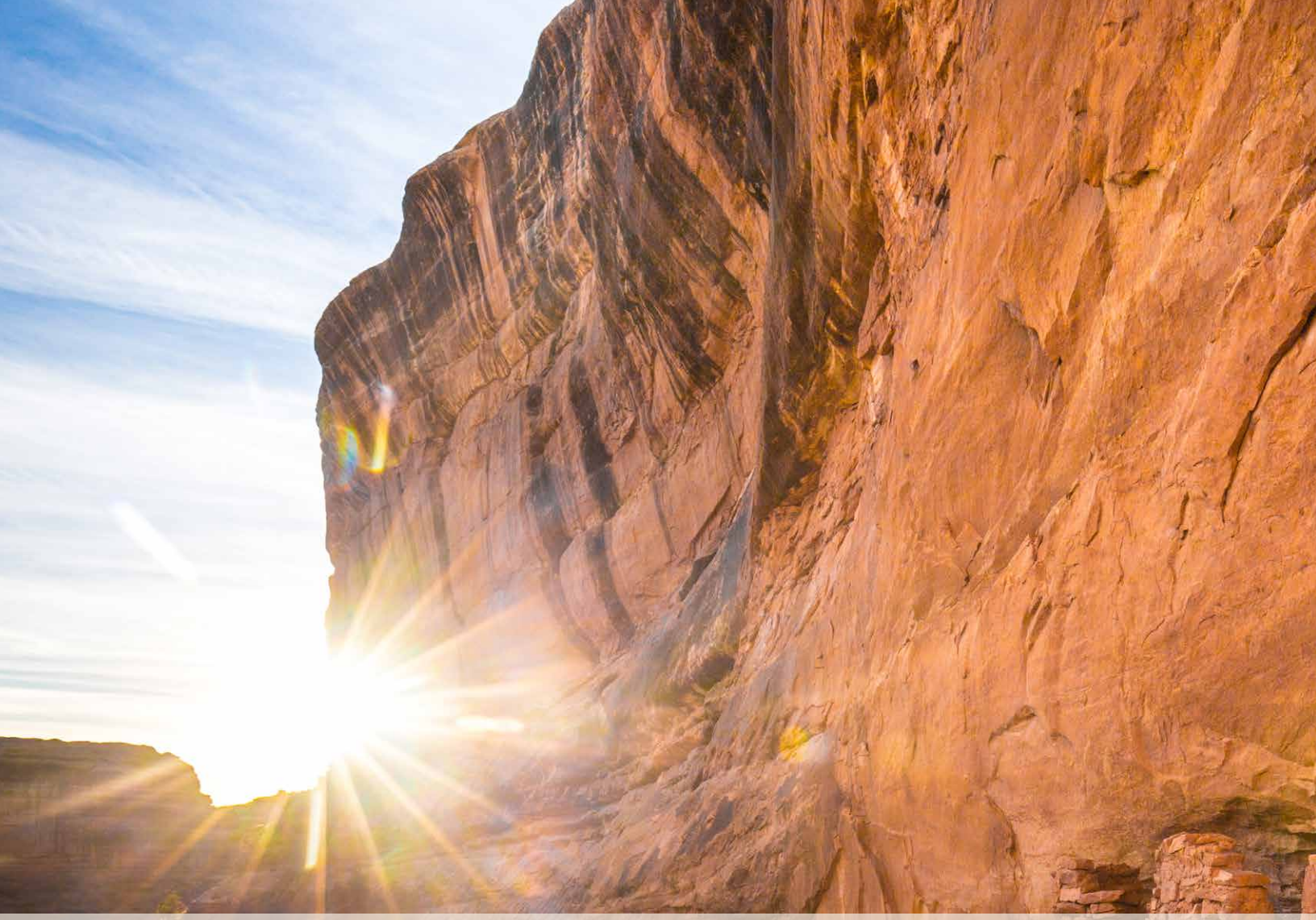

# SOUTHWEST CLIMATE SCIENCE CENTER
# ANNUAL REPORT | 2016/17

BRYCE CANYON NATIONAL PARK, UTAH

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BY ZACK GUIDO, INSTITUTE OF THE ENVIRONMENT, UNIVERSITY OF ARIZONA

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# FROM THE DIRECTORS

The Southwest Climate Science Center's 2017 Annual Report is a team effort. This year, our research focused on a number of priorities, with a major theme of addressing rising temperatures and climate extremes in the Southwest.

Our seventh year has also brought some staffing changes. Christine Schirmer moved on to another position at the University of Arizona, Anita Govert was promoted to Program Manager, and we welcomed Dr. Gregg Garfin, our new University Director. We bid farewell to our former University Director, Dr. Jonathan Overpeck, who accepted a position at the University of Michigan, in July, 2017.

In this year's report, we feature new projects documenting impacts of climate extremes in a variety of the Southwest's ecosystems, from coastal estuaries to the Colorado River and the Great Basin Desert. Projects aim to increase understanding of key phenomena, such as drought, and to develop research products to inform the management of wildlife and invasive species. SW CSC researchers also tackled the task of assessing stakeholder needs, to better serve managers and communities in the region.

As always, we are grateful for the tireless efforts of scientists in the SW CSC consortium, the expanding network of talented researchers funded through the SW CSC, and the dedicated and insightful natural resource managers with whom we work. We look forward to another year of collaboration with staff, scientists and the communities we serve to understand the complexities of the Southwest's climate and ecosystems and to deliver science and information to inform the critical resource management challenges in our region.

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Gregg M. Garfin
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UNIVERSITY OF ARIZONA

JOSHUA TREE NATIONAL PARK, CALIFORNIA

# RESEARCH THEMES

Climate science & forecasting

Hydroclimate & water availability

Ecological responses & vulnerabilities

Designing monitoring strategies

Establishing information exchange practices

# SCIENCE PRIORITIES

**Improve understanding of the consequences of changing precipitation patterns and extremes.** In the coming years, the region is likely to experience changes in precipitation frequency, intensity, and seasonality. These changes will influence key ecological, hydrological, and societal processes. Improved understanding of these linkages will inform decisions about safeguarding ecosystem and infrastructure assets.

**Improve understanding of the interactions between temperature extremes and precipitation variability.** Diagnostic analyses of the projected interactions between temperature extremes and precipitation variations will inform issues of concern to resource managers, such as the quantity and quality of water resources, vegetation composition and structure, and wildlife populations and habitats.

**Expand studies to inform management of landscape-scale disturbances.** Large wildfires and mass forest mortality combine with climatic, hydrologic, and ecological processes to set long-term successional pathways. These pathways determine habitat and landscape configurations that can persist for decades. Observational, experimental, and modeling studies will guide post-disturbance planning.

**Improve understanding of the linkages between headwaters and downstream flows and between management decisions and water deliveries.** Winter snowpack feeds Southwest rivers, reservoirs, and domestic and agricultural water resources. Better understanding of the linkages between climate, snowpack and streamflows will inform drought and water management decisions.

**Enhance learning from recent and ongoing climate events.** Examination of climate events and extremes, such as the ongoing Southwest drought, can inform evaluation of the efficacy of current management and restoration practices. Sharing the results of these analyses will help resource managers to better understand the consequences of future climate variations.

**Increase use of emergent scientific capacities and decision tools.** Scientific capacities are improving rapidly, notably in the analysis of climate model forecasts of daily weather patterns and seasonal extremes. Application of improved and diversified decision toolkits, in concert with state-of-the-art science, will advance knowledge and inform management.

INDEPENDENCE MONUMENT GRAND JUNCTION, COLORADO

# NEW PROJECTS

**Learning from recent snow droughts to improve resource management**

**Principal Investigator:** Adrian Harpold, University of Nevada, Reno

In the dry southwestern United States, snowmelt plays a crucial role as a water source for people, vegetation, and wildlife. However, snow droughts significantly lower snow accumulations, disrupting these critical water supplies for local communities and ecosystems. Despite its large influence on land- and water-resource management, snow drought has only recently been properly defined and its historical distribution and effects on key natural resources are essentially unknown. To remedy this serious knowledge gap, project researchers are examining the causes, effects, and predictability of snow drought to provide needed scientific information and guidance to planners and decision makers.

The central goals of this project are to better quantify the impact of snow droughts on municipal and ecosystem water supplies and improve the scientific information accessible to a wide range of resource managers. The project consists of three primary objectives: (1) document the types, frequencies, and proximate causes of historical snow drought using snow and climate observations; (2) assess streamflow forecasting abilities following snow drought using the operational regression-based forecasts used by water management agencies; and (3) identify areas where streamflow forecast skill is improved by incorporating snow drought information.

Preliminary analyses indicate that several different types of snow droughts occur in the Southwest, arising from a variety of different factors. “Dry snow drought” is caused by a lack of winter precipitation needed to accumulate snow. “Warm snow drought” can be caused by early snowmelt or by precipitation falling as rain rather than snow. The project team is also using SNOTEL data in models to predict the occurrence of these different types of snow droughts across the Southwest. Their next steps will be to determine how these different types of snow drought affect streamflow forecasting and develop strategies to improve these forecasts.

### Toward effective actionable science: stakeholder needs assessment

**Principal investigator:** Gregg Garfin, University of Arizona

A major goal of the Climate Science Center network is to conduct science and develop timely science products and tools that are directly relevant and useful to decision-makers and natural resource managers. A crucial first step in producing this actionable science is understanding the highest priority science and information needs of natural resource managers and planners.

Through this project, the Southwest Climate Science Center will conduct a structured rapid assessment to identify and understand manager needs and priorities in the Southwest region. The project team will also work directly with managers and stakeholders to assess their perceptions regarding the co-production of science and preferences on science-practitioner partnerships, communication, and engagement. The team will also assess the need for training and extension work that would enable managers to better use science products. Components of the assessment include listening sessions, one-on-one interviews, a survey, and focus groups.

The process of conducting this needs assessment, as well as the information gathered, will enable the Southwest CSC to foster stronger relationships with key managers in the region and to become more responsive to the real-world needs of decision-makers. The project team will develop a guidebook documenting a repeatable process for assessing stakeholder needs and will hold webinars to convey the results.

### Forecasting resource availability for wildlife populations in desert grasslands under future climate extremes

**Principal Investigator:** Erica Fleishman, University of California, Davis and Colorado State University

The desert grasslands of the southwestern United States support many wildlife species of management concern and economic value. The American pronghorn, for example, is a game species that contributes to local and state economies. Climate extremes, including severe droughts, heat waves, and atmospheric river events, are expected to occur more frequently in the Southwest. These extremes can affect the availability of food and water needed by wildlife. Wildlife management agencies and conservation organizations need information on resource availability for wildlife under future climate scenarios to design effective management strategies to sustain wildlife populations.

Project scientists are working with the Arizona Game and Fish Department, the U.S. Fish and Wildlife Service, and other partners to understand the effects of changing resource availability on four grassland species: American pronghorn (*Antilocapra americana*), Gunnison's prairie dog (*Cynomys gunnisoni*), Scaled Quail (*Callipepla squamat*), and Gambel's Quail (*Callipepla gambelii*).

The project team will use historical climate data, satellite data on vegetation greenness, and field data on the locations and abundance of wildlife populations to explore the links among climate variables, food availability, and wildlife populations. The team then will use climate models to project how forage, and ultimately wildlife populations, are likely to respond to projected changes in climate. This project will help inform landscape-level planning, establish conservation priorities, and suggest management approaches for adapting to shifting climate and resource availability for wildlife.

### Evaluation for learning and innovation in actionable science for climate adaptation

**Principal Investigator:** Alison Meadow, University of Arizona

The impacts of climate change are already being observed and felt in our ecosystems and communities. Land and resource managers, planners, and decision-makers are looking for the best scientific information to guide their decisions about adapting to and mitigating the effects of climate change now and in the future. To address this need, a primary goal of the Southwest Climate Science Center is to develop actionable science: scientific information that can be easily used to inform these decisions.

Evidence shows that more collaborative forms of knowledge development and exchange between scientists and decision makers tend to produce information that is considered more trusted and usable, and lead to higher-quality decisions about environmental management. Project researchers have developed a framework for the evaluation of collaboratively produced climate science that specifically addresses the process of producing and outcomes of actionable science. The team is using this framework to evaluate a sample of projects funded by the Southwest CSC to determine: (1) to what extent the science is being applied to management decisions in the Southwest region; (2) what the barriers are to the use of science; and (3) which practices or strategies are most associated with the production of actionable science. The information garnered from this project can then be used to further develop processes for conducting and evaluating co-production of science.

**San Diego ecosystems: the impacts of climate change on a biodiversity hotspot**

**Principal Investigator:** Dan Cayan, Scripps Institution of Oceanography

The Mediterranean ecosystems of southern California are some of the most ecologically diverse systems in the world. The diversity of plants and animals, as well as high rates of endemism, make the area a biodiversity hotspot. High diversity in plant and animal species contributes greatly to the health and productivity of ecosystems, and plays an important role in the local and state economy (e.g., tourism, food crops).

San Diego County's complex topography, highly variable precipitation, and climate play a large role in determining the biology of the region. Changing temperatures and precipitation patterns due to climate change would alter the region's climate and add to other stressors such as habitat fragmentation from roadways and suburban-rural development. Natural resource management and conservation actions would be greatly enhanced by a better understanding of which natural resources are most at risk from climate change and increased climate variability in San Diego's diverse terrestrial ecosystems.

This project aims to uncover and assess these risks to and implications for San Diego County's biodiversity and important natural resources. This assessment will include a review of efforts that have already been made to conserve open spaces and natural resources in the area. The team will also explore the most regionally relevant climate adaptation strategies that can be applied to buffer the effects of climate variability and provide several examples of adaptation projects that have been successfully implemented in San Diego. The final report from this effort will be presented as part of the 4th California Climate Change Vulnerability and Adaptation Assessment.

**Anticipating future impacts on streamflow using multi-century climate records and applied hydrologic models**

**Principal Investigator:** Connie Woodhouse, University of Arizona

The Colorado River is a crucial water source for millions of people in the Southwest. Warming temperatures, clearly documented in climate records for the Colorado River basin, are having an impact on the amount of annual streamflow from rain and snow. Recent work has revealed that warming temperatures have played an increasingly important role over the past decades, both exacerbating droughts and dampening the effects of wet winters on high streamflows. Understanding and anticipating how warming temperatures will influence future water supply in the Colorado River basin is increasingly important for resource management, particularly in light of recent drought conditions.

The overarching goals of this project are to better understand the influence of temperature on Colorado River streamflow, particularly during droughts, and assist water managers in planning for future droughts. This project extends collaborative work between scientists and Colorado River basin water managers to investigate the range of potential drought conditions under early 21st century warming, using both recent and historical data. For example, with precipitation reconstructions from tree rings for the past 500 years, the team can use a simple hydrologic model to assess the impacts of the longest and most severe droughts of the past on

the Colorado River under today's warmer temperatures. With this information, the project team will contribute to a set of plausible scenarios of future drought that planners can use to help make resource management decisions. The project will also further examine the drivers of Colorado River drought, with a focus on factors such as the phase of precipitation (rain vs. snow), the timing and rate of snowmelt, and evaporation rates. The project team will also begin to explore the ways that changing temperatures and streamflow might impact the ecological health of the upper Colorado River basin.

**Understanding changes to the timing of natural events (phenology) for plants in the water-limited Southwest: actionable phenological science for the water-limited Southwest**

**Principal Investigator:** Seth Munson, United States Geological Survey

In many places around the world, spring events, like warming temperatures, are coming earlier and fall events are coming later than they have in the past. These changes have implications for the phenology, or the timing, of natural life events (e.g., the timing of plant flowering in spring or leaves falling in autumn) of many plant species. However, not all species and regions are changing at the same rate, which can lead to mismatches (e.g., between the emergence of plants and pollinators in early spring). Many interactions in nature depend on timing and phenology affects nearly all aspects of the environment: abundance, distribution, and diversity of organisms, ecosystem services, food webs, and global water and carbon cycles.

Phenology is among the best indicators of climate change impacts, in large part because phenological events are some of the most sensitive biological responses to environmental changes. Researchers are rapidly developing datasets, models, and indices that can improve our understanding of changing phenology. However, most indices of phenological change are poorly suited for water-limited ecosystems, and existing models are lacking in their ability to represent phenological change at local scales that are relevant and useful for decision making.

MULE DEER, COLORADO

CHEATGRASS (*BROMUS TECTORUM*)

### The role of climate in shaping invasive plant abundance across different spatial locations: spatial variation in the role of climatic extremes in shaping plant invasions

**Principal Investigator:** Helen Sofaer, United States Geological Survey

Invasive plants are a major land management problem in the western United States. Cheatgrass (*Bromus tectorum*) is the most prominent and problematic invader in cold deserts, with negative effects on rangeland fire patterns, wildlife habitats, and forage/vegetation. Red brome (*B. madritensis*) is an invader in the Mojave Desert and can similarly introduce a new fire pattern to sensitive warm desert scrub. These invasions often cause management agencies to incur high costs for prevention, control, restoration, and fire responses.

Control and prevention of invasive species is challenging because the risk of invasive plants becoming abundant depends on existing plant communities, climate and weather, land use, and fire history. Moreover, scientific information on invasion risk has not always been translated into maps that planners and resource managers can use in their decision-making. Broad scale information is needed to link geographic variation in climate and disturbances (e.g., fire) to decisions on the ground regarding where to apply treatments aimed at limiting the impacts of invasions and restoring native plant composition.

This project aims to use existing datasets to understand the links between the abundance of major plant invaders and climatic extremes, land use, and fire history. The project team will examine how the drivers and limits of plant abundance vary among invasive species and across the Great Basin and Mojave Desert.

### Climate extremes and ecological impacts to California estuaries

**Principal Investigator:** Karen Thorne, United States Geological Survey

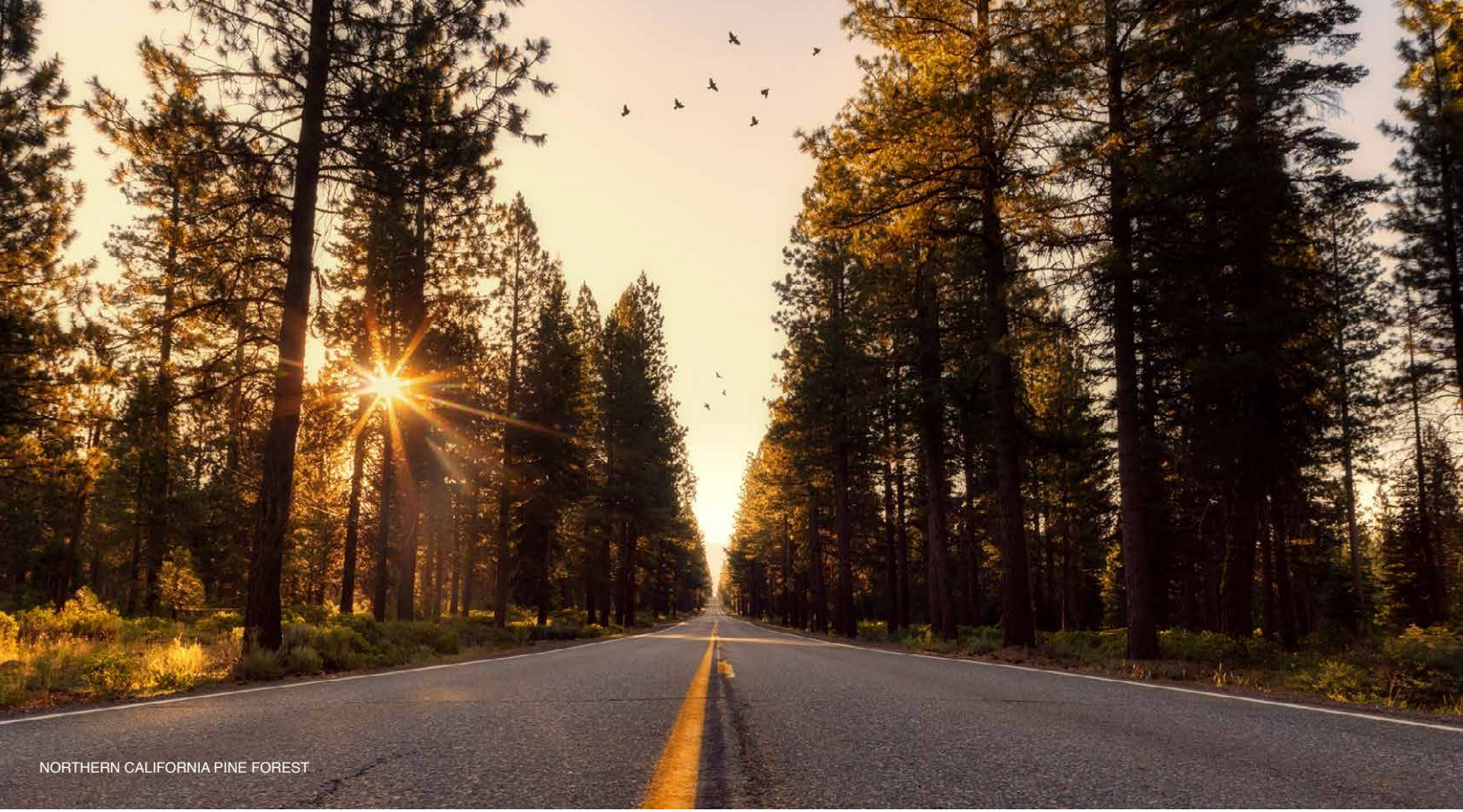
Estuaries are located at the interface where rivers meet the sea, creating unique ecosystems with complex physical and biological processes. Coastal wetlands provide essential ecosystem services to people, including flood protection from high tides and storm surges, commercial fisheries, carbon

CALIFORNIA COASTAL WETLANDS

sequestration, improved water quality, and wildlife food and habitat. Coastal wetlands are also home to hundreds of migratory and resident wildlife species including threatened and endangered species of management concern. Wetlands also have the unique ability to increase their elevation relative to sea-level rise, thereby protecting nearby communities from flooding. In California, prolonged drought and extreme storm events are projected to increase with climate change and when coupled with sea-level rise the impacts could be severe.

This project will leverage and analyze long-term biological and physical datasets as they relate to drought and extreme storm events to improve our understanding of how these events impact habitat persistence and resilience. Specifically, this project will look at storms and warm ocean temperatures related to El Niño and the 2016 and 2017 atmospheric river storms which resulted in record-breaking floods throughout California. In addition, this project will investigate how drought conditions since 2012 changed the function of the coastal wetland system. The project has three main objectives: (1) assess data on weather, water levels, salinity, and water quality to examine drought and storm conditions in estuaries; (2) examine the relationship between physical and wetland biological data; and (3) develop a systems model to help inform how tidal wetland processes are impacted during these types of climatic events, a key management question identified by resource managers.

This topic has been identified as a key management concern and the results from this project will help reduce uncertainty about extreme event impacts. This information will inform on-the-ground decision making by federal, state, and local land managers throughout the coastal zone.



NORTHERN CALIFORNIA PINE FOREST

# CONTINUING PROJECTS

**Leaf to landscape: understanding and mapping the vulnerability of forests to hotter droughts**

Principal Investigator: Koren Nydick, National Park Service

**Pyramid Lake Paiute Tribe traditional knowledge and climate change adaptation**

Principal Investigator: Karletta Chief, University of Arizona

**Building partnerships to increase tribal capacity for climate change adaptation planning**

Principal Investigator: Gregg Garfin, University of Arizona

**Supporting conservation planning for landscapes in the Southwest**

Principal Investigator: Matt Grabau, Desert Landscape Conservation Cooperative

**Hydrologic response of atmospheric river events in the Salt and Verde river basins: climatology and possible future changes**

Principal Investigators: Francina Dominguez, University of Illinois, Urbana-Champaign; Juan Valdes, University of Arizona

**Impact of drought on waterbird wetland habitats, bioenergetics, and movements in the Central Valley of California**

Principal Investigators: Joseph Fleskes, United States Geological Survey; Matthew Reiter, Point Blue Conservation Science

**Can management increase forest resistance to drought?**

Principal Investigator: James Thorne, University of California, Davis

**Producing impactful science: the effect of stakeholder engagement strategies on the use of climate science in management decisions**

Principal Investigator: Alison Meadow, University of Arizona

**Relations among cheatgrass-driven fire, climate, and sensitive-status birds across the Great Basin**

Principal Investigator: United States Forest Service; Erica Fleishman, University of California, Davis

**A coastal site network for advancing understanding and prediction of climate change effects on nearshore ecosystems: integrating interdisciplinary process studies**

Principal Investigators: Karen Thorne, United States Geological Survey; Glen MacDonald, University of California, Los Angeles

**Development, delivery, and application of data on climate extremes for the southwestern United States**

Principal Investigator: Erica Fleishman, University of California, Davis

**Evaluating the impact of climate science produced in the Southwest Climate Science Center on resource management agency decisions**

Principal Investigator: Alison Meadow, University of Arizona

CALIFORNIA EGRET BY RENNETT STOWE

KARLETTA CHIEF BY RAINA RAMIREZ

# SPECIAL PROJECT | TRIBAL ENGAGEMENT

**Southwest Tribal Climate Change Assessment Final Report**

Link: **http://www.nncap.arizona.edu/sites/default/files/pdf/NNCAP%202017%20Southwest%20Tribal%20Climate%20Change%20Assessment.pdf**

Of the 567 federally recognized tribes in the United States, 194 reside within the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah. This Tribal Climate Change Assessment helps to inform state and federal agencies as well as researchers on how they can better support climate adaptation planning of Native Nations. This report highlights recent climate-related activities undertaken by Native Nations, needs for science-based support, and areas for partnership.

The Native Nations Climate Adaptation Program (NNCAP) was founded in 2015 with the mission to build capacity to work collaboratively with Native American tribes and indigenous populations in the western United States and Mexico. NNCAP received funds from the DOI Southwest Climate Science Center (USGS Grant/Coop Agreement G15AP00172) to carry out a “Tribal Adaptation Initiative.” One of the objectives of this initiative was to conduct a preliminary assessment of tribal interest and capacity for adaptation across the Southwest.

**Summary of Key Findings and Recommendations:**
Twenty-six Native Nations participated in the NNCAP tribal climate change assessment and reported a wide array of involvement in climate change initiatives.

**Climate Change Adaptation and Mitigation Initiatives**

- Thirteen Native Nations indicated their involvement in activities focused on climate change. A number of them noted the importance of tribal council support for and involvement in climate change adaptation.
- Thirteen Native Nations have conducted some form of engagement, training, outreach, or workshops related to climate change.

- Four types of plans have been developed or are under development by Native Nations: climate change vulnerability analysis (CCVA), climate change adaptation plan (CCAP), emergency response plan (ERP), and drought, heat and/or flood plans (DHFP). The ERP was the most common type of plan developed or in development by Native Nations.
- Sixteen Native Nations have implemented some form of adaptation initiatives and strategies. The most common strategies mentioned in the interviews were associated with wildfire, water, air quality issues, and changes in availability of traditional cultural resources.
- Eleven Native Nations have actively deployed various mitigation strategies. Of these 11, some have implemented multiple initiatives to mitigate the impacts of climate change in their communities and on their lands.
- Native Nations could benefit from federal policies and programs that promote mitigation initiatives such as renewable energy resource development, energy efficiency, and sustainable infrastructure.

**Partnerships**

- Eighteen Native Nations have existing or previously established partnerships with various groups including federal and local government agencies, universities, non-profit organizations, private consultants, and other tribal governments and inter-tribal organizations to address climate change issues. Many of these Native Nations have formed collaborative relationships with multiple groups and organizations.
- The most common partnership was between Native Nations and universities. Thirteen Native Nations have collaborated with universities in Arizona, California, and Colorado to obtain various levels of education and training, planning support, and technical assistance.
- Many Native Nations engaged in partnerships with federal and local government agencies. Eight Native Nations have collaborated with multiple federal government agencies on a range of initiatives, including resource management projects, climate change adaptation planning, and outreach efforts.
- Some Native Nations have also formed partnerships with non-profit organizations, private consultants, and other tribal governments and inter-tribal organizations. Five Native Nations have worked with consultants to support climate change initiatives. There is need for partnerships that build capacity, provide opportunities for collaboration, and develop more effective policies and agreements for data sharing.

**Funding**

- A majority of the 26 Native Nations have received some level of federal funding to support climate change planning and some have acquired financial support from multiple sources. Of the 26 Native Nations, 17 have utilized various EPA grants and ten of these Native Nations specifically referenced the EPA General Assistance Program (GAP) as their primary source of funding to build capacity.
- Native Nations could benefit from a simplified grant application process, increased funding timelines, funding opportunities for implementation of strategies, and funding for tribal staff to carry out climate change planning.

**Capacity and Technical Assistance**

- All 26 Native Nations discussed challenges with initiating or advancing climate change planning due to a lack of resources and capacity. Many Native Nations are in various stages of planning and conveyed a range of technical assistance needs (e.g., dedicated staff and strategic planning expertise) to support adaptation planning and implementation.
- Many Native Nations stated a need for available, accessible, and useable scientific information, such as local climate data, modeling, and species information to help analyze impacts and vulnerabilities.
- A few Native Nations stated a need for support for outreach initiatives to communicate information and educate communities and leaders about the local effects of climate change.

GLEN CANYON NATIONAL RECREATION AREA, LAKE POWELL, ARIZONA UTAH BORDER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