Kane and Two Mile Research and Stewardship Partnership

Five-Year Report

2012-2016

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Cover Photo: Vermilion Cliffs National Monument (2016), Cerissa Hoglander, Grand Canyon Trust

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About the Research and Stewardship Partnership

The Kane and Two Mile Research and Stewardship Partnership (RSP) is a multi-stakeholder collaborative group formed in 2012 to generate knowledge, information, and tools that can inform sustainable resource management practices on the Kane and Two Mile Ranches – collectively known as the North Rim Ranches – an 830,000-acre landscape of predominantly federally-managed public lands north of the Grand Canyon. The 2012 Memorandum of Understanding (MOU) includes the non-profit organization Grand Canyon Trust; Bureau of Land Management and U.S. Geological Survey (Department of Interior); the North Kaibab Ranger District of the Kaibab National Forest, U.S .Forest Service (Department of Agriculture); the state wildlife agency Arizona Game and Fish Commission; Northern Arizona University; and University of Arizona.

The goals of the RSP are to:

- Establish a public-private partnership centered on the Kane and Two Mile Ranches that will develop, test, and deliver long-term perspectives and guidance to federal lands management challenges by bringing together citizens, scientists, and agencies to share human and financial resources and conduct rigorous management-relevant research.
- Bring added science and information-development capacity to land and wildlife managers to facilitate stewardship and/or restoration activities that achieve desired future conditions identified in resource management plans.
- Develop and implement mechanisms that enable effective and efficient collaborative and science-based adaptive management among multiple entities working on the Kane and Two Mile Ranches and on the Colorado Plateau.
- Develop a suite of tools and data products that will contribute toward anticipating and managing the implications of rapid environmental change of federal land on the Colorado Plateau and across the western United States.
- Facilitate the development of educational opportunities that will bring students at various educational levels onto the public and private lands of the Kane and Two Mile Ranches for the purposes of study, outdoor education, and service learning activities, particularly as part of interdisciplinary, organized programs that address mutually agreed-upon objectives in land and resource stewardship.

The RSP continues to support and conduct scientific research relevant to land management on the North Rim Ranches as guided by the Applied Research Plan and engages in on-the-ground stewardship actions on this landscape. The Applied Research Plan was drafted in December 2011 and is a detailed research agenda designed to inform land and resource management using science to enhance the ability of management agencies to work with their partners and the public to integrate conservation objectives with the sustainable use of public lands. The document includes research topics such as reference conditions, livestock management, wildlife habitat, cheatgrass invasion, restoring arid and semi-arid rangelands, and adaptive management tools.

For more information about the RSP, please see the Grand Canyon Trust's website: www.grandcanyontrust.org/research-and-stewardship-partnership.

The Memorandum of Understanding, including the goals of the RSP, is available at this website: www.grandcanyontrust.org/sites/default/files/resources/RSP_MOU_17FEB2012.pdf.

The Applied Research Plan is available at this website: www.grandcanyontrust.org/sites/default/files/NRR_Grand_Canyon%20Trust_2011_Applied%20Research_Plan.pdf.

About the Kane and Two Mile Ranches

The North Rim Ranches, comprised of the Kane Ranch and Two Mile Ranch, are approximately 830,000 acres of predominantly public land bordering Grand Canyon National Park and Navajo Nation. The Ranches are bound by livestock grazing permits held by the Grand Canyon Trust and operated by Plateau Ranches. The Kane Ranch permit is managed by the U.S. Forest Service (USFS) and includes over 470,000 acres of the North Kaibab Ranger District. The Two Mile permit is managed by the Bureau of Land Management (BLM) and includes its Arizona Strip District lands and the Vermilion Cliffs National Monument. Grand Canyon Trust owns approximately 1,000 acres of private lands within this boundary, including the historic Kane Ranch Headquarters.

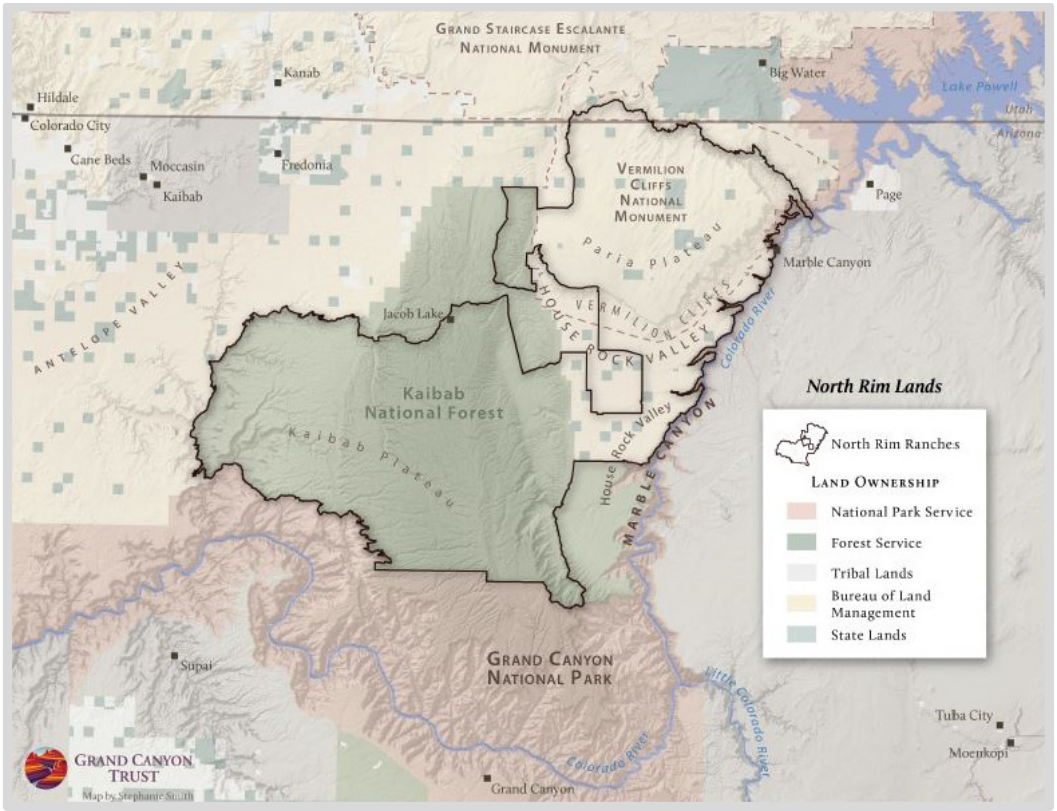

Figure 1 - The North Rim Ranches landscape is comprised of predominantly public lands north of the Grand Canyon.

Introduction

This document presents a summary of the work that we as a partnership have accomplished in the last five years, 2012-2016. This report begins with updates on management and planning that affect the land and resource management of the Ranches and on the ranching operation (*Management and Planning Updates*). We also summarize the ranching operation over this time period and describe our conservation-based approach to stocking rates and rotational patterns (*Ranching Operation Updates*). We then outline research and stewardship activities that we have completed or are continuing to work on together on the Kane and Two Mile Ranches (*Research Projects* and *Stewardship Projects*, respectively). These range from mitigating the spread of invasive cheatgrass, to using motion-activated cameras to track wildlife, to restoring spring ecosystems. We organize updates for research activities by the six research approaches outlined in the Applied Research Plan and note specific research questions addressed in each project description. We then highlight stewardship projects and also link them back to research goals. In *Appendix A*, we include administrative items specific to the RSP that cover various processes, including onboarding new research projects and communications within the partnership. We anticipate progress reports like this one to be made available regularly, approximately every five years, moving forward.

Management and Planning Updates

During the 2012 to 2016 period, the Kaibab National Forest revised its 1988 management plan and the 2001 Kane Ranch Allotment Management Plan, which updated the management frameworks for the USFS-managed Kane Ranch lands. Then-monument manager Kevin Wright also drafted the Vermilion Cliffs National Monument Science Plan, setting forth a strategy for science-informed management of the national monument, including the BLM-managed Two Mile Ranch lands. These actions are detailed below.

YEAR	MANAGEMENT OR PLANNING ACTION
2013	**Kane Ranch Allotment Management Environmental Assessment** The NEPA-based Environmental Assessment (EA) for the Kane Ranch was completed in 2013 to guide grazing management on these USFS-managed lands. This EA served as the basis for the 2015 revision of the Kane Ranch Allotment Management Plan. The EA gathered information on whether and in what manner to re-authorize cattle grazing, what mitigation measures would be needed, and what monitoring would be required within the context of several proposed alternative actions. While there is no formal link to the 2011 Applied Research Plan, most of its major research topics are referred to in the Kane EA. *Website: data.ecosystem-management.org/nepaweb/nepa_project_exp.php?project=37319*
2014	**Vermilion Cliffs National Monument Science Plan** This National Conservation Lands System Science Plan summarizes the past science, current science needs, and the strategy for integrating science into the management of the Vermilion Cliffs National Monument. It specifically states objectives to support the 2011 Applied Research Plan as well as the Friends of The Cliffs Science Strategy and Plan, the Kaibab-Vermilion Cliffs Heritage Alliance mission, and scientific investigations into landscape-level stressors on monument objects, including climate change, among others.

	Website: www.blm.gov/documents/arizona/public-room/strategic-plan/vermilion-cliffs-national-monument-science-plan OR www.blm.gov/sites/blm.gov/files/documents/files/Vermilion%20Cliffs%20National%20Monument%20Science%20Plan%20-%20Final.pdf
2014	**Kaibab National Forest Land and Resource Management Plan** The 2014 Kaibab National Forest Land and Resource Management Plan provides overall guidance for management of the Kane Ranch. Guidelines include balancing livestock numbers with resource capacity, monitoring of resource use to adjust management as need be, limiting forage utilization to 30-40%, and a commitment to an adaptive management framework. *Website: www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3791580.pdf*
2015	**Kane Ranch Allotment Management Plan** The 2015 revision of the Kane Ranch Allotments Management Plan (AMP), informed by the 2013 Kane Ranch Allotment Management EA, was completed in December 2015 and is in effect through 2025. In addition to guiding livestock management, this plan outlines various work on springs and lakes restoration, fence rehabilitation, stock pond lining, and waterline repair that will be implemented over the time period of the plan. The AMP is related to the 2011 Applied Research Plan through its emphasis on research as the basis for adaptive management of livestock grazing and through its commitment to using research results to guide the next round of grazing decisions, especially (but not limited to) on the Central Winter Allotment.

Ranching Operation Updates

Livestock grazing on the North Rim Ranches follows a conservation-oriented, rest-rotational grazing pattern that is guided by the agencies and the respective Allotment Management Plans. A rest-rotation strategy means that any open and active pasture is grazed only every other year. Within the pastures open for grazing, the rotation is further directed by research and restoration goals. The grazing rotation on the Ranches is divided into seasonal summer and winter pastures. Summer pastures are on the top of the Kaibab Plateau; livestock grazing alternates between two large pastures so that one year of use is followed by one year of rest. In winter, livestock are divided among the House Rock Valley and Paria Plateau pastures. The number of livestock, the timing of grazing season, and the related rotational grazing pattern are based on adaptive management practices and are revised as needed to respond to changes in resource conditions such as available water, drought, wildfire or declining/improving vegetation conditions.

Over the 2012-2016 period, the number of livestock grazed on the open pastures of the Ranches was limited to 600 head (including cow-calf pairs) due to conservation concerns, representing about 60% of allowable use. On the USFS-managed Kane Ranch lands, the Kanab Creek Allotment is permanently closed to grazing due to poor rangeland conditions and protection of archaeological sites. The five pastures of the Central Winter Allotment, mostly open to grazing through the period covered by this report, were closed to grazing in 2015 and will not re-open until the stock water system is repaired and operational, the existing allotment and pasture fences are repaired to functional condition, and analysis of monitoring data suggest that rangeland conditions are improving and the spread of invasive cheatgrass [*Bromus tectorum*] in the area is unlikely to be exacerbated when livestock grazing is resumed. On the Kane Ranch allotments, forage utilization was limited to 30-40% and, in Northern

Goshawk habitat and Mexican Spotted Owl foraging areas, utilization was limited to 20%.

On the BLM-managed Two Mile Ranch lands, the pastures of the Soap Creek Allotment along the base of the Vermilion Cliffs have been little-used for grazing by informal agreement with rancher Justun Jones over the period covered by this report, while the Badger Creek Allotment has restricted grazing due to resource concerns. The River pasture along the Paria River is completely closed to grazing. On the Two Mile Ranch allotments, forage utilization was limited to 45-50%.

The ranch operation is run by Justun Jones through Plateau Ranches. This includes infrastructure maintenance such as the Riggs Corral rebuild on Kane Ranch and fence, waterline, and well maintenance across the ranches. In addition, Justun supports research projects including the rebuild of the Little Mountain waterline to support the Southwest Experimental Garden Array Research (2016, see below) and the experimental grazing work associated with the Greenstrips project (2014-2016, see below).

Summary of Progress

Below we arrange the research and stewardship projects proposed, in progress, or completed during the 2012-2016 period by Applied Research Plan research question. Each of the projects listed below are detailed in the *Research Projects* and *Stewardship Projects* sections of this document. Research questions in red below represent priority questions. Only the research questions addressed during the 2012-2016 period are included below. For a full list of the research questions, please see *Appendix B*.

Table 1 - Summary of Applied Research Plan research questions addressed by research and stewardship work 2012-2016.

	RESEARCH QUESTION	PROPOSED	IN PROGRESS	COMPLETED
	Livestock Management and Soils/Vegetation			
1	Establish reference conditions, update ecological site descriptions, and develop State and Transition Models.	-	(1) Paria Plateau Ecological Site Descriptions	(1) Flora of Vermilion Cliffs
5	Influence of livestock management on the effectiveness of native species restoration efforts.	-	-	(1) Greenstrips
	Livestock Management and Wildlife			
1	Nutritional and habitat needs of wildlife, including special-status species, e.g., bighorn sheep, mule deer, chisel-toothed kangaroo rat, California condor, and pronghorn and influence of livestock management on population recruitment and forage and habitat availability for wildlife.	(1) Mule Deer Diet Quality	-	(3) Vermilion Cliffs Songbird and Bat Surveys, East Monocline Wildlife Surveys, Kaibab Plateau Mule Deer Habitat Study
2	Behavioral interactions and space use of livestock, mule deer, bison, and desert bighorn sheep.	-	-	(2) East Monocline Wildlife Surveys, Kaibab Plateau Mule Deer Habitat Study
3	Additive effects of livestock management on wildlife in concert with other factors (e.g., climate change, prescribed and/or wildfire, etc.).	(1) Livestock Early Warning System	-	-
	Revegetation and Restoration Techniques			

1	Efficacy of treatments intended to re-establish or otherwise benefit native/ desirable plant species. (e.g., effects of seeding rate and soils on seeded species establishment, plant community responses to tree mastication in pinyon-juniper woodland, identification of plant species that can compete with highly aggressive non-natives [e.g., cheatgrass]).	-	(1) Native Seedling Establishment	(2) Greenstrips, Seed Technologies
3	Development of predictive models for strategic placement of restoration/mitigation treatments.	-	-	(1) Cheatgrass-fueled Fire Connectivity
	Invasive Plants			
1	Physiographic, climatic, and other factors (e.g., management practices) affecting plant community susceptibility and establishment/spread of invasive plants. (Particularly on the west side of the Kaibab Plateau).	-	(1) Native Seedling Establishment	(1) Cheatgrass-fueled Fire Connectivity
4	Influence of fuels treatments and fire management on invasives.	-	-	(1) Cheatgrass-fueled Fire Connectivity
	Wildlife Ecology			
1	Identification of species most sensitive to changes in land use and climate.	-	(1) Southwest Experimental Garden Array	(1) Vermilion Cliffs Songbird and Bat Surveys
2	Response of Kaibab mule deer to wildfire and management-related habitat changes on the west-side winter range.	-	-	(1) Kaibab Plateau Mule Deer Habitat Study
4	Influence of environmental and anthropogenic factors on habitat connectivity.	-	(1) East Monocline Wildlife Surveys	(1) Pronghorn fencing
5	Identification of movement pathways for species of high conservation value.	-	-	(1) East Monocline Wildlife Surveys
	Monitoring			
1	New tools to design and monitor at landscape level (e.g., remote sensing techniques for monitoring invasive species, plant productivity, etc.).	(1) Livestock Early Warning System	-	-
	Climate Change			
2	Predicted trajectories in soil conditions and plant communities under various climate change scenarios.	-	(1) Southwest Experimental Garden Array	(1) Climate Change Adaptation Plan
	Springs and Seeps Restoration and Management			
1	Identifying best practices for maintaining ecosystem function/water availability at springs and seeps while also providing water for livestock and wildlife.	-	-	(2) Vermilion Cliffs Springs, Fencing Natural Lakes
3	Options for restoring springs and seeps.	-	-	(2) Vermilion Cliffs Springs
	Riparian Restoration			

2	Efficacy of methods for removing invasive woody species (e.g., biological control of tamarisk).	-	-	(1) Paria River Tamarisk Removal
3	Effects of invasive woody species removal on native plants, animals, and ecosystem functions.	-	-	(1) Paria River Tamarisk Removal

Research Projects

Establishing Reference Conditions and Refining Ecological Site Descriptions

The 2011 Applied Research Plan described a need to understand and clarify reference conditions and ecological site potential across the North Rim Ranches. Ecological Site Descriptions, as defined by the Natural Resources Conservation Service, and the USFS equivalent, Terrestrial Ecosystem Units, are fundamental units for monitoring, assessment, and planning management actions. This data would identify desired plant communities and other desired conditions, and guide management objectives and actions. While four roughly 45-year old livestock exclosures exist on the Ranches (two on Paria Plateau and two in House Rock Valley) and provide valuable reference conditions, the small number and area covered by these exclosures limit the inference that can be drawn from these, given the wide range of soil and ecological site types that occur.

Since 2012 there has been an effort to update the ecological site descriptions for the Paria Plateau which demonstrate the potential vegetation for a site based on soil, physical, chemical, and climate factors. To characterize the current vegetation, an inventory of the flora on the Vermilion Cliffs National Monument was completed in 2014. For wildlife, a 2013-2015 study inventoried the songbird and bat species on the Paria Plateau.

Paria Plateau Ecological Site Descriptions (In Progress)

In January 2013, the Natural Resources Conservation Service (NRCS) shared an update with the RSP that the original soil survey for the Paria Plateau had inaccurate climate, soil, and ecological site mapping and therefore did not meet the needs of the Bureau of Land Management (BLM) and other users of these data. The revised survey effort, completed in 2013, resulted in two Land Resource Unit (LRU) categories and nine ecological sites, including two new soil types. The original, inaccurate survey had just one LRU and two ecological sites. Ecological sites are assigned based on soil, physical, chemical, and climate characteristics – not on current vegetation but rather what the soil itself can support (e.g., if soil and climate factors are ideal for a particular plant, but the plant is not present, another factor or disturbance must be present). Using this information, the NRCS will create state-and-transition models to inform management. Once the ecological site description work is completed, the BLM has planned to revisit key areas to determine how current plant communities differ from desired or potential plant communities prior to updating the Land Health Assessment for the Sand Hills Allotment, part of the Two Mile Ranch.

RESEARCH QUESTIONS ADDRESSED

Livestock Management and Soils/Vegetation:

1. Establish reference conditions, update ecological site descriptions, and develop state-and-transition models.

Flora of Vermilion Cliffs (Completed 2014)

The Flora of Vermilion Cliffs project, 2011-2014, was led by graduate student Amy Prince at Northern Arizona University and supported by the National Fish and Wildlife Foundation, BLM, Friends of The Cliffs, and the National Landscape Conservation System's Research Support Program, as well as Brigham Young University, the Desert Botanical Garden, and the Arizona Natural Heritage Program within the Arizona Game and Fish Department. This project was an effort to collect, inventory, and map specimens and populations of little-known flora across the remote reaches of the Vermilion Cliffs National Monument. The project included a Budding Botanist training through the Grand Canyon Trust where 47 volunteers were trained as citizen scientists and, through eight volunteer-driven field trips, they supported the addition of over 2,500 new collections to the regional online database. These plant collections also yielded 30 new populations of the narrow endemic Paria Plateau pincushion cactus (*Sclerocactus sileri*), two locations for the endangered Welsh's milkweed (*Asclepias welshii*), and one location of a narrow Grand Canyon National Park endemic (*Euporbia aaron – rossii*). Although one of the project's objectives was to construct statistical habitat models for *Pediocactus bradyi*, *Pediocactus paradenei*, *Sclerocactus sileri*, *Asclepias welshii*, and *Mentzelia memorabilis*, not enough individuals of each were located to construct these models. The project did, however, generate habitat models for associated species which were intended to serve as a first approximation for future efforts.

A final grant report was sent from the Grand Canyon Trust to the National Fish and Wildlife Foundation in 2015, and 4,946 plant records were added to SEINet data portal (swbiodiversity.org/seinet/).

RESEARCH QUESTIONS ADDRESSED

Livestock Management and Soils/Vegetation:

1. Establish reference conditions, update ecological site descriptions, and develop state-and-transition models.

Vermilion Cliffs Songbird and Bat Surveys (Completed 2015)

As the threat of the lethal White-nose Syndrome (a disease caused by a white fungus, *Pseudogymnoascus destructans*, which disrupts hibernation) moves west across the United States, understanding the diversity and distribution of bat species in this region is a critical first step in conservation management. Songbird species data can also inform conservation management and be used as an important indicator of species diversity. Between 2013 and 2015, Grand Canyon Trust worked with BLM, O'Farrell Biological Consulting, and the non-profit Friends of The Cliffs to develop foundational datasets on native bat and songbird species diversity on the Paria Plateau. Grand Canyon Trust collected bat presence data using Anabat acoustic monitors (Anabat Bat Detector, Titley-Scientific, *www.titley-scientific.com/us/sd2-with-stainless-microphone.html*, accessed Spring 2017) placed at 29 of the Grand Canyon Trust's Baseline Assessment points on the Paria Plateau. The study detected 19 native bat species on the Paria Plateau out of the 28 known species in the state of Arizona (Arizona Bat Information, Arizona Game and Fish Department, *www.azgfd.gov/w_c/bat_conserv_az_bats.shtml#azbats*, accessed Spring 2017). During the summers of 2013 and 2015, the Trust worked with interns to document songbird species at 32 of the Grand Canyon

Trust's Baseline Assessment points and identified over 20 native songbird species. These datasets will be cross-walked with other spatial data in a Geographic Information System to map species distribution. The final results will be shared land managers through maps and reports, and with the greater public through songbird and bat public data forums.

RESEARCH QUESTIONS ADDRESSED

Livestock Management and Wildlife:

1. Nutritional and habitat needs of wildlife, including special-status species, e.g., bighorn sheep, mule deer, chisel-toothed kangaroo rat, California condor, and pronghorn and influence of livestock management on population recruitment and forage and habitat availability for wildlife.

Wildlife Ecology:

1. Identification of species most sensitive to changes in land use and climate.

Testing Livestock Management Strategies on Arid and Semi-Arid Public Lands

The management of livestock grazing can influence native plant communities and soil conditions across the arid and semi-arid grassland regions of the ranches: House Rock Valley and the Paria Plateau. The Applied Research Plan outlined a need to better understand which livestock management strategies can most effectively lead to meeting desired ecological conditions across these landscapes. The current rest-rotation grazing pattern used has been in play since 2009 and will continue to be employed on the ranches. No research projects on this topic were conducted during the 2012-2016 period.

Effects of Range Management on Wildlife

The livestock grazing operation on the ranches can influence the use and movement of wildlife across the landscape. The 2011 Applied Research Plan identified the influence of forage utilization by livestock, the distribution of water and fences, and vegetation management on the pronghorn population in House Rock Valley as one of the most significant management concerns. Other significant management concerns included: the effect of range management on mule deer habitat; the effect of forage use by livestock on the food, cover, and other habitat attributes of wildlife species, especially sensitive species; and the impact of infrastructure on wildlife habitat use and survival.

To address these concerns, the RSP has worked with researchers on projects characterizing wildlife presence and habitat connectivity on the Ranches. In 2014 and 2015, wildlife camera traps were used to detect wildlife presence and understand wildlife habitat along the East Monocline and on top of the Kaibab Plateau. These studies helped to identify important connectivity pathways, document habitat use, and understand seasonal herd movements.

East Monocline Wildlife Surveys (Completed 2014)

In 2013, the Grand Canyon Trust and volunteers worked with Conservation Science Partners and Northern Arizona University to test spatial models of habitat connectivity on the ground using 44

motion-triggered wildlife cameras across five sites along the East Monocline of the Kaibab Plateau. This camera trapping pilot study resulted in 969 wildlife detections including several detections of mountain lion (*Puma concolor*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), bighorn sheep (*Ovis canadensis*), bobcat (*Lynx rufus*), and coyote (*Canis latrans*). It also laid the groundwork for a 2015 camera trapping effort led by a Northern Arizona University graduate student (see *Kaibab Plateau Mule Deer Habitat Study* below).

RESEARCH QUESTIONS ADDRESSED

Livestock Management and Wildlife:

1. Nutritional and habitat needs of wildlife, including special-status species, e.g., bighorn sheep, mule deer, chisel-toothed kangaroo rat, California condor, and pronghorn and influence of livestock management on population recruitment and forage and habitat availability for wildlife.
2. Behavioral interactions and space use of livestock, mule deer, bison, and desert bighorn sheep.

Wildlife Ecology:

4. Influence of environmental and anthropogenic factors on habitat connectivity.
5. Identification of movement pathways for species of high conservation value.

Kaibab Plateau Mule Deer Habitat Study (Completed 2016)

During the summer (June-August) of 2015, Northern Arizona University graduate student Jackie Thomas, supported by Grand Canyon Trust volunteers and university staff, led the data collection for mule deer seasonal movement and other wildlife species distributions on the Kaibab Plateau using 100 motion-activated wildlife camera traps. This project collected 107,137 images of wildlife representing 28 different wildlife species or taxa. Northern Arizona University researchers, led by Dr. Brett Dickson, used these detections to estimate probability of detection and occupancy across the Kaibab Plateau. Mule deer and cattle occupancy peaked in mid-July (probability of occupancy = 0.74 and 0.83, respectively) while other species occupancy increased from the beginning to the end of the study period. In addition, researchers compared occupancy with environmental variables to determine driving factors of wildlife presence on the Kaibab Plateau. Researchers found that for all wildlife, there was a higher likelihood of a detection in areas with more dominant vegetation richness, farther from roads, and/or with greater canopy cover. Researchers also noted that cows were detected in areas with more open canopy (strong negative relationship between cow detections and canopy cover). These datasets have provided foundational data for wildlife presence on the Kaibab Plateau, demonstrated the utility of wildlife camera traps, and have also provided volunteer opportunities for the broader public to participate directly in wildlife conservation efforts.

Related publications: Dickson, B.G., C. Ray, V. Horncastle, and J. Holm. 2016. Measuring and monitoring patterns of wildlife habitat occupancy on the Kaibab Plateau, northern Arizona. Landscape Conservation Initiative, Northern Arizona University, Flagstaff, AZ. 17pp.

RESEARCH QUESTIONS ADDRESSED

Livestock Management and Wildlife:

2. Nutritional and habitat needs of wildlife, including special-status species, e.g., bighorn sheep, mule deer, chisel-toothed kangaroo rat, California condor, and pronghorn and influence of livestock management on population recruitment and forage and habitat availability for wildlife.
3. Behavioral interactions and space use of livestock, mule deer, bison, and desert bighorn sheep.

Wildlife Ecology:

2. Response of Kaibab mule deer to wildfire and management-related habitat changes on the west-side winter range.

Mule Deer Diet Quality (Proposed 2015)

Led by Dr. Doug Tolleson (then University of Arizona, now Texas A&M University), the Mule Deer Diet Quality project has worked to assess diet quality for mule deer in Arizona based on a near-infrared spectroscopy (NIRS) analysis of scat fecal nitrogen and fecal phosphorus using a multi-species ruminant calibration. In 2015, Doug indicated that they are still working on the appropriate ruminant calibration (for example, domestic sheep or goats) for mule deer and pronghorn. While this work has shown that NIRS can be used to monitor fecal nitrogen, protein and digestibility need additional work. The goal of this ongoing pilot study was to apply this approach as a broader statistical array of seasonal habitat sampling rather than just opportunistic sampling. This approach remains a potential tool for application in future research projects.

This study was conducted on the V-bar-V Ranch, as part of the V-bar-V Range Program at University of Arizona. More information about this project can be found here: cals.arizona.edu/vbarv/rangeprogram/research/kaibab-mule-deer-diet-quality

Related publications: Vance, C.K., D.R. Tolleson, K. Kinoshita, J. Rodriguez, and W.J. Foley. 2016. Near infrared spectroscopy in wildlife and biodiversity. Journal of Near Infrared Spectroscopy. Accessible here: journals.sagepub.com/doi/pdf/10.1255/jnirs.1199

RESEARCH QUESTIONS ADDRESSED

Livestock Management and Wildlife:

1. Nutritional and habitat needs of wildlife, including special-status species, e.g., bighorn sheep, mule deer, chisel-toothed kangaroo rat, California condor, and pronghorn and influence of livestock management on population recruitment and forage and habitat availability for wildlife.

Environmental and Management Factors Influencing Cheatgrass Invasion

The 2011 Applied Research Plan identified a need to prioritize where and how limited management resources can be allocated in the most efficient and effective ways to address invasive cheatgrass (*Bromus tectorum*), an introduced annual grass that is widely dispersed across the western United

States. The intrinsic climate-driven properties of cheatgrass can fundamentally influence and alter a fire regime by changing the timing of fire occurrence, increase the continuity of fuels and increase the extent and rate of wildfire movement. The Applied Research Plan also stated that there is a need to better understand how management of livestock grazing, recreation, wildlife habitat, and vegetation affect cheatgrass abundance and spread.

The 2005-2006 Baseline Assessment, a comprehensive ecological assessment focused on characterizing the rangeland, forest, and water resource conditions across the entire landscape, informed a 2006 computer model of cheatgrass spread across the Ranches. In 2014, Northern Arizona University researchers used this data to model the spread of wildfire via invasive cheatgrass for the Kaibab Plateau and identified potential places to focus restoration.

Cheatgrass-fueled Fire Connectivity Modelling (Completed 2014)

Using vegetation data from the 2005 Baseline Assessment, researchers at Northern Arizona University's Lab of Landscape Ecology and Conservation Biology modeled the phenologic and fuel-related properties of cheatgrass in a Geographic Information System to model the potential firescape, or landscape of wildfire potential based on fuels connectivity, across the West Side of the Kaibab Plateau. The models found 68 cheatgrass patches (ranging from 0.1-96 km^2 [10-9,600 hectares] in size), highlighted the patches that were most central to firescape connectivity, and identified "pinch points" or narrow areas of high connectivity that could be potential points for using fuelbreaks to sever fuels connectivity. The results of the modeling are useful for identifying target patches of cheatgrass for restoration and locating areas for fuelbreaks that will be likely most effective. For example, the cheatgrass patches with the highest centrality occurred in the southern part of the West Side, around JumpUp Point and on the plateaus south and north of Big Sowats Canyon, and could be primary target areas for future restoration.

Related publications: Gray, M. E., B. G. Dickson. 2016. Applying fire connectivity and centrality measures to mitigate the cheatgrass-fire cycle in the arid West, USA. Landscape Ecology 31:1681-1696.

RESEARCH QUESTIONS ADDRESSED

Revegetation and Restoration Techniques:

3. Development of predictive models for strategic placement of restoration/mitigation treatments.

Invasive Plants:

1. Physiographic, climatic, and other factors (e.g., management practices) affecting plant community susceptibility and establishment/spread of invasive plants. (Particularly on the west side of the Kaibab Plateau).
4. Influence of fuels treatments and fire management on invasives.

Methods for Restoring Arid and Semi-Arid Rangelands

Restoration of semi-arid grasslands, such as in House Rock Valley, is inherently challenging because of limited and highly variable precipitation which is projected to only worsen with climate change-driven increases in aridity. The presence of invasive annual grasses, like cheatgrass on the Kaibab Plateau, also

increases the difficulty of improving grassland ecosystem health. The Applied Research Plan stated a need "to increase perennial plant cover, rejuvenate decadent shrublands, stabilize soils, and improve watershed conditions on various locations adversely affected by wildfire and historical management practices." The plan also outlined a need to understand "factors such as species selection, seeding rates, soil chemistry, and site selection which influence the efficacy of treatments intended to re-establish or otherwise benefit native and desirable plant species."

From 2014-2016, the Greenstrips project evaluated opportunities to sever the fuels connectivity of cheatgrass using native plant fuelbreaks, known as greenstrips. Within the Greenstrips project, seed-coating technologies were tested to see if they supported native seedling establishment. A common garden experiment also started in 2014 is seeking to understand the factors in restoration of sagebrush-dominated native perennial grasslands currently invaded by non-native cheatgrass.

Greenstrips: Using Greenstrips and Grazing to Weaken Cheatgrass-fire Feedbacks (Completed 2016)

Begun in 2013, the Greenstrips project is a broad-scale, multi-site study investigating restoration tools that may be able to weaken feedbacks between cheatgrass and wildfires. Cheatgrass is quick to propagate after disturbance, especially wildfire, and also increases fuels for future wildfires. Land managers use a variety of techniques to combat cheatgrass, including native plant seedings and fuelbreaks. This project evaluates the potential utility of greenstrips (fuelbreaks made of native plants), seed coating technologies, and targeted grazing as tools to weaken cheatgrass—fire feedbacks. Led by Dr. Lauren Porensky (Agricultural Research Service) and Dr. Beth Leger (University of Nevada-Reno), this project involves nine 50-acre enclosure/exclosure pairs with ten greenstrip fuelbreaks each (control plots and treatment plots) which were established on the West Side of the Kaibab Plateau (Kaibab National Forest, North Kaibab Ranger District) in 2014. Treatments include fall and spring livestock grazing, five seed treatments (including seed-coating and low and high seeding density), two watering treatments, and herbicide treatments. A parallel study site is in Nevada.

A final report is expected before the end of 2017 and follow-up monitoring is tentatively scheduled for 2019. Initial findings included that, when comparing among different resident mature perennial grasses, squirreltail grass (*Elymus elymoides*) was most effective at competing with cheatgrass. However, planted seedlings did not establish at high densities, which was in stark contrast to high establishment success at the more heavily invaded parallel site in Nevada. Seedling establishment in the Arizona site may have been limited by the greater density of already-established native perennials in Arizona – suggesting greater ecosystem resilience in Arizona than in Nevada. For the grazing treatments included in the Arizona plots, there were signals that spring grazing had slightly more perennial grass seedlings than ungrazed greenstrips. This was thought to be related to the high grazing pressure on adult native perennial grasses, which then released additional resources for planted seedlings (and also potentially for cheatgrass). Alternatively or additionally, cattle use could have improved seed-soil contact for the broadcasted seeds.

RESEARCH QUESTIONS ADDRESSED

Livestock Management and Soils/Vegetation:

5. Influence of livestock management on the effectiveness of native species restoration efforts.

Revegetation and Restoration Techniques:

1. Efficacy of treatments intended to re-establish or otherwise benefit native/ desirable plant species. (e.g., effects of seeding rate and soils on seeded species establishment, plant community responses to tree mastication in pinyon-juniper woodland, identification of plant species that can compete with highly aggressive non-natives [e.g., cheatgrass]).

Invasive Plants:

2. Influence of grazing practices and forest/woodland treatments on invasives. (Can the west side of the Kaibab Plateau or other heavily invaded areas be grazed in a way that does not spread cheatgrass [or even reduces cheatgrass] and continues to maintain or improve our native grassland vegetation?).
3. Efficacy of approaches for preventing spread of invasive plants, e.g., enhancing resilience of native communities by seeding native species, protection of soils from disturbance, seeding with non-native species, herbicidal control of invasives.

Seed Technologies: Overcoming the Limiting Factors Impairing Seeding Success on the Kane and Two Mile Ranches (Completed 2016)

Embedded within the Greenstrips project (above) was another study focused on the potential for different types of seed-coating to encourage native plant establishment, led by Dr. Matt Madsen. These seed-coating technologies included: a surfactant seed-coating which leeches into the soil and increases water access for plants after wildfire, the agglomeration of seeds into clusters to improve performance, an extruded seed meal pellet with added material which can swell and lift seeds to a better emergence position, and a similarly constructed seed pillow to support broadcast seeding success. Within the Greenstrips project, initial results suggested that various seed-coating technologies actually reduced seedling establishment success in Arizona. This reduced success was thought to be related to enhanced visibility of the coated seeds after broadcast planting, which could have encouraged loss to gramnivores.

RESEARCH QUESTIONS ADDRESSED

Revegetation and Restoration Techniques:

1. Efficacy of treatments intended to re-establish or otherwise benefit native/ desirable plant species. (e.g., effects of seeding rate and soils on seeded species establishment, plant community responses to tree mastication in pinyon-juniper woodland, identification of plant species that can compete with highly aggressive non-natives [e.g., cheatgrass]).

Native Seedling Establishment in Cheatgrass-invaded Habitats (In Progress)

This multi-year native seedling establishment in cheatgrass-invaded habitats study is led by Dr. Paul Dijkstra (Northern Arizona University) and is looking to understand the factors in the establishment of sagebrush (*Artemisia tridentata*), squirreltail (*Elymus elymoides*), and Indian ricegrass (*Achnatherum hymenoides*) seedlings in cheatgrass invaded areas, including the role of the rhizosphere, or root microbiome. This study compares burned and unburned sites to understand how fire and cheatgrass

invasion change microbial communities. The treatments within this study included exclusion of competition (i.e., cheatgrass exclusion), fertilizer (nitrogen, phosphorus, and sucrose – which has been found to counteract cheatgrass' acceleration of the nitrogen cycle), and microbial inoculation. The goal is to provide management-relevant information on sagebrush restoration in the face of cheatgrass expansion into these habitats. The project involves a large transplant garden at Jump-Up Divide on the Kaibab Plateau with undisturbed, burned, and cheatgrass-invaded plots. Seedling transplants and soil sampling are ongoing at the garden and inoculation studies are being conducted in a greenhouse off-site using soil from the Jump-Up garden. Parallel study sites are in Utah and Idaho. Initial results of this study suggest that cheatgrass does not alter microbial communities and that, while inoculation of soil microbes does seem to support growth, the effect is complex, population-dependent (i.e., dependent on the genotype used), and not very big. However, the root cloth used for the cheatgrass competition exclusion seemed to increase deep root moisture (i.e., 20-cm depth), favoring sagebrush. Compared to the Idaho and Utah sites, Arizona's sagebrush had much higher survival likely due to the unique monsoon effect in Arizona.

RESEARCH QUESTIONS ADDRESSED

Invasive Plants:

1. Physiographic, climatic, and other factors (e.g., management practices) affecting plant community susceptibility and establishment/spread of invasive plants. (Particularly on the west side of the Kaibab Plateau).

Revegetation and Restoration Techniques:

1. Efficacy of treatments intended to re-establish or otherwise benefit native/ desirable plant species. (e.g., effects of seeding rate and soils on seeded species establishment, plant community responses to tree mastication in pinyon-juniper woodland, identification of plant species that can compete with highly aggressive non-natives [e.g., cheatgrass]).

Development of Landscape Scale Tools for Monitoring Vegetation Conditions and Change

The Applied Research Plan outlined a need to develop landscape-scale monitoring tools that can support management actions through efficiently and accurate depiction and prediction of on-the-ground changes in plant communities, particularly invasive species in response to dynamic processes (e.g., climate or fire). The plan specifically highlighted monitoring tools that support the understanding of non-native plant invasion and plant community productivity to inform fire and livestock management strategies under changing land management and climate change scenarios.

In 2014, researchers from University of Arizona and Texas A&M University proposed a Livestock Early Warning System, a data-driven model of real-time and near-term drought conditions that can inform livestock management strategies and has shown success in other ranches in the Southwest. In that same year, researchers broke ground on three common gardens within the Southwest Experimental Garden Array, including exclosure fencing and weather stations, which provide research space along an elevational gradient for multiple projects evaluating plant responses to climate change. In 2016, the Grand Canyon Trust completed the North Rim Ranches Climate Change Adaptation Plan which evaluated relative climate vulnerability across the landscape, outlined climate change impacts, made

recommendations for adaptation actions, and identified overlap with USFS and BLM management strategies.

Livestock Early Warning System (Proposed 2014)

In May 2014 and November 2015, Dr. Doug Tolleson (then University of Arizona, now Texas A&M University) and colleague Dr. Jay Angerer (Texas A&M University) presented the Livestock Early Warning System (LEWS) project to the RSP. LEWS is a data-driven drought early warning system for land and ranch managers that can be used at large landscape scales, is specific to vegetation types on the ground, and can be tied in with information such as fuel models and animal nutrition (Global Livestock Early Warning System, Texas A&M University, *glews.tamu.edu*, accessed Spring 2017). Rangeland simulation modeling allows managers to move away from the need for constant on-the-ground data collection and provide a framework for fire modeling and drought monitoring. Also, stocking rates can be determined with respect to distance from water and slope position and wildlife species, e.g., deer, can be included. The LEWS incorporates the PHYGROW model, developed at Texas A&M University, which can simulate plant growth and species-specific preference-based grazing and can be coupled with the Burning Risk Advisory Support System (BRASS) a decision-making tool that incorporates near real-time weather conditions, a vegetation model, a fuel moisture simulator, a fire effects model, and a fire spread model. The data incorporated into the model includes soil characteristics, vegetation/forage characteristics (based on growth stage), grazing information, and weather data (spatially-explicit rainfall data from NEXRAD). On-the-ground vegetation transects (representing ecological sites and a North-South gradient) and clipped quadrats were used to parameterize and calibrate the model. Doug and Jay pointed to case studies at the 172,000-acre Catto-Gage Ranch in West Texas including fenceline differences with other ranches at this site as well as successes at Fort Hood, V-Bar-V Ranch, and in sites in East Africa and Mongolia.

In the November 2015 meeting, Grand Canyon Trust identified that data from the 2005 Baseline Assessment that could inform vegetation data needs for a LEWS application on the Kane and Two Mile Ranches, although ecological sites, soil data, and biomass information were also identified as needs. USFS terrestrial models and Paria Plateau ecological site descriptions can be difficult to crosswalk, but this could provide ecological site data needed for modeling. Additional resources would include field work time to collect data (e.g., biomass clippings) to calibrate the model as well as research and Geographic Information Systems time. At the meeting, Doug, Jay, and Dr. Amy Whipple (Northern Arizona University, Southwest Experimental Garden Array) committed to continue working together to determine what resources would be necessary to develop at LEWS for the North Rim Ranches landscape.

RESEARCH QUESTIONS ADDRESSED

Livestock Management and Wildlife:

3. Additive effects of livestock management on wildlife in concert with other factors (e.g., climate change, prescribed and/or wildfire, etc.).

Monitoring:

1. New tools to design and monitor at landscape level (e.g., remote sensing techniques for monitoring invasive species, plant productivity, etc.).

Southwest Experimental Garden Array (In Progress)

The Southwest Experimental Garden Array, or SEGA project, is a series of ten experimental common gardens established across an elevational gradient in Northern Arizona. Three of these gardens – Bear Springs, Little Mountain, and White Pockets – have been established on the USFS-managed land of the Kane Ranch. A fourth garden is currently being established in the Soap Creek area on land managed by the BLM. This project is led by Dr. Amy Whipple (Northern Arizona University) and coordinated by Dr. Diane Hope (Northern Arizona University) and is funded by a National Science Foundation grant. These common gardens provide the infrastructure (fencing, water with irrigation infrastructure, weather stations, and a variety of field sensors which relay data in real time back to the Northern Arizona University campus) to allow numerous studies and manipulative experiments to determine how native species respond to changing climate and to inform land management, native plant restoration, and climate adaptation action. A current list of these studies is in the table below.

The successful start of this project is attributed to the collaboration of the RSP, particularly the North Kaibab Ranger District in the assessment and permitting process and rancher Justun Jones in the water infrastructure work. Grand Canyon Trust volunteers have also contributed over 1,600 hours across five 2015 and 2016 volunteer trips to support infrastructure development, native plant transplants, and data collection for various studies. These various studies are tabulated below (Table 2).

Table 2 - Research projects within the Southwest Experimental Garden Array sites as of 2016.

PROJECT TITLE	SEGA SITE	START DATE	END DATE
Are soil organisms the key to assisted plant migrations in response to climate change?	Bear Springs, White Pockets, Little Mountain	Jun-14	Ongoing
Bee microclimates	Bear Springs, White Pockets, Little Mountain	Jun-16	Sep-17
Blending ecology & evolution using emerging technologies to determine species distributions with a non-native pathogen in a rapidly changing climate	Bear Springs, White Pockets, Little Mountain	May-15	Jul-20
Middle School Science Extension: Exploration of climate change outcomes for reciprocally transplanted lichen along an elevation gradient	Bear Springs	May-15	Ongoing
Seasonal changes in Hantavirus tissue tropism	Bear Springs	May-14	Dec-14
Ground-dwelling arthropod inventory	White Pockets	Jun-14	Dec-16

RESEARCH QUESTIONS ADDRESSED

Wildlife Ecology:

1. Identification of species most sensitive to changes in land use and climate.

Climate Change:

2. Predicted trajectories in soil conditions and plant communities under various climate change scenarios.

Climate Change Adaptation Plan Development (Completed 2016)

In the summer of 2016, Grand Canyon Trust completed a Climate Change Adaptation Plan (CCAP) for the Ranches which included a literature-based overview of the climate change projections for the southern Colorado Plateau. It crafted these projections into climate change impact scenarios specific to the Ranches: prolonged drought and reduced water resources, prolonged drought and reduced forage resources, shifting vegetation communities, loss of habitat connectivity, species-specific and livestock stresses, and increased risk of unnaturally severe wildfire and related invasive species spread. The CCAP coupled this literature review with a spatial analysis using a Geographic Information System to identify landscape-scale climate vulnerability across the Ranches. It also made scenario-specific recommendations for adaptation actions and highlighted opportunities to work with partners and align with existing agency and RSP missions to track climate change impacts, implement climate adaptation efforts, and monitor progress. The plan was shared with the RSP in the summer of 2016.

RESEARCH QUESTIONS ADDRESSED

Climate Change:

1. Predicted trajectories in soil conditions and plant communities under various climate change scenarios.

Stewardship Projects

Habitat Restoration Projects

Paria River Tamarisk Removal and Monitoring (Completed 2014)

Supported by an Arizona Water Protection Fund grant, the Grand Canyon Trust engaged in a five-year effort to remove invasive tamarisk (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*) from a 13-mile stretch of the Paria River, one of the largest and most important tributaries of the lower Colorado River system below Glen Canyon Dam. This project aimed to restore and preserve natural conditions in the Paria River Canyon and associated wilderness by decreasing the negative impacts of nonnative tamarisk and Russian olive trees and to enhance wildlife habitat by protecting and restoring native riparian vegetation through natural recruitment following treatment. It also provided an opportunity for public outreach through volunteer stewardship facilitated by the Grand Canyon Trust's Volunteer Program. A site assessment was conducted March-May 2008 over three backpacking trips. These trips established baseline reference, treatment (tamarisk and/or Russian olive present), and "beetle" (tamarisk and/or Russian olive present but not treated) transects for monitoring vegetation, soils, and active channel width. From 2008-2012, invasive species were removed and related monitoring continued in 2013-2014. Crews led by the Grand Canyon Trust's Volunteer Program removed 28,030 tamarisk and 1,601 Russian olive seedlings, saplings, and mature trees. Overall, crews removed over three acres of exotic canopy cover. Tamarisk was completely removed from six miles of the Paria River project area and intermittently from transects along an additional three and half miles of project area. Russian olive was removed from over 10.5 miles of the project area. Overall, Russian olive and tamarisk

cover decreased while species diversity increased in 2014 in treated sites more so than in untreated sites. Site monitoring and maintenance is expected to continue on an as needed basis.

RESEARCH QUESTIONS ADDRESSED

Riparian Restoration

2. Efficacy of methods for removing invasive woody species (e.g., biological control of tamarisk).
3. Effects of invasive woody species removal on native plants, animals, and ecosystem functions.

Vermilion Cliffs Springs Assessment and Restoration (Completed 2016)

In collaboration with partners Arizona Game and Fish Department, U.S. Fish and Wildlife Service, Natural Channel Design, Justun Jones, and many volunteers, Grand Canyon Trust led the restoration of three springs on private land parcels on the North Rim Ranches from 2013-2015. This effort included adding water bars to mitigate erosion during large precipitation events; removal of invasive tamarisk and annual plants; transplanting of native salt grasses, rushes, and coyote willow (*Salix exigua*); and small pool construction to increase wildlife water access. In addition, the spring box at one site was modified to incorporate a variable valve that could redirect water otherwise piped out to remain on site when not in use by the livestock. To evaluate the success of the project over time, Grand Canyon Trust and partners monitored wildlife presence using motion-activated cameras and assessed other springs condition indicators through periodic surveys. A summary of these findings is forthcoming. This pilot project provided lessons-learned to apply to other springs across the ranches. For 2017 and beyond, Grand Canyon Trust is working with the USFS and other partners to do both springs condition assessment and springs restoration across the Kane Ranch.

RESEARCH QUESTIONS ADDRESSED

Springs and Seeps Restoration and Management:

1. Identifying best practices for maintaining ecosystem function/water availability at springs and seeps while also providing water for livestock and wildlife.
3. Options for restoring springs and seeps.

Livestock and Ranch Management Projects

Pronghorn Fencing: Modifying Fences for Safe Pronghorn Passage (In Progress)

In 2013 and again in 2016, Grand Canyon Trust volunteers worked to modify fences for safe pronghorn passage around Kane Ranch Headquarters and House Rock Valley, accomplishing several miles of modification. This work included replacing the bottom barbed wire with smooth and raising the bottom wire to approximately 16-18” from the ground to allow for safe pronghorn passage under the fence. Volunteers also recorded fence condition and, where possible, removed any obstructions like tumbleweed piles. Fence modification will continue in 2017 in collaboration with the Arizona Antelope Foundation.

RESEARCH QUESTIONS ADDRESSED

Wildlife Ecology:

4. Influence of environmental and anthropogenic factors on habitat connectivity.

Fencing Natural Lakes (Completed 2013)

In 2013, Grand Canyon Trust volunteers worked with North Kaibab Ranger District staff to repair and replace existing fencing around natural lakes on the top of the Kaibab Plateau. Additional exclosure fencing repair or construction is recommended for several Kaibab Plateau lakes in the 2015 Kane Ranch Allotment Management Plan, some of which are spring-fed lakes. These fences will be evaluated and addressed over the next several years.

RESEARCH QUESTIONS ADDRESSED

Springs and Seeps Restoration and Management:

1. Identifying best practices for maintaining ecosystem function/water availability at springs and seeps while also providing water for livestock and wildlife.

Appendix A: Partnership Administrative Updates

The Applied Research Plan was compiled in December 2011 and included this statement about additional research planning and design development:

> "Other important aspects of managing the research program require further consideration and development. These include an explicit plan for data management and information sharing; a streamlined and transparent process for obtaining the necessary research permits; a clear process for proposing new research activities; and a research funding strategy that will provide matching funds or other incentives to help attract researchers who will address the most relevant issues facing land managers, as articulated in the Research Plan. After adoption by the Partnership, this Research Plan will serve as a blueprint for build-out of the research capacity and development of related management plans, and it will be formalized as an appendix to the Kane and Two Mile Applied Research Plan."

Since the completion of the Applied Research Plan, the RSP has identified additional amendments to the plan that aid in developing research capacity and conducting and completing research. These include a process for taking on new projects and vetting them through agency partners and a process for updating the Applied Research Plan. In addition, the RSP discussed opportunities for improved communications (April 2016 meeting) and confirmed decision-making as informal consensus (November 2015 meeting).

Amending the Applied Research Plan

The Applied Research Plan was compiled in December 2011 and, as research questions are addressed, new information becomes available, and new research priorities are identified, the plan may require periodic updates. The RSP began discussing the Applied Research Plan update in the 2013 and 2014 meetings citing the broader group of partners and expertise that had become linked to the RSP and the interest of adding cultural resources and climate change focal areas to the plan. In 2015, RSP representatives were asked to give feedback on their desired changes to the research priorities outlined in Appendix 1. However, later RSP discussions revealed that there was not a desire to change the list or priority level of the key research questions. The group also expressed the desire to limit the changes to the Applied Research given the substantial work, discussion, and collaboration that was involved in its construction. In April of 2016, the RSP decided that any amendments should happen on a five-year cycle and should occur only after the five-year summary of progress (this document) has been finalized and accepted by the group.

New Research Project Vetting and Permitting

PASS Protocol

The North Kaibab Ranger District introduced its PASS Form in 2015. This form is intended to be filled out by any new researchers seeking to have study sites on the Kane Ranch. The PASS form aids the USFS in managing and scheduling things such as cultural resource surveys and allotting and tracking time contributing to RSP-related research. The BLM indicated that a similar process should be followed for research on the Two Mile Ranch.

New Research Project Process

A process for taking on new research was drafted in November 2016 and finalized in March 2017 after feedback from the RSP. The drafted document provides an overview of initiating research on the North Rim Ranches, including identifying alignment within the Applied Research Plan, navigating agency clearances for on-the-ground work, and RSP capacity to host and support work. During this process development, the RSP discussed that Grand Canyon Trust should take the lead as the clearinghouse for new research and emphasized the need for continuity and keeping commitments among various groups, perhaps through written agreements.

Communications and Decision-making

Reports

Communication of accomplishments and Applied Research Plan progress is important for future funding asks, justification of time and resource commitments to the RSP, and applying frameworks and project outcomes to a broader landscape. In April of 2016, the RSP decided on that an annual summary of progress and a five-year (2012-2016) summary of progress would be useful reports. Both reports, the 2016 annual report and the 2012-2016 summary report (this document) were completed in early 2017.

Data-sharing

Shared internet drives (i.e., cloud storage such as Google Drive or Dropbox) were identified to not be useful means of data sharing given agency limitations on shared internet drive use (discussed during April 2016 meeting). However, there are some key datasets, including the Grand Canyon Trust's Baseline Assessment data, which could be useful for all in the RSP. In addition, the Grand Canyon Trust created a Research and Stewardship Partnership page on its website.

To access the Research and Stewardship Partnership website: www.grandcanyontrust.org/research-and-stewardship-partnership#overlay-context=north-rim-ranches.

Decision-making

In the November 2015 meeting, the RSP confirmed that decision-making was done by informal consensus.

Appendix B: Applied Research Plan Questions (Full List)

This is the full list of research questions that can be found in Appendix 1 of the Applied Research Plan, including a tally of the number of proposed, in progress, and completed projects from 2012-2016.

	RESEARCH QUESTION	PROPOSED	IN PROGRESS	COMPLETED
	Livestock Management and Soils/Vegetation			
1	Establish reference conditions, update ecological site descriptions, and develop State and Transition Models.	-	1	1
2	Influence of grazing strategies (including rest) on short and long-term trajectories of aridland soils and plant communities in relation to desired future conditions.	-	-	-
3	Effects of post-fire livestock management on recovery of soils and native plant communities, including high severity burn areas (e.g., Bridger Knoll, Slide, and Warm Fire areas).*	-	-	-
4	Short- and long-term interactive effects of livestock grazing and drought/climate on soils and plant communities, including below- and above- ground processes. (e.g., below-ground biomass, woodland expansion into shrub-grassland, species composition and productivity, soil erosion/stability, etc.).	-	-	-
5	Influence of livestock management on the effectiveness of native species restoration efforts.	-	-	1
6	Effects of livestock management on trajectories of physical and organic soil crust formation.	-	-	-
7	Identify levels of plant cover and litter required to protect soils from wind and water erosion and effects of livestock management on these attributes.	-	-	-
	Livestock Management and Wildlife			
1	Nutritional and habitat needs of wildlife, including special-status species, e.g., bighorn sheep, mule deer, chisel-toothed kangaroo rat, California condor, and pronghorn and influence of livestock management on population recruitment and forage and habitat availability for wildlife.	1	-	3
2	Behavioral interactions and space use of livestock, mule deer, bison, and desert bighorn sheep.*	-	-	2
3	Additive effects of livestock management on wildlife in concert with other factors (e.g., climate change, prescribed and/or wildfire, etc.).	1	-	-
4	Potential for and impacts of disease transmission between wildlife and livestock, e.g., among cattle, bison, pronghorn, mule deer, and bighorn sheep surrounding Vermilion Cliffs and House Rock Valley.	-	-	-
	Revegetation and Restoration Techniques			

1	Efficacy of treatments intended to re-establish or otherwise benefit native/ desirable plant species. (e.g., effects of seeding rate and soils on seeded species establishment, plant community responses to tree mastication in pinyon-juniper woodland, identification of plant species that can compete with highly aggressive non-natives [e.g., cheatgrass]).	-	1	2
2	Options for revegetating high-severity burned areas (e.g., Bridger Knoll and Slide fires).*	-	-	-
3	Development of predictive models for strategic placement of restoration/mitigation treatments.	-	-	1
4	Influence of pinyon-juniper treatment design on wildfire severity and spread.	-	-	-
	Invasive Plants			
1	Physiographic, climatic, and other factors (e.g., management practices) affecting plant community susceptibility and establishment/spread of invasive plants. (Particularly on the west side of the Kaibab Plateau).	-	1	1
2	Influence of grazing practices and forest/woodland treatments on invasives. (Can the west side of the Kaibab Plateau or other heavily invaded areas be grazed in a way that does not spread cheatgrass (or even reduces cheatgrass) and continues to maintain or improve our native grassland vegetation?).*	-	-	-
3	Efficacy of approaches for preventing spread of invasive plants, e.g., enhancing resilience of native communities by seeding native species, protection of soils from disturbance, seeding with non-native species, herbicidal control of invasives.*	-	-	-
4	Influence of fuels treatments and fire management on invasives.	-	-	-
	Wildlife Ecology			
1	Identification of species most sensitive to changes in land use and climate.*	-	1	1
2	Response of Kaibab mule deer to wildfire and management-related habitat changes on the west-side winter range.*	-	-	1
3	How to design and implement project activities (e.g. forest restoration, prescribed fire) and special uses (e.g., grazing) to avoid impacts to wildlife populations or sensitive habitats.*	-	-	-
4	Influence of environmental and anthropogenic factors on habitat connectivity.	-	1	1
5	Identification of movement pathways for species of high conservation value.	-	-	1
6	Effects of broom snakeweed on selenium levels in wildlife.	-	-	-
	Monitoring			
1	New tools to design and monitor at landscape level (e.g., remote sensing techniques for monitoring invasive species, plant productivity, etc.).	1	-	-

2	Development of range monitoring metrics that incorporate watershed condition and affected wildlife communities (e.g., stubble height, forb and shrub diversity in relation to pronghorn fawning and habitat).*	-	-	-
	Climate Change			
1	Thresholds for sustainable livestock use under current and future climatic conditions.*	-	-	-
2	Predicted trajectories in soil conditions and plant communities under various climate change scenarios.	-	1	1
	Forest Restoration/Management			
1	What spatial arrangements, types, and extent of treatments maximize objectives related to fire management, desired future conditions for forest structure and special-status wildlife species identified in agency management plans.*	-	-	-
2	Post-fire mitigation techniques for achieving plant community and soils desired future conditions identified in management plans.	-	-	-
3	Long-term effects of post-fire seeding with non-native species (e.g., *Lolium*, *Agropyron*) on plant community composition and dynamics.	-	-	-
	Springs and Seeps Restoration and Management			
1	Identifying best practices for maintaining ecosystem function/water availability at springs and seeps while also providing water for livestock and wildlife.*	-	-	2
2	Ecological effects of spring diversion for livestock and wildlife water developments.	-	-	-
3	Options for restoring springs and seeps.	-	-	1
4	Historical reference conditions of springs and seeps.	-	-	-
	Biodiversity			
1	Environmental and habitat contributors to plant and animal population 'hotspots' (i.e., areas with relatively high abundance or numbers of species) or 'coldspots' (i.e., relatively low abundance or numbers of species on the landscape.	-	-	-
2	Effects of pinyon-juniper treatments on plant and animal diversity.	-	-	-
	Riparian Restoration			
1	Effects of biocontrol on tamarisk reproduction and spread.	-	-	-
2	Efficacy of methods for removing invasive woody species (e.g., biological control of tamarisk).	-	-	1
3	Effects of invasive woody species removal on native plants, animals, and ecosystem functions.	-	-	1
4	Influence of flow regime, and site conditions on reestablishment of native woody species.	-	-	-