could decrease the abundance of *Coccidioides* by reducing the favorable habitat, or by creating competition from a more diverse and active soil microbiome. Our overarching research objective is to determine if soil remediation with biocrust can reduce the occurrence of *Coccidioides* spp. in the air and/or soil by stabilizing the soil surface, reducing associated dust, and increasing belowground microbial competition. Desert soil was inoculated with *C. posadasii* with different biocrust restoration treatments to determine whether the presence and abundance of biocrusts reduce the incidence of *C. posadasii* in the soil and surrounding air. A filter was placed above the surface layer for 14 days to capture aerosolized spores. We quantified spores with a hemocytometer and qPCR. These findings provide evidence that restoration of natural dryland communities can decrease the human fungal pathogen burden. Management practices that reduce the disruption of soil surfaces or restore disturbances with biocrusts may reduce the abundance of airborne soil pathogens, and thus reduce the spread of endemic pathogen ranges.

Emory Oak Collaborative Tribal Restoration Initiative (EOCTRI) —fostering the protection and restoration of culturally sensitive natural resources

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ABSTRACT: Emory oak acorns are a critical resource for Ndee (Apache) Tribal Nations due to the acorn's importance as a food source and its cultural and ceremonial significance. Ndee elders attest that over recent decades, Emory oak groves have yielded fewer acorns, declined in overall health, and failed to regenerate new trees. If trees are unable to replace themselves, the long-term persistence of Emory oaks, as well as associated cultural traditions, are threatened. The EOCTRI seeks to restore and ensure the long-term persistence of Emory oak (*Quercus emoryi* Torr.) and other traditional subsistence foods for present and future generations using land management best practices and Traditional Ecological Knowledge.

Managing for ecological resilience of pinyon-juniper ecosystems during an era of woodland contraction

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ABSTRACT: Dryland woodland ecosystems worldwide have experienced widespread drought- and heat-related tree mortality events coupled with extreme wildfire behavior. In contrast to other forest types where the emphasis has been on the silvicultural enhancement of ecosystem resilience and restoration of structural heterogeneity, limited frameworks are available for management to improve drought resilience in semi-arid woodlands. This challenge is especially acute in pinyon-juniper woodlands, a dominant vegetation type across western North America that has experienced extensive tree die-off over the past several decades. In this talk, we provide an overview of the vulnerability of these ecosystems to global change pressures, describe the critical and urgent need to manage for future drought, and synthesize the current state of knowledge on how to enhance woodland resilience to hotter drought and associated disturbances. We present a landscape prioritization framework for guiding management goals and practices that requires prioritization of efforts based on the need for action and the probability of a positive outcome. Four guiding factors include: historic woodland structure and drivers of long-term landscape change, current vegetation structure and composition, future climate suitability, and habitat and resource value. In summarizing the strength of evidence supporting our recommendations, we identify critical knowledge gaps and highlight the importance of adaptive management strategies that reflect current uncertainties. This will ultimately allow for improved management of diverse semi-arid woodland ecosystems that are undergoing substantial changes due to past and present land-use, biological invasions, and climate change.

Plant water-use efficiency predictors along an aridity gradient

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ABSTRACT: Water is a limiting factor for productivity in drylands, which could be particularly vulnerable to longer and more intense droughts, with feedbacks to the global carbon and water cycles. Quantifying plant water-use efficiency (WUE), or the ratio of carbon gained to water lost, is one of the main challenges to understanding dryland carbon and water relationships. Ecosystem WUE is often calculated using eddy covariance data, based on the ratio of gross primary productivity (GPP) to evapotranspiration (ET). However, this provides a coarse approximation of WUE because ET includes evaporation (E), in addition to transpiration (T), or water lost during plant photosynthesis. Using ET partitioning models to relate T to GPP allows

for more accurate ecosystem WUE estimation. However, the most common ET partitioning methods employ assumptions about WUE that are not well suited to drylands or they assume that WUE does not vary temporally. We integrated eddy covariance and satellite data (ECOSTRESS) to develop an ET partitioning model to estimate a WUE index that overcomes some of these challenges. We subsequently evaluated the influence of environmental variables on WUE along an elevation gradient in New Mexico using cross-wavelet coherence analysis to calculate temporal coherence (R^2). We found that WUE at higher elevation (less arid) sites was correlated ($R^2 > 0.8$) to environmental variables associated with seasonality (e.g., vapor pressure deficit [VPD], air temperature, leaf area index, photosynthetically active radiation) at yearly scales. At lower elevation (more arid) sites, WUE was inconsistently correlated ($R^2 > 0.8$) with soil water content and precipitation at weekly and seasonal scales. WUE at all sites was inconsistently correlated with VPD at shorter timescales, demonstrating that dryland plants do not always respond optimally to VPD at the ecosystem scale. Thus, across dryland ecosystem types, different variables that operate at different temporal scales primarily control WUE.

Ecological correlates of recruitment and mortality in the acuña cactus (*Echinomastus erectocentrus* var. *acunensis*)

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ABSTRACT: Annual monitoring has taken place on six 20x50 m plots since 1988. Annual recruitment of new adults ranges from 1 to 19 percent (average 8.7). Adult mortality ranges from 0 to 37 percent (average 9.4). Since 1988, the number has increased or remained the same in 20 years and decreased in 14 years. Major declines occurred 1996-1999 and 2006-2008 with only modest gains in other periods. The six plots had 197 adults in 1992 and 35 in 2008. There were 78 in 2022. Cool season precipitation ranges from 0.0 to 10.2 inches (average 3.80) and warm season precipitation ranges from 0.3 to 9.4 inches (average 3.71). Trends in precipitation are not significant. Good years for recruitment are preceded by multiple consecutive seasons of near to above average precipitation. Number of flowers is correlated with individual size (height). Residual variation is correlated with winter precipitation and fruit as percent of flowers is also highly correlated with winter precipitation. Of 339 adults lost since 1988, 180 were dead, 99 missing, 25 uprooted, 32 eaten, and 3 not recorded. The two biggest spikes in dead coincide with very wet winters (1993 and 1998). Rates for uprooted and missing are correlated among years. The two biggest spikes in missing and uprooted (1997 and 1999) coincide with very dry winters. Dead adults had below average growth and flowers in the last year alive. Eaten, uprooted, and missing plants had above average growth and flowers in the last year alive. Fourteen plants were recorded as having a bore hole or probable beetle larva. Observations of incisor marks, scat, and trail camera photos reveal herbivory by mammals affecting buds, flowers, fruits, the top of the cactus, or the entire plant. These events are also associated with very dry winters (1999, 2007, and 2022).

Long-term forest structure and tree growth responses following landscape-scale ponderosa pine restoration treatments

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ABSTRACT: We evaluated treatment responses on forest structure, old-tree mortality, regeneration, and tree growth 21 years following the initiation of an operational, landscape-scale restoration project in a ponderosa pine-Gambel oak forest in northern Arizona. Project goals were to increase ecological resiliency to fire, pathogens, and drought by thinning and burning to alter forest structure to more closely resemble conditions prior to fire exclusion in 1870. We measured plots in 1996/1997 before treatment implementation and in 2017/2018 after treatment. The plots were evenly distributed across a 2,114 ha study area, of which 21% was an untreated control. Pre-treatment tree density and basal area in the treated area were reduced by 56% and 38%, respectively, compared to the control which showed a slight decrease in density and slight increase in basal area over 21 years. Post-treatment density (399.2 trees ha^{-1}) and basal area (18.3 m^2 ha^{-1}) in the treated area were significantly lower than in the control (859.7 trees ha^{-1} and 35.4 m^2 ha^{-1}). Pre-treatment canopy cover was reduced from 54% to 34% in the treated area and increased from 55% to 65% in the control over the study period; the treated area had significantly lower cover than the control following treatment. Old-tree mortality was significantly higher in the treated area compared to the control. This result was primarily driven by mortality of oaks that likely died due to fire effects. Regeneration was variable, but trends indicated reduced conifer regeneration and substantial increases in sprouting hardwood species following treatment. Post-treatment mean annual basal area increment was 2,082 mm^2 yr^{-1} $tree^{-1}$ in the treated area, 88% higher than in the control (1,106 mm^2 yr^{-1} $tree^{-1}$). The Mt. Trumbull landscape restoration project resulted in increased resiliency to disturbance and drought and served as a useful collaboration of research and management over more than 20 years.

Drought and wildfire drive transitions to non-forest cover in two trailing-edge forest landscapes

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ABSTRACT: Climate change is altering the distribution of woody plants by influencing demographic processes and modifying disturbance regimes. Trailing-edge forests may be particularly vulnerable to climate- and disturbance-driven transformations because they are located at the warm, dry margins of forested ecosystems. To better understand recent climate-driven changes in trailing-edge forests, we used Landsat time series and 1,558 field reference plots to develop annual maps of land cover from 1985 to 2020 in two landscapes in Arizona, USA. We assessed temporal trends in four forest types and non-forest cover and identified annual rates of transitions among these cover types. To characterize drivers of transition from forest to non-forest cover, we combined annual land cover maps with tree-ring records and

spatial data describing inter-annual climate, terrain, bark beetle (Curculionidae: Scolytinae) activity, wildfire, and timber harvest. Overall, the two trailing-edge landscapes had relatively consistent levels of forest cover over time, with net declines of 0.3% and 0.8% from 1985 to 2020. However, variation also occurred within the study period, with abrupt (ca. 1-2 years) declines in forest area followed by gradual (ca. 10 years) recovery. Pinyon-juniper cover increased from 1985 to 2000, but declined from 2000 to 2020, a period of extreme drought and regional tree die-off. Similarly, pine-oak cover increased from 2000 to 2020, primarily due to decreases in more mesic forest types. Where transitions from forest to non-forest cover occurred, wildfire was a key driver, with the occurrence of multiple short-interval drought years playing an important role in unburned areas. Wildfire and drought will increasingly shape forest dynamics and ecosystem transformations throughout the western US. Monitoring of changes in forest composition and extent, as well as the causal mechanisms of such changes, provides critical insight into management activities designed to resist, accept, or direct ecosystem transitions in seasonally dry forests.

Evaluating the effects of drought conditioning, container size, and planting season on Ponderosa pine seedlings in post-fire reforestation

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ABSTRACT: Ponderosa pine (*Pinus ponderosa*) forests in the southwestern US are diminishing rapidly due extended droughts, insect and disease issues, and catastrophic wildfires. In high-severity post fire environments, natural regeneration of ponderosa pine is not common due to harsh abiotic conditions and a lack of seed trees. However, when utilizing artificial regeneration, survival and performance of planted seedlings are often categorized as poor. Since future climatic conditions in the Southwest are predicted to be warmer and drier, modifications in the nursery components are critical to potentially improve survival and performance of planted seedlings. In this study, we test effects of container size, drought conditioning, and planting season on performance of planted ponderosa pine seedlings. The container sizes used in this study were the 10 in^3 - Ray Leach SC10 and 30 in^3 - Deepot D30. Drought conditioning treatments were implemented using a dry-down method in which seedling were subject two irrigation levels (High = 85% and Low = 55% of container water capacity). Seedlings from each of these treatments were then planted across three seasonal windows (Summer in July 2021, Fall in October 2021, and Spring in March 2022) at the Philmont Scout Ranch property (36.507, -105.029) within the Ute Park Fire burn scar near Cimarron, New Mexico, USA. Each treatment was replicated by 6 blocks for a total of 1080 seedlings (15 seedlings per treatment block combination). Data regarding survival, physiological performance, and growth are currently being evaluated. We expect the results of this study to show significant gains in both survival and growth of planted ponderosa pine seedlings, providing valuable information for large scale reforestation projects across the western US.

What can a rare plant tell us about post-fire recovery in an old-growth piñon-juniper stand?

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ABSTRACT: Post-fire recovery in piñon-juniper woodlands take centuries. We monitored a globally rare but locally abundant herbaceous piñon-juniper obligate, Chapin Mesa milkvetch (CMM, *Astragalus schmolliae)* pre-and post-burn. We collected plant density, recruitment, and mortality, along with repeat photos from 2001-2022. In addition, we collected plant cover data for two indicator grasses- cheatgrass and western wheatgrass - as well as soil moisture and soil temperature. The results from the first two decades provide insight about post-fire recovery. We see little evidence of tree recruitment; however, shrub recruitment is quite good. Cheatgrass, became the dominant ground cover, peaking around 13 years post-fire, at 60% cover. However, this trend reversed and cheatgrass now has less than 10% cover. Western wheatgrass was part of the seed mix that was planted in 2003 and surged from 0% cover pre-burn to an average of 20% cover 2015-2022; many patches now have >40% cover. This perennial, rhizomatous grass has deep and shallow roots which compete for soil moisture that is otherwise available for trees, shrubs, and CMM. The lack of trees and high herbaceous ground cover translates into a hotter and drier climate in the burned areas: deep (35 cm) soil moisture was 50% drier in burned areas and summer soil temperatures were generally 4°C hotter in burned areas. CMM germination in the burn is now negligible compared to that in unburned areas, which are cooler, moister, shadier, and have low herbaceous cover with no rhizomatous grasses. At current trends, the burned area will lose its CMM population in about 15 years. Because CMM needs many of the same conditions conducive to woody species recovery, but does so more quickly, it provides some leading indicators for forest recovery. In addition to providing guidance on unintentional consequences of reseeding practices, we present one "new" recommendation for post-fire tree restoration.

Building capacity to use Earth observations for wildfire risk reduction and resilience applications: a summary of NASA's DEVELOP 2022 wildfire projects

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ABSTRACT: NASA's DEVELOP Program engages individuals and organizations in 10-week feasibility studies to apply NASA Earth observations (EO) to decision makers' needs. DEVELOP maintains a balance of projects across nine application areas, one of which is Wildfires. DEVELOP's Wildfires application area supports pre-fire (fuel loading, fire risk), during (active fire detection), and post-fire (fire extent, intensity) monitoring and modeling. In 2022 so far, DEVELOP has conducted six projects with Wildfires as a primary or secondary component across a diverse set of study areas. This presentation introduces DEVELOP, its

approach to capacity building, key partnerships, and project results highlighting the capabilities of EO for enhanced decision-making regarding wildfires.

Local biodiversity monitoring efforts aggregate into meaningful outcomes

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ABSTRACT: In this era of the Anthropocene, human actions now dominate natural processes, resulting in rapid global change. Habitat destruction, pollution, disease, and climate change are leading to unprecedented biodiversity loss and radical changes in the way our environment functions. These problems not only affect our natural world but also humankind, which depends on ecosystems to provide productive lands for agriculture, pollination of plants, clean water, medicine, and many other ecosystem services. To address the unprecedented loss of biodiversity and impacts to our environment, natural resource managers and policymakers need relevant data to make decisions. That vital information can be derived through dedicated monitoring programs that occur in sufficient detail and at appropriate spatial and temporal scales to inform planning, design, and budgeting phases. The speakers in this session represent non-profits, government agencies, and academic programs and will give examples of efforts to collect and analyze this important data to inform decision making. I will give examples of how researchers and organizations use academic and community-based data to analyze species trends, providing critical information to managers and policy makers on biodiversity. These examples highlight how organizations can make a difference through dedicated long-term monitoring that can be aggregated for policy decisions at regional and national scales. At the end of the session, we will have time for Q & A and discussion.

Sonoran Desert threats and protection mapping for rare, threatened, and endangered plant species

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ABSTRACT: In order to help slow the unprecedented global loss of biodiversity, we need tools that quickly and effectively evaluate species at risk and threats facing them. Several researchers have created threats maps for the purpose of identifying priorities for conservation. These maps provide tools for allocating conservation resources to where they are most needed. Over the past two years, NAU undergraduate students have been developing a threats map for the Sonoran Desert by compiling spatial layers of interest. Recently, we merged the layers producing a combined threats layer. The new combined threats layer can be compared with species distribution points to identify threats to a species using tools in ArcGIS Online. The threats included are urbanization, agriculture, mining activities, renewable energy infrastructure, non-native grazing (burros and horses), fire intensity predictions, and roads. Threats not available in

map layers include climate change impacts, invasive plant species distribution, and plant collections/illegal harvesting. We have identified threats to listed threatened and endangered succulent species using the threats map and compared these threats with documentation of threats as described by the Fish and Wildlife Serve on their ECOS website (https://ecos.fws.gov/ecp/). Threats identified through the threats map for each species had some overlap with the threats listed in the ECOS website, but the threats map and the ECOS website each listed distinct threats as well. This tool will soon be publicly available and should be highly useful for scientists and managers to conduct rapid threat assessments, especially for plant species with limited distributions.

Reproducible Climate Futures – an R package and other tools

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ABSTRACT: Divergent future climate projections (climate futures) help resource managers work with uncertainty and prepare for a wide range of plausible future conditions, thus avoiding surprises. While many tools are available that summarize climate data based on emissions scenarios, these model averages do not capture a wide range uncertainty in the near team and may miss consequential outcomes in all timeframes. We have found the use climate futures offer an adaptable approach to planning across a broad range of management contexts and have spent the past decade developing and refining tools to help with their creation. We describe a set of tools developed for creating reproducible climate futures, that standardize and streamline their production. These tools include an R package and training materials that enables users with varying data and coding experience to develop their own climate futures and provide guidance on their use.

Risk bounding in scenario planning using 'Climate Futures'

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ABSTRACT: When trying to adapt to a changing climate, with all the inherent uncertainties about how the future may play out, resource managers often turn to scenario planning as a tool to bound risk. Managers use scenario planning to explore plausible ways the climate may change, allowing them to work with climate change uncertainty rather than being paralyzed by it. Once identified, scenarios of the future are used to develop proactive measures to prepare for and adapt to scenarios of change. A key part of scenario planning is generating a list of potential future climates we may experience. In this presentation, we will describe and compare three different approaches to generate the climate futures: ensemble averages of emissions scenarios, ensemble averages of projections defined by their location in quadrants of average annual temperature and precipitation change, and individual contrasting projections. Results identify that the individual projections capture the broadest range of climate conditions (a key ingredient to developing

scenarios) across both near and long-term planning horizons. We conclude with discussion of limitations for the three approaches and tradeoffs to consider when selecting climate futures for resource management planning.

Assessing combinations of nucleation size and planting density to improve survival and performance of planted ponderosa pine seedlings

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ABSTRACT: Southwestern ponderosa pine (*Pinus ponderosa*) forests are threatened by impacts of a changing climate. A combination of catastrophic wildfires, long-lasting droughts, and bark beetle attacks have caused large scale tree mortality in this region. Artificial regeneration by planting presents an opportunity to compensate for these recent losses of ponderosa pine forests; however, early survival of planted seedlings is often low and site dependent. Different approaches to improve early survival and performance of planted ponderosa pine seedlings are currently being tested. In this study, different combinations of nucleation size and planting density are being assessed by using a 2 x 4 factorial design with 2 nucleus sizes (1/2 acre and 1/8 acre) and 4 planting densities (1742, 889, 436, and 194 trees per acre) for a total of 8 treatment combinations. Each treatment combination is replicated by 4 blocks for a total of 32 plots. Ponderosa pine seedlings for this study were grown under operational greenhouse conditions from February 2021 to October 2021. In October 2021, a total number of 8,152 seedlings were planted at Philmont Scout Ranch, New Mexico (Lat = 36°30.195' N, Long = 105°1.837' W). At the time of planting, each seedling was enclosed with vexar tube for protection against herbivory. Data regarding survival, herbivory damage, growth, and site climatic conditions are currently being analyzed. We expect the results of this study to provide insights on the optimal combination of nucleation size and planting density required to improve survival and performance of planted ponderosa pine seedlings in the southwestern United States.

Riparian vegetation trends in health and water use using the two-band Enhanced Vegetation Index and SSEBop methods in restored and unrestored reaches of the Lower Colorado River in the USA

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ABSTRACT: Active restoration sites have potential to revitalize habitat and increase ecosystem services in the Lower Colorado River riparian corridor. We use Landsat two-band Enhanced Vegetation Index (EVI2; a proxy for greenness) and actual evapotranspiration calculated from EVI2 and potential ET from three AZMET stations near the river (ET(EVI2), $mmyr^{-1}$). We evaluated whether the Bureau of Reclamation's Multi-Species Conservation Plan restoration sites, with only a fraction of the riparian landcover, had an impact on the riparian corridor by measuring two metrics, EVI2 and ET(EVI2). We also used energy balance methods to evaluate the Simplified Surface Energy Balance operational (ET(SSEBop)) in the restored and unrestored riparian sites, as a comparison method for our findings. A key finding is that since 2000, EVI2 decreased, and ET(EVI2) decreased by 22% (286.12 $mmyr^{-1}$); ET(SSEBop) decreased 14% (116.96 $mmyr^{-1}$). In the recent 5-year period (2017-2021), the unrestored reaches decreased 6% in ET(EVI2) (65.30 $mmyr^{-1}$); ET(SSEBop) decreased 11% (80.67 $mmyr^{-1}$). Another key finding is that restoration has a positive effect that we could measure since the initial plantings have matured; over the last 5-year period, restored sites showed a minimal decrease of 2% in ET(EVI2) (26.82 $mmyr^{-1}$) and ET(SSEBop) decreased only 5% (47.64 $mmyr^{-1}$). The unrestored riparian reaches showed losses ranging from 4 to 6% more than the restored sites' losses. Comparing ET(EVI2) and ET(SSEBop) we found a difference of 260.62 $mmyr^{-1}$ over the recent five-year averaged period (996.30 ET(EVI2) versus 735.69 ET(SSEBop)) which may be explained in part by the 100 m thermal band used in SSEBop. Unrestored riparian areas are in decline and restored sites slightly mitigate these decreasing trends in EVI2, ET(EVI2), and ET(SSEBop). Small-area restoration sites do not impact unrestored adjacent riparian areas; however, restoration contributed to increasing greenness and water use despite the overall declining trends.

Adaptation strategies for managing fire in a changing climate

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ABSTRACT: As the changing climate alters fire regimes and ecosystem characteristics, fire managers must juggle existing goals with new mandates to operationalize adaptation. Managers face the tasks of interpreting the best available climate and fire information and determining what feasible adaptation actions to take to avoid undesirable outcomes as they work towards current management objectives. The Climate Change Response Framework (CCRF) Adaptation

Workbook is a vetted tool that has helped hundreds of groups translate climate science into a management context and identify tangible ways to incorporate climate adaptation into project planning. The Adaptation Workbook relies on "menus" of adaptation strategies and approaches tailored to a target audience, which are used to link challenges and adaptation goals to actionable tactics. This presentation will focus on the development a menu of adaptation strategies and approaches specific to climate-fire interactions and their effects on ecosystems, based on codeveloped research from a science-management partnership. The resulting "Fire Menu" is a flexible and useful tool for fire managers who need to connect the dots between fire ecology, climate science, adaptation intent, and management implementation.

Clover's cactus (*Sclerocactus cloverae*) conservation and the benefits of ensemble habitat modeling

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ABSTRACT: The Bureau of Land Management (BLM) manages public lands across the western US for multiple uses, resources, and values ranging from energy development to rare plant conservation. Intensified energy development across the Southwest has increased the need for proactive management to mitigate impacts to rare plant species, including clover's cactus (*Sclerocactus cloverae*). Geospatial information, such as habitat suitability models, can inform BLM decision-making and lead to more effective conservation of rare plants and their habitats. High quality habitat suitability models are currently unavailable for many rare plant species. This reality necessitates the development of new models that combine existing occurrence data, environmental predictors, and specialist knowledge through an iterative process of coproduction to increase model quality and utility for end users. A team of US Geological Survey modelers and BLM rare plant experts developed an ensemble of habitat suitability models, that combines and leverages the strengths of multiple model algorithms, to predict low, medium, and high habitat suitability for *Sclerocactus cloverae*. Developing peer reviewed models using the best available science increases the quality and defensibility of rare plant analyses in Environmental Assessments and Environmental Impact Statements under the National Environmental Policy Act. Involving agency experts and end users in an iterative, coproduced modeling approach strengthens the process and the resulting model, and builds understanding and trust in the final products, promoting effective use to inform subsequent on-the-ground management decisions that may impact rare plant species and their habitats. Overall, habitat suitability models can inform management practices and guide energy development away from critical rare plant habitat, while also facilitating more robust, consistent, and transparent environmental analyses

Ponderosa pine forest patterns following wildfires managed for resource benefit: comparison with reference landscapes

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ABSTRACT: Managers seeking to utilize naturally occurring wildland fires (managed wildfire) to restore southwestern ponderosa pine forests need better evaluations of success at multiple scales to improve future strategies and policy. While the use of managed wildfire as complementary or as an alternative to mechanical treatments continues to see increased interest and use, little research has been done to assess patterns and compare outcomes with reference landscapes. In this study, we quantified landscape patterns of reference landscapes; tested differences in landscape metrics across a range of extents for managed wildfires and reference landscapes and explored ecological implications of observed differences. Our results showed that restored (treated) forests exhibited patterns similar to those of ecologically functional landscapes, patterns resulting from managed wildfire differed significantly from references for nearly all landscape metrics considered and became increasingly different with increased extent. Generally, managed fires exhibited greater canopy cover, larger patch size, lower patch density, and divergent shape complexity as compared with reference landscapes. Proportion of the landscape, mean patch area, and normalized landscape shape index were the most informative metrics for separating managed wildfires and reference landscapes at extents smaller than 240 ha whereas patch area and division index were the most informative for assessing comparisons at larger (up to 840 ha) extents. Our findings indicate that predominately single-entry, low-severity fires managed to improve resource conditions did not effectively reduce tree densities, break up large contiguous areas of canopy cover, or restore patterns typical of ecologically intact and mechanically treated forests. More work is needed to identify wildfire management strategies for meeting restoration objectives at landscape scales.

Effects of hunting pressure on resource selection and movement in the Kaibab Plateau bison herd, Arizona

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ABSTRACT: Predation risk is a known predictor of ungulate habitat selection and movement patterns. Ungulates may reduce the risk of predation by selecting habitat where predation risk is lower (refugia), or by adjusting movement rates, temporal patterns, or selection of cover variables in areas with greater predation risk. A population of plains bison (*Bison bison bison*) currently reside on land managed by Grand Canyon National Park (GRCA) and the adjacent Kaibab National Forest (KNF), collectively referred to as the "Greater Kaibab Plateau ecosystem." The Park provides refuge from year-round bison hunting pressure that is permitted on the KNF. To evaluate bison spatial response to predation risk, we collected 2-hr GPS relocations from 31 bison (*n*= x males; *n*= x females) from 2018-2020. Bison utilize lands along-

and within- the GRCA and KNF boundary in spring, summer, and fall, but not in winter when they move to distant winter range along the Canyon rim. Thus, we censored winter locations from analysis because there was no predation risk from hunting during that time period. We used integrative step selection analysis (iSSA) to test four alternative hypotheses about bison response to predation risk: (1) bison are avoiding spatial areas of high predation risk and selecting areas that provide predation refuge (2) bison are moving faster in areas where they experience high predation risk (3) bison are entering high predation risk areas more frequently at night when predation risk is reduced (4) bison are entering high predation risk areas more frequently in habitats that provide cover (e.g.. coniferous forest) to reduce predation risk. All of the models we used to test these hypotheses contained the core model: NDVI + cos(TurnAngle) + log(StepLength):WaterDist + log(StepLength):TPI (':' signifies an interaction between the two covariates). We compared four models among bison-years and used lowest Akaike Information Criterion (AIC) scores to assess best models. The highest performing model (core model + log(StepLength):Risk(start)) showed highest movement rates when predation risk was high. Bison movement in high predation risk areas was faster than in areas that provided refuge from hunting across all vegetation classes (coniferous forest, shrub or sparse vegetation, quaking aspen, grass-forb meadow) and across all types of topography (valley, slope, ridge). The average step length in areas that provided predation refuge was shorter, compared to interval length in areas where bison experienced high predation risk. This supports the hypothesis that bison may be responding to predation by hunters with higher movement speeds and avoiding special areas where hunting is permitted. Management actions that reduce predation risk during certain periods of the year or within specific spatial areas may affect bison distribution and movement speeds in the Greater Kaibab Plateau ecosystem.

Integrating multiple data sources for species' distribution models to evaluate management effects on focal bird species

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ABSTRACT: Combining multiple sources of information with theory-inspired models and biological applications can increase the temporal and spatial scale of inference to answer conservation and management questions and increase efficiencies in data collection. Data integration methods for species' distribution models (SDMs) combine both structured (i.e., presence-absence surveys) and unstructured (i.e., volunteer-surveys) data. Most applications of data integration for SDMs have focused on conservation questions, with few applications to management. With management applications, focal species are primarily selected based on habitat relationships aligned with desired resource conditions and secondly based on feasibility in monitoring population trends. Insufficient detections with focal species are possible in monitoring programs, especially when species are rarer on the landscape due to limited habitat, low population size, or both. Innovative statistical approaches to integrating such data sources

with SDMs can increase inference with rare focal species. We use a case study to illustrate differences in occupancy precision gain using data integration with SDMs of focal forest bird species that are comparatively rare (Ruby-crowned Kinglet [*Regulus calendula*]) versus common (Grace's Warbler [*Setophaga graciae*]) within a National Forest in the United States. In our application, we consider the temporal and spatial mismatch in sampling effort and observation data when integrating a novel set of data sources from eBird and Integrated Monitoring in Bird Conservation Regions. This approach could inform broad scale long-term monitoring efforts of focal species in response to management actions and illustrates the potential of partnerships with volunteer-based organizations for broad monitoring efforts to increase data collection efficiencies and shared stewardship of public lands.

Ground-based lidar remote sensing of the water storage capacity of tinajas used by desert bighorn sheep at the Cabeza Prieta National Wildlife Refuge

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ABSTRACT: Cabeza Prieta National Wildlife Refuge was established in 1939 for the protection of Desert Bighorn Sheep. The refuge is located at the USA border with Mexico and comprises 1,344 square miles of Sonoran Desert in Pima and Yuma counties, Arizona, including the largest wilderness area managed by the US Fish & Wildlife Service outside of Alaska. There are no naturally occurring perennial bodies of water on the refuge. Surface water is limited to developed water catchments and tinajas, which are holes or depressions in bedrock. The refuge's tinajas are important water sources for Desert Bighorn Sheep yet are relatively small and frequently require hauling of water in truck trailers during dry periods. The refuge must balance the desire to keep the tinajas full to provide water for sheep and other wildlife, while minimizing vehicle travel into designated wilderness. A simple method to monitor the water volume in tinajas did not exist previously but would provide the refuge with a useful tool for deciding when to haul water to refill the tinajas while meeting wilderness stewardship goals. In cooperation with the US Fish and Wildlife Service, the US Geological Survey's Southwest Biological Science Center employed ground-based lidar remote sensing to measure the water storage capacity for three tinajas. We conducted field surveys with lidar and real-time kinematic global positioning systems and analyzed those data to develop a stage-volume relationship between the water surface elevation to water holding capacity for each tinaja. The lidar-derived stage-volume relationships permit the refuge managers to: 1) easily estimate water available for wildlife at any point of time; 2) make management interpretations of tinaja recharge following rainstorms; and 3) make important and potentially expensive management decisions of whether and when to transport water via vehicles to mechanically refill the tinajas in designated wilderness.

Ecohydrologic and geomorphic effects on riparian plant species occurrence and encroachment: remote sensing of 360 km of the Colorado River in Grand Canyon

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ABSTRACT: A common impact on riparian ecosystem function following river regulation is the expansion and encroachment of riparian plant species in the active river channels and floodplain, which reduces flow of water and suspended sediment between the river, riparian area, and upland ecosystems. We characterized riparian plant species occurrence and quantified encroachment within the dam-regulated Colorado River in Grand Canyon, Arizona, USA. We mapped 10 riparian species with high-resolution multispectral imagery and examined effects of river hydrology and geomorphology on the spatial distribution of plant species and open sand. Analysis spanned image time series of 2002-2009 and 2009-2013, periods when plant species and sand were spatially dynamic and operations of Glen Canyon Dam included daily hydro peaking and small episodic controlled flood releases. Plant species occurrence and encroachment rates varied with hydrology, geomorphology, and local species pool. Encroachment was greatest on surfaces frequently inundated by hydro-peaking. Seep willow (*Baccharis* spp.), tamarisk (*Tamarix* spp.) and arrowweed (*Pluchea sericea*) were the primary encroaching woody species. Common reed (*Phragmites australis*) and horsetail (*Equisetum xferrissii*) were the primary encroaching herbaceous species. Encroachment composition from 2002 to 2009 was similar to the entire riparian landscape, whereas encroachment from 2009 to 2013 primarily consisted of seep willow and early colonizing herbaceous species. Emergence of seep willow and arrowweed after burial by sand deposited by controlled floods indicated that those species were resilient to this form of disturbance. Describing patterns of species encroachment is an important step towards designing flow regimes that favor riparian species and ecosystem functions valued by stakeholders.

Risk of erosion of archaeological sites along the Colorado River in Grand Canyon owing to long-term operations of Glen Canyon Dam

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ABSTRACT: Hundreds of archeological sites, including masonry dwellings, seasonal campsites, roasting pits, ferry boat crossings, and river runner camps display evidence of 12,000 years of human activities in Grand Canyon National Park. Many of these sites are located in Colorado River sediment deposits on river terraces and other river channel margin deposits. Many of these archaeological sites have physically deteriorated over time due to both human and non-human factors. Here we describe the effects of Glen Canyon Dam's operation since

completion in 1963 on the physical condition of these archaeological sites. We report the results of two site monitoring systems that describe long-term changes in: 1) the risk of site erosion caused by rainfall-runoff driven processes, relative to 2) the potential for burial of sites by sediment deposition that may help offset erosion and thus protect against physical deterioration. Results suggest that a majority of sites have become more prone to erosion over approximately six decades of dam operations and increasing levels of human visitation. More recently during the time period from 2016 to 2022, approximately 1/3 of all sites either became more vulnerable to erosion by gullies or became less likely to be buried by sediment deposition that might help protect them from erosion. Monitoring of individual sites by archaeologists from the National Park Service corroborates effects of dam operations on archaeological sites, but also illustrates that human visitation contributes to the physical deterioration of sites in the park. Even though sites appear to be sediment starved and eroding, management options exist to improve physical site conditions. These include mitigation projects to excavate and record site information, as well as restoration efforts such as environmental flow releases from the dam and vegetation management, aimed at keeping sites buried in river sediment and thus better protected in-situ from erosion.

Soil moisture response to seasonal drought conditions and post-thinning forest structure

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ABSTRACT: Prolonged drought conditions in semi-arid forests can lead to widespread vegetation stress and mortality. However, the distribution of these effects is not spatially uniform. We measured soil water potential at high spatial and temporal resolution using ~120 sensors distributed across a ponderosa pine forest in northern Arizona, USA during three abnormally dry years with below-average total precipitation. We used the data to assess the effects of fore-summer drought period on the timing, magnitude, and extent of drying throughout the top 100 cm of the soil profile. Additionally, we use high spatial resolution terrestrial lidar measurements of forest structure to develop relationships between soil drying and fine-scale forest structure. We find that increasing drought from 2019 to 2021 caused significantly earlier onset of soil drying at all depths (25, 50, 100 cm) and more days below a critical drying threshold for ponderosa pine. Additionally, we show that significantly drier soils are found in non-thinned areas with higher stand-level basal area, canopy cover and tree density, and shorter trees compared to the thinned areas. Our results with unprecedented spatial and temporal resolution suggest that tailored restoration thinning with specific tree density and size parameters can be used to increase and prolong the availability of deep soil water to trees during drought.

Forest fire, thinning, and flood in wildland-urban interface: UAV and lidar-based estimate of natural disaster impacts

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ABSTRACT: Wildland-urban interface (WUI) areas around the world are increasing where rapidly growing populations and infrastructure are expanding into adjacent forests. The WUIs are facing increased forest fire risks and extreme precipitation events in some regions due to climate change, which can lead to large post-fire flood events in urban areas. At the nexus of these global challenges, the city of Flagstaff in northern Arizona, USA experienced WUI drought, thinning, and forest fire, followed by record rainfall events, which collectively caused large floods and damages to the urban infrastructure. We quantify the combined impacts of these events to inform forest management and infrastructure development in WUIs. Using pre- and post-thinning unmanned aerial vehicle (UAV) multispectral images and photogrammetry, we estimate that the thinning significantly reduced forest canopy cover, patch size, tree density, and mean canopy height resulting in substantially reduced active crown fire risks in the future. However, the thinning equipment ignited a forest fire. Analysis of Sentinel-2 satellite images shows that the fire burned the WUI at varying burn severity with moderate-high severity burns within 3 km of downtown Flagstaff. The burned area then experienced 100-year and 200-500-year rainfall events, which resulted in large runoff-driven floods and sedimentation, the geomorphic effects of which we measured with pre- and post-flood lidar data and UAV photogrammetry. Cities such as Flagstaff need to prepare their WUIs for catastrophic fires and increase capacity to manage sediment-laden stormwater since both fires and extreme weather events are projected to increase in many regions of the world.

Rethinking indicators of dryland resistance and resilience for the 21st century

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ABSTRACT: Climate change is intensifying stressors of dryland ecosystems in the western US including heat, drought, fire, and invasive species. Management and restoration of these ecosystems is challenging because they depend on scarce and variable moisture and on

recruitment that is restricted to infrequent favorable periods. Information on ecological resilience (capacity to recover) and resistance (ability to limit invasive species) can aid in addressing these challenges. Here, we quantified the impacts of projected future climate on resilience and resistance indices (R&R) for the sagebrush region based on two emission scenarios and 20 climate models. We utilized a novel R&R algorithm based on ecologically-relevant predictors. We did not consider future vegetation-fire feedbacks and results may represent low estimates of potential impacts. We found, averaged across 20 climate projections, large areas with lower R&R and some areas of stability. Outcomes at the low end of variation among climate projections included larger areas of stable or even higher R&R, particularly in the eastern parts of the region, and outcomes at the high end of projections included smaller areas of stability and larger areas with lower R&R, particularly across the Intermountain West. Results for late century and under a high emission scenario showed stronger trends but were otherwise analogous to scenarios for mid-century and medium emissions. Whereas temperature and climatic water deficit are among the most important predictors of geographic variability in historical R&R, projected changes in R&R are most closely related to changes in rainfall since changes in temperature are relatively consistent. Changes in resilience were additionally related to historical levels of precipitation in the driest quarter and to duration of dry soil spells; changes in resistance, however, were additionally related to changes in climatic water deficit. Our quantification of projected future R&R may provide long-term perspectives on risk assessments, prioritizations, and management strategies.

Fungal endophyte communities are similar in composition but have different effects on a native and an invasive plant species

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ABSTRACT: Root associated fungi are highly diverse and have important ecological functions, yet most studies focus on mycorrhizal or pathogenic fungi. The more poorly understood root endophytes and a sub class of these fungi, the dark septate endophytes (DSE) are widespread, abundant and appear equally likely to colonize the roots of native and non-native host plants. While DSE can improve plant soil resource uptake, provide defense against pests, and produce plant growth regulators, it is unclear if these fungi differentially affect native and invasive plants and their competitive interactions. We surveyed the root endophyte community of both *Populus fremontii*, and *Tamarix spp.* and assessed how three common DSE influenced *P. fremontii* and *Tamarix* growth, resource allocation and functional trait expression using greenhouse experiments. We found *P. fremontii* hosted twice as many DSE isolates than *Tamarix*, but both species had similar but diverse DSE communities. We isolated a total of 27 fungal root endophyte genera from the trees, with 19 genera found on *P. fremontii* roots and 17 genera on *Tamarix* roots. Inoculation with the DSE *Phialophora* sp., *Phomopsis* sp. and Pleosporales sp. affected the growth and biomass allocation of both *P. fremontii* and *Tamarix* relative to sterile-inoculated controls. In both species, inoculation decreased root biomass. However, DSE increased specific root length and decreased root to leaf surface area in *Tamarix*, while having a stronger effect on the roots of *P. fremontii* and decreasing the root to leaf surface area for all DSE treatments. For aboveground traits, *Tamarix* was not influenced by inoculum, while leaf

mass increased in *P. fremontii*. Results demonstrate that DSE colonize the roots of native and invasive riparian plants similarly. However, the fungi differed in how they affected growth, allocation, and functional trait expression of the two species, which could have implications for their survival, and competitive interactions.

Bison and elk herbivory in Great Sand National Park: natural patchiness or overgrazing?

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ABSTRACT: Plant communities in rangeland ecosystems vary widely in the degree to which they can compensate for losses to herbivores. Ecosystem-level factors have been proposed to affect this compensatory capacity, including timing and intensity of grazing, and availability of soil moisture and nutrients. Arid ecosystems are particularly challenging to predict because of their high degree of temporal variability in moisture inputs. We used a replicated herbivore exclusion experiment to evaluate herbaceous plant responses to grazing by large ungulates to test current theory and identify constraints on plant compensation in a dryland ecosystem. We measured nitrogen (N) yield and herbaceous production in three plant communities: meadows, willow-associated herbaceous communities, and riparian communities. We implemented grazing exclusion treatments from 2005 to 2008 in areas with elk+bison and areas with only elk. Grazing by large ungulates increased herbaceous production and N yield in herbaceous riparian communities. In willow communities, herbaceous plants displayed equal compensation in response to grazing in total aboveground production and N yield. Our results support the idea that plant compensation in this semi-arid system is contingent on soil moisture availability, wherein the most productive sites (that received substantial moisture inputs from subsurface flow) exhibited overcompensation. Although the herbaceous riparian communities we studied are isolated patches of productive grassland in an otherwise shrub-dominated and minimally productive semi-arid landscape, grazing by a combination of bison and elk removed only 44-53% of ANPP during the growing season, and 25–38% of production overwinter. Consumption by ungulates was a positive linear function of herbaceous production, similar to reported patterns from other temperate and tropical grazing ecosystems. The slope of this relationship was lower or similar to reported slopes for other intensively grazed systems (Yellowstone, Serengeti, Laikipia) that have sustained high ungulate densities for decades to centuries. Given that the vegetation communities exhibited equal or overcompensation in terms of total herbaceous ANPP in both years, elk and bison population levels during our study period did not appear to occur at densities leading to degradation of herbaceous communities.

How ecosystem water and carbon fluxes across southern Arizona are responding to the drier and more extreme climate of the 21st century

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ABSTRACT: The climate is getting drier and hotter throughout many of Earth's dryland regions. With these changes, dryland ecosystems are experiencing more extreme climatic conditions, and over the last two to three decades, we have seen long-term drought conditions as well as a greater frequency of weather extremes here in the Southwest. However, we lack understanding of how these climate shifts impact carbon sink functioning in semiarid ecosystems that play a globally important role in modulating the trend and variability of the terrestrial carbon sink. In this presentation, I will show what long-term measurements of land-atmosphere carbon and water fluxes reveal, in never-before seen detail, about semiarid ecosystem responses to, possibly, this new climate regime of the Southwest. First, we will look at an ecosystem's precipitation pivot point, defined as the amount of precipitation where the annual net carbon uptake pivots between positive carbon gain and loss, to see how the drier-than-average 21st century has affected southern Arizona flux sites' carbon sink behavior. Second, we will examine the ecosystem functional response to weather extremes at shorter time scales by looking at the flux sites' responses to the 2020/2021 weather whiplash, where one of the driest years on record was followed by one of the wettest. Lastly, we will mine the long-term flux data records to understand how extremes in atmospheric and soil moisture dryness affect the precipitation pulse flux response. Understanding ecosystem functional response to climate forcing at multiple time scales is critical for the improvement of earth-monitoring satellite algorithms and land surface models needed for improved land management.

Population dynamics of bison inhabiting the edge of historic range

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ABSTRACT: Little is known about the ecology and habitat interactions of bison in semi-arid ecosystems. Population dynamics of bison on the edge of their historic range are not well studied and quantitative data are scarce. We used Bayesian state-space modeling to estimate population demographics of bison in a cold desert ecosystem in southern Colorado USA, within the Great Sand Dunes National Park ecosystem. We applied data collected from 1997 to 2021 to estimate age specific survival rates and population growth and evaluated climate variables for their effect on bison survival. Survival rates of all age/sex classes during study years were ≥75%. The highest survival was in adult females and the lowest in yearling females. Results of survival probabilities for calves, adult females, and males will be presented, along with calf sex ratio at birth and calf recruitment rates. Demographic parameters of bison inhabiting semi-arid ecosystems can contribute to management and conservation of these unique populations.

Zuni cultural importance of bison

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ABSTRACT: I will talk about the spiritual importance of bison to the Zuni. Our ancestors traveled to the eastern plains to hunt bison. They provided sustenance and also spiritual strength to our people.

Maintaining Zuni ties to the Grand Canyon

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ABSTRACT: The Zuni Cultural Resources Advisory Team conducts annual river trips on the Colorado River through Grand Canyon to monitor places of traditional cultural importance associated with the Zuni emergence and subsequent migrations that are part of Zuni traditional history. These places require protection and spiritual attendance by Zuni religious leaders. The cultural, biological, and physical resources located in the Grand Canyon are held most sacred by the Zuni as they are associated with the Zuni emergence, migrations, and enduring ceremonies. These monitoring trips are accommodated by the Bureau of Reclamation and result in cultural renewal and continuity for the Zuni people, relationship building with federal agencies, and Zuni input for management of these important ancestral places.

LiDAR and PlanetScope metrics for predicting forest inventory parameters in Texas and Oklahoma songbird habitat

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ABSTRACT: National Wildlife Refuges (NWR) in Texas and Oklahoma manage forested habitats to support priority bird populations in the West Gulf Coastal Plain and Ouachitas Bird Conservation Regions. Airborne laser altimetry or light detection and ranging (LiDAR) captures detail on forest vertical and horizonal structure helpful for determining bird species diversity, density, and distributions. PlanetScope (PS) multispectral imagery with channels in the blue (455–515 nanometers), green (500–590 nanometers), red (590–670 nanometers), and near infrared (780–860 nanometers) wavelengths provide a high spatial resolution (4 m) and frequently acquired (daily) data source that can add tree composition information when fused with LiDAR. Forest management on refuges relies on continuous forest inventory (CFI) plots and songbird point counts to monitor habitat conditions and species abundance. As an initial step, we developed machine learning ensemble models for estimating basal area, quadratic mean diameter, cubic foot volume, and tree density by combining CFI plots (n = 65) with LiDAR voxel and PS phenology metrics. We found that individually tuned regression tree models

outperformed ensembles developed from moderately tuned 'base learners', showing improved cross validation model fit (R^2) and lower root mean squared error. Variable importance measures showed that time series phenology metrics such as seasonal amplitude of the modified triangular vegetation index (MTVI2) improved inventory models distinguishing between broadleaf and conifer species (e.g., broadleaf vs. conifer basal area). Future work will use these and other metrics to estimate songbird habitat relationships and density. Project outputs will range from standardized data collection protocols to mapped forest inventory parameters, bird density estimates, and information on habitat preferences. Remote sensing applications and songbird models will help inform forest management actions developed to maintain diverse habitat conditions and songbird populations.

The 2022 Antelope Fire, fuels management, suppression repair, and lessons learned for cultural resource management at Wupatki National Monument

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ABSTRACT: The human-caused Antelope Fire was detected at 13:09 on Monday, May 2nd, along the east side of Highway 89 northeast of Flagstaff, Arizona. The fire was primarily driven by winds and fine fuels, burning 372 acres in grassland with interspersed juniper before being suppressed by Coconino National Forest wildland fire personnel. This poster summarizes lessons learned during Burned Area Emergency Response (BAER) assessments of archaeological sites within the fire perimeter at Wupatki National Monument, including optimal fuels management strategies for reducing adverse impacts to sites in consideration of historical fire regimes. Lessons learned from suppression repair activities in the unique volcanic soils characterizing Wupatki are also discussed. These insights can be employed to increase park readiness and BAER response strategies during future wildland fire incidents.

A model for tribal collaboration and information sharing during baseline archaeological and biological survey

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ABSTRACT: Tribes in Arizona and New Mexico see a need to have tribal members participate in the thousands of federal and state-mandated cultural resource and biological baseline surveys that occur each year throughout their traditional land base. Tribal cultural preservation offices are unable to check each proposed project for areas of tribal concern, and the purpose of the tribal cultural consultant or "monitor" is to serve as the eyes and ears of the community. By sharing information directly from the field, the monitor facilitates early involvement of tribal stakeholders in land management planning and decisions. The Tonto National Forest Tribal Monitor Program was established in 2018 to increase tribal participation in the cultural resource and biological baseline studies for the proposed Resolution Copper Project near Superior,

Arizona. The Gila River Indian Community, White Mountain Apache Tribe, Yavapai-Apache Nation, Hopi Tribe, Pueblo of Zuni, Ak-Chin Indian Community, and Mescalero Apache Tribe sent dozens of tribal members to be part of the program and two-week training by the Forest Service. The monitors work with archaeologists on cultural resource surveys, including surveys for culturally sensitive areas such as shrines, trails, and springs. The tribal monitors can also identify plants that are important to the tribes and are also skilled at conveying the value of the projects they work on to their communities, presenting their findings at tribal council meetings and community gatherings. WestLand's tribal monitor group manager and department director will discuss their experiences and successes employing tribal members in the environmental consulting industry.

Increasing mortality and declining recruitment driven by warm, dry conditions leads to decline of western US woodlands

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ABSTRACT: Piñon-juniper woodlands inhabit areas with climatic conditions near the physiological limits for trees and may be especially vulnerable to climate change. Despite evidence of increasing mortality in response to drought and warming temperatures, overall population trends of piñon-juniper woodlands are largely unknown because we lack comparable tree recruitment data at range-wide scales. We fit range-wide demographic models for five widespread piñon and juniper species using forest inventory and analysis from western US and estimated current population trends, climate vulnerability, and the relative role of both morality and recruitment in driving population trends using integral projection models. We estimate that four of the five piñon-juniper species are declining in parts of their range. Population vulnerability increases with aridity and temperature, with up to ~50% of populations in forest inventory sites declining in the warmest and driest conditions. Mortality and recruitment were both essential to explaining where populations are declining, with few populations declining with elevated mortality alone. Our results suggest that increasing temperatures and ongoing drought may threaten the long-term viability of many dry forest populations in their current range, and that understanding patterns and drivers of tree recruitment will be essential to anticipating climate driven range contractions. These models also provide an approach to anticipate coming shifts in forest distributions based on underlying demography.

Understory herbaceous and shrub species richness and abundance variation among burn severities in warm-dry mixed conifer in the 416 Fire, southwestern Colorado

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ABSTRACT: Wildfires can alter the composition and productivity of understory species communities, which play a major role in overall forest diversity. Factors that determine species composition and productivity include disturbance, physical factors (soils, microclimate), biological processes (dispersal, competitive exclusion), and site history (anthropogenic impacts, successional age). Warm-dry mixed conifer forests of the Southwest, prior to Euro-American settlement in the 20th century, experienced frequent, low intensity surface fires with infrequent mixed severity fire. In 2018, the 416 Fire occurred, which was an unplanned wildfire that burned 54,130 acres of warm-dry mixed conifer under varying burn severities. We randomly selected 10 points from each severity level (no burn, low, moderate, and high) using ArcGIS to quantify forest understory dynamics during the summer of 2022 (N=40). The main purpose of our research was: (1) quantify 4-years post-fire effects on herbaceous and shrub species richness, diversity, abundance and community dynamics among four burn severities; and (2) quantify burn severity on understory forest floor substrate groups (bare soil, litter/duff, and wood). We hypothesize that understory species richness and productivity will be highest in moderate burn severity based on disturbance hypotheses that suggest intermediate disturbance results in the highest diversity and productivity. Resource management and conservation practices are challenging in mixed woody-herbaceous systems where the ratio of woody to herbaceous plants is dynamic and can change in response to fire, herbivory, and climate. This study will contribute to foundational knowledge of how post-fire understory community dynamics vary among different burn severities in warm-dry mixed conifer and to identify where post-fire restoration efforts may be needed.

Identifying barriers to and opportunities for adopting biochar production to reduce fire risk and improve soil health in northern New Mexico

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ABSTRACT: Many land managers in the Intermountain West thin woody biomass to reduce wildfire risk and increase productivity. The resulting slash can be pyrolyzed in low-oxygen conditions, converting it into biochar. This biochar can serve as a soil amendment, improving soil health and productivity. In this study, we investigated the socioecological barriers to biochar adoption among land managers in the Sangre de Cristo region of northern New Mexico. We distributed surveys to land managers throughout northern New Mexico, particularly targeting community agricultural, grazing, and forestry organizations, such as extension offices, conservation districts, natural resource departments, and community wildfire planning committees. We found that 69% of the respondents (n=51) were familiar with biochar, and 16% were already producing biochar on small scales. Participants identified the most important benefits of biochar being improving soil water and nutrient holding capacity, increasing

productivity, fuel load reduction, and carbon sequestration. The most prevalent barriers for adopting biochar production and/or use were a lack of knowledge about biochar production and how to apply it, as well as a lack of access to equipment. Given land manager preferences, outreach efforts to encourage biochar adoption should focus on delivering information via demonstrations, field days, and workshops. None of the results were influenced by participants' demographic information. The findings of this research could be key information for programs oriented to promote biochar adoption in northern New Mexico and the broader Intermountain West.

Evaluating ecocultural impacts of climate change in the Southwest

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ABSTRACT: Climate change drives broadscale changes in abundance and distribution of species. In the southwestern US and elsewhere, Indigenous communities often use local plants and animals in cultural activities, including the preparation traditional foods, arts, crafts, clothing, and structures. Given cultural connections to natural resources, Indigenous communities will be disproportionately impacted by climate change, as spatial distributions of species shift, while geopolitical boundaries of Native American reservations remain fixed. We built upon a priority species conservation list developed by Arizona and New Mexico tribes participating in the Tribal Nations Botanical Research Collaborative (TNBRC) to evaluate regional ecocultural consequences of climate change. We used Forest Inventory and Analysis (FIA) and Global Biodiversity Information Facility (GBIF) data to parameterize ensemble Species Distribution Models (SDMs) to forecast changes in spatial distribution of several plant species used by Arizona tribes, including Emory oak (*Quercus emoryi* Torr.) and Pinyon (*Pinus edulis* Engelm.). Using these models, we evaluated how climate change affects distances to these resources for particular Indigenous communities and identified biocultural refugia. Resultant models support implementation of restoration and conservation projects taking place across public and tribal lands in the Southwest, while spotlighting the need to protect biocultural resources, the loss of which represents a significant ecological and cultural loss.

Reduced forest vulnerability due to management on the Hualapai Nation

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ABSTRACT: Tribal nations in the US have worked to uphold their long history of managing forests in ways that reduce fuels, support ecosystem functioning, and enhance Indigenous livelihoods. Forests on the Hualapai Nation have been actively managed for decades using fire and other treatments. We collected data on tree size and age structure, forest understory

characteristics, and surface fuels to explore how the legacy of forest management, historical surface fire, and recent prescribed fire, have influenced the contemporary structure of the ponderosa pine-Gambel oak forest on the Hualapai tribal lands (hereafter Hualapai forest). Current overstory tree density (range: 361.1 to 1664.0 trees ha^{-1}) and basal area (16.0 to 29.8 m^2 ha^{-1}) place the Hualapai forest in an intermediate state among more open vs. denser southwestern forests, but additional characteristics set the Hualapai forest apart from others in the region. In particular, diameter distributions of live ponderosa pine in the Hualapai forest are dominated by mid-diameter trees (trees ~18-33 cm dbh), while diameter distributions of live ponderosa pine on forest lands across Arizona indicate a higher number of small-diameter trees (trees <23 cm dbh) and a lower number of large-diameter trees. This finding of a relatively lower number of small-diameter trees, which serve as ladder fuels, in the Hualapai forest may indicate better protection against severe wildfire, although some individual sites might be at greater risk. Beyond fire risk, the Hualapai forest is lacking in large live trees and snags that support cultural needs and sustain its ecological functioning, but current management approaches are helping address this shortcoming. Continued management informed by Indigenous perspectives can best position the Hualapai forest to sustain its structure and function as climate warms as well as achieve socio-cultural and ecological outcomes most important to the people of the Hualapai Tribe.

Potential use of zero valent iron to reduce toxicity in uranium mine detention pond water

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ABSTRACT: Uranium deposits of relatively high grade are mined from breccia pipe formations in the Grand Canyon region in northern Arizona, USA. The mining site includes a containment pond that holds water pumped from the mine shaft and surface runoff from the mine site. Water in the containment ponds has elevated levels of arsenic, copper, cobalt, molybdenum, nickel, selenium, and uranium. As surface water is uncommon in the desert landscape, containment pond water could be an attractive nuisance to wildlife. In a two-phased study, we examined the toxicity and potential treatability of waters from the containment ponds. Toxicity of containment pond water was examined using the cladoceran, *Ceriodaphnia dubia.* Toxicity results were analyzed using an additive mixture model derived from laboratory toxicity studies for individual metals. These studies found nickel to be a primary driver of toxicity in the mixture. In the second phase, the treatability of the water using zero valent iron (ZVI) or biochar was examined. ZVI is used in diverse settings to remove metals from contaminated waters through a combination of redox and sorption. A synthetic water mixture, similar to that in the containment ponds, was created in the laboratory for the experiments. Water was pumped through treatment cells packed with zero-valent-iron (ZVI) and biochar in separate experiments to quantify the degree of removal for uranium and other trace metals. The ZVI effectively removed most metals present, including uranium and nickel, with a greater capacity for removal than biochar. Additional, coupled studies are underway to assess and understand how ZVI treatment affects overall toxicity and bioaccumulation related to the metal mixtures in containment pond waters. Untreated and treated waters will be assessed for changes in metal and anion concentrations and

sequential toxicity testing will use the same waters. The results will help better identify which elements are driving toxicity in the mixture and how treatment influences the overall toxicity response.

Balancing ecosystem resiliency with Pinyon Jay habitat needs on the Kaibab National Forest

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ABSTRACT: The Pinyon Jay is an obligate bird of piñon-juniper and other pine-juniper woodlands. It has been identified as a Species of Greater Conservation Need under the State Wildlife Action Plan for Arizona and may be particularly vulnerable to climate change and other stressors. The current range of Pinyon Jay is predicted to contract 25-31%, 2010-2099. The Range wide Conservation Strategy for the Pinyon Jay a joint product by the Partners in Flight Western Working Group and US Fish and Wildlife Service (as part of the Working Group) recommends several priority actions including the development of a standardized survey protocol across the species range, assessing response to vegetation management treatments, and addressing occupancy and pinyon nut availability and nest colony locations. The Kaibab National Forest is collaborating with partners to collect critical information to begin to address some of these recommendations. Through this project we are refining a data collection protocol suitable for use in Pinyon Jay surveys by other partners and the Pinyon Jay Working Group, a large collaborative across the intermountain west. Breeding bird monitoring is one way to assess effectiveness of vegetation treatments and changed conditions on the ground. Data collected through this project is integral to begin assessing whether restoration actions on the Kaibab National Forest are having the intended effects and provides information to course-correct through the adaptive management process, contributing to the overall regional priority of Restoration. In this presentation we will describe our survey approach and preliminary results which includes bird occupancy data. We will also present information on pinyon nut surveys, a critical food resource for Pinyon Jay and important for some Native American Tribes. Finally, we will provide an overview on next steps and how we are working with our partners to harness the power of community science through eBird observations.

Common reed (*Phragmites australis americanus*) ecology and responses to flow regulation along the Colorado River in Grand Canyon, Arizona, USA

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ABSTRACT: The culturally and ecologically important wetland plant, *Phragmites australis* (common reed) supports unique riparian communities and has dramatically altered wetlands across North America. Here we describe the distribution, ecology, cultural significance, and

responses to changing flow regimes and climate of P. australis, described as native P. a. ssp. americanus (PAA) in the Colorado River ecosystem between Glen Canyon Dam (GCD) and Lake Mead, Arizona. PAA naturally co-occurs at low elevation springs in Grand Canyon, with PAA dominance increasing during drier climate phases. Historic photographs and field observations document increased PAA stand density of more than two orders of magnitude since completion of GCD in 1963, with marked changes accompanying major changes in discharge management including: slow advances during broad hydropeaking from 1964-1982; scour and burial during 1983-1987 high flows; slow re-advances during resumption of hydropeaking from 1988-1991; and continuing increases following reduced flow variability after 1991. PAA increases over time contribute to increased sediment aggradation and stabilization, acting similarly to tall, stiff shrubs. Dense stands are forming in low-gradient reaches, a process that limits the effectiveness of sandbar rejuvenation. High stem-density, relatively high stem strength, clonal growth form, adaptive inundation and drought tolerance, seed longevity, and autumn seed release all contribute to the success of PAA in the post-dam river corridor. PAA plays an increasingly important role in this regulated river ecosystem by supporting honeydew producing aphids that sustain dozens of autumn pollinator species as other nectar sources disappear and by providing breeding habitat for Common Yellowthroat (*Geothlypis trichas*) and other Neotropical migrant birds. Additionally, PAA figures prominently as an important ethnobotanical species for many Native American cultures in the region. Given its increasing presence and cover, an assessment of the roles of native and nonnative genotypes in contrast with dam operations in this study area is warranted.

Land of Enhancement: stories from New Mexico's forest treatments for changing climates

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ABSTRACT: A few years ago, the New Mexico Forestry Division gathered ideas from diverse stakeholders, hundreds of layers of spatial data, state of the art thinking on climate change, some innovative modeling, and lots and lots of staff hours to develop the New Mexico Forest Action Plan. The plan identified the need to greatly escalate the pace and scale of forest restoration, including prescribed burning and reforestation in addition to re-imaging how to get ten times more acres thinned each year. In what has been a few years of superlatives, the Division's challenges and capacities have greatly escalated, including experiencing the most devastating fire season in the history of northern New Mexico. As special budget increases, directives, and opportunities escalate, New Mexico's planning is paying off. Mary Stuever, Chama District Forester, will share tales from field that illustrate the challenges, successes, and efforts to effectively steward forests into a specifically unknown, but surely stressful future.

Navigating post-fire response on non-federal, non-Tribal lands

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ABSTRACT: The absence of a federal, state, or local government with full authority to respond to all the post-fire needs caused by flooding and debris flows does not mean an absence of activity. Rather, there is a wealth of programs and services provided by many agencies and organizations, and the challenge is to bring these disparate threads together to weave practical response strategies. This presentation will review multiple approaches to this issue as informed by experience and lessons learned in New Mexico.

Undisturbed? Effects on shifting climate on pinyon-juniper woodlands in protected places.

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ABSTRACT: National Park Units are often considered to be “undisturbed” ecosystems. Many of these areas are protected from disturbance, domestic livestock grazing and other stressors. However, anthropogenic climate change is stretching the definition of undisturbed and compromising the National Park Service’s ability to preserve natural resources unimpaired. Pinyon juniper woodlands are an increasingly imperiled vegetation type across the Colorado Plateau, threatened by drought, rising temperatures, high-intensity fire and insect damage. Large-scale mortality events of pinyon (*Pinus edulis*) and juniper (*Juniperus* spp.) have become more common. The Southern Colorado Plateau Network of the National Park Service Inventory and Monitoring Division has been collecting data in five pinyon juniper ecosystems across four national park units since 2007. Between 2007-2021, pinyon juniper ecosystems monitored by SCPN received average to significantly less than average precipitation 14 out of 15 years (except for Bandelier National Monument which experienced wetter than average conditions 2013-2019). During this period, overstory tree density has remained stable with little mortality. Cover and species richness of shrubs and herbs responded to changing seasonal precipitation, but we have not detected large, directional change. Non-native species were generally infrequent. The climate in Southern Colorado Plateau Network parks over the next few decades is predicted to bring higher temperatures, less spring precipitation and an unstable monsoon. Higher temperatures, even with stable or increasing precipitation, will result in less water available to plants. As a result, areas that were previously considered “undisturbed” are likely to undergo rapid, irreversible ecological change despite their apparent resilience. Increasing risk of widespread mortality events is driving managers to take a more active role managing extensive NPS lands. Difficult choices to resist, adapt or direct change are most successful when supported by robust datasets like those provided by the NPS Inventory and Monitoring Division.

Sclerocactus mesae-verdae (Mesa Verde cactus) status update for the Navajo Nation

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ABSTRACT: *Sclerocactus mesae-verdae* (Boissev. & C. Davidson) L.D. Benson (Mesa Verde cactus; Cactaceae) is a federally threatened and G2 (threatened) species on the Navajo Endangered Species List that is endemic to San Juan County, New Mexico and Montezuma County, Colorado. These cacti occupy land managed by BLM, Navajo Nation tribal trust, New Mexico state trust, private entities, and Ute Mountain Ute, with most individuals occurring on the Navajo Nation. In response to observations suggesting significant species decline, an extensive survey was completed in 2004 to document *S. mesae-verdae* abundance across suitable and occupied habitat on the Navajo Nation. In 2022, we resurveyed all sites where *S. mesae-verdae* cacti were documented during the 2004 survey. When *S. mesae-verdae* cacti were observed, we tallied stems by size and health classes, and reproductive status with the objective of comparing our results to those from 2004. We also used this data to assess how effective four conservation areas established in 2008 have been at protecting this species. Finally, we recorded submeter geospatial data for a subset of all documented stems and collected detailed habitat data, including dominant plant associates, aspect, elevation, soil type, slope, and topographical position. This data can be used for ongoing population monitoring and to inform future species distribution models for this threatened cactus.

Climate Science Alliance tribal working group: a model for advancing tribal and non-tribal collaboration

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ABSTRACT: On-going climatic changes in southern California pose significant challenges for the region's natural and human communities. These changes threaten the health of people, places, and natural resources with synergistic impacts to culture and tradition. For the 18 federally recognized Tribes in San Diego County, these unfolding impacts necessitated the need for a united approach to safeguarding Tribal communities from climate impacts, and as such the Tribal Workgroup was created. The Climate Science Alliance's Tribal Working Group (TWG) was established in 2017 through a partnership of Southwestern Tribes and has since grown to include over 30 members and 18 Tribes working collaboratively to test climate-smart strategies that will ensure Tribal resilience for generations to come. Through the use of education, environmental programs, traditional ecological knowledge, and a focus on community priorities, local ecosystems, and holistic management, the Tribal Workgroup collaborates to safeguard the lands and cultures of southern California's Indian Tribes from the threat of climate change. The Tribal Working Group serves as a model of collaboration, innovation, and diverse partnerships that is increasingly necessary to continue and expand moving forward. The proposed presentation will share the story of the TWG with case studies of collaborative projects, partnerships, and the

value of this model for advancing the resilience of our region's communities now and into the future.

Geomorphic change detection on the Upper Verde River using historical transects and terrestrial lidar

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ABSTRACT: Rivers in the Southwestern United States are a critically important resource. Not only do they provide water for human beings, but they also provide habitat for both plant and animal species. Terrestrial laser scanning (TLS) uses light detection and ranging (lidar) to provide detailed and accurate data for studying fluvial geomorphology. It is also useful for studying changes in river systems at a wide range of spatial scales. Quantifying geomorphic changes on the Upper Verde River between Paulden, Arizona and Sycamore Canyon is significant because of its value to migratory birds, native fish, rare reptile species, and native plant species. Between 1997 and 2000 the United States Forest Service (USFS) installed permanent geomorphology transects at many sites along the Upper Verde River for the purpose of estimating trends in the river. Topographic and vegetation data were collected repeatedly along these transects between 2000 and 2021 using traditional, line transect-based measurements. We re-visited and imaged 20 of these transects with a TLS. Comparing the TLS data to the USFS topographic data from 2000- 2021 will result in geomorphic change detection estimates at the 20 sites along the Upper Verde River to provide information about how the system is changing. The objectives of this research are to: (a) estimate geomorphic changes at the 20 historic monitoring sites, and (b) create a more objective baseline dataset for future monitoring. This information is impactful because the Bureau of Reclamation (BOR) will use it as new baseline dataset to both understand how the river has changed over the last 20 years and inform future management decisions about the feasibility of installing fish barriers to protect both the native fish habitat and the river itself as important natural resources.

Thinning increases forest resilience during unprecedented drought

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ABSTRACT: Regional droughts are now widespread and are projected to further increase. Semi-arid ponderosa pine forests across the western USA, which occupy > 56 million ha, are experiencing unprecedented levels of drought due to the currently ongoing North American megadrought. Using unpiloted aerial vehicle thermal images and ground-based hyperspectral data, we show that ponderosa pine forest canopy temperatures increased during the 2021 summer drought up to 34.6 °C, well above typical canopy temperatures thresholds where ponderosa pine trees no longer uptake carbon. We infer that much of western US ponderosa pine forests likely served as a net carbon source rather than a sink during the 2021 summer drought period. We also

demonstrate that regional forest restoration thinning significantly reduced the drought impacts. Thinned ponderosa pine forests had significantly lower increase in canopy temperature and canopy water stress during the drought period compared to the non-thinned forest stands. Furthermore, our extensive soil moisture network data indicate that available soil moisture in the thinned forest was significantly greater at all soil depths of 25 cm, 50 cm, and 100 cm compared to the non-thinned forest, where soil moisture dry-down in the spring started significantly earlier and stayed dry for one month longer, causing critical water stress for trees. Forest restoration thinning benefits that are otherwise unappreciated during average precipitation years are significantly amplified during unprecedented drought periods.

Health impacts of wildfire smoke and mitigation efforts in the Hoopa Valley Tribe reservation

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ABSTRACT: Air quality has been dramatically affected by the frequency and magnitude of wildfires throughout the United States. Wildfires emit hazardous fine particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) and other gaseous compounds that pose risks to developing respiratory and cardiovascular illnesses. In the Hoopa Valley of Northern California, annual air quality between August and October is affected by wildland fire smoke and to a lower extent, prescribed fires, burn piles, smoke from wood-burning stoves, highway traffic, and sand and gravel operations. The valley's atmospheric inversion traps smoke, decreasing the air quality between October and May. There are about 4,000 Hoopa Valley Tribe (HVT) residents who live on the reservation and the many relatives who come for the ceremonies between June and October coincide with months of poor air quality, which may increase their risk of illness. Most inhabitants live in the 3,500-acre valley floor and adjacent bench lands of the Trinity River. The reservation is 96,000 acres, dominated by mixed conifer and hardwood forests. Since January 2020, the Hoopa Tribal Environmental Protection Agency (TEPA) continues to evaluate the air quality using field monitors and Purple Air sensors. TEPA is also spearheading education outreach, participation, and collaboration. TEPA has partnered with the HVT Office of Emergency Services and the local radio station KIDE to inform the community about mitigation measures. The objective of this research will inform the development of a tribal air pollution control program to monitor and report ambient air quality, community outreach efforts through print, social media and radio broadcasts, and education programs to increase awareness of air pollution-related health impacts and mitigation measures to reduce smoke exposures.

Introduction—bison history and herds in the SW and CO Plateau

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ABSTRACT: Bison are one of the great success stories of conservation, having recovered from near extinction in the late 1800's. And yet in some ways they have been left behind as they were not restored to the landscape the way many species were after the era of colonial expansion and market hunting. Bison have always been of cultural, spiritual, and nourishment importance to many of the Native American Tribes and in 2016 bison were designated the US national mammal. This is a brief introduction to bison in the SouthWest and on the Colorado Plateau and the reason for this symposium.

Grand Canyon National Park bison herd reduction

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ABSTRACT: In 2014, the NPS initiated a science-based planning process to manage bison overpopulation at Grand Canyon National Park. In 2017, using the best science available and working closely with the public and American Indian tribes, the park finalized the Initial Bison Herd Reduction Plan Environmental Assessment (EA) to reduce the herd from 600 to fewer than 200 bison using live capture and transfer, as well as limited lethal removal. The NPS has been collaborating closely on these efforst with partners at the InterTribal Buffalo Council, Arizona Game and Fish Department, USGS-Fort Collins Science Center, US Forest Service, and the NPS Office of Public Health. Since reduction efforts began in 2019, park staff have removed 138 bison from the North Rim with 124 transferred to six different American Indian tribes through partnership with the InterTribal Buffalo Council. The state of Arizona concurrently removed 154 bison through authorized hunts outside of the park. In total 292 bison have been removed over the last three years.

Southwest partnerships for understanding and exchanging knowledge on fire and climate change

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ABSTRACT: Fires in southwest woodlands and forests have been getting larger and more severe over the last three to four decades and this increase can be linked to land management practices and changes in climate. The wildland fire world and the climate science world don't always know each other, much less work together or share science. Here we describe two efforts to connect fire-climate information and networks. The Southwest FIreCLIME project was a multi-year research partnership between scientists and resource managers to synthesize current knowledge of regional climate-fire-ecosystem dynamics. This included the creation of a web

searchable fire-climate annotated bibliography, modeling of fire and fuel management scenarios with future climates, development of a vulnerability assessment and finally development of a Fire Climate Adaption Menu. The Southwest Fire Science Consortium works to get emerging science on the ground by connecting land managers, scientists and the public. In 2019, the SWFSC and the Southwest Climate Adaptation Science Center (SW CASC) partnered to create the Southwest Fire and Climate Adaptation Partnership, or SWFireCAP. A brief overview of these resources and partnerships will be given along with ideas for new collaborative work.

Succulents in the Southwest: the overview

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ABSTRACT: Succulents – plants with fleshy leaves, stems or roots that conserve water – are an important component of Southwest ecosystems. Succulents are species within the Agavaceae (alternately Asperagaceae), Cactaceae, and Crassulaceae. They are subject to the modern-day stressors of all Southwest biota– competition from invasive non-native species, habitat degradation through conflicting land uses, fire, and drought and rising temperatures –as well as unique threats from illegal harvesting and limitations to pollination. Many succulents are slow growing; it may take years for a plant to reach reproductive age and then the frequency of germination and rate of establishment may be low. These characteristics make succulents overall a vulnerable group of plants. While some succulents are Southwest icons and common such as saguaro cactus and Joshua tree, many others are rare and hard to survey and monitor as they occur in hard to access remote areas. Succulent richness is high in the Southwest. For example, Arizona has the second highest cactus richness of all states, with 93 species (excluding taxonomic subgroups); the state also supports 26 species of Agavaceae and 13 of Crassulaceae. The vulnerability of succulents has already resulted in endangered or threatened listings under the Endangered Species Act. Thirty-one cacti species are listed nationally. Eight of these listed cacti are in Arizona and of these five are endemic. No Agavaceae species are currently listed in the Southwest; however, the US Fish and Wildlife service is reconsidering listing the western and eastern Joshua tree. Bartram's stonecrop is the only Crassulaceae listed in Arizona. In this session we consider the challenges, research, and conservation efforts for this group of unique plants that face unprecedented threats.

From data to information: exploring uranium concentrations in groundwater in the Grand Canyon region through an online interactive map

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ABSTRACT: The Grand Canyon region in northern Arizona is a home or sacred place of origin for many Native Americans and is visited by more than 6 million tourists each year. Most communities in the area depend entirely upon groundwater for all water uses. Some of the highest-grade uranium ore in the United States also is found in the Grand Canyon region. The US Geological Survey (USGS) has collected water-quality data in the region for many years as

part of numerous investigations. Most recently, extensive groundwater sampling by USGS and National Park Service personnel is being conducted to better understand the current state of groundwater quality, to monitor for changes in groundwater quality that may be the result of mining activities, and to identify "hot spots" with elevated metal concentrations and investigate the causes. While water-quality data from all USGS sampling activities are in publicly accessible databases, these formats do not allow easy answers to question such as: What are metal concentrations in water near where I live? What are average concentrations throughout the region and how does a particular spring or well compare? What springs or wells have higher than normal concentrations? Are these near uranium mines or deposits? The USGS Uranium in Groundwater in the Grand Canyon Region interactive map was developed to provide usable, accessible information to answer questions such as these for groundwater uranium concentrations. Uranium concentrations through 2021 from 583 groundwater samples from 206 locations are presented on the online map. Sites are color-coded by maximum uranium concentration observed, allowing a quick overview of concentrations in the area. Additional information can be obtained by selecting individual sites or adding additional layers. Uranium concentrations from ongoing sampling will be updated on the map on an annual basis and additional metal results will be added in coming years.

The Havasupai perspective of uranium mining in Grand Canyon Watershed: a conceptual risk model

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ABSTRACT: Indigenous Havasupai knowledge and western science represent different yet equally important ways of knowing. Yet, much of the quantitative western science fails to consider the role of indigenous Havasupai knowledge. For example, classic human health and ecological risk assessment approaches do not include traditional or ceremonial collection or uses of resources that represent different exposure and risk scenarios to Tribes in Northern Arizona. For this presentation, we will describe a conceptual risk model for uranium mining in the Grand Canyon watershed from the perspective of the Havasuw baja (“People of the Blue Green Water”) that includes indigenous knowledge components. As descendants of the original peoples who live in the Grand Canyon for centuries, the Havasupai have long and deep connections to water, plants, animals, and geology throughout the Colorado Plateau. The model will include connections to the sacred Wi’i Jgwal Gwa (“Lungs of Mother Earth” also known as Red Butte), the site of the Tribe’s creation stories. Plants and animals important to the Havasupai for subsistence, ceremonial, and medicinal practices and how mining affects these practices will be described. The final model will include Havasupai nomenclature to help preserve the language and historical cultural practices for future generations.

Mapping semantic networks in risk informed decision-making to improve integrated science

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ABSTRACT: Natural and public resource management organizations use risk-informed decision-making processes to monitor conditions, continually assess risk, develop strategies and mitigation actions, respond to incidents, and apply lessons learned from across sectors. These risk management practices require the best available science to inform processes, decisions, and understand uncertainty throughout the risk cycle. USGS science is applied across sectors and risk management practices, particularly in the west where local natural hazards are magnified by risk multipliers. This presentation describes the initial stages of testing and selecting a semantic network (SemNet) knowledge graph software platform and designing the SemNet with a schema of entities (nodes), connections (edges) and relationships, to visualize and consistently map knowledge transfer for complex scenarios between the USGS and partners. Partners include Federal bureaus and agencies, State natural resource management departments in Wyoming, Colorado, New Mexico, Utah, Nevada, California, Arizona, and tribal communities managing natural resources. The partners identified complex risk management scenarios centered around climate change and long-term drought impacts escalating with the following multiplying factors:

• Extreme wildfires and post-fire impacts such as landslides and debris flows posing risks to critical infrastructure including roads, bridges, dams, levees, and recreation areas

• Declining lake levels impacting endangered aquatic species, increasing dust production, and impacting environmental and human health

• Energy and mineral development resulting in land-use change, impacts to ecosystem services, increased prevalence of invasive species, and challenges with species conservation

• Alternative water-supply production leading to decreased groundwater levels, impacts to groundwater-dependent ecosystems, wildlife migration patterns, and refugia management

We expect the SemNet analyses to reveal commonalities and differences between stakeholder sectors, risk management structures, and patterns of scientific information flow as resource managers respond to increasingly complex risk-management scenarios across the landscape. The goal is to inform strategies for scientists to provide relevant and timely science to partners.

Influence of fire and cheatgrass legacy on mycorrhizae and pinyon-juniper regeneration: what's going on in the rhizosphere twenty years post-burn?

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ABSTRACT: In recent decades, wildfires and drought have intensified across the Southwest. Within Mesa Verde National Park and Ute Mountain Ute tribal lands, large swaths of mature pinyon-juniper (PJ, *Pinus edulis* and *Juniperus osteosperma*) woodlands have been lost in a series of stand-replacing fires. Managers of these lands are concerned that PJ ecosystems may not be returning following wildfire. Our team evaluated soil and vegetation characteristics at three sites that burned in the early 2000s within these parks. Western wheatgrass (*Pascopyrum smithii*) was seeded post-fire and cheatgrass (*Bromus tectorum*) also colonized the burn areas, but no tree regeneration has been observed. We hypothesize that interactions between introduced grasses, fire legacy effects on soils, and mycorrhizae explain the lack of tree seedlings. We conducted several greenhouse experiments to measure the ectomycorrhizal, arbuscular mycorrhizal, and dark septate endophyte inoculum potential of post-fire, post-thinning, and intact PJ soils, using pinyon pines and the native grass *Poa fendleriana* as trap plants. Preliminary results indicate that the level of arbuscular mycorrhizal inoculum across soils did not differ, but dark septate endophyte levels were greater in burned soil compared to the unburned control. We also investigated the effects of growing pinyons concurrently with a cheatgrass, western wheatgrass, or pinyon neighbor, as well as the effect of preconditioning soils with these three species on mycorrhizal colonization and growth of pinyon seedlings. In the competition experiment, the presence of cheatgrass reduced ectomycorrhizal colonization and pinyon biomass relative to the conspecific pairing, while wheatgrass had an intermediate effect. We did not observe differences in ectomycorrhizal colonization or pinyon growth among treatments in the grass legacy experiment. Our work suggests that cheatgrass interferes with beneficial symbionts necessary for pinyon establishment, and that interactions among plant species and belowground partners may help determine the trajectory of recovery in post-fire western ecosystems.

Hydrologic research pre-and post-low impact development in an ephemeral drainage

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ABSTRACT: Hydrologic monitoring pre- and post-Grade Control Structure (GCS) installations was conducted at the Boy Scouts of America (Boy Scouts), Heard Scout Pueblo (HSP) located on the north side of South Mountain Park, Phoenix, Arizona. The Study included one year of

pre-GCS installation monitoring; installation of GCS's during the second year; and about two years of post-GCS installation monitoring. At the end of the Study, the Flood Control District of Maricopa County assumed monitoring for a minimum of three years. USGS installed one surface water flow monitoring station, a video camera, sediment scour chains and piloted an Unmanned Aircraft System for channel surveys. Reclamation installed weather stations provided in-kind by Northern Arizona University and installed two wells equipped with water level sensors. This research builds on the work of others and collects data to inform policy. The research showed that the structures slowed storm flows and reduced the flashiness of peak flows (which should limit erosion). It was found that the GCS installations increased the infiltration occurring in the stream channels by approximately 15% for a variety of storms. Microclimate at the site was monitored and although the sample size (number of storms) is small, results of the analyses are strong and potentially important because they demonstrate that this kind of green infrastructure treatment creates roughly a three-degree microclimate cooling effect for at least two days following rainfall.

Slow down! Surface and subsurface actions to enhance groundwater recharge and storage in arid hydrology

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ABSTRACT: In the arid southwestern United States, groundwater resources are being consumed at a rate that exceeds recharge. Carbon-14 based age-dates indicate that regional recharge likely occurred at the end of the Pleistocene when the climate was colder and wetter. Aquifers tapped by some remote rural communities in Arizona, however, exhibit recent aquifer recharge. These younger aquifer systems are more vulnerable to drought, but they are also more likely to retain the isotopic signature of recent recharge. The stable isotope signature of the 2014 Season Hurricanes (Norbert, Odile, and Simon) confirmed aquifer recharge where the landowner practiced active stormwater management and capture with constructed detention gabions. This rapid assessment of groundwater vulnerability to climate variability in Arivaca, Arizona, resulted in the community responding to the surprising results with increased interest in managing their water for sustainability in the face of climate variability and change. Across arid regions around the world, subsurface structures combined with the surface gabions allow for the storage of captured recharge to support water supply. Although yet to be permitted in the United States, constructed subsurface retention structures in ephemeral arid streams, combined with surface gabions, could allow for local more secure groundwater sustainability. Numerous examples of these groundwater storage dams are presented and proposed for Arizona.

Singleleaf pinyon pine trait variation and implications for restoration in a changing climate

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ABSTRACT: Fires and drought have caused widespread impacts to pinyon-juniper woodlands across the Great Basin, resulting in the loss of ecological and cultural values associated with *Pinus monophylla* (singleleaf pinyon pine). Following overstory losses, restoration is challenged by an incomplete understanding of tree establishment requirements, complicated by intraspecific variability in establishment responses across the species' range. Information on trait variation and corresponding seedling responses to drought can inform restoration decisions, including the selection of seed sources. We quantified trait variation among adult trees and seedling offspring from 23 sites distributed throughout the range of *P. monophylla*. We then used common garden experiments to assess seedling responses to a range of drought scenarios. We found high trait variation among individual trees within sites, yet some traits were consistently structured along regional climatic gradients. Reproductive traits were related to a gradient of water stress, with larger, fewer seeds produced in more arid climates. Foliar traits such as specific leaf area were related to a gradient of growing season precipitation. Trait differences were maintained in seedling offspring grown in a greenhouse: under a broad range of water availability, seedlings from more arid climates produced larger aboveground and belowground biomass compared to seedlings from more mesic environments. These differences were associated with meaningful differences in performance in a field common garden experiment, where seedlings sourced from arid climates had higher survival under multiple simulated drought scenarios. Results suggest that the selection of drought-adapted seed sources can improve restoration success, particularly given climate-change-associated trends towards increasing frequency and severity of drought. Ongoing work includes post-fire restoration trials to evaluate whether observed patterns hold in a burned environment. While long-term outcomes are yet unknown, our results may help to increase the success of management efforts aimed at restoring woodland ecosystems for ecological and cultural values.

Geology, geochemistry, and genesis of uranium deposits hosted by solution-collapse breccia pipes in northwestern Arizona

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ABSTRACT: Unique uranium deposits, within solution-collapse breccia pipes, are scattered across northwest Arizona. The host structures are pipe-like columns filled with clasts of broken rock (breccia) that formed by partial dissolution and collapse of sedimentary strata. The breccia pipes initiated in caverns of the Mississippian Redwall Limestone and grew upward by intermittent collapse of overlying strata. The breccia pipes average about 90 meters in diameter and can extend vertically as much as 1,200 stratigraphic meters, from the Redwall Limestone up to the Triassic Chinle Formation. Hundreds of identified breccia pipes occur on the plateaus north and south of the Grand Canyon. Not all are mineralized, but 63 are known to contain uranium ore. The breccia ore zones consistently occur where the pipes intersect Permian strata of the Coconino Sandstone, Hermit Formation, and Esplanade Sandstone. Uranium oxide (UO_2) concentrations can be as high as one percent; the largest deposit mined to date produced 7 million pounds of uranium oxide. The uraninite is intergrown with sulfide minerals that together

have high concentrations of Cu, As, Co, Pb, Ni, and Zn, with some Cu potentially reaching coproduct grades. Sulfur isotopes are strongly fractionated among the sulfides. This study presents new results suggesting that the sulfur in these minerals came from dissolution of gypsum layers in strata 150 meters above the ores. The uraninite infilled around the sulfides and detrital minerals, indicating a post-sulfide precipitation. Metallogenesis likely involved oxidized groundwaters carrying uranium in solution that encountered the pre-existing sulfides, reducing the uranium and depositing uraninite. Uraninite age determinations are variable, clustering around periods of regional erosion. Weathering of ash beds in the Chinle Formation is a potential source of the uranium, similar to many other uranium deposits of the Colorado Plateau. These deposits have no relationship to magmatism or magmatic-hydrothermal processes.

Comparing full annual cycles of the Cordilleran Flycatcher (*Empidonax occidentalis*) on the Colorado Plateau and Mount Lemmon, AZ

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ABSTRACT: Full annual cycle describes a bird's ecology across the entire year. The Cordilleran Flycatcher (*E. occidentalis*) breeds over much of the Colorado Plateau and into the Sky Islands in southern Arizona. This neotropical migratory flycatcher's annual cycle can be divided into four phases: breeding, migration away from the breeding grounds, a stationary period between late fall and early spring (the overwintering period) and migration back to the breeding grounds. I will discuss similarities and differences in the Cordilleran Flycatcher breeding ecology between the Colorado Plateau site on the Dolores River, and Mt. Lemmon in Arizona. Utilizing data from malaise traps at both locations, I found that flying insect biomass was an important indicator of flycatcher breeding phenology. I will also compare how birds utilized nesting platforms that we provided at each breeding location. Utilizing data from light-level geolocators I will compare migration routes and timing away from and back to breeding areas. The flycatchers are loyal to breeding sites with some returning over five years to the same nesting location. However, during the wintering period, birds from one breeding location are found scattered over a wide region in southern Mexico. Those wintering locations stretched from Guadalajara to Morelia, through Morelos and to east of Mexico City. During each of the phases of the annual cycle birds occurred in different habitat types, but all were riparian-like in composition. We now have sufficient information to identify important breeding, migration stop-over, and wintering locations to help with better management actions (e.g., habitat protection) for this neotropical migrant flycatcher. The development and refinement of nesting platforms will also provide land managers with a useful conservation tool to enhance Cordilleran Flycatcher breeding on the Colorado Plateau.

Learning from the past and planning for the future: experience-driven insights into climate adaptation and land management strategies on the Colorado Plateau

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ABSTRACT: Current adaptive land management strategies utilized by federal and state agencies involve a great deal of challenges, and a great deal of research needs to be conducted on the extent to which these strategies are able to be successfully implemented. Effective adaptation and what it entails involves tremendous levels of uncertainty, as both scientists and managers cannot predict the extent of human-caused climate change impacts. Policy decisions at the international level will have a great deal of influence over the level of warming that occurs, and the structure of existing institutions limits the ability and effectiveness of responses. Scientists cannot comprehensively predict what the climate will look like in the coming decades, meaning that climate-caused impacts will often limit the ability for management strategies to be implemented effectively, prior to the occurrences of large-scale changes. Ecosystems have and will continue to undergo landscape level transformations, following the interrelated effects of temperature change, wildfire, and drought. Land managers in the Southwest have experienced varying degrees of wildfire and drought intensification and have insights on how ecosystems have responded to these stressors. Managers can learn from each other based on their previous and current experiences with climate-induced changes. Findings based on interviews I conducted with over 30 natural resource managers and scientists from a wide variety of agencies will be discussed, as well as results from a survey based on the insights and perspectives of land managers across the Colorado Plateau.

Knowing your students by working with them: a science faculty perspective of working exclusively with a primarily Hispanic student population

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ABSTRACT: Northern Arizona University - Yuma Branch campus is located in southwestern Arizona and facilitates the 2+2 community college/university academic experience for students in this region to earn their bachelor degrees. With Yuma county situated on the US/Mexico border the campus has an enrollment demographic of 66% Hispanic/Latine students (with a majority being of Mexican/American ethnicity). Significant factors of the county population that influence the academic performance of our students include high unemployment (14-18%), low education attainment, and migrant agricultural worker family units. Despite these factors the Biological and Natural Resource sciences program, with the assistance of federal grants for scholarships and research collaborations with our Flagstaff campus, have graduated over 80% of its students with Bachelor of Science degrees (4-5 years for degree completion including community college course work). Presented here will be the results of a case study the program completed recently discussing strategies and activities that worked as well as those that did not and why.

Qualities of anthropogenically derived habitat types across the Middle Rio Grande Bosque in New Mexico predict soil fungal community structure

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ABSTRACT: The Middle Rio Grande Bosque (bosque) in New Mexico has long borne the brunt of anthropogenic disturbances, yet little is known about how these disturbances impact the structure of the fungal communities with which foundational cottonwoods interact. The virtual elimination of seasonal flooding, a moderate disturbance which historically structured the bosque, coupled with other ongoing anthropogenic disturbances, has resulted in a threatened ecosystem of senescing cottonwood forests. The valuable ecosystem services and critical wildlife habitat the bosque still provides engender broad public support for bosque restoration. Because mycorrhizal fungi can confer many benefits to plants like cottonwoods, we believe restoration work should place greater emphasis on the fungal community. Therefore, we ask how soil fungal community compositions vary across this riparian landscape due to anthropogenic disturbances, including restoration. We hypothesize that we will see a healthier composition, defined by a greater diversity of fungi, including a higher abundance of ectomycorrhizal fungi, in sites with mature trees, fewer exotics and more frequent flooding. We will characterize soil fungal community composition in five anthropogenically derived habitat types. High-throughput sequencing of fungal amplicons derived from soil environmental DNA will be combined with R statistical analyses to determine how fungal diversity and composition varies across habitats. In identifying a composition common to sites representing a healthy bosque, our work will provide a more holistic picture of the bosque community. Using this picture, restoration managers will be better able to identify areas with fungal communities best suited to support cottonwoods and other native riparian plants, choose inoculants for pole plantings more appropriate to existing fungal communities and monitor another metric of bosque health to determine project success.

When good indices go bad: Why NDVI is unreliable for tracking vegetation dynamics in pinyon-juniper ecosystems

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ABSTRACT: Satellite-derived phenology metrics are valuable tools for understanding broad-scale patterns and changes in vegetated landscapes over time. However, the extraction and interpretation of phenology in ecosystems with subtle growth dynamics can be challenging. US National Park Service monitoring of pinyon-juniper (PJ) ecosystems in the western US revealed an unexpected winter-peaking pattern in normalized difference vegetation index (NDVI) time series derived from Moderate Resolution Imaging Spectroradiometer (MODIS) imagery. We assessed the validity of the winter peaks through ground-based observation of phenology and examination of solar and satellite geometry effects. To test the premise of a true winter vegetation response, we analyzed NDVI values extracted from ground-based camera

('phenocam') images collected from September 2017 to December 2018 in a PJ woodland in Arizona. All species in the phenocam field of view peaked in the warm season. Examination of NDVI time-series (2003-2018) derived from daily 250-m MODIS data in the broader PJ ecosystem revealed that solar-to-sensor angle, sensor zenith angle, and forward/back-scatter reflectance explained >80% of intra-annual variability. Solar-to-sensor angle, which exerted the greatest influence, is controlled seasonally by solar zenith angle and daily by variations in satellite overpass geometry. Mapping phenology across the western US in Google Earth Engine using Nadir BRDF-Adjusted Reflectance (NBAR) MODIS data revealed that winter peaks are consistent (>= 14 years, 2003 to 2018) in many conifer ecosystems and common (>= 5 years, 2003 to 2018) in many shrublands. We attribute winter peaks to the positive correlation of NDVI with solar-to-sensor angle and solar zenith angle in combination with sparse evergreen canopies. These findings are significant for the appropriate interpretation of phenology signals from satellite time-series for assessments of ecological health, status, and trends. Future research will investigate the susceptibility of alternate vegetation indices to solar-sensor geometry effects to determine the most accurate method of representing vegetation dynamics.

Flux and metal concentrations in dust collected across the mine life cycle at breccia-pipe uranium deposits, northern Arizona, USA

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ABSTRACT: US Geological Survey is investigating how environmental effects vary across the mine-life cycle at breccia-pipe uranium deposits in northern Arizona. To this end, dust flux and geochemistry have been monitored at an unmineralized site (Little Robinson Tank) and at mines representing conditions before mining (Canyon/Pinyon Plain Mine), during active mining and during and after mine reclamation (Pinenut Mine), and after mining, before reclamation (Arizona 1 Mine). Dust samples were collected using passive dust samplers at heights of 15, 50, 100, and 150 centimeters (cm) above ground surface at transects upwind (3 samplers) and downwind (9 samplers) from mine yards, with a maximum distance of 100 meters downwind from the yards. Dust samples are removed from the samplers about 4 times per year, and sampling started at sites between 2013 and 2015. The sample mass is used to calculate variation in dust flux through time at each site. The dust samples are composited by site and (or) height to achieve sufficient mass for chemical analysis. Results indicate that dust flux is generally elevated in dust collectors immediately downwind from mine sites relative to both upwind collectors and collectors at the unmineralized site. Concentrations of uranium and uranium-ore related elements in dust, including arsenic, are generally less at unmineralized and unmined sites than at sites during active mining and reclamation. Concentrations decrease with time after reclamation and generally with distance downwind but are greater in the 50-100 cm than in 15-cm samples at downwind locations. These patterns generally parallel concentration patterns found in soils at the same sites and support other studies indicating that trace elements in dust mobilize into areas surrounding the mines during mining and reclamation. This information may help inform strategies to better manage trace-element transport during mining activities and (or) design different reclamation techniques.

Casting a broader net—using art to communicate environmental effects of mining

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ABSTRACT: Stakeholders for scientific studies of the environmental effects of uranium mining in the Grand Canyon region include the general public, non-governmental organizations, scientists, Native American tribes, state and federal resource managers, and elected officials. It is a challenge to effectively communicate science to this broad audience and for the work to be understood and considered in resource-management decisions. Herein, we present two novel visual-art-based products designed to enhance science communication beyond what is achievable using conventional outlets such as press releases, fact sheets, or public presentations. The first is a geonarrative that uses graphic images to convey results of monitoring radon gas near an active uranium mine. The product has 11 cartoon-like panels displaying background information on radon gas, its health effects, and the scientific results. The second is a four-page Geological Survey Fact Sheet summarizing 20 peer-reviewed studies of the environmental effects of uranium mining in the Grand Canyon region. A drawing on the center two pages of the product highlights aspects of the studies and shows regional scenes designed to appeal to all stakeholders. Each of the 20 studies is summarized in one or two jargon-free sentences keyed to the drawing. These are but two examples of how art and non-conventional media might increase the appeal and understanding of scientific studies. This area is primed for growth and innovation.

CCAST: A community of practice and case study platform to support landscape-scale partnerships for climate change adaptation

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ABSTRACT: Natural resource managers and restoration practitioners have voiced a need to increase coordination around key conservation challenges such as climate adaptation planning, and to more effectively communicate lessons learned from on-the-ground project management experiences. This is particularly important when addressing landscape-scale challenges such as climate change. The Collaborative Conservation and Adaptation Strategy Toolbox (CCAST) is a multi-organizational partnership directed by the US Fish and Wildlife Service, Bureau of Reclamation, and the University of Arizona that supports Communities of Practice (CoPs) focused on issue-based conservation and management challenges that span geographies and jurisdictions. CCAST develops decision-support tools and Case Studies that communicate

lessons learned from on-the-ground activities and applied science. Furthermore, CoP partners help CCAST identify critical challenges and research priorities, and host webinars and workshops to create multiple opportunities for peer-to-peer knowledge exchange. To date, CCAST has published 36 Case Studies related to climate change and 46 related to drought adaptation. Topics range from helping pollinators adapt to climate change in southern Arizona and northern Mexico to collaboratively improving seed-based restoration success on the Colorado Plateau. CCAST partners include multiple climate change-focused, landscape-scale networks and organizations that use the CCAST platform as a communication tool. CCAST has collaborated with these partners to develop Case Studies and multiple toolkits focused on climate connectivity and drought/climate adaptation in arid river basins in the Western US Current CCAST efforts include cataloging nature-based solutions to climate adaptation in aquatic systems, supporting restoration of grasslands in a changing climate, and developing Case Studies on the nexus of climate adaptation and fire. CCAST's modular and scalable platform and templates have enabled it to grow into an expanding partnership that supports hundreds of active climate service providers and participants from federal, state, and local governments, NGOs, research institutions, and private land managers.

"What's a pinyon-juniper?" Incorporating dynamic landscapes within pinyon-juniper woodland classifications

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ABSTRACT: Pinyon-juniper (PJ) woodlands cover large portions of western North America, spanning over 15 degrees of both latitude and longitude and encompassing a broad range of environmental conditions (at least 15 US-EPA Level III ecoregions). PJ woodlands can include at least eight species of pinyon pine and six species of juniper that substitute for one another as canopy co-dominants. Differences in vegetation composition and stand structure arise from variation in climate and soil conditions at both regional and topographic scales, which in turn generate differences in the available species pool, disturbance regime, and the ecosystem processes that mediate post-disturbance recovery. Woodland structure and dynamics are also shaped by historical influences, which have varied spatially in type and intensity. These include a diverse array of land-use legacies ranging from the cultural uses of indigenous peoples, to the long-term cumulative effects arising from agriculture, resource extraction, and recent management actions. Yet despite their tremendous diversity, PJ woodlands are often considered as though they represent a single homogeneous vegetation type. Scientific findings are transferred indiscriminately across disparate woodland ecologies. To be useful, classification frameworks must integrate the key elements defining functional variation in PJ woodland current condition and likely response to environmental change. These include the limiting climate factors; overstory-understory relationships and the abundance of perennial herbaceous understory species; fuel conditions and fire regimes; the potential for exotic plant invasion following disturbance; and impacts of historical land-use legacies. In light of the above, I explore the utility of simple classifications commonly used for framing the conversation around PJ woodland management: the dichotomy between persistent vs. expansion woodland, and the trichotomy that includes PJ savanna, persistent woodland, and wooded shrubland.

Plant materials development for the Four Forest Restoration Initiative

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ABSTRACT: The Four Forest Restoration Initiative (4FRI) is a collaborative effort between the Kaibab, Coconino, Apache-Sitgreaves and Tonto National Forests to restore fire-adapted forests in Northern Arizona. 4FRI projects encompass a variety of landscape-scale treatments, including prescribed burning and mechanical thinning of forests to reduce the risk of unnaturally severe wildfires. Following ground disturbing treatments, seeding with native species can prevent establishment of invasive plants, increase species diversity, and establish fuel breaks. However, local and diverse sources of native seed are difficult to find due to high costs and insufficient seed volume to handle the scope of these restoration projects. This lack of locally sourced and genetically diverse native seed leaves potentially less adapted and sometimes non-native seed as the only option. Despite all these challenges, there is a growing demand for ecotypic native seed supported by research that shows seeding with locally-sourced seed will likely be more successful and resilient to the changing climate. To address the need for locally-adapted seed, the Institute for Applied Ecology (IAE), the US Forest Service (USFS), and other partners are collaborating to implement wildland seed collection and agricultural seed increase. This work contributes to the Southwest Seed Partnership (SWSP), a regional effort to increase availability of ecologically appropriate seed for restoration and conservation. Since 2015, the SWSP has been building wild seed collections and working with local farmers to increase seed in production fields. To date, 83 wild collections have been completed and 0.9 of acre have been put into production to initiate seed increase for 4FRI post-treatment understory restoration. With funding from the USFS Region 3, wild seed collections and seed production continue in 2022 on 4FRI forests.

Accumulation of uranium in mutton and sheep bone on the Navajo Nation from abandoned mine tailings

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ABSTRACT: Native Southwest tribes consider mutton culturally important and have for generations. Mutton is defined as sheep meat and bones that are used in cooking on the Navajo Nation (NN). In 1948, land belonging to the NN began being mined for uranium by the US government. In the 1960's, when the uranium market no longer required such a demand, all the mines were left exposed and abandoned allowing for uranium to become a part of the ecosystem in the southwest; there has only been recent remediation efforts on cleaning up these mine sites. These uranium mine tailings have been contaminating the soil, plants, water, and animals on the NN as a result of the lack of remediation. The uranium travels through the water and soil and into plants that are ingested by sheep which are then eaten by the Indigenous peoples, causing potential uranium related illnesses and contamination to tribes in the southwest. In sheep, the uranium can accumulate in their bone and continue to be distributed through their bodies. In this project, microwave digestion, column separation, and inductively coupled plasma mass spectrometry (ICP-MS) were used to quantify the amount of uranium found in sheep bone.

Additionally, to find out how much uranium is ingested by Indigenous persons consuming contaminated mutton, various kinds of cooked mutton will also be analyzed. By quantifying the contamination amount, additional precautions and valid advocacy for cleaning up the sites may be achieved. Methods will be carried out and completed by August 2022.

Spatial and temporal variation in wood density and its impact on tree growth in the Southwest

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ABSTRACT: Worsening droughts are predicted for much of the southwestern US, which makes elucidating drought-related mechanisms thwarting tree growth critical to inform adaptive forest management. While tree-ring widths are commonly used to assess drought impacts, incorporating other wood property information, such as wood density, will likely strengthen our predictive understanding of how drought governs tree growth. We hypothesize variations in wood density may affect subsequent tree growth by altering hydraulic conductivity and non-structural carbohydrate storage capacity, both of which could affect a tree's future ability to respond to either abundant resources or another drought. This motivates the objectives of this study: (1) investigate the large-scale climatic and spatial drivers of wood density variation and (2) quantify the influence of prior wood density on tree growth for three prevalent species (*Pinus edulis*, *Pinus ponderosa*, and *Populus tremuloides*) in the Southwest. We measured annual ring widths on cores collected from spatially and climatically diverse sites (13 aspen total from 6 sites, 12 pinyon total from 6 sites, 103 ponderosa total from 18 sites), and sub-annual wood density was measured for paired cores using X-ray densitometry. Linear mixed-effects models were implemented to (1) explore temporal and spatial variation in wood density and (2) to quantify how concurrent and past climate and wood density influence ring widths. Spatial variables (e.g., elevation, aspect) better predicted landscape-scale variations in average tree core density compared to climatic predictors, especially for *P. tremuloides* (R^2 = 0.63 [spatial covariates] vs. 0.33 [climatic covariates]), suggesting spatial context may better indicate the influence of microclimate on wood formation. Our exploratory analyses found a minimal effect of prior wood density on tree growth. However, we will implement more detailed statistical models to more deeply explore how climate drives fluctuations in wood density and how wood density can limit tree growth.

Collaborative Risk Communication: Reducing landslide losses in Puerto Rico

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ABSTRACT: Landslides are frequent and damaging natural hazards that threaten the natural and built environment. In 2017, more than 70,000 landslides were triggered across Puerto Rico by heavy rainfall from Hurricane María, prompting requests by local professionals for landslide outreach materials. A novel Collaborative Risk Communication framework was developed to meet those requests, shaping the creation of a Spanish- and English-language *Landslide Guide for Residents of Puerto Rico* followed by creative derivative products. Collaborative risk communication is defined as an iterative process guided by principles for co-production of hazards information by local and external stakeholders. The process involves mapping out the risk communication stakeholders in an at-risk location—in this case Puerto Rico—and collaborating over time to address a shared challenge, such as landslide hazards. In this case, a core team of government and university partners was formed to conduct collaborative work with an informal network of hazards professionals from diverse sectors in Puerto Rico. The following principles guided this process: cultural competence, ethical engagement, listening, inclusive decisions, empathy, convergence research, mentoring, adaptability, and reciprocity. We describe these principles and process to motivate collaborative risk communication efforts in different geographic and cultural contexts. Although this work focused on addressing landslides, the principles and processes are transferable to other hazards and contexts. They may also provide a roadmap for future partnerships among government agencies and university researchers to inform the co-creation of science and risk communication tools.

Forest restoration and education through a partnership between Diné College and Northern Arizona University

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ABSTRACT: Natural resources are critically important on Native American lands but research on how to protect and restore resources is very limited. At the same time, students at tribal colleges need opportunities to learn research skills and pursue advanced degrees. Our project links these concerns in a partnership between the Land Grant Office at Diné College (Navajo Nation) and the School of Forestry, Northern Arizona University (NAU). Funded through the USDA´s Tribal College Research Grant Program, we established experimental sites in pinyon pine and ponderosa pine forests in the heart of the Navajo Nation. Forest plots were set up to measure characteristics such as tree species composition, density, fuels, and understory plant communities. Restoration treatments are oriented towards recapturing natural productivity, diversity, resilience to drought and fire, and key cultural values such as sheep forage and traditionally used plants. Additional student-led projects include assessing fungal communities and measuring pinyon nut production. All elements of the project are carried out collaboratively by Diné College and NAU students, faculty, and staff. Reciprocal campus visits and shared work in the field and lab provide opportunities for learning from each other. We are interested in sharing this experience to encourage other Tribal College-University partnerships for meaningful research and educational opportunities.

Conserving species interactions may be more important than conserving species: the importance of interactions and a community approach

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ABSTRACT: "No single species on Earth lives without interacting with other species. These interactions are the backbone of biodiversity and create the architectural foundation of ecosystems" Jordano (2016). Intuitively, scientists know that interactions are important, but in practice, interactions get little recognition in conservation because intuitively we also feel that if we maintain species, the interactions are automatically maintained. However, this is not necessarily the case; for example, stress created by drought can dramatically reduce interactions and biodiversity. Interactions are also conditional – positive under one set of conditions, negative under another set of conditions and neutral with other conditions. Furthermore, the practice of conservation is generally focused on saving individual species, especially rare and endangered species, but by the time many rare and endangered species are listed their interactions have become negligible and their roles in the community greatly diminished. Here, I show why interactions are so important and why conservation should be more focused on maintaining these interactions, because without them, conservation efforts are likely to fail, especially at a time of great environmental change as we are currently experiencing with global change. Key approaches for demonstrating where interactions are most important include: (1) species addition or removal experiments, (2) species interaction networks, (3) community interaction networks, (4) network heritability, (5) community reaction norms, (6) genetic covariance, (7) community heritability, and (8) feedback loops. These types of interactions commonly co-occur in the same system, are genetically based and can evolve.

Field trials to quantify local adaptation, ecotype formation, and associated communities to enhance genetic approaches to maintain p-j woodlands suffering from climate change

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ABSTRACT: Most plants are adapted to their local environments allowing them to best survive and thrive under local conditions. However, with climate change, local adaptation may have negative effects. Why? As the environment changes, locally adapted species may not evolve or acclimate fast enough to a new environment. Importantly, if they are diminished or go locally extinct as in the case of pinyon pine, associated species may also be lost such as specialized insects, pinyon jays and the pinyon mouse. Thus, to mitigate climate change, we need to know much more about how locally adapted individual plant species might be and prioritize species or ecotypes that are especially sensitive to climate change. We also need to focus on foundation species such as pinyon pine because they support a community of about 1000 other species that would be at risk. Here I show how the Southwest Experimental Garden Array (SEGA) can be a

model for developing field trials with p-j woodland species that can: 1) quantify the degree of local adaptation and sensitivity to climate change, 2) identify species ecotypes best suited to ecoregions, 3) identify what genotypes and populations are best suited for restoration at specific sites that will survive both current and expected future climates, 4) show how planting in association with nurse plants can increase restoration success, 5) quantify how climate change and drought stress affects the biodiversity of associated communities (e.g., insects, lichens, understory vegetation), 6) develop a network of field trials that can inform managers throughout the southwest to help mitigate the impacts of climate change, and 7) advance a Congressional Restoration Bill to secure funding for a network approach to mitigate climate change for p-j woodlands. In combination, use of these approaches will gain greater precision in addressing climate change mitigation and cost effectiveness.

Examining the role of faults, folds, and collapse features on groundwater flow in the Coconino Plateau, North-central Arizona

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ABSTRACT: Faults and other geological structures on the Coconino Plateau, in north-central Arizona, are commonly thought to play a role in the movement of groundwater in that area, but limited data exist to understand their influence. Some groundwater models of the region have used zones of enhanced permeability and porosity along or near geologic features to simulate their effect on groundwater flow but are often based on assumptions about the features acting as preferential pathways along their entire length. The goal of this work is to identify areas where additional subsurface data may be most useful to constrain the role of faults, folds, and collapse features on groundwater-flow in the Coconino Plateau. The US Geological Survey completed gravity transects across several prominent features on the Coconino Plateau, to determine if the existence and width of high porosity (low density) zones could be inferred from the resulting gravity contrasts, which could be used to update groundwater-flow models of the region. Only one of the transects resulted in a gravity low that could be inferred as a low-density or enhanced permeability zone, but this does not rule out the existence of such zones along faults or folds at other locations. To attempt to constrain where additional data would be most useful, a simplified model of the area was used as a baseline comparison to determine how modeling different features in different ways affected the groundwater flow within the system.

Climate change and visitation to public lands in the Southwest

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ABSTRACT: Changes in climatic conditions are likely to shift the demand for outdoor recreation opportunities in both space and time. We use 14 years of geotagged social media data

to explore how the climatological mean of maximum temperature affects visitation to public lands in the continental United States by season. We also investigate how visitation to public lands may change by 2050 under two climate change scenarios. Across all public lands in the continental US, visitation is expected to decrease 18% by 2050 in the summer under a moderate emissions scenario (RCP 4.5) but increase 12% in the winter and 5% in the spring, with no significant changes in the fall. There is substantial variation in the magnitude of projected changes by region. In the southwest, visitation to public lands is generally higher in locations with cooler climates. The Lower Colorado Basin is expected to see small declines in visitation in the summer, fall, and spring, and no changes in winter visitation under warming scenarios. The Upper Colorado Basin is expected to see small declines in the summer, fall, and winter, with no changes in the spring. These findings suggest a warming climate is likely to decrease visitation in the Colorado Basin area, but across the US there is substantial variation in where, when, and by how much, visitation is projected to change. Results could be used by outdoor recreation managers to plan and prepare for changing visitation patterns as the climate warms.

Vegetation response to restoration using rock detention structures in the Madrean Archipelago of the southwestern USA

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ABSTRACT: The Madrean Archipelago is a globally recognized biodiversity hotspot. This ecoregion is threatened by increased pressure on water resources, changing land use, and increased drought which has resulted in negative impacts to ecosystem function. Land managers are working with restoration practitioners to mitigate pressures by using rock detention structures (RDS). Positive effects of RDS on hydrological processes are documented internationally, but limited research exists on vegetative response. In a landscape where vegetation dynamics are driven by water availability, we hypothesized that RDS would result in increased vegetation and shifts in species composition. Three project sites in southeastern Arizona were monitored for five years after the installation of RDS in a modified Control-Impact-Paired-Series study design. Sites varied in the type of RDS, baseline vegetation community, access to groundwater sources, and level of degradation. Vegetation frequency and species composition were measured using quadrats in a systematically randomized arrangement. Vegetation frequency was compared over time and species composition was analyzed using Bray-Curtis dissimilarity index and non-metric multidimensional scaling ordination. The study revealed differences in vegetation response along a gradient of degradation. The least-degraded site showed little difference in vegetation frequency and composition between treatment and control sites. The moderately- and severely-degraded sites showed an increase in perennial vegetation at treatment sites. The moderately-degraded site showed a difference in perennial vegetation composition at treatment sites as species from the banks were recruited in the channel. Both moderately- and severely-degraded sites showed an increase in a pre-existing wetland facultative bunchgrass and the recruitment of a wetland facultative weedy sedge. At the moderately-degraded site, the introduction and increase of two nonnative perennial grass species occurred. More research is needed to investigate the impacts of surface-to-groundwater interactions on vegetation response. However, these findings provide valuable information for restoration planning.

Understanding the impacts of and identifying mitigation strategies for domestic grazing under drought on the Colorado Plateau

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ABSTRACT: The Colorado Plateau has over a century long history of grazing domestic livestock. This form of land use has become an accepted practice for much of the area and has contributed to the iconic symbol of the west. However, the removal of biomass, soil disturbance, and altered ecosystem processes, such as plant competition and plant-soil feedbacks, have negatively impacted some Plateau rangelands. In addition, warming and drought from climate change add further pressures to the Plateau. Temperatures have already increased by 2.57 degrees C since pre-industrial periods in some areas of the Plateau, allowing a 20-year drought to intensify. Impacts from climate change have delayed green up and shortened growing seasons for many perennially plants. Drought induced plant mortality is also predicted to trend upwards, driven mainly by perennial grasses which are important forage for domestic livestock. The combination of climate change and grazing has the potential to further exacerbate existing impacts and lead to profound and irreversible transformations of Plateau ecosystems. To understand the complexity of these issues, we started a new project that is examining how the interaction between drought and seasonal grazing practices impact Plateau plants and soils. To do this, the study has two precipitation treatments, ambient and drought (-66% of ambient) along with four grazing treatments (winter grazing, spring grazing, winter & spring grazing, and not grazed). To simulate grazing, grasses are clipped by hand to stubble height based on BLM utilization monitoring. Along with seasonal clipping, hoof disturbance is simulated to understand the effects of physical soil disturbance. With this study, we hope to demonstrate the effectiveness of reduced or delayed grazing strategies to alleviate impacts of drought on Plateau rangelands and further inform management to increase resilience in perennial grasslands.

Scaling climate change impacts on the keystone saguaro cactus (*Carnegiea gigantea*)

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ABSTRACT: Keystone plant species can have inordinate effects on the persistence of other species and can even shape entire ecosystems. Their ecological roles and importance are shaped, at least in part, by their ability to establish and survive in locations where other species cannot. These species are oftentimes ecosystem engineers and modify their environments to an extent that new, occupiable habitat is created for associated species. The iconic saguaro cactus (*Carnegiea gigantea*) is keystone species supporting more than 100 plant and animal species in the Sonoran Desert but has been negatively impacted by human activity in various ways during the past century. Climate changes including prolonged and increasingly severe droughts, altered habits with abundant invasive species and increasing wildfire occurrence, and continued human development have resulted in reduced recruitment or landscapes with visibly fewer saguaros than

occurred historically. We present recent research examining the influence of climate change on saguaros and describe future research needs to ensure land managers working to protect saguaros have the correct tools to meet goals. We also define the utility of considering impacts at multiple temporal and spatial scales ranging from an individual plant interacting with a particular microclimate, a population of saguaros with differential responses to drought related to physiographic location, and several populations across a region experiencing multiple land-use and climate change pressures that are likely redefining the saguaro cactus' role as a keystone species in the Sonoran Desert.

Southwestern Willow Flycatcher patch occupancy modelling

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ABSTRACT: Understanding how animals are distributed among habitat patches over broad landscapes can inform survey designs and help mangers in prioritizing locations for management interventions. Prior habitat modelling of Southwestern Willow Flycatcher (SWFL; *Empidonax traillii extimus*) has enabled scientists to forecast habitat range-wide at a pixel grain using metrics derived from remotely sensed products (e.g., Landsat), but has stopped short of delineating patches and predicting their probability of occupancy. Here, we describe work to automate the delineation of patches derived from remote sensing only and determine patch attributes that contribute to the probability the patch is occupied. We find that by focusing on patches formed by aggregating pixels predicted to be moderate to very good habitat, we can identify areas in which most SWFL in intensively studied areas were found. Furthermore, we find a strong association between probability of occupancy and the size of habitat patches delineated from remotely sensed data. The distributions and sizes of habitat patches are constantly changing, however the ability to identify high quality patches using annual remote sensed information is valuable for designing range wide surveys and helping to prioritize management actions over large landscapes. We also find that when survey data from recent years (within the last 2 years) is available we can predict occupancy even more accurately. When an area has not been surveyed in many years (or has never been surveyed), satellite imagery can be analyzed to determine the age of riparian habitat (for each pixel within a habitat patch) and we find that both the average age and the variability in the age of pixels in a habitat patch are positively associated with its probability of occupancy. Our work, while focused on a few well-studied regions, forms a basis for future work focused on predicting patch occupancy across the range of SWFL.

Long-term effects of resource objectives wildfires: meeting restoration objectives while balancing the forest carbon cycle

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ABSTRACT: The dry conifer forests in the southwestern United States and elsewhere have been transformed by decades of fire exclusion, resulting in a loss of fire resiliency over much of the landscape. Increasingly, fires are burning at higher severity and over larger areas with adverse effects on long-term forest conditions. There is a growing sense of urgency to address these challenges given recent projections of a warming climate. To meet this mounting threat, the practice of managing wildfire in concert with traditional restoration activities to expeditiously meet land management objectives has been increasingly applied in dry conifer forests of the southwestern United States. We explore the long-term effects of this practice on a 778,000-ha study area in northern Arizona using a landscape model designed to manage wildfire risk by considering both fire proximity to values on the landscape and daily weather conditions. Managing wildfires for resource objectives diminished the likelihood of extreme fire events and reduced the proportion of high-severity fire in relation to total area burned. Resource objective wildfires also improved forest heterogeneity and wildlife habitat, and when used alongside the current pace of traditional restoration activities, expanded the footprint of restoration treatments by fivefold. Incorporating resource objective wildfires into land management practices also contributed to restoring forest conditions in 25 years when used alongside restoration treatments five times the rate of the current implementation. Concurrently, a balance was returned to the forest carbon cycle on manageable lands when resource objective wildfires were used alongside restoration treatments at this elevated rate. While limiting disturbances maximized forest carbon storage, this carbon was increasingly vulnerable under future warmer climates with elevated wildfire activity. Results are discussed in the context of possible resource objective wildfire futures under increased political scrutiny of using wildland fires to meet land management goals.

What makes biocrust happy? Examining abiotic conditions that lead to carbon exchange and increased biocrust cover

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ABSTRACT: Biocrusts are ubiquitous communities across southwestern drylands, but their ability to exchange carbon and accumulate biomass under changing abiotic conditions is unclear. Multiple field studies have observed significant declines in cover of certain biocrust species with changing abiotic conditions. Here, we examine three greenhouse studies that manipulate abiotic conditions for diverse southwestern biocrust communities to ask what conditions lead to either carbon exchange or increased cover. Our first experiment examines how variations in soil texture,

soil moisture, and soil nutrients impact cover of biocrust communities. We find an interactive effect of soil texture and water in increasing biocrust cover, but that biocrust species are able to grow across texture and water continuums. Our next experiment examines the cover of multiple biocrust species assemblages with two levels of water amount and frequency. We found that over time, cover was similar across the two watering amounts and frequencies and between the species assemblages. Our final experiment examines carbon exchange under variations in watering amounts and frequencies between two late successional biocrust communities. We found that biocrusts are able to maintain carbon exchange levels and photosystem II activity through time over a wide range of watering amounts and frequencies, contrary to field-based studies. Overall, these greenhouse studies suggest biocrusts are able to exchange carbon and increase cover over a variety of different abiotic conditions. The contradictions between these greenhouse studies and field-based studies imply that variables beyond water amount and frequency, possibly evaporative demand, are controlling factors in observed field-based biocrust decline.

The National Ecological Observatory Network (NEON) Biorepository: a developing resource to facilitate long-term biodiversity monitoring efforts

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ABSTRACT: Natural history collections are rapidly being recognized as critical resources for monitoring and forecasting rapid ecological change. Archival specimens allow researchers to directly observe populations, communities, and ecosystem properties over otherwise inaccessible spatial and temporal scales. The National Ecological Observatory Network (NEON) Biorepository is dedicated to providing access to natural history collection samples, specimens, and related data collected at a continental and decadal scale with the explicit purpose of facilitating ecological monitoring. Over sixty distinct types of specimens and samples are collected at NEON's 81 terrestrial and aquatic field sites located across the country. Seventeen off these sites are located within the broader Southwest region. Samples are collected using systematic resampling protocols in concert with fine-scale environmental and organismal data collection. The samples housed at the NEON Biorepository reflect the within species variation, community composition, and ecosystem properties of NEON sites over time and are preserved with methods that maximize their long-term research potential. NEON Biorepository samples are available for many uses by external labs and currently involved in about 40 research projects spanning a variety of themes including macroecology, population structure, biogeochemistry, and ecosystem ecology.