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THE DESERT TORTOISE COUNCIL

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ABSTRACTS OF PAPERS AND POSTERS

(Abstracts arranged alphabetically by last name of first author)
*Speaker, if not the first author listed

STUDENT PAPER

Upper Respiratory Disease Dynamics: Insights from Transmission Studies

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Pathogen colonization, infection and spread through a host population is a dynamic process. Epidemiological models help make sense of this process and can be used to predict the potential impact of pathogen spread and disease on population persistence. However, without empirical data to guide the model structure, the predicted dynamics can fail to reflect real-world biological processes. Little data exist concerning natural transmission of the bacteria causing upper respiratory tract disease in the desert tortoise, and so limits the development of appropriate models to assess disease effects in this species. We conducted transmission studies of *Mycoplasma agassizii* using captive desert tortoises to: estimate transmission probability for different levels of exposure to an infected host; document the progression of new infections and clinical signs of disease; and describe patterns of infection load, antibody response, and nasal discharge over time. We used a combination of laboratory (qPCR, ELISA) and veterinary (health assessments) techniques to determine infection status before and after exposure trials and document disease characteristics over multiple years. Models based on transmission results estimate low *M. agassizii* transmission probability unless a naïve host either interacts for extended periods with an infected host or encounters a highly infectious host. Tissue analyses suggest qPCR detects early stages of bacterial colonization prior to development of clinical disease, while antibody production and seroconversion can be extremely delayed - over 1 year in some cases. Individual response to infection was variable: 8 of 15 tortoises colonized with *M. agassizii* developed severe clinical signs while the remaining 7 developed primarily mild to moderate signs. These data imply a complex host-parasite system that will benefit from models that incorporate heterogeneity in multiple aspects of the transmission and infection process. We discuss the implications of our findings on disease modeling, management, and research in tortoise populations.

Relationships between Annual Plant Productivity, Nitrogen Deposition and Fire in California Desert Scrub

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Fire size and frequency have been increasing in the California desert scrub due to exotic annual grass invasions, and these may be exacerbated by anthropogenic nitrogen (N) deposition. N from fossil fuel emissions and agricultural activities is deposited downwind with values up to 16 kg N $ha^{-1}yr^{-1}$ in the desert (background values < 2 kg N $ha^{-1}yr^{-1}$), sufficient to increase biomass of exotic grasses (primarily *Bromus rubens* and *Schismus* spp). We report on three objectives: 1) We tested the effects of elevated N across a N deposition gradient and in experimental fertilization plots, and determined that elevated N increased exotic and native annual biomass above the critical load of N for fire risk at higher levels of watering and during years of higher precipitation. 2) We used DayCent to model annual production under elevated N and determine critical load of N for fire risk; using 1 T ha^{-1} as a threshold for fine fuel productivity we modeled increased fire risk at 3-9 kg N $ha^{-1}yr^{-1}$. 3) We used a 28 year fire record of 582 burns to compare the relationship between nitrogen deposition and precipitation with fire size to that of modeled herbaceous fine fuel biomass and fire size, and to identify a biomass threshold. Using quantile regression, models of annual biomass had similar predictive ability as models using precipitation and N deposition for small fires. For intermediate-to-large fires, two years of winter precipitation were significantly correlated with fire size. No biomass threshold was found except for the 99th percentile of fires, in which fire size increased with greater than 1.25 T ha^{-1} of winter fine fuel production. While no single N deposition threshold was found, overall more area burned than expected at both 7 and 14 kg-N $ha^{-1}yr^{-1}$. Legislative controls on N deposition would reduce exotic grass productivity, but modeling the exact critical load of N for increased fire size is still elusive.

Translocations to the Large Scale Translocation Site, Nevada, 1997-2014

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The Desert Tortoise Conservation Center (DTCC) facilities were gifted in 1990 to the BLM to hold tortoises displaced by development and to conduct research. In 1996, an environmental assessment was developed to implement a research-based translocation program on BLM lands now referred to as the Large-Scale Translocation Study (LSTS) site near Jean, Nevada. In 1996, 1-hectare plot surveys were used to estimate there were 1449 tortoises larger than 180 mm midline carapace length (MCL) at the LSTS. The DTCC is now permanently closed but between 1997 and 2014 translocated a total of 9110 tortoises, including 4400 that were larger than 180 mm MCL ("adults"). Line distance surveys were conducted starting in 2001 to train field crews for other projects, allowing us to estimate annually the number of tortoises in the LSTS. Surveys from 2001 through 2007 mostly estimated abundances of over 1000 adult tortoises but these estimates were undoubtedly inflated by release of translocatees right before spring surveys. Since 2008, coinciding with release of translocatees after surveys, estimates of adult abundance have been less than 550. Since translocations ceased altogether, two surveys in 2015 indicated abundance in the LSTS of approximately 320 adults. Resightings of marked translocated animals also provide an opportunity to estimate survivorship of translocated tortoises, an analysis currently underway which should also give a more accurate picture of the change in real abundance. The LSTS has become a renewed area of interest as highways and renewable energy development in the Ivanpah Valley constrict movement through this linkage in the Eastern Mojave Recovery Unit. With collaborators from the San Diego Zoo, UCLA, Great Basin Institute, and the BLM, we are collecting samples to evaluate genetic and disease risk of removing fences that currently prevent movement of tortoises up the valley and through the LSTS.

U.S. Fish and Wildlife Service Update on the Desert Tortoise Recovery Activities

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Major activities within the Desert Tortoise Recovery Program in 2015 included 1) advancing recovery implementation through the Desert Tortoise Management Oversight Group (MOG). The MOG agreed to a set of range-wide priorities on which to focus recovery activities, and member agencies have taken several steps to implement related projects developed by the Recovery Implementation Teams. Increased attention is being placed on supporting range-wide monitoring and reconvening a Science Advisory Committee to interface with and provide recommendations to the MOG. 2) We coordinated ongoing monitoring of the greater Trout Canyon, Eldorado Valley, and Boulder City Conservation Easement translocation sites. Surveys were also conducted in the Large-scale Translocation Site to continue building a dataset to estimate survival and abundance of tortoises at that site and to provide samples of health and genetic analysis of the population. 3) A broad, inter-disciplinary, inter-agency workgroup

completed a disease risk assessment relative to translocation. This assessment, plus additional new information, is being used to revise the Fish and Wildlife Service's translocation guidance. 4) Emphasis on captive-tortoise management included two registration/micro-chipping clinics for private tortoise custodians and a second sterilization clinic for privately held tortoises in collaboration with Tortoise Group, the Nevada Department of Wildlife, and others in Las Vegas. 5) Range-wide monitoring surveys occurred at a much reduced level in 2015, including four strata in California.

Identifying Climate Refugia for Agassiz's Desert Tortoise: Identifying Conservation Priorities for a Warmer Future

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Agassiz's desert tortoise, *Gopherus agassizii*, faces threats from climate change. With limited mobility to move long distances to more suitable habitat as climate change advances, whether protecting tortoises in situ or translocating them out of harm's way, a critical conservation task is identifying refugia, lands that will remain suitable under the current climate and projected, end of the 21st century warming and drying. While researchers have modeled tortoise habitat suitability, they have done so at coarse scales and did not identify climate refugia that may become apparent only with a fine scale approach. It is at that scale that managers can implement measures that will foster habitat protection for tortoises throughout their current range. In this study, we employed fine scale habitat suitability modeling to identify current habitat and climate refugia within and surrounding the Marine Corps Air Ground Combat Center (MCAGCC) at Twentynine Palms, California. We modeled nearly 284,000 ha of currently suitable tortoise habitat within an 858,800 ha study area. Projected end of the century summer temperatures could reduce the area of tortoise habitat 55% to 127,650 ha, however almost 115,800 ha would overlap current tortoise habitat and would serve as climate refugia. Applied elsewhere, where tortoise protection must be balanced with other land uses, this approach could increase the efficacy of conservation for this threatened species. Nevertheless, until validated with field studies, habitat suitability models represent hypotheses as to current and future distributions of appropriate tortoise habitat. These hypotheses should foster additional research identifying whether tortoise densities and demographic structure are more secure, and whether tortoises can adapt to shifting climates more effectively within than outside modeled refugia.

Desert Tortoise: Protected? And Still Declining…

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Through science-based advocacy, participation in administrative processes, public information and litigation, the Center for Biological Diversity continues our conservation and recovery campaign for desert tortoise and its habitat in California, Nevada, Arizona, and Utah. Over the last 20 years, the Center has consistently supported increased protections for the desert tortoise as the path to desperately needed species recovery. Some challenges that the Center focused on in the past year include: large-scale renewable energy projects; the development of the Desert Renewable Energy Conservation Plan (DRECP); desert counties' renewable energy plans in California; limiting ORV impacts in DWMAs and other habitat from both authorized and unauthorized use; ongoing translocation projects into already occupied habitat; supporting efforts to secure permanent retirement of allotments in desert tortoise habitat in the CDCA as mitigation; pushing for new national monuments as permanent protection; mining issues; the ongoing legal challenge to the new ISDRA RAMP (Algodones Dunes); the ongoing legal challenge to the SNWA water grab in Nevada; opposing new oil and gas leases that would allow fracking in Nevada; and the Las Vegas RMP revisions. After the DRECP was split into 2 phases, we concentrated on the proposed BLM Land Use Plan Amendments (LUPA) with particular attention to proposed rollbacks to existing conservation commitments and the effects of the proposed DRECP LUPA on the most at-risk recovery unit for the desert tortoise - the West Mojave. We continued our work to protect other species that share habitat with the desert tortoise including flat-tailed horned lizard (FTHL) which we successfully petitioned to protect under the California ESA and which is now a candidate species in California. Despite the overall bleak picture of decreasing numbers and on-going habitat losses for the desert tortoise, we remain hopeful that our efforts will safeguard existing conservation lands, secure new conservation designations, and improve on the ground management of key habitat, which may benefit the desert tortoise in the long run.

Introducing the Coalition for a Balanced Environment (CBE)

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We are all aware of the explosive growth in raven populations, particularly in the California desert, and of the impact this growth has had on desert tortoise populations. Nevada and Idaho have implemented programs to stabilize or reduce the raven population. It is time California took action. The Coalition for a Balanced Environment (CBE) was formed in late 2015. Its primary goal is to accelerate raven management and control efforts in the California

desert to preserve the diminished desert tortoise population. In addition to addressing the urgent situation in the desert, the Coalition will also work to enhance raven management practices throughout California. The CBE will spearhead a long overdue effort to accelerate enforcement of existing local raven management ordinances and the implementation of the U.S. Fish and Wildlife Service's 2008 Desert Tortoise Recovery Plan. The Coalition will leverage that effort to bring enhanced raven management practices throughout California. CBE's objectives are: to reduce human subsidies associated with raven population growth, accelerate raven management and control per USFWS' Desert Tortoise Recovery Plan, and advocate for changes in federal and state laws to permit active raven population control measures. The CBE will form a broad based coalition of environmental organizations. Through public outreach and education, subsidized ordinance enforcement programs and media campaigns, the CBE will reduce the human subsidies associated with raven overpopulation. By attacking the problem at its source, the CBE will demonstrate the efficacy of human subsidy reduction on stemming raven population growth at the local level. Behind the strength of a broad based coalition, the CBE will run a concurrent program in Sacramento to amass the necessary political support required to accelerate the effort. Lawrence Alioto is the CBE's Executive Director. In conclusion, the CBE needs your support. Will you join us?

A One Health Approach: Comparisons of Three Populations of Agassiz's Desert Tortoises in the Mojave Desert

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In spring of 2012, we evaluated 125 adult desert tortoises (*Gopherus agassizii*) for health at 3 sites in the Mojave Desert, California (Edwards Air Force Base, western Mojave Desert, N = 51; northwest of Barstow, central Mojave Desert, N = 33; and south of Daggett, southern Mojave Desert, N = 41). We tested for two known pathogens (*Mycoplasma agassizii, M. testudineum*), for levels of elemental toxicants in fresh whole blood (selenium, arsenic, cadmium, lead, mercury, nickel, thallium, antimony, beryllium, chromium, and vanadium) and evaluated the tortoises for clinical signs of upper respiratory disease, shell disease, and trauma. Tortoises with infectious disease, moderate or severe shell disease and trauma, as well as elevated levels of selenium, arsenic, cadmium, lead, mercury, nickel and thallium occurred at one or more sites. Test results and clinical signs varied by area, possibly as a result of human access, domestic animals, and land use histories.

Bighorn Sheep Pneumonia: Determining the Cause and Exploring its Implications for Population Management

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Epizootic bronchopneumonia has contributed to the population declines experienced by bighorn sheep since the European settlement of western North America, and is now widely recognized as an important factor limiting population recovery. The precise cause of this disease has been the subject of controversy and debate for decades and that debate continues today; however, new data resulting from application of molecular microbiology and molecular epidemiology has clarified the disease etiology and led to new ideas for disease management. This presentation will touch upon the evidence supporting each of several hypothesized causes of the disease, the source(s) of pathogen transmission to bighorn sheep, the implications of the current understanding of the disease biology for novel management and control interventions, and identify several important questions for future research having meaningful implications for recovery of bighorn sheep populations.

Wilderness Legislation Confounds Wildlife Conservation: Desert Bighorn Sheep as a Model Organism

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Wilderness management objectives and wildlife conservation objectives often conflict with each other, despite conservation being one of six basic reasons for which wilderness is established. Most wilderness areas appear to have been established as the result of political or societal desires, but in the absence of critical ecological thought. In an era of increasing anthropogenic impacts to wildlife populations and to wildlife habitat outside of wilderness, those ostensibly "pristine" areas in and of themselves will become less and less effective as conservation tools, particularly for large, vagile mammals. Impacts occurring outside of wilderness areas have ramifications for wide-ranging animals that use those areas during portions of their annual cycles, and thereby affect wilderness character. Similarly, impacts occurring inside of designated wilderness also have ramifications for large, vagile mammals that also utilize proximate lands. There is a need to re-ignite the debate over the value of wilderness, both in the context of its societal role as well as that of a conservation strategy. It is essential that wildlife conservation be elevated to the same level of importance that is accorded solitude and other subjective attributes of wilderness.

Prehistoric, Historic, and Recent Patterns of Fire in the Mojave Desert

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Arid desert conditions in the Mojave Desert ecoregion are currently much more prevalent, and fire is now less widespread, than at the beginning of the Holocene Epoch (13,000-12,000 YBP). However, the trend towards drier conditions during the Holocene was not linear, and it included two significant periods of cooler/wetter conditions, the Neoglacial (5,000 to 4,000 YBP) and the Little Ice Age (600-300 YBP). Evidence suggests that fire occurrence likely increased during these time periods, and that this increase may have been associated with increased regional extent of native vegetation types that were more conducive to fire. These vegetation types still exist today, along with less flammable types, all of which collectively form the basis of understanding of how fire varies across the Mojave Desert. Significant changes in fire occurrence also occurred during the historical era (since the 1800s), and more recently the advent of fire records and remote sensing allow us to comprehensively characterize fire patterns during the current time period (mostly since 1980). In this presentation we describe these fire patterns and their implications for fire management in the Mojave Desert.

Effectiveness of Post-fire Aerial Seedings in the Mojave Desert

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Native plants are sometimes seeded following fires to stabilize soils, compete with and suppress invasive non-natives, and promote the recovery of native species. The vast majority of post-fire seedings in the Mojave Desert have been done aerially using fixed-wing aircraft or helicopters. The effectiveness of these seedings have rarely been evaluated in the Mojave Desert, or even in other regions where they are used more frequently (e.g. the Great Basin). In this

presentation we focus on the results of two post-fire seeding studies. We first describe the effectiveness of 47,000 acres of aerial post-fire seedings done following the 2005 Southern Nevada Complex fires. Results include the initial 3 post-fire years. We then describe vegetation conditions 2-16 years following aerial seedings applied after several different fires. We also summarize the results of a comprehensive post-fire seeding chronosequence study from the Great Basin and describe the implications for management of post-fire landscapes in the Mojave Desert.

Habitat Selection by Desert Bighorn Sheep: Past, Present and Future Directions

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Studies of habitat selection by desert bighorn sheep are relatively common in the ecological literature. Motivations for desert bighorn habitat selection studies are varied, but are typically related to development of specific management applications, to resolve particular conservation issues, or are prompted by a desire to develop a more a thorough understanding of desert bighorn sheep ecology and life history. Common management goals for studying desert bighorn habitat selection include efforts to determine the impact of human developments or land use changes (e.g., surface mines, transportation infrastructure, housing developments), assessing success of restoration efforts (e.g., effects of prescribed fire treatments), and modeling to identify potential sites for introductions. Other work, however, has sought a more basic understanding of desert bighorn ecology including aspects of sexual segregation, predator avoidance strategies, foraging ecology, and reproductive strategies, as well as efforts to understand how desert bighorn alter habitat selection patterns in relation to recurring drought or the potential long-term effects of climate change. More recently, habitat selection studies have been expanded to include a wider suite of environmental characteristics than in the past, including spatial-temporal changes in forage conditions, land surface temperature, and solar radiation. These expanded areas of ecological inquiry are now possible largely due to the wider availability of ecologically relevant remote sensing and geospatial data. In this presentation I will review some of the early habitat selection modeling efforts, discuss how more recent investigators have built on the foundation of those earlier studies, and provide suggestions for future habitat selection modeling efforts.

Clark County Multiple Species Habitat Conservation Plan Update

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The Clark County Desert Conservation Program (DCP) continues to administer the Multiple Species Habitat Conservation Plan (MSHCP) as mitigation for an Endangered Species Act section 10 incidental take permit for desert tortoise and 77 other species of plants and animals. During the period from January to October 2015, the DCP collected mitigation fees for 1,593 acres of take, leaving 56,063 acres of authorized take remaining under the permit. The 2015-2017 Implementation Plan and Budget was approved for $8,206,407. Program accomplishments from the past year include: completed the third year of a desert tortoise occupancy monitoring project; worked in coordination with the U.S. Fish and Wildlife Service to conduct a post-translocation monitoring project in the Eldorado Valley; initiated a post-translocation telemetry monitoring project on the Boulder City Conservation Easement; continued to manage reserve properties including providing for law enforcement, weed control, and conducting habitat restoration projects; supported the creation of a desert tortoise habitat at the Las Vegas Springs Preserve; and conducted numerous outreach efforts to teach children and adults about the desert tortoise and spread the message of responsible recreation and environmental awareness.

STUDENT PAPER

Evaluating Indoor-rearing as a Component of Head-starting the Mojave Desert Tortoise: Methods and Preliminary Results

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Head-starting is a management tool that protects animals during the first part of their life, when they are most vulnerable, before releasing them into the wild at a larger size in an effort to augment recruitment in depleted populations. In 2015 we initiated a comparative study to evaluate the potential for indoor-rearing, as a component of head-starting desert tortoises to reduce the time animals are captive compared to outdoor-rearing. During May-June 2015, we collected 123 eggs from female desert tortoises in Ivanpah Valley of the Mojave National Preserve, CA. Of the 123 eggs, 74 hatchlings successfully emerged (60.2%). We assigned 70 of these neonates to three treatment groups: 1) indoor-reared (n = 30), 2) outdoor-reared (n = 20), and 3) directly released (control group; n = 20). The indoor- and outdoor-reared treatment groups will be held in captivity until Spring 2016, when they will be released and monitored via radio-telemetry. In late September, we began housing the indoor treatment group in indoor vivaria and offering them food five times weekly. Concurrently, we also placed the outdoor treatment group

in predator-proof pens and began providing them with artificial rain and supplemental food weekly. On 28 September, we released the 20 hatchlings into the wild, and began monitoring them with radio-telemetry. During fall dispersal, one hatchling was predated by a bird and one by a mammal. A third hatchling is missing and its fate is unknown. We have not observed mortality in either the indoor- or outdoor-reared treatment groups. Indoor-husbandry has been effective in increasing growth. In the first two months, the indoor hatchlings increased 45.2% in mass (*SD* = 6.1%) and 23.7% in midline carapace length (*SD* = 4.9%). We will monitor growth and nutrition throughout the rearing period, and evaluate survivorship, microhabitat use, and movement of each treatment group post-release.

Recovery Progress at Mojave National Preserve

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Progress towards recovery of the desert tortoise at Mojave National Preserve has included habitat restoration, threat abatement, planning, monitoring, and research towards population augmentation. Effectiveness monitoring of restored piospheres showed noticeable decompaction and increases in herbaceous cover on some, but not all sites. Some 2,094 acres of private land were acquired in 2015, including 803 acres in desert tortoise critical habitat. These acquisitions augment 24, 677 acres total (7,728 ac in critical habitat) received since 1994. Planning efforts are ongoing with the BLM and USFWS for construction of tortoise fence on 12 miles of roads in Ivanpah Valley and expanded raven monitoring and control efforts. Development of a Grazing Management Plan, Biological Assessment and consultation covering livestock management in the Preserve is ongoing with a target completion of 2016. The annual survey of 508 miles of powerlines encountered 20 active raven nests, including seven new nests and three where ravens replaced red-tailed hawks in 2015. Four juvenile tortoise mortalities were found associated with towers 62-T1 and 63-T4 in Ivanpah Valley and 144-T1 in Fenner Valley yet the associated ravens were not removed. Eight tortoises were reported killed on roads in the Preserve. Juvenile tortoise headstarting research is ongoing at the Ivanpah Desert Tortoise Research Facility, donated to the National Park Service from Chevron Environmental Management Company in 2014; research is being conducted by the University of Georgia, Savannah River Ecology Lab and the University of California, Davis.

Applying Remote Sensing Metrics to Quantify Invasive Annual Plant Distributions and Assess Spatio-Temporal Variation in Annual Wildfire Risk Across the Mojave Desert

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Productivity of invasive annual grasses, such as cheatgrass (*Bromus tectorum*) and red brome (*B. rubens*), increases in response to increases in winter precipitation, thus increasing fine fuels available to carry fire in sparsely vegetated landscapes. To identify and prioritize land areas where non-native annual plants currently dominate the understory and significantly increase wildfire risk, our research focused on two objectives: 1) modeling and mapping the relative quantity and extent of invasive annual grasses across the Mojave using satellite imagery, topographic, and environmental data; and 2) developing a methodology to evaluate year-to-year variability in fine fuel biomass and relate that to potential fire risk. Weekly composite data for Normalized Difference Vegetation Index (NDVI) from the Moderate Resolution Imaging Spectrometer (MODIS) platform were used to derive phenological metrics for peak greenness and the start and end of season greenness across the Mojave bioregion. Discriminant models included these phenological metrics along with precipitation regime, vegetation type, and cumulative winter precipitation to predict relative cover of invasive annuals. Results successfully predicted the relative amount and distribution of invasive annuals with >80% accuracy for two precipitation regimes with low summer rainfall, comprising approximately 60% of the Mojave bioregion, but ranged between 50% and 75% accuracy for the remaining 40% of the region. The NDVI phenological metrics were derived for 14-year time span to assess year-to-year variation in fuel load correlated to increases in annual herbaceous biomass. A spatially explicit, probabilistic model was developed to incorporate the annual difference in MODIS peak NDVI from the 14-year median peak NDVI, antecedent winter precipitation, road density and lightning density data for vegetation types at low, middle and high elevations within the ecoregion to predict the annual relative potential fire occurrence for each pixel. The overall accuracy of prediction from 2001 through 2014 was 78% with the model slightly under predicting potential wildfire risk.

From Systematics to Stewardship;
The Characterization of a New Species of Desert Tortoise Promotes Actions to Protect It

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For decades, herpetologists have noted the distinctiveness of Mexican populations of desert tortoises in the southern part of the range of *G. morafkai*, particularly where they occur in thornscrub and tropical deciduous forest environments. Recent studies have shed light on the ecology, morphology and genetics of these southern populations, which warrant species recognition. We review supporting literature and present the new taxonomic description for the "Sinaloan" lineage of desert tortoise. Molecular analyses can easily diagnose all species of *Gopherus* and their hybrids. We also note that, morphologically, the Sinaloan lineage is distinguishable from the "Sonoran" (*G. morafkai*) and "Mojavean" lineages (*G. agassizii*) by several characters, among the most obvious of which is the coloration of both the shell and integument. The Sinaloan lineage primarily occurs in the state of Sonora, Mexico, extending southward into the northerly extensions of tropical deciduous forest in southern Sonora, northern Sinaloa, and extreme southwestern Chihuahua. This lineage occurs only in thornscrub and tropical deciduous forest, leaving it the smallest distribution of the three desert tortoise species. To assess the conservation status of the Sinaloan lineage, additional field work is necessary as very little research on this newly described species exists and a comprehensive understanding of its ecology and behavior must be determined to inform conservation and management initiatives. However, we set an important precedent by complimenting this taxonomic description with a tangible action that contributes to the preservation of the new species in its native habitat. Through auctioning the naming rights of this new species in collaboration with the Turtle Conservancy, we have generated funds that are going directly toward the purchase of land in Mexico, extending the already existing Reserva Monte Mojino in Sonora.

The Process of Speciation Among the Three Lineages of Desert Tortoise

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The evolutionary history of desert tortoise provides an *in situ* opportunity to study theoretical aspects of speciation. We test hypotheses on which mechanisms of speciation drove diversity among three distinct lineages of desert tortoise in the genus *Gopherus* (Mojave, Sonoran and Sinaloan). These lineages offer a powerful system to study speciation, because different biogeographic patterns (physical vs. ecological segregation) are observed at opposing ends of their distributions. Divergence between Mojave and Sonoran lineages best fits an allopatric model having resulted from physical isolation driven by the Bouse embayment (currently the Colorado River). In contrast, Sonoran and Sinaloan lineages are not separated by any major geographic boundaries and we hypothesize that their divergence best fits a parapatric model where there was potential for gene flow during the process of speciation. Genetic studies of closely related species can assess if gene flow was present during speciation, because signatures of past introgression often persist in the genome. We employ a multi-locus phylogenetic analysis using mtDNA and 4 nuclear loci and performed to estimate the species tree. We then performed RNA-seq to characterize synonymous variants throughout the genome of each lineage and analyzed the data using a diffusion approximation for demographic inference (software package ∂a∂i) to test the null hypothesis of no gene flow during divergence. The best-fit demographic model for the three taxa is concordant with the species tree, and the ∂a∂i analysis yielded no evidence of gene flow during divergence among any of the three lineages. These analyses suggest that divergence among the lineages occurred in the absence of gene flow, whether through physical allopatry or ecological niche segregation. Our results also validate species-level differentiation among the three lineages of desert tortoise.

Habitat Fragmentation, Connectivity, and Metapopulation Conservation of Bighorn Sheep

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Bighorn sheep have naturally-fragmented distributions in many portions of their range. Therefore, local extinction and recolonization dynamics likely have been an important aspect of their natural and evolutionary history. Much attention has been given to loss of local populations, particularly because of anthropogenic causes. However, due to early assessments that bighorn

sheep were strongly philopatric, recognition of the importance of natural recolonization and inter-population movements was delayed. With the onset of the metapopulation paradigm, and new tools for characterizing interpopulation movements, that understanding has been revised. Increasingly, the conservation relevance of areas between core habitats is recognized, as well as the potential for anthropogenic habitat fragmentation to contribute to metapopulation declines. The importance of managing for connectivity and metapopulation function is now widely acknowledged, although such management is not always achieved. Yet, as I review here, large-scale energy developments as well as recent outbreaks of respiratory disease in bighorn sheep point to the critically important need to better understand and manage links among populations, and make adopting regional management strategies ever more important. I conclude that cooperation among agencies, universities, and non-governmental organizations is vital for efforts to manage bighorn sheep, and discuss examples of recent successes and challenges.

Consequences of Invasive Food Plants on the Growth, Health, and Survival of Mojave Desert Tortoises

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(Esque*) Habitat disturbance in the Mojave Desert alter the native plant composition used for food by the desert tortoise (*Gopherus agassizii*). Tortoise forage is comprised of mixed native grasses and forbs that are frequently intermixed with or replaced by non-native invasive Mediterranean grasses such as red brome (*Bromus rubens*). We hypothesized that changes in available forage species and nutrition would negatively influence the growth, body condition, and survival for tortoises occupying disturbed habitats. To test this hypothesis, we conducted an experiment with neonatal and juvenile Mojave tortoises (n=100) monitoring the effects of altered diets on their overall body condition, growth, and survival. Tortoises were assigned to one of five annual plant diets grown in a greenhouse. Diets included: a mixture of four native forbs, a native grass, a non-native grass, and native forbs combined with either the native or non-native grass. Tortoises eating forbs grew more and had higher survival rates (>95%) than tortoises consuming any of the diets that included grasses. At the end of the experiment, 32% of individuals fed only native grass (*Vulpia octoflora*) and 37% fed *B. rubens* were removed from the experiment due to poor body conditions or were deceased. In contrast, tortoises fed the forb diet had zero mortality and were in good condition.

(Drake*) We also hypothesized that changes in forage species would negatively impact the physiological ecology, immune-competence, and health of tortoises. During our experiment,

we compared changes in body condition and clinical status for tortoises weekly and sampled for blood before (Mar) and after (July) the experiment. Blood samples were analyzed for immune functions (i.e. gene transcription profiles) using a quantitative polymerase chain reaction (qPCR) assay, incorporating multiple genes that are indicative of physiological responses to stressors (i.e. nutrition, metabolism). Tortoises eating native forbs had better body condition and immunological responses than tortoises consuming any of the diets that included grasses. Health and body condition quickly declined for tortoises foraging only on the native grass (*V. octoflora*) or invasive grass (*B. rubens*), with notable loss of fat and muscle mass, and increased muscular atrophy. *B. rubens* seeds were found embedded in the oral mucosa and tongue in most individuals eating that diet, with subsequent inflammation. Genes indicative of physiological, immune, and metabolic functions were transcribed at lower levels for individuals foraging on *B. rubens*, indicating potential greater susceptibility to disease or other health related problems. This study highlights the potential negative impacts of habitat disturbance, altered diet, and nutrition on the health of juvenile tortoises.

Desert Tortoise Research Natural Area as an Important Venue for Desert Ecology Research

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For more than forty years, the Desert Tortoise Research Natural Area (DTRNA), managed in a cooperative effort by the Desert Tortoise Preserve Committee, Inc. and the Bureau of Land Management, has been a prominent area for research. As the first and only desert tortoise preserve in the southwestern United States, the DTRNA provides a unique opportunity to study various aspects of desert ecology and management within and outside of a fenced, protected area. To date, studies have focused on impacts of human-related activities to surrounding land, biological and behavioral studies of the desert tortoise (*Gopherus agassizii*) and other resident animal species, and ecological studies on native and invasive flora. With the growing pressure of development throughout the Mojave Desert, the need to preserve and utilize the DTRNA as an important venue for research increases. Future research studying topics such as the impact of renewable energy development on local ecology, noise pollution, and changes in micro-climate will further the understanding of the desert's capacity for alterations, and promote better management practices.

California BLM: Update on Tortoise Management Actions and Change in Policy

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In 2015, BLM continued to work on projects such as signing routes, restoring habitat, public outreach, and acquisitions of private land. Much effort and time was focused on solar and wind energy projects, primarily on implementation of approved projects. Brief status updates will be provided. Based on information and input from concern citizens, California BLM is formalizing policy related to data used for management decisions and monitoring of project implementation. This policy, and its implications, will be presented. We continue to look for ways of leveraging the effectiveness monitoring associated with renewable energy projects into larger research projects and coordinating the data to better inform us on impacts to tortoise.

Understanding the DRECP BLM Land Use Plan Amendment: What Do We Gained for Tortoise Conservation

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The Desert Renewable Energy Conservation Plan and Land Use Plan Amendment Final Environmental Impact Statement was published in November 2015. It represents the Bureau of Land Management's portion of the multi-agency Desert Renewable Energy Conservation Plan. To realize conservation within California desert to its fullest extent, the private lands portion of the DRECP should be completed. There are limitations as to what BLM can provide in a Land Use Plan, based on its authorities (e.g. BLM cannot make designations on private lands). But until such time that the private lands portion of the DRECP is completed, there are several key advantages the DRECP LUPA provides for species conservation. These advantages, some of which are not immediately obvious or easy to understand, will be discussed. Several examples of this follow. The amount of land identified for conservation purposes is substantially larger than previous Land Use Plan designations. Connectivity across the landscape is identified as a key management priority. The amount of allowable disturbance is smaller and not limited to authorized activities. The amount of compensation is similar or greater than identified in existing Land Use Plans. The definitions of allowable uses are better defined. The scope and scale of conservation measures is broader and more clearly identified to allow for better implementation. While there is no "perfect" land use plan, the DRECP LUPA makes large strides to improve the conservation of wildlife and plants on BLM administered lands.

Factors Influencing Survival of Translocated Juvenile Desert Tortoises

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In September 2012, 60 captive juvenile desert tortoises (*Gopherus agassizii*) (29 female, 30 male, 1 unknown) between 100-150 mm MCL were translocated from the Desert Tortoise Conservation Center in Las Vegas to three recipient sites within the Nevada National Security Site. The main objectives were to assess translocation as a possible means of recovery by measuring survival of translocated juvenile tortoises and to investigate factors influencing juvenile survival. Each tortoise had a VHF transmitter affixed to the carapace for tracking purposes. Tracking occurred at least weekly during March through October and at least monthly during November through February from September 2012 to January 2016. More than three years post-release, 27 (47%) juveniles remain alive including 19 males (63%) and 8 females (28%). Of the 31 mortalities, 24 (17 females, 6 males, 1 unknown) had signs of Canid predation or scavenging, 3 (2 females, 1 male) were attributed to exposure to extreme weather conditions, and 4 (1 female, 3 males) died of unknown causes. Two animals (1 female, 1 male) are missing due to battery failure or long-distance movements and transmitter detachment. Carcasses were found with evidence of predation throughout the year including four where the burrow had been dug up, but mortality was higher during fall than at other times of the year. We also investigated the relationship between release site, size and weight, health status, burrow use, activity and survivorship. The differential mortality between sexes warrants further study particularly in wild tortoise populations. This work was done by National Security Technologies, LLC, under Contract No. DE-AC52-06NA25946 with the U.S. Department of Energy.

Progress Report: Use of Wildlife Underpasses by Mojave Desert Tortoises (*Gopherus agassizii*) along U.S. Highway 93 South of Coyote Springs, Clark County, Nevada

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Anthropogenic habitat fragmentation threatens to isolate remaining Mojave desert tortoise (*Gopherus agassizii*) populations into ever smaller islands. On an island, the probability that a species will be extirpated is a function of island size and dispersal barrier permeability. Fortunately, the permeability of dispersal barriers can often times be augmented, with the

installation of connectivity structures, such as, ecoducts and wildlife underpasses. But how effectively do connectivity structures aid desert tortoises cross dispersal barriers? To answer this question, eighteen motion sensitive camera traps where attached to the 'ceiling' at either end of nine tortoise-specific wildlife underpasses, which are located along U.S. Highway 93 just north of its split with I-15 and south of Coyote Springs, NV. Camera traps where installed on March 1, 2015 and will seasonally monitor culvert use until at least November 1, 2016. From March 1 to July 1 (spring monitoring period) and September 1 to November 1 (fall monitoring period), 2015, over 60,000 images were captured, of which, ~40,000 images have been analyzed. Multiple vertebrate and invertebrate species have been observed sheltering in and moving through the underpasses, but no desert tortoises have been observed. A single fresh desert tortoise scat was, however, observed on a culvert apron at the time of camera trap installation. While troubling, the lack of tortoise observations is not completely surprising, and could be explained by a number of plausible hypotheses. The three leading hypotheses are 1) the local rate of tortoise dispersal is very low, 2) tortoise populations directly adjacent to US HWY 93 were depleted prior to the installation of tortoise fencing and underpasses, and 3) a combination of both. In an effort to better address our central question and mitigate the confounding effects of variable desert tortoise population densities, this project is now being expanded to include culverts along additional roadways and rail lines throughout southern Nevada.

STUDENT PAPER

A Tale of Two Tortoises and Tiny Local T-value

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A central line of inquiry in basic ecology has been the study of species-environment relationships, which has proliferated substantially due to the rise and continued accessibility of species distribution modeling (SDM). SDM is a prominent method with which to investigate these species-environment relationships, though most SDM methods assume that these relationships remain stationary across a species' range. However, spatial non-stationarity may be appropriate when local populations deviate from a species' norm. Spatial non-stationarity may also arise when multiple processes influencing species-environment relationships act on different spatial scales, or when local conditions alter these relationships through biotic factors such as competition, predation or herbivory. This may be exemplified in hybrid zones between sister taxa. Geographically weighted regression (GWR) has become the dominant method to incorporate spatial non-stationarity in a regression framework, and uses local statistics to explore evidence of spatially varying relationships. Here, we use GWR to explore locally varying species-environment relationships between two species of North American tortoises, *Gopherus*

agassizii and *Gopherus morafkai*, and in particular, focus on a hybrid zone where an apparent secondary contact zone has occurred between them after 4-8 million years of geographic isolation by the Bouse embayment, resulting in allopatric speciation. We find that populations in and around the secondary contact zone exhibit different species-environment relationships than do populations from either lineage separately, and that spatial patterns of these relationships do not conform to hypothesized differences between climate, physiographic and vegetation habitat factors.

Sustaining Tortoise Populations While Sustaining the Military Mission: 15 Years of Tortoise Conservation on Arizona Army National Guard Installations

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One of the missions of the Arizona Army National Guard (AZARNG) is to maintain Soldier readiness. In order to meet that mission, the AZARNG must provide realistic and diverse environments in which to train. This is accomplished by maintaining ecosystem integrity and function, thus ensuring that existing training installations will sustain this mission for future generations. Installation-specific management strategies for the Sonoran Desert Tortoise (*Gopherus morafkai*) have played an integral part in meeting the Army's mission while contributing to the breadth of knowledge for this species. In 1997, AZARNG personnel conducted the first official desert tortoise surveys on Florence Military Reservation (FMR). These initial surveys prompted a 15-year history of research and monitoring on National Guard installations with the Arizona Game and Fish Department. Earlier research conducted between 2000 and 2007 focused on understanding habitat use and home range size relative to military activities on Arizona State Trust Lands. More recent efforts (2008-present) have placed emphasis on determining population trends and reducing mission impacts to tortoises within AZARNG managed training areas. Occupancy monitoring surveys from 2011-2015 and vegetation inventories indicate that tortoise populations within FMR have been stable, available shelters and forage abundant and impacts from military activities within the primary training areas managed by the AZARNG have been minimal. In addition to annual long-term occupancy monitoring, a spatially explicit model of habitat suitability and functional connectivity will be completed this winter. Once complete, GPS transmitters will be used to validate the model with emphasis on areas that overlap with military training. Results will further assist in reducing potential future threats from military training activities to this species.

Captive Desert Tortoise Overpopulation and Management Options

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Despite the decline of wild desert tortoises through ranges or regional areas, captive tortoises are doing well which has created a significant overpopulation problem requiring attention. Captive desert tortoise overpopulation management is reducing funds and time available to better study, manage, and ultimately protect wild populations.

Unwanted captive desert tortoise populations have been managed in long- or short-term holding and through adoption in the past. Prior to its closure in 2014, the Desert Tortoise Conservation Center in Las Vegas, NV received over 500 tortoises per year, and held up to 2500 tortoises on approximately 100 acres. Facilities operated by state agencies, private tortoise rescues, or enthusiast groups often exceed holding capacities, and inadequate housing causes stress making captive tortoises more prone to health problems, and increasing the possibility of disease spread. Excluding hibernation and for medical reasons, it is inappropriate to hold tortoises older than 2 years of age in small bins or cages for extended periods of time. Short-term holding in confined areas (bins, cages, or small enclosures 8 times the size of the tortoise or less) should not exceed 30 days. Tortoises maintained indoors should also be provided exposure to UVB lighting. Ideally desert tortoises should be maintained in outdoor enclosures with appropriate burrows and space to thermoregulate, forage, maintain muscle strength, and be mentally stimulated. There should not be too many tortoises placed together in outdoor holding pens. Tortoises that are provided proper diet and husbandry in suitable enclosures often thrive and reproduce, leading to an ongoing significant part of the desert tortoise overpopulation problem in captivity.

Reproductive sterilization is the most common non-lethal tool used to manage animal overpopulation. Several complicated endoscopic surgical techniques have been developed to sterilize chelonians over the past decade. Within the past few years, a more simplified and economical non-endoscopic surgical technique has been developed to sterilize desert tortoises. Tortoise sterilization surgeries are safe and have few complications when performed properly. The USFWS has sponsored classes to teach this surgical technique to veterinarians to address overpopulation in the Las Vegas area for the past 2 years, and has plans to continue this in the future. The biggest limitation surgical sterilization of desert tortoises is the time of year that it can be performed. Surgeries should not be performed when pre-ovulatory follicles are greater than 2 cm, when eggs are present, and within less than a month from hibernation. To complicate things further Mojave and Sonoran desert tortoises have different reproductive cycle times.

Rules and regulations implemented by state agencies pertaining to captive desert tortoise propagation have not existed until recently. The Arizona Game and Fish Department recently changed their rules and regulations making it illegal to breed captive desert tortoises. The USFWS should consider similar changes to discourage backyard breeding for captive Mojave desert tortoises.

Euthanasia, excluding use for ill or suffering animals, is not desirable, but may be necessary and appropriate at times. Prolonged inappropriate husbandry for the sake of maintaining life is not acceptable. If good quality of life cannot be attained in a reasonable time frame, euthanasia is the more humane decision.

A uniform multi-factorial approach needs to be taken by State and Federal agencies and other stakeholders to address excessive reproduction including: implementation of rules and regulations preventing captive tortoise propagation, regulations on the number and sex of tortoises housed together, requirements for surgical sterilization in multi-tortoise homes and holding facilities, development of standards for care for holding facilities, and protocols for determining when euthanasia is necessary.

U.S. Geological Survey—Fire, Weeds, Disease, Restoration, Bighorn Sheep, and a Head Start Program

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The Western Ecological Research Center has five Principal Investigators (PIs) working in the Mojave Desert. Four of those PIs and their staff will make presentations this weekend. Dr. Kristin Berry will tell us about a disease and toxics analysis of 126 tortoises at three geographic locations. Jeremy Mack works under Dr. Berry, and he will discuss the head start program at Edwards AFB. Young tortoises were released into the desert starting in 2013, and he has been tracking and evaluating them since release. Dr. Matt Brooks will be leading a session on Sunday morning on the ecology and management of fire in the Mojave Desert. Dr. Rob Klinger, from Matt's staff, will be presenting in this session as well. Dr. Brooks will present the prehistoric, historic and recent patterns of fire in the desert, and speakers will discuss invasive annual plant dynamics and the effectiveness of post-fire seeding. Dr. Todd Esque and PhD candidate Kristina Drake will talk about their work with tortoises fed junk food (invasive grasses) vs those eating native forbs, or native grasses, or some combination thereof. Kristina is using gene transcription measurements to assess physiological responses to stressors, including a poor diet. Dr. Kathy Longshore will inform us about bighorn sheep behavior at the wildland-urban interface, in an effort to inform land use decisions and mitigation for impacts. Dr. Lesley Defalco will not be presenting this year. She is working with a large group of collaborators across the desert, using genetics and landscape-level data to more clearly define appropriate geographical sources for seeds for restoration projects. They are planting and monitoring gardens to test their findings.

Linking Short and Long-term Patterns of Post-fire Vegetation Dynamics to Models of Invasive Plants in the Mojave Desert

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We began an ecoregion-scale study in 2006 of short and long-term post-fire vegetation dynamics with five primary goals: (1) evaluate the relationship between aboveground vegetation and seed bank composition; (2) compare long-term post-fire vegetation dynamics among elevation zones; (3) evaluate the influences of burn severity and frequency on post-fire vegetation dynamics; (4) model ecoregional-scale habitat suitability for three non-native annual grasses (*Bromus rubens*, *B. tectorum*, *Schismus barbatus*) and one non-native annual forb (*Erodium cicutarium*); and, (5) develop state-transition models of post-fire vegetation dynamics. To asses short-term post-fire vegetation patterns we collected aboveground and seed bank data from 2006 through 2008 at > 400 plots that burned in 2005 (N = 6 fire perimeters). To evaluate long-term post-fire vegetation patterns, we used a chronosequence design (space for time substitution) and collected aboveground vegetation and seed bank from 2009 through 2013 at 585 plots that burned across three elevation zones between 1972 and 2006, as well as at 222 unburned reference plots. Although short-term post-burn patterns suggest that state changes in vegetation communities may be inevitable, the long-term chronosequence results indicated vegetation structure and, to a lesser degree, diversity, often returned to levels similar to unburned conditions. Species composition generally did not resemble unburned conditions though; there was a high degree of heterogeneity in species identity and relative abundance. Areas that burned once but at high fire severity or burned multiple times tended to be characterized by persistent changes in plant community composition and were dominated by non-native annuals. The four non-native annual species occurred in a very high proportion of soil seedbank samples across all elevation zones, including unburned areas. A large proportion of the ecoregion was predicted as highly suitable for one or more of the non-native species, and areas with the highest predicted suitability values were the areas with the highest fire frequency. The results suggest that even though a small proportion of the ecoregion has burned, a high proportion is vulnerable to fire-induced transitions to non-native dominated communities, especially areas that have burned at high severity or have high fire frequencies.

Quadstate Local Governments Authority

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Quadstate Local Governments Authority represents 10 local governments in the Mojave and Sonoran Deserts. The Authority was organized 17 years ago to inform the local governments and provide input into the tortoise recovery actions for some 2.7 million people that we represent. The Authority is and has been dedicated to recovery of the Mojave Desert Tortoise through our continued involvement in the process. Through the years we have found that there are a number of other issues to be addressed but our main focus is still on tortoise recovery.
After a long wait we are pleased that the Sonoran tortoise population does not warrant being listed due to a stable population and efforts being done to protect the species and their habitat.
We are pleased to see the studies and research that has been or is been conduction on the tortoise and their habitat. However, we would like to see more effort place on implementing the identified recovery actions. We support the tortoise population monitoring but feel that there is a broader need to monitor the habitat that is required for the tortoise to survive. We continue to look for scientific information related to protecting and conserving habitats to keep them in balance with historic and new uses of desert lands.

Implications of Habitat Management for Conservation of Bighorn Sheep

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Manipulation of habitats by humans to benefit wildlife dates back thousands of years. More recently, state and federal agencies with support from non-profit organizations have altered habitats across the southwestern United States to enhance suitability for bighorn sheep (*Ovis canadensis*). These efforts include widespread development of water resources (e.g., guzzlers, developed springs, etc.) and manipulation of vegetation. Additionally, state agencies have responded to naturally caused (primarily fire) changes in habitat suitability for bighorns by introducing them into historic habitat where they formerly were extirpated. These changes and enhancements to bighorn habitats have furthered conservation for this species, but remain controversial. Recent research provides a framework to understand some of these influences, but more work remains to be done. For development of water resources, as an example, at least five fundamental elements are important to an integrated understanding of the potential impact of this habitat enhancement effort. These elements include (1) consideration of the variable nature in time and space of available surface (drinking) water; (2) location and availability of pre-formed water, metabolic water, or both; (3) seasonal temperature and precipitation patterns that influence the physiological need for water; (4) behavioral constraints that limit use of otherwise available surface water; and (5) proper spacing of water sources for target species (bighorn in this example). A similar framework can be applied to management of vegetation and other habitat enhancement projects. Ultimately, successful conservation of bighorn sheep will require preservation and management of habitat.

Monitoring Lessons at the Lynx Cat Mountain Mine, San Bernardino County, California

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Tortoise protective measures identified in state and federal regulatory documents issued in June 2015 for sand and gravel extraction for construction of Highway 58 between Barstow and Hinkley were implemented at the 56.7-acre Lynx Cat Mountain Mine site and 3.4-linear mile access road located five miles northwest of Hinkley, in the Superior-Cronese Desert Wildlife Management Area, San Bernardino County, California. Between 9/23/2015 when preconstruction surveys were performed and 10/23/2015 when construction monitoring activities were completed, seven biologists observed 14 Agassiz's desert tortoises (*Gopherus agassizii*), 4 of which were handled 10 times to remove them from harm's way. We believe that the clumped aggregation of tortoise sign through the center of the site was due, in part, to concentrations of *Pleuraphis rigida*, which was consumed by at least three tortoises during these late-fall monitoring activities. Protective measures implemented to prevent tortoises that exhibited sustained fence-walking behavior from over-heating included installation of PVC shade structures, diligent biological monitoring, and physically moving tortoises to known burrows when temperatures exceeded approximately 32 °C. Below-ground egg shell fragments suggesting successful hatching were found in 5 of the 35 tortoise burrows excavated from the 27.25-acre impact area at the mine site and 13.75-acre impact area along the access road. No tortoises were found in 4,120 rodent burrows excavated from the mine site and access road, although two hatchling tortoises were observed, including one found in a rodent burrow during preconstruction surveys. Adult tortoises precluded from active burrows within the fenced mine site were observed combating on two occasions, copulating on one occasion, and crawling beneath a vehicle on one occasion. Clearance surveys and diligent monitoring of vegetation brushing, topsoil collection, and bedrock outcrop removal confirmed that no tortoises were injured or killed during authorized activities.

Return to the Sonoran Desert Tortoise Demographic Plots: Chapter 1 Tortilla Mountains and Maricopa Mountains

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In Arizona, the Sonoran Desert Tortoise has been the subject of monitoring for multiple decades. One of the longest term monitoring efforts that has been conducted on Sonoran Desert Tortoises during this time has been demographic monitoring by a partnership between the Bureau of Land Management and the Arizona Game and Fish Department. Here we will provide

an overview of this monitoring strategy, the long-term monitoring plots, and recent evaluations. Finally, we will highlight the outcome of the 2015 return to the Tortilla Mountains and Maricopa Mountains long-term monitoring plots. We will compare population estimates, sex ratios, age structure, and mortality in these populations over their course of study. Recommendations regarding the monitoring strategy for Sonoran Desert Tortoises will be provided based on current knowledge and logistics.

Recent Findings from 20 years of Research on Agassiz's Desert Tortoises at an Operating Wind Energy Facility

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Research on Agassiz's desert tortoise ecology at the Mesa Wind Energy Facility near Palm Springs, California began in 1994, about 10 years after the 460 turbine facility was permitted for operation. This is the only renewable energy facility with long-term published research on tortoises including over 20 peer-reviewed scientific papers to date. Highlights from 2015 publications include research showing that voiding behavior does not appear to affect survivorship of tortoises as previously suggested in the literature. The probability of voiding increases with handling time, winter precipitation, and varies greatly by sex and age class. In another study we used camera traps to describe seasonal activity and the thermal niche of tortoises. The relative probability of activity was associated with temperature, sex, and day of the year. Male tortoises were generally more active than female tortoises. We found significant support for interactions between sex and day of the year, and sex and temperature as predictors of the probability of activity. Using our models, we were able to estimate air temperatures and times (days and hours) that were associated with maximum activity during the study. Another publication based on long-term data of reproductive output reported the highest clutch frequency and annual egg output of any population of Agassiz's desert tortoises. Clutch frequency and annual egg production were generally unrelated to winter precipitation. Tortoises use a spatial and temporal bet-hedging strategy in the face of a variable and unpredictable environment. Finally, we published a paper comparing the survivorship of tortoises living in developed vs. more natural areas of the facility and found that survivorship was significantly greater in the developed area, a possible result of predator avoidance of the industrial area. These and other publications from 2015 and before are available at https://profile.usgs.gov/JEFFREY_LOVICH and more are in preparation.

Use of Predation Risk Theory to Predict Behavioral Responses of Bighorn Sheep to Human Activity at the Urban-Wildland Interface

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As urbanization increases throughout the western U.S., a growing number of bighorn sheep (*Ovis canadensis*) are living at the wildland-urban interface. Bighorn sheep living at the interface are often exposed to non-lethal human activities that include development of housing, roads, and trails, hiking, and dogs. Habitat may be altered due to fire suppression. The effects of these activities can be cumulative. General behavioral responses of bighorn sheep can range from attraction to resources at the interface to permanent avoidance of habitat that may ultimately lead to a population decline. Population declines in Arizona, California, and New Mexico have been implicated with urbanization in or near bighorn habitat. When resources (e.g., food, water, refuge from predators) at the wildland-urban interface are of higher quality than those of the adjacent wildland, bighorn sheep can be attracted to developed areas. Sheep that continue to use developed areas along the urban-wildland interface often exhibit changes in foraging or habitat selection. Use of these areas may have substantial costs, such as increased parasite loads. Predicting the reaction of bighorn sheep to human-caused disturbance has been difficult because there is considerable heterogeneity in the response of sheep to human activities. Studies examining responses to disturbance have lacked a theoretical framework for making predictions and understanding why particular responses occur. Recently, behavioral ecologists have begun applying economical models of antipredator behavior to the responses of animals to disturbance. I explore the effectiveness of using predation risk theory to predict behavioral responses of bighorn sheep at the urban-wildland interface and discuss consequences of those behaviors. Understanding the mechanisms for behavioral responses of sheep to human activity at the urban–wildland interface can provide insight into the way urban development affects populations, and can inform land use decisions to help mitigate those impacts.

Rocky Road to Recovery

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What now? What next?

The Desert Tortoise Council was established in 1975 to promote conservation of the desert tortoise in the deserts of the southwestern United States and Mexico. The Council is a non-profit organization comprised of hundreds of professionals and laypersons who share a common concern for desert tortoises in the wild and a commitment to advancing the public's understanding of the species.

"…to insure the continued survival of desert tortoises and the maintenance of their habitat in a natural state…."

---Excerpt from the First Desert Tortoise Symposium Proceedings

From then to now, how has the tortoise been doing? What has your Desert Tortoise Council been up to? What happened last year? What's the future? What's your role?

Into the Great Wide Open: Health, Growth and Survival of 119 Head-started Agassiz's Desert Tortoises at Edwards Air Force Base, CA

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Edwards Air Force Base initiated an Agassiz's desert tortoise (*Gopherus agassizii*) head-start program in 2002. Head-start pens were installed and adult females from surrounding areas were used to deposit eggs from 2003 through 2010. A staggered release of 119 juveniles with an average midline carapace length (MCL) of 70 mm (range: 51–132 mm) started in 2013 and occurred in three seasonal groups, at two release locations: (1) fall 2013, 35 juveniles released at Leuhman Ridge; (2) spring 2014, 36 juveniles released at Baker-Nunn; and (3) fall 2014, 48 additional juveniles released at Leuhman Ridge. As of December 2015, 60 (50%) were known to be alive, 21 (18%) were dead and 38 (32%) were unable to be found. The likelihood of mortality was best explained by tortoise size and release group, with causes of death attributed to small mammals, raven predation, and poor condition. Since release, we observed seasonal shifts in condition indices (CI). Spring-to-fall decreases in median CI have lessened with increased precipitation, but despite increased rainfall, growth in MCL has been minimal, a possible consequence of recent drought conditions and/or stunting from high densities in the head-start pens.

Evaluation of Movement Corridors using Remote Cameras

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Five culverts, specifically designed to facilitate tortoise movement, were built in 2012 along the Red Hills Parkway. These culverts were constructed to mitigate the impacts of a road expansion that bisected an existing high density tortoise population within the Red Cliffs Desert Reserve. Anecdotal information, based on presence of sign (e.g., tracks and scat) indicates that tortoises use the culverts as temporary shelters; however, it is unknown if they are used as movement corridors. We are currently monitoring these five culverts along Red Hills Parkway to: 1) record and identify the species using the culverts, with an emphasis on the desert tortoise,

2) determine how they are used (e.g., movement corridor, shelter) and 3) determine use patterns (e.g., frequency).

From February 2014 to December 2015, a variety of mammals, birds, and reptiles were observed using the culverts as temporary shelters; a few species used the culverts as movement corridors. Desert tortoises have been recorded at six of the ten culverts; preliminary data shows that they use the culverts as temporary shelters and not movement corridors. We have recorded several unexpected observations, including a series of photos of an individual entering the Reserve, picking up a desert tortoise, and walking out of the Reserve with the tortoise in hand. We will continue to monitor the culverts to document the species using the structures as well as the type of use (e.g., shelter vs. movement corridor). This study is a preliminary assessment of roads and their relationship to fragmentation and connectivity of the Red Cliffs Desert Reserve.

Causes and Consequences of Changes in Horn Size of North American Wild Sheep

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Horn-like structures in male artiodactyls are among the most spectacular examples of male ornamentation among mammals. Their primary function is tied to display and male-male combat, and the positive association of size of horn-like structures with phenotypic quality, sperm production and quality, body size, and reproductive success of male ungulates indicates that large horns and antlers are favored by natural selection. As a consequence, selective removal of individuals with large horns by hunters has been purported to result in removal of the genes that favor development of large horns. Substantial controversy has arisen during the past decade over the potential effects of harvest (especially trophy hunting) on size of horns among hunted populations. Hunting remains the cornerstone of the North American model of wildlife conservation and management, and increased interest among hunters in harvesting males with large horns has fostered interest in identifying factors that affect their size. Evidence suggests that unrestricted and highly selective harvest of large, fast-growing males in bighorn sheep in localized areas can result in striking decreases in size through time. The effects of conservative harvest regimes that are more common in much of North America however, are less well understood. Indeed, it is critically important that ecologists and management agencies have a firm understanding of the factors that dictate size of horn-like structures and are able to convey effects of different management regimes and harvest strategies to stakeholders and the general public.

Seeking to Hide: Habitat Effects on Dispersal and Survival of Translocated Juvenile Desert Tortoises

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In spite of growing use of translocation and reintroduction as conservation tools in wildlife conservation programs, their overall efficacy remains inconsistent. One of many factors that can contribute to failed translocations is the release of animals into poor quality or otherwise inadequate habitat, especially for reptiles. Here we sought to use a targeted approach to test the ability of habitat characteristics to improve translocation outcomes through reducing post-release dispersal and increasing survivorship of translocated juvenile Mojave desert tortoises (*Gopherus agassizii*). We selected three habitat characteristics, including burrow abundance, substrate, and dry water ways (washes), which have been tied to habitat selection, ecology, or fitness of desert tortoises. We subsequently tested the relationship of these habitat characteristics to dispersal, survival, and fatal encounters with predators up to one year after release. All three characteristics were important for either post-release dispersal or survival, but they were not all important for both. We found that juveniles released into washes dispersed almost half as far as those released outside of washes, but their relative use of washes had no effect on overall survival or predation. In contrast, we found that the abundance of burrows at the release site had no effect on dispersal following translocation, but was a strong predictor of both overall survival and predation. Finally, substrates that presumably functioned to increase their camouflage were associated with both reductions in dispersal and predation-mediated mortality following release.

POSTER

Modeling Habitat Suitability for the State Threatened Texas Tortoise, *Gopherus berlandieri,* in the Eastern Region of its Range

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Recent observations indicate a decrease in the historic range of the Texas tortoise, *Gopherus berlandieri*. The eastern region of the current range has fewer detections of tortoises, either because of unsuitable habitat or due to it being understudied. Assessing the habitat suitability of this eastern region, and determining whether it still supports the species will aid in its conservation. Road surveys were conducted in this region, from March to October of 2014, and only seven tortoises were found during this period. GPS coordinates of tortoises from these surveys along with coordinates obtained from online databases, such as VertNet and iNaturalist, were used with environmental predictors such as land use, shrub cover, and climatic variables to

model habitat suitability for the species using ArcGIS (v10.2) and Maxent (v3.3.k). Multiple models were tested and the best fit model was selected. It was found that there are some patches of habitat in the eastern portion that retain the potential to continue to support the species. In addition, areas of suitability were found in far south Texas, as well as in the northern, western regions and also outside of their historical range. The greatest success of the model is in its ability to identify areas of greatest concern and factors impacting the species so that conservation management efforts can be engaged in the remaining suitable habitat patches. The study has also enabled us to update the species rank on NatureServe. Several concurrent anthropogenic landscape alteration activities (e.g hydraulic fracturing, mining, and road development) within the range of the Texas tortoise have perpetuated change in the habitat of South Texas. Until we are able to gain a better understanding of the effects of ongoing and increasing disturbances in the region, and considering our very low number of observations under extensive survey effort, it is imperative that continued progress be made toward the protection of the Texas tortoise.

POSTER

Population Genetic Analyses for Wayward Texas Tortoises, *Gopherus berlandieri.*

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The Texas tortoise, *Gopherus berlandieri,* is a threatened species in the state of Texas and strict conservation action is required to ensure that continuing population loss does not occur. Over the past few decades there has been an increase in the number of tortoises found outside their historical range, likely due to human translocations or release of pet tortoises. In 2010, Fujii and Forstner looked at the population structure of *G. berlandieri* and determined that there are two weakly differentiated populations, one to the north and one south in the species Texas range, defined by a boundary at southern Duval County. We used 11 polymorphic microsatellite loci (8 previously untested in the species) to determine if there is a clear separation of these two populations, and whether these 'wayward' tortoises are from a northern or southern sub-population. We genotyped blood and tissue samples from 117 Texas tortoises collected over multiple field seasons. Out of these 117 tortoises, 63 were collected in the northern region, 29 from the southern region, and 25 were found outside the historical range of the species. MICROCHECKER (v2.2.3) was used to detect genotyping errors and null alleles, ARLEQUIN (v3.5.2) was used to determine genetic diversity across microsatellite loci, and STRUCTURE (v2.3.4) was used to assign each sample to a sub-population. Mean allelic richness was 5.6, H_O=0.378, H_E=0.41, and allelic size range was 16.8. STRUCTURE results corroborated the existence of two weakly differentiated populations, with most wayward tortoises falling into the northern sub-population. This novel data allows us to better understand genetic diversity and variation in this under studied species and the population structure of captive tortoises as more markers are tested. A repatriation protocol that incorporates disease risks, climatic considerations, and identifying potential stable habitat sites, would be a logical step towards better management of the Texas tortoise.

Mesocarnivore Visitation and Interactions with Agassiz's Desert Tortoises (*Gopherus agassizii*) and their Burrows

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Mesocarnivores, such as bobcats (*Lynx rufus)*, coyotes (*Canis latrans)*, American badgers (*Taxidea taxus*), gray foxes (*Urocyon cinereoargenteus*) and skunks (*Mephitidae)*, are all documented or suspected predators of the federally threatened Agassiz's desert tortoises (*Gopherus agassizii*). These predators play a crucial top-down role in the ecosystem by regulating populations of prey species at lower trophic levels. Disruption of predator-prey dynamics can result in cascading changes in the food web. Because of the life-history characteristics of desert tortoises, predation pressures can have significant, deleterious effects on tortoise population size or structure. Mesocarnivore predation and interactions with desert tortoises are frequently reported but poorly documented with real time observations. In the summer of 2013, 48 trail cameras were placed near the entrances of active *G. agassizii* burrows at a utility-scale wind energy facility near Palm Springs, California. Wildlife visitation of tortoise burrows was recorded as a series of five to ten photographs taken at 0.2 s trigger speed. We documented mesocarnivore (including bobcats, coyotes, gray foxes, and a western spotted skunk) visitation at burrows as well as interactions with tortoises. All of these species are speculated or documented to be predators of various life stages desert tortoises, yet no evidence of predation was observed in our study. It is possible that mesocarnivore visits to tortoise burrows are motivated by searching for alternative prey items, such as small lizards, mammals, or birds, all of which were recorded on some of our approximately 3,300 wildlife camera trap events inside or near tortoise burrows. These smaller vertebrates are often burrow commensals, using tortoise burrows for shelter or food. Our results suggest that mesocarnivore visits to burrows result from complex interactions between burrows and the local food web, and these visits do not necessarily result in predation on tortoises.

Top-down Dynamics, Subsidized Predators, and Desert Bighorn Sheep

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Despite eons of evolutionarily separation, desert tortoise (*Gopherus agassizii*) and desert bighorn sheep (*Ovis canadensis*) have some remarkable similarities. In recent history, desert bighorn sheep were relatively rare due to myriad factors, have made a considerable comeback in some places, and have become or remain threatened or endangered in others. Although desert bighorn sheep are prey to numerous predators, only mountain lions (*Puma concolor*) have been documented to have population-level consequences. In small isolated populations this predation may so high as to result in local extirpations. In many desert ecosystems where mountain lion predation dominates cause-specific mortality rates, mountain lions are "subsidized predators". This subsidy is derived by preying on non-native ungulates including feral equids and domestic livestock. This subsidy invokes the 'apparent-competition' hypothesis whereby prey-switching to a rarer prey item, in this case bighorn sheep, can result in population declines that mirror direct competition. Density of desert bighorn sheep in predator-free systems such as islands or predator-free enclosures can be more than an order of magnitude greater than densities in the presence of lion predation. Virtually all translocation stock of desert bighorn sheep comes from predator-free islands, predator-free enclosures, or habitats with very low levels of mountain lion predation. Western state wildlife agencies have used predator control of mountain lions to enhance recovery of threatened or endangered populations of desert bighorn sheep and to reduce mortality rates in populations with high management value as tranlocation stock or as huntable surplus.

Sonoran Desert Tortoise Movement on the Buckeye Army National Guard Training Area

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In 2015 we conducted a VHF radio-telemetry and GPS tracking study of Sonoran Desert Tortoises (*Gopherus morafkai*) on an active military training base 35 miles west of Phoenix, Arizona. As concerns rise regarding the Sonoran Desert Tortoise across its range in Arizona, military bases within the state may act as refuges for this species. Previous occupancy study efforts in this area had suggested that this may be a low density population. In an effort to enhance our understanding of this population and its potential use of the military property, we tracked the movements of 8 tortoises from May 18 to October 27. Foot surveys were conducted during the spring activity period in an initial effort to locate and affix VHF radio and GPS transmitters to tortoises. Over the duration of one season, a total of 14 individuals were detected either within the base property or within a surrounding 1-km buffer area. Here we report on what we have learned about the status of this population, their habitat use patterns, and what we expect continued investigation will tell us.

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20 Years Operating Under the Washington County Habitat Conservation Plan

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With the listing of the Mojave desert tortoise in 1990 Washington County established a Steering Committee charged with creating a plan which allowed development in certain areas of desert tortoise habitat while increasing the likelihood of recovery of the tortoise. Following 5 years of challenging discussions and negotiations, the Washington County Habitat Conservation Plan was signed February 23, 1996, one of the first such HCP's, and ushered in a new era for Washington County.

With the marking of the twenty year anniversary of that signing, the HCP and attendant "take permit" is set to expire giving rise to anxiety and anticipation as to the future of the Red Cliffs Desert Reserve, the cover for private land owners under the HCP, the take permit, continuation of development in Washington County and the infrastructure of the HCP organization for the County and the Partners in the HCP

With twenty years of experience operating under the HCP, those involved feel the HCP has functioned as intended providing a win/win for both conservation and development and should be renewed. With such a feeling, the Washington County Commission has petitioned the US Fish and Wildlife Service for renewal of the HCP.

Sonoran Desert Tortoise Species Status Assessment

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In 2015, the U.S. Fish and Wildlife Service (Service) re-evaluated the status of the Sonoran Desert Tortoise (*Gopherus morafkai*), a candidate for listing under the Endangered Species Act since 2010. In October, the Service published a finding that the species is not warranted for listing as threatened or endangered. Specifically, the Service conducted a Species Status Assessment (SSA). The Service assembled a team of experts on Sonoran desert tortoises from both the private and public sectors to collect, evaluate, and model information on the species' needs, potential habitat, and predominate risk factors that may be affecting, or could affect, population resiliency, redundancy, and representation into the foreseeable future. In addition, the Service contracted with the USGS Alabama Cooperative Fish and Wildlife Research Unit to create a population viability model capable of running thousands of simulations, hundreds of years into the future, under a varied array of possible baselines. The SSA process identified six primary risk factors that could affect Sonoran Desert Tortoises at varying scales: 1) altered plant communities; 2) altered fire regimes; 3) habitat conversion; 4) habitat fragmentation; 5) human-tortoise interactions; and 6) drought associated with climate change. While all of the scenarios showed slightly declining overall abundance into the future,

our model suggested no measurable risk of quasi extinction in the next 50 years. At 75 years, the risk of quasi extinction ranges from 0-3.3%; 100 years, 0-8%; and 200 years, 7-32%.

FEATURED SPEAKER

THE MOJAVE PROJECT

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The Mojave Project is an experimental transmedia documentary led by Kim Stringfellow exploring the physical, geological and cultural landscape of the Mojave Desert. *The Mojave Project* reconsiders and establishes multiple ways in which to interpret this unique and complex landscape, through association and connection of seemingly unrelated sites, themes, and subjects thus creating a speculative and immersive experience for our audience.

The Mojave Project will explore the following themes: *Desert as Wasteland*; *Geological Time vs. Human Time*; *Sacrifice and Exploitation*; *Danger and Consequence*; *Space and Perception*; *Mobility and Movement*; *Desert as Staging Ground*; *Transformation and Reinvention*.

The Mojave Project is told through the voices, stories and research of historians, geologists, biologists, cultural geographers, native speakers, visionaries, land management officials, military personnel, miners, desert rats, environmental activists, aerospace engineers, land speed racers, along with diverse cross-section of the region's residents and stakeholders including Kim Stringfellow, who is a full-time resident of Joshua Tree, California located in the southern Mojave Desert.

The Mojave Project will materialize over time through deep research and direct field inquiry involving interviews, reportage and personal journaling supported with still photography, audio and video documentation. Field Dispatches will be shared throughout the production period at *www.mojaveproject.org* and through our publishing partner KCET Artbound, beginning in August 2014. Installments will include those of notable guest contributors. The initial phase of the project is designed to make ongoing research transparent, inviting the audience into the conversation as the project develops.

Funding for *The Mojave Project* is provided through a Cal Humanities 2015 California Documentary Project production grant with additional support from San Diego State University. *The Mojave Project* is a project of the Pasadena Arts Council's EMERGE Program. The Mojave Desert Heritage & Cultural Association and KCET Artbound are project partners. For more information concerning Stringfellow's practice, visit www.kimstringfellow.com.

Four Years of Home Range Data of Sonoran Desert Tortoises (*Gopherus morafkai*): Fidelity and Sex Differences

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Since 2011 we have been using radio-telemetry to study the spatial ecology of *Gopherus morafkai* on the northern edge of Phoenix metropolitan region along the eastern edge of the Union Hills. Results from over 48 months of radio-telemetry provide insights on consistency in: 1) refuge use, and 2) spatial organization of home ranges across multiple seasons. Our study population now numbers 26 radio-tagged subjects (9 ♂♂, 15 ♀♀ and 2 juveniles), and we obtained 43 "home range years" (more than 60 relocations per year) for half of these individuals, allowing us to assess consistency in home ranges across years. Home ranges of males and females average 12 ha and are surprisingly consistent annually: repeatability = 92% for HR size ($F = 20.81$, $N = 11$ tortoises, mean = 30 months per individual HR estimate); ~ 80% overlap of HRs year to year within individuals. Nonetheless, some home range variation may still be critically sex dependent. Males have largely non-overlapping home ranges, and exhibit a pattern of movement in which they visit females on the periphery of their home range at the same refuge year after year.

Habitat Selection by Juvenile Mojave Desert Tortoises in the Eastern Mojave Desert

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Growing pressure to develop public lands for renewable energy production places several protected species at increased risk of habitat loss. One example is the Mojave Desert Tortoise (*Gopherus agassizii*), a species often at the center of conflicts over public land development. For this species and others on public lands, a better understanding of their habitat needs can help minimize negative impacts and facilitate protection or restoration of critical habitat. We used radio-telemetry to track 46 neonate and juvenile Mojave Desert Tortoises in the Eastern Mojave Desert and quantified habitat at tortoise locations and paired random points to assess habitat selection by this species. Tortoise habitats near burrows were more likely than random points to be under canopy cover, to be in areas with greater coverage of perennial plants (especially creosote, *Larrea tridentata*), to have more coverage of washes, to have a greater number of small mammal burrows, and to have fewer white bursage (*Ambrosia dumosa*). Active tortoise habitats away from burrows were closer to washes and perennial plants than were random points. Our results provide information that can help planners locate juvenile tortoises and avoid impacts to

habitat critical for them. Additionally, our results provide targets for habitat protection and restoration and suggest that diverse or abundant small mammal communities and the availability of creosote in habitats are vital for juvenile desert tortoises in the Eastern Mojave Desert.

STUDENT PAPER

A Draft Genome Sequence for Agassiz's Desert Tortoise (*Gopherus agassizii*): a Resource for the Conservation of a Threatened Species

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For threatened species, genome reference sequences are a resource to assess population diversity and to direct conservation priorities. We describe the whole genome and deep transcriptome sequencing, assembly, annotation and initial analysis of the genome of Agassiz's desert tortoise (*Gopherus agassizii*), a threatened species resident primarily in the Mojave Desert. Genome and deep transcriptome sequences were generated from a male from southern Nevada using multiple paired-end small insert and mate pair "jumping" libraries on the Illumina platform. RNA-seq was carried out using multiple tissues from the same source, including skeletal muscle, whole brain, liver, and blood, which contributed to both extension of scaffolds and genome annotation. The draft genome assembly for *G. agassizii* has a scaffold N50 length of 251.6 kb. Repeat analysis reveals that the desert tortoise genome consists of 43% repetitive sequences. Annotation based on deep transcriptomes and publicly available data identifies 20,172 protein-coding genes, with 94% of 458 core eukaryotic genes represented. Population genomic analysis of tortoises across the Mojave Desert reveals an initial map of polymorphic loci across the genome. Thus, this draft genome and annotation can serve as a reference for future population genomic efforts, and comparative genomic studies may yield insights into the genetic basis of adaptations to arid environments and longevity for this species.

STUDENT PAPER

Evolution of Sexually Dimorphic Traits in the *Gopherus* Tortoises

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The *Gopherus* tortoises are a unique group of species within the Testudinidae, as they exhibit both female-biased (*polyphemus* clade: *G. polyphemus* and *G. flavomarginatus*) and

male-biased sexual size dimorphism (SSD; *agassizii* clade: *G. agassizii*, *G. berlandieri*, and *G. morafkai*), and all species in the genus exhibit gular horn weaponry. Male-biased SSD and gular horn weaponry typically co-evolve in male tortoises in response to sexual selection pressures in species with mating systems featuring male-male combat; female-biased SSD evolves in response to natural selection pressures for females to produce larger eggs and hatchlings. To track the evolution of SSD and gular horn weaponry in the group, I examined their condition in *G. laticuneus*, the basal *Gopherus* species. I hypothesized that: 1) *G. laticuneus* exhibited male-biased SSD, which would implicate a reversal with respect to the evolution of female-biased SSD in the *polyphemus* clade, and 2) that gular horn weaponry has relaxed in the *polyphemus* clade in response to relaxation of male-male combat. I obtained measurements (carapace length, epiplastral projection, and sex) from fossil *G. laticuneus*, and from skeletal material for extant species. I compared the expression of sexually dimorphic traits to behavioral traits to determine how selection forces influenced their evolution. *G. laticuneus* exhibited male-biased SSD, and gular horn expression in the *polyphemus* clade is less sexually dimorphic than seen in *G. laticuneus*, but weaponry expression has also relaxed (though less so) in the *agassizii* clade. Higher population densities in the *polyphemus* clade species may explain the evolution of female-biased SSD, though a deeper commitment to burrowing likely reinforced a selection for gular horn weaponry in males. Based on these findings, I clarify the mating systems in extant *Gopherus* tortoises, offer hypotheses for the divergent evolution of sexually dimorphic traits in *Gopherus*, and provide implications for managing social behaviors in *Gopherus* tortoise populations.

Desert Bighorn Sheep in Mexico

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Mexico has one of the most successful wild sheep conservation programs in the world. Desert bighorn sheep numbers in Mexico have increased substantially during the past 30 years. They were extirpated in the states of Chihuahua, Coahuila, and Nuevo Leon but have since been reestablished in those states; the total number of wild sheep in Mexico is now approximately 10,600. As an example of a successful reestablishment program, 26 sheep captured in Baja California Sur during 1995–1996 were established on Isla del Carmen in the Sea of Cortez; the island now has 500 sheep. Private land owners and rural communities have benefited economically from wild sheep sport hunting enterprises. Land managers formerly dependent on the livestock industry, which is not economically viable in arid environments, now gain greater profits from wildlife than livestock. Sport hunting programs and their conservation interventions (captive breeding, reestablishment, and private enterprises) have been the primary impetus for increasing wild sheep populations. Without such programs, the status of wild sheep populations would have continued to deteriorate. Major cross-border wild sheep conservation issues include the construction of the border fence that could curtail wild sheep movements, the increasing human population and associated urbanization near the border, and the degradation and fragmentation of wild sheep habitats. At the socio-economic level, formerly marginalized communities have benefited from sport hunting programs. The importance of the empowerment

of local people in nature conservation, by recognizing the right and stewardship responsibility of rural communities, cannot be overemphasized.

Desert Tortoise Management and Research in Joshua Tree National Park

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Joshua Tree National Park (JOTR) protects nearly 800,000 acres of public land of which 240,000 is considered high quality desert tortoise habitat. The park has supported the recovery of the tortoise through participation of region wide planning efforts, management of habitat, educational outreach and scientific research.

JOTR staff and managers are active in efforts that promote the recovery of the tortoise through education, information exchange and research. The park is also an active participant in the Colorado Desert workgroup under the California Mojave RIT to guide future recovery efforts in the region.

Within the park, educational specialists provide desert tortoise educational presentations to many of the local (Morongo Basin and Coachella Valley) schools. The park also has an active habitat restoration program that works to return impacted habitats to functional ecosystems for tortoises and other animals. Desert tortoise awareness talks are given to all NPS employees, construction workers and even researchers doing work in the park that may impact the desert tortoise.

Since 2007, the park's wildlife staff has been tracking desert tortoises near roads as part of a study to understand the effect of roads on tortoise movement patterns. Currently, the park is analyzing the data with some interesting preliminary results.

Translocation Strategies and the Implications of Translocation for the Conservation of Bighorn Sheep

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Populations of bighorn sheep (*Ovis canadensis*), and the habitat they occupy, have declined substantially since the latter part of the 19th century. Currently, many populations of these ungulates face a precarious future. Since the 1920s, considerable effort has been exerted and money spent to restore populations of bighorn sheep into historic ranges. Despite those efforts, from 1923 to 1997, only 41% of translocated populations of bighorns were deemed successful. Much has been learned recently to improve translocation and reintroduction success. Some of those improvements include genetic considerations of source populations for translocations, modeling risk of disease outbreaks or encounter rate with domestic sheep in restoration areas, how intensive recreational activities can affect these ungulates—especially the

sexes of bighorns, and modeling habitat connectivity and migration routes for male and female bighorn sheep prior to release. All of that information has advanced our understanding and success of bighorn translocations. Additional information is needed on the ways that released individuals from different source areas interact, as well as understanding ecotypic differences among source stocks and how they may have implications for predator avoidance, recruitment, and demographic performance of reestablished populations. Answers to these questions will help wildlife biologists plan, conduct, and implement successful introductions of bighorn sheep into historic habitat.