ABSTRACTS

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Hybrid And In-person

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FORTY-EIGHTH ANNUAL MEETING AND SYMPOSIUM
THE DESERT TORTOISE COUNCIL

Hybrid: in person and virtual by Zoom
Thursday, Friday, and Saturday, February 23–25, 2023

ABSTRACTS OF PAPERS AND POSTERS

(Abstracts arranged alphabetically by last name of first author)
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Desert Tortoise Protection and Recovery in a Changing Climate

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The Center for Biological Diversity works towards recovery of the desert tortoise and its habitat in California, Nevada, Arizona, and Utah, using science-based advocacy, administrative processes, public information, and litigation. Natural and man-made threats to desert tortoise from development of new roads and routes, mines, transmission lines, and large-scale renewable energy projects are increasing. In addition to direct habitat loss, increasing habitat fragmentation and loss of connectivity also impair the tortoise's ability to seek more suitable habitat in a changing climate.

In California, the Center and others are pursuing litigation challenging the BLM's West Mojave Plan for failure to comply with NEPA, FLPMA and the ESA, and the Center works to ensure BLM's implementation of the Desert Renewable Energy Conservation Plan (DRECP) provides critically needed conservation for tortoise and other species.

In Utah, the Center and a conservation coalition continue to challenge Interior's decision approving a new Northern Corridor 4-lane highway through the Red Cliffs National Conservation Area.

In Nevada, the Center fights against development in tortoise habitat including by: pushing back against the Clark County lands bill, which would open up tens of thousands of acres of tortoise habitat to development; advocating for Nevada to adopt a DRECP- like model for renewable energy, steering development to lower conflict areas while protecting habitat and connectivity; and opposing new gold mining proposals near Beatty, in an essential climate connectivity corridor on the northern edge of the tortoise's range. In the southeast, the Center is reviewing the FWS decision not to list the eastern gopher tortoise throughout its range and in the eastern portion of its range and will continue to fight to get the protections the gopher tortoise needs to survive, and the Center is fighting new policies in Florida that are intended to accelerate development in tortoise habitat.

Status Review of the Mojave Desert Tortoise 2012–2022

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In 2011, the U.S. Fish and Wildlife Service (Service) published a revised recovery plan for the Mojave Desert Tortoise (*Gopherus agassizii*), which is listed as Threatened under the Endangered Species Act (ESA). In 2022, the Service published a status review that included information on populations east of the Colorado River beyond the range currently listed. Populations declined in 4 of 5 recovery units between 2004 and 2014 with a net decrease of 37% in adult tortoises. All 7 conservation areas with road densities above 0.75 km/km^2 had declining populations. Since 2011, approximately 31,000 ha of habitat have been approved for utility-scale solar energy development, although about 5300 ha are being constructed to allow the possibility of forage, cover plants, and tortoises to reoccupy the sites. Military training areas have increased, invasive grass-fueled wildfires remain a concern, and illegal cannabis farms have rapidly increased in southern California. Raven predation remains a concern, and badgers may exert severe effects on local populations. Insufficient law enforcement compromises agencies' ability to enforce regulations across the range. Potential effects of climate change are an increasing concern. Despite being in a more precarious situation than when the revised recovery plan was published, recognition of *G. agassizii* populations east of the Colorado River makes the range of the species slightly larger than the currently listed entity, and the total range-wide population consisted of hundreds of thousands of individuals at last estimation. The total estimated population size, combined with increasing population trends in parts of the range, suggest that the species is not in imminent danger of extinction in the foreseeable future, so the Service did not recommend a change in status. However, if greater progress is not made in alleviating threats, a recommendation to uplist the species to Endangered may be warranted in the next status review.

A Full-Scale Test of AI-Assisted Drone Surveys for the Mojave Desert Tortoise (*Gopherus agassizii*)

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Resi has developed a method for conducting AI-assisted drone surveys for the Mojave desert tortoise (*Gopherus agassizii*) and for generating abundance and density population estimates using a novel implementation of distance sampling. The method was tested during the 2022 survey season in two ways. First, a survey was conducted of the US Fish and Wildlife Service's desert tortoise training arena outside of Las Vegas, NV. Drone/AI survey results were compared with known counts of juvenile and adult surrogates ("styrotorts"). Second, a full-scale drone survey was conduced in Zone 6 of the Red Cliffs Desert Reserve in Washington County, UT. Pedestrian surveys utilizing traditional line-distance sampling techniques were conducted simultaneously for comparison and validation. Although survey intensity varied, both methods produced a sufficient

number of tortoise detections (n = 107 for drones and n = 154 for pedestrian) to produce reliable tortoise density and abundance estimates in the newly established Reserve. The drone/AI method performance was comparable or superior to that of pedestrian surveyors when target availability was high. However, in conditions of lower target availability detection rates were lower and confidence intervals were wider than for pedestrian teams. We suggest that the drone method be modified in future surveys to maximize the availability of tortoises for detection. With that modification, we believe that the application of drones and AI-assisted image search technology is ready for more widespread adoption to support tortoise population monitoring, pre-project surveys or in situations with limited, restricted, or remote access.

STUDENT PAPER

Genome Comparison of Sonoran and Mojave Desert Tortoises (*Gopherus morafkai and G. agassizii*) and Analysis of Immunological Gene Evolution

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The three desert tortoise species, *Gopherus morafkai, G. agassizii,* and *G. evgoodei,* diverged into separate lineages around 5 million years ago. To screen for any structural chromosomal changes in the genomes, such as insertions, deletion, and inversions, we used the published genome assemblies and annotations for *G. agassizii* (Dolby et al., 2020) and *G. evgoodei* (Rhie et al., 2021) and the assembly and annotation we generated for *Gopherus morafkai* to conduct pairwise synteny analyses for the three species. This analysis to date has confirmed structural similarity between the three species, but we are continuing with finer scale analysis. *TLR8* is a member of the Toll-like receptor (TLRs) gene family that serves an important role in the innate immune response, which plays a key role in protection against pathogens such as *Mycoplasma*. Earlier studies (Dolby et al., 2020) identified *TLR8* gene duplications in chelonian and crocodilian species, with a third copy in some turtles, including *G. agassizii.* We have analyzed the genomes and annotations of *G. morafkai* and *G. evgoodei* to confirm the presence of three *TLR8* gene copies, as well as the presence of the early stop codon in *TLR8B*, which is also present in *G. agassizii*. We are continuing to compare genomes of these three *Gopherus* species to identify the genetic basis of adaptations of each to their environments and the basis of increased susceptibility of *G. agassizii* to Mycoplasmal upper respiratory tract infections.

Settling, Movements, Home Range Sizes, and Growth of Small Head-started Tortoises After Release During the Megadrought

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We released two groups of head-started juvenile and small immature tortoises in early October of 2013 and 2014 at a site on Edwards Air Force Base (EAFB), in the western Mojave Desert, California. Monitoring of these tortoises continued through 2022. The existing population was depleted and consisted of few adults. In total, we released 83 tortoises of different sizes from 8 cohort years 2003–2010. We describe rapid settlement of tortoises released in 2013, based on observations made in the first weeks and through hibernation. Growth ranged from non-existent for most individuals in years of low rainfall to rapid in years of moderate to high rainfall, although individual differences existed. Similarly, extent of movements and sizes of home ranges retracted or expanded depending on whether precipitation was adequate to produce forage supporting above ground activities of the tortoises. We offered the tortoises opportunities to drink when transmitters were changed twice yearly in late winter and early fall, a decision that may have allowed longer survival during the 20-year megadrought. When our project ended, 18 of the 83 remained alive. Six tortoises had grown to a size of sexual maturity (≥180 mm in straight line carapace length); most, if not all, were females. The tortoises in our study followed patterns of behavior and growth previously reported in adult tortoises. Edwards Air Force Base provided support for this project.

STUDENT PAPER

Applications of Near Remote Sensing Imagery obtained with Unmanned Aerial Vehicles on Evaluating Desert Tortoise Densities at Local Scales

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Mojave Desert tortoises (*Gopherus agassizii*) are patchily distributed throughout their range even in areas of suitable habitat, and due to this irregular pattern, we seek to examine influential factors on tortoise densities at local scales. At landscape scales imagery derived from satellites allows for the analysis of explanatory environmental covariates in relation to range wide tortoise densities. Recently, advancements in remote sensing using unmanned aerial vehicles (UAVs) have become a viable option for obtaining environmental data at finer scales. Imagery obtained using UAVs has the potential to bridge the gap between large-scale satellite imagery and small-scale species distribution and occupancy analyses. To evaluate the effectiveness of UAV imagery in local desert tortoise density analyses environmental covariates are derived from

imagery obtained with UAVs and input into models alongside desert tortoise mark-recapture data. Point process models (PPMs) are an effective tool for evaluating the influence of covariates on the density pattern of a set of points. Examining factors that shape tortoise densities at local scales will aide in our understanding of tortoise distributions and contribute to future studies on habitat quality in which the sole focus is not only range wide suitability but local suitability and density patterns as well. Exploiting new technologies and their applications such as UAVs and fine-scale remotely sensed imagery will provide new opportunities to further our knowledge on variation in the densities of endangered and threatened species like the desert tortoise.

Cannabis Invasion: What We Need to Know and Do About It

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Abstract prepared by Heidi Brannan, a summary for the topics covered by the speakers
In 2016, Californians passed Proposition 64, Adult Use of Marijuana Act, which legalized personal use and cultivation of marijuana for adults 21 years of age or older; reduced criminal penalties in the state from felonies to misdemeanors and some misdemeanors to infractions; and authorized resentencing or dismissal of prior, eligible marijuana-related convictions. The proposition also included provisions to regulate, license, and tax legalized use to establish a legal market.

When Proposition 64 passed, it was thought that the establishment of a legal market for weed would hamstring the illegal market in the state. However, its implementation has had the opposite effect throughout California, and the illegal market has flourished while the legal market has floundered due to high operational and regulatory costs and a glut of illegally grown weed in the state.

California's Mojave Desert, with its abundant sunshine, vast open spaces, and cheap land, has proven itself as an ideal location to grow weed. Illegal grow operations popped up nearly overnight in the desert after the passage of Proposition 64, at a huge environmental consequence to the desert, its wildlife, and its communities. Decriminalization of cultivation under Proposition 64 has made eradicating these grows difficult as they are a misdemeanor offense. Work is needed at the state level to ensure that our environment and communities are not at risk while allowing the legal market to thrive.

This panel will discuss the implementation of Proposition 64, efforts made by the San Bernardino County Sheriffs' Department to combat illegal grows, the California Department of Fish and Wildlife's environmental permit review process for legal growers, reasons why the illegal market has overtaken the legal market, and how California State Treasurer Ma is working to legitimize banking for the state's marijuana industry in a federal banking landscape where marijuana is illegal.

Recovery Progress at Mojave National Preserve

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Recovery efforts for the desert tortoise (Gopherus agassizii) at Mojave National Preserve in 2022 included planning tortoise mitigation measures for major road projects, development of a tortoise habitat model, ongoing invasive plant control, raven management, monitoring of road maintenance projects, implementation of tortoise-focused public outreach, pre-project surveys, and habitat acquisition. Continued collaboration with Federal Highways Administration and USFWS to incorporate strategic tortoise fencing along Cima Road and other roads. Development of a tortoise habitat model for Mojave National Preserve to facilitate tortoise mitigation planning for future projects. Multiple vegetation projects were performed to survey for native plants and treat invasive species. Raven management continued in Mojave National Preserve with future plans for egg-oiling. 130 hours of tortoise monitoring to protect tortoises and their habitat. Tortoise monitoring included a large road maintenance project that required hauling road aggregate through vital habitat, and road clearing associated with monsoonal flooding which started in late July. Desert tortoise public outreach centered around "Drive Like a Tortoise"™ safe driving campaign and included a law enforcement special operation to target speeding on our paved roads. We continue to support ongoing research in head starting at the Ivanpah Desert Tortoise Research Facility. Land acquisitions continued with a total of 4347 acres acquired in FY2022 including parcels important for tortoise recovery.

Clark County Connectivity Management Plan

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The Clark County Desert Conservation Program (DCP) recently completed a five-year Southern Nevada Public Lands Management Act grant to evaluate the connectivity of desert tortoise habitat in Clark County and to develop a management plan to help maintain or increase connectivity across the county. The project included solutions modeling that looked at how future development may affect connectivity and various scenarios were modelled to see how they may affect both movement and genetics of tortoises over time. The DCP worked with the U.S. Fish and Wildlife Service and the Bureau of Land Management to gain a better understanding of if and how tortoises use culverts on the landscape. Contractors performed mark-recapture surveys around existing culverts to determine local population densities that could later be related to movement. We also evaluated each culvert associated with fencing in the county and assessed them for passability. Lastly, we created a Connectivity Management Plan to synthesize all the existing information and develop recommendations that can be used to maintain and enhance connectivity going forward. Some key recommendations include connecting all currently passable culverts to the existing fencing and upgrading all other culverts so that they are passable; installing desert tortoise fence in high priority areas; preventing large wildfires though fire management planning and fire prevention; and conducting further research on several topics including how strategic translocation may be used to fill in road dead zones and to increase connectivity across fenced roads.

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) on behalf of the Cities, Clark County, and Nevada Department of Transportation as mitigation for an Endangered Species Act Section 10 incidental take permit for desert tortoise and 77 other species of plants and animals. The DCP has collected mitigation fees for 3,382 acres of take during the period of January to October 2022, leaving 46,443 acres of take authorization remaining under the current permit. The 2021-2023 Implementation Plan and Budget allocated up to $19,617,877.05 for the funding of staff and projects starting in July 2021to run through June 2023. Highlights of desert tortoise-related work conducted over the past year include: occupancy surveys on the Boulder City Conservation Easement (BCCE); completed year 8 of post-translocation monitoring and conducted health assessments of desert tortoises on the BCCE; performed a translocation of 31 desert tortoises onto the BCCE; performed restoration on the BCCE to facilitate passive restoration of 4 km of closed roads; completed an initial analysis of predator-prey dynamics on the BCCE and surrounding areas; completed fence monitoring and road mortality surveys under the road warrior program; and continued work on public information and education through the Mojave Max program.

Restaurants Helping Ravens Return to Natural Population Sizes: Gold Star Restaurants

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Ravens have benefitted from resource subsidies provided by humans so much that their population has increased by over 800% in the western Mojave Desert over the last 50 years. Human food waste is an especially large subsidy. Raven predation is one of the greatest threats to young desert tortoise survival and adult recruitment in the California desert. We created and evaluated a behavioral change program among restaurants in Yucca Valley and Twentynine Palms, California in the western Mojave involving interventions designed to build empathy for tortoises, awareness of health code implications, and value for keeping the surrounding desert healthy. The initial intervention test led to significant increases (Wilcoxon p value = 0.002) in closure rates among treatment restaurants due to the interventions. The average increase was 9.5% toward maximum possible lid closure, translating to an average increase in dumpster lid closure of 35 days/year. Restaurants achieving 80%+ closure received “Gold Star Awards” to further stimulate community-wide behavior change by publicly recognizing and encouraging desired behaviors. The Gold Star program uses a social norming model of change involving window clings, tabletop informational tents, and in-restaurant posters, all of which are popular among awarded restaurants. We subsequently expanded the project with similar interventions in nearby Joshua Tree, across the Coachella Valley, and in Desert Hot Springs. We found that restaurants in those communities that are either heavily dependent on nature tourism (Joshua Tree and Twentynine Palms) or are strongly tied to the local ecosystem (Yucca Valley and Desert Hot Springs) were more likely to comply with closing their dumpster lids than more urban and seasonal communities (Coachella Valley). These observations help to more closely target where these interventions may be successful to benefit desert tortoises.

STUDENT PAPER

Fill in the Blanks: Modelling Juvenile Mojave Desert Tortoise Rates Past and Future

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Detection probability for juvenile and neonatal desert tortoises (*Gopherus agassizii*), during both transect based and capture recapture surveys, is consistently much lower than it is for adults. This is problematic for assessing demography, as the encounter rates for these smaller size classes do not accurately reflect the proportion of juveniles on the landscape that would be necessary to support populations with the numbers of adults typically encountered. This creates difficulty when modeling for the effects of stressors on changes in population structure, as many assumptions must be made leading to potential sources of error. However, accurately modeled population change is vital toward understanding recruitment of juvenile tortoises into adult size classes, which must consider an almost 20-year delay between hatching and reproductive age. In this research we used individually based modeling to estimate the survival during these less-detectable life stages that would be necessary to sustain adult population numbers measured in the field. We then evaluate different effects of habitat, predation, and anthropogenic impacts. We strive to use these improved juvenile population estimates, along with recently published estimates of egg production to create a spatially-explicit range wide population viability analysis.

Updates on the Desert Tortoise Recovery Office Staffing and Range-wide Monitoring Program for Mojave Desert Tortoises

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The U.S. Fish and Wildlife Service – Desert Tortoise Recovery Office (DTRO) was established in 2005 largely to address recommendations provided by the U.S. General Accounting Office in 2002 and the Desert Tortoise Recovery Plan Assessment Committee to "develop and implement a coordinated research strategy that would link land management decisions with research results." Staff within the DTRO focus on research, monitoring, recovery plan implementation, associated recovery permitting, and providing a central point of contact for which these activities are coordinated. Additionally, the DTRO works with the Desert Tortoise Management Oversight Group in coordinating range-wide issues and works with the California Desert Managers Group, research scientists, and many local, state, or regional working groups and community experts to promote updated science, tracking and reporting new information about the efficacy of management actions, and novel community ideas needed to support recovery. Since 2005, the DTRO was primarily comprised on five or less biologists including a Recovery Coordinator, Monitoring Coordinator, and 2-3 Recovery Biologists. Staffing within the DTRO changed significantly in 2022 and efforts are underway to replace remaining staff openings by February 2023. Staff changes and logistical constraints will likely prevent range-wide monitoring from occurring in 2023 for Mojave desert tortoises (*Gopherus agassizii*); however, efforts are underway to streamline monitoring starting again in 2024.

STUDENT PAPER

Isolating and ecotone: Landscape Genetics of Mojave Desert Tortoises near the Transition Zone of the Mojave and Sonoran Deserts

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Anthropogenic disturbance intensifies habitat loss and fragmentation for many species and is one of the greatest threats to Mojave desert tortoise persistence. Understanding historic connectivity across the landscape is important in quantifying impacts to determine appropriate conservation strategies and can be evaluated using genetic techniques. We used high resolution SNPs (single nucleotide polymorphisms) to understand desert tortoise population genetic structure and identify potentially important conservation corridors in the Desert Sunlight Solar Project area near the transition zone between the Mojave and Sonoran Deserts. We successfully genotyped 159 unique

samples and data were evaluated hierarchically, establishing population genetic clusters first, then estimating genetic differentiation, diversity, and kinship within our focused study area. We found that the survey area is part of a larger genetic cluster (Southern cluster) and that within that genetic group there are unique genetic subpopulations. Isolation-by-distance has played a large role in detectable genetic patterns across the landscape, along with historic features such as mountains and sandy bajadas. Genetic differentiation results indicated that the area is not of central importance to connectivity, but there were relatively high levels of gene flow within and among genetic population clusters. Preliminary long term dispersal distance in the area was estimated to be over 30 km based on third order relatives, supporting multi-generational dispersal events and the need to maintain large connective networks across the landscape. Our results foreshadow additional risk for the loss of connectivity due to increasing development pressures, with possible isolation of subpopulations and disruption of dispersal ability throughout the area.

Collaborative Partnerships: The Key to Conservation Planning in the Nation's Fastest Growing and Utah's most Biologically Diverse County

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Washington County has been the fastest growing county in Utah over the previous 30 years and one of fastest growing areas by percentage in the United States. The current growth rate of St. George is above 19% making it the fastest growing small metro area in the United States in 2022. This rapid population growth is projected to continue well into the foreseeable future. Washington County lies at the intersection of the Mohave Desert, Great Basin, and Colorado Plateau leading to a diverse mosaic of habitats and making it the most biological diverse area in Utah. Land and water development to accommodate rapid growth coupled with unique biological diversity has led to the potential for conflicts between economic development and sensitive / endangered species conservation. Several largescale collaborative programs between local, state, and federal entities have been established to manage these potential conflicts. We will provide a summary of many of these long-term cooperative planning efforts including the Washington County Habitat Conservation Plan and the Virgin River Resource Management Plan. Thoughtful land use and water development planning is instrumental in continuing to find solutions to maintain quality of life for the human population while enhancing sensitive wildlife and aquatic species habitat.

STUDENT PAPER

Examining Variation in Environmental Variables within Texas Tortoise (*Gopherus berlandieri*) Utilization Distributions in Cameron County, Texas

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The Texas tortoise (*Gopherus berlandieri*) is an understudied species compared to federally protected *G. agassizii* and *G. polyphemus*. Research is needed to better understand its basic ecology and inform conservation efforts. In south Texas, *G. berlandieri* inhabits Tamaulipan scrublands. Coastal populations are historically associated with *lomas*, low relief clay ridges with thick mesquital scrub typically surrounded by salt prairie grasslands. Our study examines seasonal patterns in *G. berlandieri* habitat use at a protected natural area in Cameron County, Texas. Twelve tortoises were outfitted with GPS loggers which recorded location once an hour from March 2020 to March 2022. We estimated utilization distributions (UDs) for tracked tortoises as Autocorrelated Kernel Density Estimates (AKDEs) using a 95% and 50% isopleth for each tortoise during each of the four seasons over each year. Compared to an estimated home range, a UD is a more refined and exact delineation of an area actually used by an organism. We compared UD size to determine if the amount of space used by tortoises differs among seasons. For each UD, we then examined environmental factors including canopy cover and a variable (flow accumulation) that assessed the potential for standing water to accumulate after a precipitation event. We compared canopy cover and flow accumulation within each UD to a surrounding buffer area that extended 100 m from the edge of the UD. We found that the sizes of UDs differed significantly across seasons for most tortoises, regardless of whether estimated as 95% or 50% isopleth AKDEs. Core UDs (i.e., 50% isopleth of an AKDE) were notably small during the winter months, with several UDs < 200 square meters in area. Further, tortoise UDs sometimes differed from surrounding areas in the amount of canopy cover and potential for water to accumulate. In particular, the potential for flow accumulation tended to be less in the utilization distributions than in the surrounding areas, indicating that tortoises avoid low-lying flood-prone portions of the study site. These results could inform effective conservation planning for the Texas tortoise, as understanding environmental variables (e.g., low-lying flood-prone areas) associated with *G. berlandieri* presence could assist in habitat protection and management.

Desert Tortoise Translocation of the Marine Corps Air Ground Combat Center (Combat Center) in 2022

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Annualized survival in the Combat Center's translocation was 95.8% overall at the end of December 2021, the 57 month mark, with high survival among Controls (C; 95.5%), Residents (R;

97.3%) and Translocatees (T; 94.8%). After the five-year mark in 2022, we removed transmitters to reduce tracking per the six-to-ten year protocol (large: 50 Controls, 50 Residents, and 50 Translocatees). We also monitored 59 small tortoises headstarted prior to release at 120 to 160 mm carapace length. We did not translocate animals in 2022, because there were few animals (ca. 50) that met the carapace length criterion (120 to 160 mm), and 2022 was the second year of drought, which began in mid- to late-2020. Absolute and annualized survival since the removal of transmitters from the respective groups and sites was moderately high (for large C, R and T tortoises: absolute: 88.0, 92.0 and 96.0% respectively; annualized: 82.6, 88.2 and 94.1%, respectively), but suggestive of drought conditions reducing survival. Most of the mortality (58%) was attributed to predation by coyote and badger (n=6 and 1, respectively).

2020-2022 Common Raven Density Trends throughout California's Tortoise Conservation Areas: Signs of Initial Success in Five of Six Intensively Treated Areas

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To restore and maintain annual common raven (*Corvus corax*, raven) predation hazard rates experienced by Mojave desert tortoise (*Gopherus agassizii*, tortoise) juveniles (≤10-year old) to <0.078, we are implementing an adaptive common raven management program throughout California's seven Tortoise Conservation Areas (area). Between 2020 and 2022, raven densities declined in five of the six intensively managed areas and remained stable at a low density in the Chemehuevi area. Linear trend estimates ranged between approximately -0.33 and 0.43 ravens year^{-1} km^{-2} in the four areas where three years of monitoring data were available. Percent within-area raven abundance change estimates ranged between approximately -62 and 57%, for an average raven abundance change among areas of approximately -31%. In 2022, density estimates from five of seven areas were below the target 0.89 ravens km^{-2} tortoise-raven conflict threshold (threshold). Raven density, nevertheless, remains above the target threshold in two treated areas and is increasing at a rate of 0.43 ravens year^{-1} km^{-2} in the Superior-Cronese area. Following our adaptive management strategy, we have begun transitioning to maintenance management strategies within areas where raven density is below the conflict threshold. Accordingly, the two areas where raven density estimates are still above the threshold will continue to receive reset management until raven densities are below the threshold and raven predation no longer limits tortoise vital rates.

Climatic Variables Drive Past and Future Mojave Desert Tortoise Dispersal: Implications for Connectivity

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Describing dispersal is key to understanding how populations connect across a landscape, especially for species with long generation times. Different variables, both intrinsic and extrinsic, can be important in determining dispersal processes. Understanding the relative importance of these variables is important in preserving historic genetic and demographic connectivity in imperiled species such as the Mojave desert tortoise (*Gopherus agassizii*). We used multiple long-term tortoise telemetry datasets (4,860 combined years of data from 950 individual tortoises) across the range of the species to determine rates of dispersal. We fit logistic regression models to understand how seasonal weather and individual-level characteristics determine the propensity of a tortoise to make a dispersal movement. We also used a generalized linear model to determine which covariates influence the net distance a tortoise moved during a dispersal. We then informed an agent-based model with our results to assess how alterations in dispersal propensity under future climate scenarios may alter genetic connectivity of tortoise populations in the Ivanpah Valley region, along the California-Nevada border. Our dataset included 149 dispersal events from 116 different tortoises with displacement distances ranging from 106 to 13,650 meters. Dispersal propensity was higher in years of lower winter precipitation, higher summer precipitation, and warmer April temperatures; smaller tortoises were more likely to disperse. We did not find a relationship between net dispersal distance and any covariates. Simulated population connectivity under future climate projections did not differ between various CMIP5 emission scenarios over 100 years, though dispersal propensity trended slightly downward. Climatic changes in the near future do not appear to pose a direct threat to tortoise population connectivity via changes in dispersal propensity or dispersal distance.

WINNER: POWER OF PERSISTENCE AWARD

Highways and Desert Tortoise Habitat in Mojave National Preserve: Recommendations for Barrier Fencing

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Critical habitat for the desert tortoise (*Gopherus Agassizii*) was finalized in 1994 and published in the Federal Register mere months prior to passage of the California Desert Protection Act that created Mojave National Preserve. Tortoise mortality on highways continued unabated, however, despite these conservation advancements. Two-lane, asphalt-surfaced roads through the preserve are shortcuts between Coachella Valley and Las Vegas and between Interstates 15 and 40. Managed and maintained by the County of San Bernardino until 2012, there were few opportunities and little political will to remedy the situation despite known detrimental impacts (Boarman and Sazaki, 1996). The General Management Plan for the newly minted preserve concluded, "Mojave does not support the concept of installing new desert tortoise barrier fencing on paved roads in the Preserve" while at the same time recommending that CalTrans, "fund and install desert tortoise barrier fencing" along 64-miles of interstate (NPS, 2002). One bureaucratic consequence of this decision, the Biological Opinion for the General Management Plan, required NPS to report tortoise road mortalities annually. The results were sobering. We concluded mortality rates were sufficient to drive local extinction (Hughson and Darby, 2013). Transfer of roads to the U.S. government in 2012 brought the involvement of the Federal Land Transportation Program (FLTP) and the Federal Highway Administration (FHWA), opening the possibility of federally funded highway improvement projects. The shortcut from Palm Springs to Las Vegas, for example, is especially dangerous for motorists, having one of the highest rates of fatal accidents in the Pacific West Region of the National Park Service, and is thus a priority for highway safety improvements. The FHWA and FLTP are strong partners in conservation. Construction will begin on Cima Road in 2023 with five miles of tortoise barrier fencing planned. To assist with the scoping of safety improvements for Kelso-Cima and Kelbaker Roads, I developed, validated, and compared spatially distributed tortoise habitat models to guide the construction of tortoise barrier fencing. Environmental covariates included: elevation, slope, aspect, roughness, STATSGO2 soil unit, surficial geology, PRISM 30-year normal maximum temperature, minimum temperature, and precipitation, the new Mojave Network Inventory and Monitoring Program vegetation layer, and apparent thermal inertia (Nowicki et al. 2019). I compared three approaches: Generalized Linear Models, Maxent, and Random Forest using the continuous Boyce index for presence only data, first training the models on U.S. Fish and Wildlife Service line distance sampling data, then testing the models against our own anecdotal observations collected between 2001 and 2016. The Random Forest method appeared to be best at explaining our observations and most robust to poor prediction of anecdotal observations outside of critical habitat. At a suitability threshold of 0.2 and greater, approximately 49.3% of the combined area of Mojave National Preserve and Castle Mountains National Monument is tortoise habitat. Nearly 77% of paved highways in the preserve, however, are in tortoise habitat. In addition to 5-miles of tortoise barrier fencing already planned for Cima Road, at least 36.5-miles of road from Cima to Interstate 40 will require tortoise barrier fencing. Future planning will assess other paved roads for installation of tortoise barrier fencing, where needed, or removal of asphalt.

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STUDENT PAPER

Comparative Thermal Ecology and Activity Patterns of three species of *Gopherus* tortoises

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Almost 50% of modern tortoise species are endangered or already extinct. The compact body plan of tortoises favors heat conservation compared to other terrestrial ectotherm vertebrates, potentially increasing risk of overheating. Desert-dwelling tortoises dig burrows or seek refuge in rock crevices to avoid the heat. However, tortoise habitat in arid environments is increasing in temperature and prolonged drought reducing available habitat due to climate change. There are six tortoise species in North America and Mexico (genus *Gopherus*) and they differ in genetics, distribution, morphology, body size, diet, habitat, and shelter site selection. Most *Gopherus* species have been assumed to have a similar physiology as *G. agassizii* despite differences in genetics and ecology and more recent evidence suggesting varying thermoregulatory strategies for different species. Therefore, understanding each species' specific habitat requirements and physiological properties are important to allow inferences about tortoises' potential to cope with temperature shifts and habitat alterations. Niche modeling predicts extensive range contractions for many chelonian species, but there is a lack of sufficient physiological data at an appropriate resolution of microhabitats to refine these models and improve predictions to guide conservation action for specific populations and species. Our study measures core physiological data, operative environmental temperatures, and movement and activity patterns of species occupying differing habitats: *G. flavomarginatus*, *G. morafkai*, and *G. evgoodei* in the Southwestern US and Mexico. Our results suggest *G. flavomarginatus* occupy lower average (external) body temperatures than *G. evgoodei* and *G. morafkai*. *G. evgoodei* has the highest body temperature similar to *G. morafkai* but has a narrower temperature range than either *G. flavomarginatus* or *G. morafkai*. All three species exhibit similar voluntary maximum body temperatures but *G. evgoodei* has a higher voluntary minimum body temperature than *G. flavomarginatus* and *G. morafkai*.

Mojave Desert Tortoise Week 2022: Making Outreach Count

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Establishing and sustaining an environmental education program is identified as a high-priority recovery action in the Mojave Desert Tortoise Recovery Plan. The goal of these planned events aspired to build public support for and involvement in Mojave Desert tortoise (*Gopherus agassizii*) recovery. The U.S. Fish and Wildlife Service (Service) organized and hosted a public outreach campaign to inform the public about desert tortoise conservation issues, aimed to change any misinformation of the Mojave desert tortoise, and raise awareness of how public actions may affect the species. The campaign called 'Desert Tortoise Week 2022' occurred within the first week of October; nevertheless, events occurred throughout the entire month. The education campaign was preceded by the hosting of hybrid (in-person and virtual) events and advertisement through social media. Events were hosted within multiple states and included a series of desert tortoise talks, guided tours, and presentations. The Service also implemented a social media campaign that challenged members of the public to engage in desert tortoise awareness activities including posting photos of desert tortoise habitat during recreational outings. The Service encouraged conservation partners to develop and host educational events to promote conservation and recovery actions for the desert tortoise. These partners developed educational virtual lesson plans, hosted webinars, recruited volunteers to remove invasive plants, and established scavenger hunts for the public to enjoy and learn more about the species. After Desert Tortoise Week 2022, our conservation partners reported public participation resulting in attendance of over 3,000 people at events and over 1.2 million social media impressions. Overall, Desert Tortoise Week 2022 was a success. The Service will continue to support and coordinate Desert Tortoise Week into the future.

WINNERS: ROBERT C. STEBBINS RESEARCH AWARD

Genomic Approaches for Chelonian Conservation in a Changing World

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Desert tortoises have evolved over the last 5-6 million years to adapt to the varied and changing xeric habitats within the Mojave and Sonoran Deserts[1,2]. Their ability to function in these environments is encoded in their genomes, the complete set of genetic instructions, which interact with environmental characteristics during their development and lifespan to shape the features of species, populations, and individuals that we observe today. Until recently, the cost of sequencing an entire genome was prohibitive, even for a single representative species and especially for several individuals within a species. However, over the past two decades, the cost of sequencing has steadily fallen to make individual and population level sequencing possible[3]. Costs continue to fall for other sequencing technologies, driven by economies of scale and new markets, for example analysis of pathogens such as SARS-CoV-2 and precision medical diagnostic sequencing of patient DNAs. In terms of sequencing costs, we are now at the cusp of large-scale sequencing analyses in the desert tortoises and other species under wildlife management review that are feasible within current grant funding levels. The reference genomes of a number of chelonians have already been reported, including the Aldabra giant tortoise[4,5], Galapagos giant tortoise[6], snapping turtle[7], Chinese three-keeled pond turtle[8], Asian yellow pond turtle[9], big-headed turtle[10], northwestern pond turtle[11], red eared slider[12], western painted turtle[13], Chinese soft-shell turtle[14], and green sea turtle[14]. The rate-limiting step for conservation genomic analysis is becoming the availability of trained expertise in the computational analysis of large data sets among researchers trained in evolutionary and population genetics. University training programs recognize this need for conservation data scientists and are beginning to respond, and continuing education through online and hands-on training will also be important for the current wildlife management workforce.

What window into conservation and organismal biology does having genome sequences of desert tortoises open up? First, the availability of a reference genome for each species or population can be the basis for finding the genetic differences that might account for their adaptations including i.) morphology and size, ii.) food and water metabolism, iii.) resistance to pathogens and immune response, iv.) reproductive strategy, and v.) behavior that will shape resilience to climate change[15]. Second, while not intuitively obvious, the genomes of each species also represent a historical record of past populational divergence, changes in effective population size in response to habitat and climatic changes, and hybridization and gene flow/introgression events among related lineages. As we look forward to a rapidly changing planet with growing climatic extremes in the US southwest, the historical adaptation of *Gopherus* tortoises to glaciation and other major changes could be instructive. Third, having genomic reference sequences permits environmental DNA (eDNA) analysis from soil samples and scat to determine the presence and identity of tortoises in the habitat. This approach is noninvasive and can avoid the need for intensive and expensive ground surveys[16]. Fourth, genomic sequences from individuals within populations and species can give us a snapshot of the biodiversity of each species or population across the southwestern landscape, including the identification of i.) genetic diversity and adaptation hotspots that should be high on the list of preservation to maintain the genetic reservoirs for functional adaptation of *Gopherus* to a changing planet, ii.) the contributions of males and females to subsequent generations, which affect effective population size and is important to gauge the effectiveness of translocations[17], and iii.) monitor the effects of roads and other human development on gene flow between populations[18].

As with the applications of sequencing to human therapeutics, there are potential avenues for actions based on these findings. Identifying the genetic and environmental factors that make the Mojave desert tortoise more susceptible to *Mycoplasma* disease could identify interventions to improve population health, understand the recovery units that are most likely to benefit from intervention. Similarly, identifying the genetic factors that have allowed tortoises to adapt to different rainfall, temperature and vegetation differences across the southwest could be combined with climate forecasting to estimate which gene alleles may be most adapted to future conditions, allowing for a *pro*active conservation approach[19]. An organism's DNA and supporting chromatin proteins encode epigenetic marks that affect function and that may change in response to stressors such as wildfire or extreme drought. Newly adopted sequencing technologies can detect these epigenetic marks to understand a whole new level of 'genetic' variation that has not yet been assessed in wild tortoises, but which may play an important role in current population health with potentially *trans*generational impacts. Are there epigenetic marks of 'stress' tortoises carry on to the next generation? Genome sequences have also permitted the development of CRISPR-Cas9 based gene editing techniques in reptiles[20], and the application of this technique to tortoises may aid in study of the confirmation of genetic factors regulating behavior, physiology, and resistance to pathogens. The emergence of these new genomic tools coincide with the great need from conservation challenges in our increasingly changing world.

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NON-PROFIT ORGANIZATION: WINNER, POWER OF PERSISTENCE AWARD

50 Years of Desert Tortoise Conservation at the Desert Tortoise Research Natural Area

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Five decades ago, the Desert Tortoise Research Natural Area (DTRNA) was created through a private-public partnership of grass-roots conservationists, prominent scientists, and the U.S. Department of the Interior, Bureau of Land Management (BLM). This presentation will provide an overview of three main lines of conservation actions that have defined and guided 50 years of activities undertaken in support of the DTRNA. An overview of the timeline of conservation actions during each decade from the 1970s to present will illustrate a historical background of the formative years.

The main thru-lines of conservation strategies employed at the DTRNA and other preserve areas such as land acquisition, stewardship, environmental education and public advocacy will be discussed to inform future conservation strategies.

Land Acquisition at the DTRNA has evolved in three phases. Initially small private funding raised by the Desert Tortoise Preserve Committee, Inc. (DTPC) in the 1970s were utilized by The Nature Conservancy (TNC) to acquire inholdings. In the 1980s, the DTPC-TNC land acquisitions were acquired by the BLM with funding from the Congressionally-appropriated Land and Water Conservation Fund with proceeds 'recycled' for additional acquisitions. From the mid 1990s, Congressional land acquisition funding was limited and the DTPC reframed its approach by leveraging mitigation funds under federal and state incidental take permits; starting with the Yucca Valley Churches Project which was the first federal Section 10(a) and state Section 2080 mitigation transaction for the desert tortoise in 1992. Protecting habitat requires a mix of funding and acquisition approaches in light of changing policy priorities and availability of funding mechanisms.

Stewardship in support of the DTRNA historically was and currently is focused on constructing and maintaining perimeter fencing around the preserve and enforcement of use and access restrictions. In 1975, BLM received a congressional appropriation which kick-started protective fencing culminating in the protection of 32.5 square miles by 1977. On a parallel track, the BLM began the process of withdrawal of the public lands within the DTRNA from mineral entry and the general land laws by surveying the area for mineral values, followed by proposed withdrawal in 1975 and 1977 published in the Federal Register. The withdrawal of public lands from mineral extraction and general land uses currently requires renewal. The continuing need to maintain basic protective infrastructure at the DTRNA highlights the need for adaptive resource management to ensure long-term viability of preserve areas.

Environmental programs and public advocacy in support of the DTRNA is a case study of the long-term trajectory and benefits arising from environmental education. The DTPC launched an environmental education initiative in 1973 highlighting the population declines of the desert tortoise shortly following the 1970 and concurrent with the 1973 listing of the desert tortoise as threatened under the California and federal Endangered Species acts, respectively. Modeled on other conservation efforts, educational presentations initially focused on grass roots local organizations such as local chapters of the Garden Clubs and the Sierra Club. Over time educational efforts expanded with the assistance of a small grant from the BLM in 1976 for brochures, slide presentations, and conceptual designs for an interpretive kiosk at the DTRNA, which was eventually built in 1980. In response to the growing public awareness of the desert tortoise, since 1989 the DTPC and BLM have jointly funded a Naturalist during the spring visitation season at DTRNA. Increasing public support of conservation issues involves grass roots education that expands over a long arc of consensus-building.

The development and evolution of conservation strategies applied to the creation and growth of the DTRNA underscores strategic considerations for increased and enhanced conservation efforts for the recovery of the desert tortoise.

Management of Desert Tortoise Habitat on Bureau of Land Management Lands in California

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The BLM California Desert District administers nearly 3 million acres of desert tortoise critical habitat within 8 critical habitat units across 5 BLM field offices. In 2022, the BLM and CDFW completed the first use of the Durability Agreement to mitigate impacts of solar development on private lands through management actions on BLM lands. Mitigation funds will be used primarily to restore unauthorized routes, fencing and signage within areas of critical environmental concern and critical habitat. The BLM and USGS completed a monitoring protocol in 2022 for the restoration of linear disturbances which will be used to determine the success of route restoration within critical habitat. Raven control continued this year in all critical habitat units on BLM land in the CDD (except the Chemehuevi CHU). Control effort consisted mainly of egg oiling to reduce reproductive success. Using compensation funds from solar projects several thousand acres of priority desert tortoise habitat have been acquired in 2022 in the Chuckwalla CHU. Route restoration efforts continue in the West Mojave Plan area through multi-year partnerships and grants.

WINNERS: POWER OF PERSISTENCE AWARD

Where Are We Now? 32 Years of Desert Tortoise Recovery in Southwest Utah

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The Utah Division of Wildlife Resources (UDWR) has been monitoring desert tortoises for over 30 years, both on the Beaver Dam Slope (BDS) and in the Red Cliffs area, north of St. George. Shell remains documented on the BDS and concurrent declines of tortoise populations, prompted an emergency listing of the Mojave Desert Tortoise in 1989 (USFWS 1989). The federal listing of the entire population north and west of the Colorado River followed in 1990 (USFWS 1990). Two Recovery Units, based on unique morphological, ecological and genetic characteristics, were identified in Utah, the Northeastern Mojave and the Upper Virgin River, with the latter existing entirely in Utah and significantly smaller than other recovery units (USFWS 1994, USFWS 2011).

In the mid-1990's, Washington County, Utah was one of the fastest growing counties in the United States. Population growth fueled conflict between economic development and protection of Utah's only native turtle, the desert tortoise. Since the listing of the desert tortoise, Washington County's population has grown 297%, from a sleepy town of 48,600 people to a growing metropolitan area of 192,900 in 2022 (USCB 2022). For comparison, the population in the United States grew 33% and Utah grew 93% during that same time period. Utah's long term trends suggest the state will continue to grow, especially south of St. George, where the proposed city, Desert Color, is planned.

To resolve conflicts and in an effort to provide long term protection to the desert tortoise, Washington County, under Section 10 of the Endangered Species Act, partnered with federal, state, and local agencies to create the Washington County Habitat Conservation Plan, setting aside habitat for the long term protection of the desert tortoise (WCC 1995, 2020). Under the Omnibus Public Land Management Act of 2009, federal lands in both Recovery Units were designated as National Conservation Areas (NCA), creating the Beaver Dam Wash and Red Cliffs NCA's (Public law 111-11, March 30, 2009).

The State of Utah has been committed to the protection and recovery of desert tortoises and actively engaged in habitat protection, restoration, translocation and population monitoring. Early studies helped identify and describe the distribution and abundance of desert tortoises, demography, reproductive strategies, as well as document mortality on the Beaver Dam Slope (Coombs 1977, Jarchow 1989, McLuckie and Fridell 2002, Minden 1980, Minden and Keller 1981). In early 1990, UDWR participated in an interagency desert tortoise health study focusing on hematological, bacteriological and parasitic characteristics of free-ranging desert tortoises in the City Creek study area, north of St. George (Dickinson and Reggiardo 1992, Dickinson 1993). UDWR established and monitored long term mark recapture plots at City Creek, Woodbury-Hardy, Beaver Dam Wash, and Welcome Wash, conducting surveys throughout the 1980's and 1990's, until the focus shifted to regional monitoring with the implementation of distance sampling (Fridell 1995, Fridell and Coffeen 1993, Fridell and Shelby 1996, Fridell et al. 1995a, Fridell et al. 1995b, Nickolai and Fridell 1998). In 1997, the Utah Division of Wildlife Resources designed and implemented a monitoring program within the Reserve to determine long term population trends

(Fridell et al. 1998), a critical component of both the Desert Tortoise (Mojave Population) Recovery Plan (USFWS 2011) and the HCP (WCC 1995). Tortoises within the Red Cliffs NCA have been monitored for 15 years, over a 27 year period (e.g., 1997 to 2023; Allison and McLuckie 2018, McLuckie et al. 1998, McLuckie and Fridell 1999; McLuckie et al. 2000a, 2001a, 2002a, 2002b, 2002c, 2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018, 2020, 2022c). Regional population monitoring has also been conducted in Zion National Park (McLuckie et al. 2000b) and the Beaver Dam Slope (McLuckie et al. 2001b); these one year projects helped inform our federal partners, who, in turn, incorporated the results into subsequent monitoring and management programs.

UDWR has also been active in additional research including a genetic assessment of desert tortoise recovery units (Murphy et al. 2007), distribution and habitat use and their predictive value (Fridell et al. 1998, Bennion 2009, Jones et al. 2015), and occupancy estimation using data from long term monitoring plots (McLuckie et al. 2013). In addition, we have been compiling a road kill mortality database since 1987 as well as recording incidents of suspected illegal take, summarizing the data in annual field reports for agency partners (McLuckie 2022a, McLuckie 2022b). We also participated in an interagency effort to understand the distribution and abundance of desert tortoise populations on the Shivwits Band of the Paiute Tribe Lands (McLuckie et al. 2022b) as well as exploring Indigenous knowledge as a valuable and effective counterpart to western science (Barickman et al. 2022). Working with tribal, nongovernment agencies (Conserve Southwest Utah), local (Washington County), and state (Utah Tech University, Southern Utah University) partners, we not only increased our knowledge of tortoise distribution across the landscape but strengthened partnerships, producing a multifaceted study integrating biology and the Shivwits culture.

Further, UDWR has taken the lead in translocation since 1999, monitoring our long term translocation program (McLuckie et al. 2019), and using that information to inform our Translocation Management Plan, a strategy to move displaced tortoises in the Upper Virgin River Recovery Unit (McLuckie and Fridell 2023). Finally, following major wildfires in 2005 and 2020, UDWR has been actively monitoring long term impacts of large scale wildfires on tortoise populations (McLuckie et al. 2007, Kellam et al. 2022). Funding from Utah's Watershed Restoration Initiative (WRI), a partnership based program to improve high priority watersheds throughout the state, has been utilized to help restore fire ravaged areas in desert tortoise critical habitat within the Red Cliffs NCA. UDWR was instrumental in initiating funding for a large scale outplanting project on the Northeastern Mojave and Upper Virgin River Recovery Units to help restore burned habitat (Devitt et al. 2020, McLuckie 2020). Significant WRI funding has allowed UDWR habitat biologists to actively seed and treat burned habitat on a large scale.

Future directions include implementation of the Translocation Management Plan, expanding translocation sites, continuation of long term monitoring in the Red Cliffs National Conservation Area, surveying the Beaver Dam Slope to better understand the current status of Utah tortoise populations in the Northeast Mojave Recovery Unit, and actively working with agency partners to restore burned habitat and protect unburned habitat. Finally, we are participating in an interagency effort to develop a spatially explicit population model of the Mojave desert tortoise to assess primary threats and habitat responses for proactive conservation and recovery efforts. Challenges to recovery include wildfires, due primarily to the proliferation of nonnative grasses, and long term drought, a result of climate change. Local, state and federal partnerships are critical to successfully implement the HCP and recover desert tortoises. For millions of years, the tortoise has evolved adaptations to allow it to survive in the desert; its ability to persist in a harsh and unrelenting environment is testimony to its resilience. It will take a similar resolve and commitment to successfully manage and protect the Reserve and recover the desert tortoise in the face of continued population growth.

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

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The Desert Tortoise Recovery Program has made great headway and accomplishments in the year of 2022 ranging from efforts in research to outreach and community science. We have completed and published the 5-Year Review about the Mojave Desert Tortoise. There was a success in our adaptive management and implementation within five of our six desert tortoise conservation areas because the densities of ravens have declined, leading to declining predation risk to desert tortoises up to 10 years old. The Palm Springs Fish and Wildlife Office hosted their 4th annual Desert Tortoise Week with a combination of in-person and virtual events across California, Nevada, Utah, and Arizona to raise awareness and interest in conservation of the species. We implemented new recovery strategies across states regarding rehydration techniques to combat the effect of drought and increase survivorship. Through a habitat conservation plan, the St. George Fish and Wildlife Office worked together with Washington County to prevent the development of 6,000 acres in desert tortoise habitat.

Limits of Burrows to Buffer Against Climate Extremes–Iinsight for Headstarting as a Tool to Bolster Mojave Desert Tortoise Populations

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Organisms increasingly face extreme temperatures due to climate change and may depend upon flexible, behavioral strategies to cope with altered thermal regimes. Burrows and cavities provide animal-engineered microhabitats with more stable and moderate temperature and humidity profiles that can benefit their occupants, and by modifying burrow architecture and use, animals can mitigate their exposure to high temperatures. However, the extent to which burrows alter thermal regimes and mitigate against extreme heat events in the wild is often unknown. These questions are key for burrowing species of conservation concern, like the Mojave desert tortoise. Here, we characterize how desert tortoise burrows buffer exposure to surface temperature and humidity regimes using data from natural tortoise burrows in the wild. We then link these results to data from natural and artificial burrows used by nesting females at outdoor head-start enclosures, including data collected during a heat-wave that resulted in complete nest failure. We also discuss our decision to excavate late term nests at the Edwards Air Force Base head-start facility in advance of an extended heatwave in 2022. Our results highlight the high buffering potential of burrows, but also suggest that in some cases –particularly for younger life stages–burrows may not be sufficient to protect animals from extreme temperatures that are projected to increase under climatic change. These results can inform future head-starting methods for this species and incorporate contingencies for climate emergencies in protocols.

The "Road Warriors" project: Partnering with non-governmental organizations to implement citizen scientist monitoring of road effects on the Mojave desert tortoise (*Gopherus agassizii*)

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The U.S. Fish and Wildlife Service has identified installation of permanent tortoise exclusion fencing and undercrossings along roads as a significant priority for desert tortoise recovery. Data regarding road mortality throughout the range of the tortoise are necessary to evaluate effects to recovery of the species and to prioritize areas for installation of fencing. We used citizen scientist volunteers trained and supervised by qualified biologists to conduct systematic road surveys to document tortoise mortalities and presence on or near roads in areas where tortoise exclusion fencing has not been installed. In collaboration with the Center for Large Landscape Conservation, the Western Transportation Institute, and Tortoise Group, the Roadkill Observation and Data System (ROaDS app), was specifically customized for Mojave Desert fauna, including raven observations on or near roads. The Tortoise Group uses this app for documenting observations of tortoise road mortality, live tortoise encounters, carcasses, tortoise burrows, and tortoise sign on or near roads. Data regarding road mortality of other species observed during surveys is also collected. Species mortality data collected during road surveys conducted prior to and after installation of desert tortoise fencing can be used to identify mortality hotspots that should be prioritized for installation of desert tortoise exclusion fencing and provide information regarding potential benefits to other Mojave Desert fauna. In coordination with the Nevada Department of Transportation (NDOT), Tortoise Group citizen scientist volunteers also conduct inspections of existing fencing for damage that may that would allow tortoises to gain access to roads. The use of citizen scientists to conduct fencing inspections assists the NDOT with budgeting staff time that can be directed to expedient and cost-effective fencing repairs. Engaging citizen scientists in projects, such as Road Warriors, may increase public awareness, outreach, and education and the level of participation in conservation by the general public.

Evaluating Barriers to Connectivity Among Desert Tortoise Populations Using Agent Based Modeling

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One of the recovery actions listed in the 2011 Revised Recovery Plan for the Mojave Population of the Desert Tortoise is to determine the importance of corridors and physical barriers to desert tortoise distribution and gene flow (Recovery Action 5.5). In areas subject to anthropogenic pressures, corridors improve opportunities for individual contact and gene flow. It is important then to determine attributes of corridor suitability (e.g. size in the context of suitable habitat and disturbance levels), and to examine how linear barriers may impede otherwise connected habitat. Corridors are needed to allow movement between habitat patches, prevent genetic isolation, and ultimately to ensure persistence of the species.
This study explores the potential of individual (agent) based modeling as a new approach toward understanding the potential for tortoises to maintain connectivity in light of disturbance on landscapes associated with urbanization and other anthropogenic impacts and features. We seek to address these questions by modeling connectivity of tortoise populations among areas in fragmented habitat to better understand the possible influences of anthropogenic disturbance on genetic connectivity and population demographics of desert tortoises differentially impacted by anthropogenic activities and barriers to movement by modeling movement, mating and demographics, and population genetics. We simulated animal movements and associated gene flow across complex landscapes to evaluate multiple barrier scenarios. We incorporated areas predicted to fail to maintain genetic connectivity based on low connectivity index scores determined by previous work. Simulations were run forward-in-time for 100 years using empirically derived parameters for movement, mating, and mortality derived from field studies. Demographic and genetic patterns were predicted from simulation output to better understand the consequences of specific development alternatives.

Understanding the Regional Adaptive Potential for the Mojave Desert Tortoise using an Integrated Approach

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The Mojave desert tortoise (*Gopherus agassizii*) has suffered population declines yet continues to persist in a fragmented landscape that is influenced by changing land use and climate patterns. These stressors have been increasing across the species range for decades, but have recently accelerated, occurring on a shorter time scale than one tortoise generation. While adaptation and acclimatization may help species like the desert tortoise persist under environmental disturbances, adaptive intraspecific genetic variation is not often considered in studies examining extinction risk

under forecast models of climate change. The spatial distribution of adaptive genetic variation is a function of historical interactions between genetic drift, natural selection, habitat connectivity, and demography; therefore, adequately characterizing adaptive genetic variation for sensitive species such as the tortoise would benefit from pairing high-resolution genomic datasets with current and future habitat modeling as well as connectivity efforts. We used genome-wide single-nucleotide polymorphisms (SNPs) as well as outlier detection and Genotype-Environment Association (GEA) approaches to identify loci associated with climatic gradients between various regions across the species range. We pooled the identified loci into a dataset of 653 potentially adaptive SNPs and results indicate that there may be greater adaptive genetic variation along edge regions compared to core habitat. These GEA analyses were then compared to regional and range-wide habitat suitability models and landscape resistance models to delineate corridors and areas for conservation action now and into the future.

Living Along Unfenced, Moderately Trafficked Roads on the Nevada National Security Site

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Road installation impacts Mojave Desert tortoise (*Gopherus agassizii*) populations beyond the immediate barrier to movement and adjacent footprint of degraded habitat. Data collected on the Nevada National Security Site revealed an average of 1.04 roadkill among 23.04 roadside observations per year. This study quantified tortoise activity near unfenced roads with a wide range of vehicle activity (0–647 passes/day) at the northern extent of the species' range. We monitored 30 tortoises captured on or near paved roads, each for three active seasons (March–October) with GPS and radio telemetry tags. We examined road-crossings, the road-effect zone, and home range. There were 1,206 road-crossing attempts among 22 study animals, with 13 reported vehicle encounters. No study animals were killed or injured by vehicles. Road-crossing events increased during the nesting season for females and during mating season for males. Tortoises spent most of the time near (201–320 meters) roads and less time far (>320 meters) from roads. Possible road avoidance behaviors were observed with five tortoises not returning to or crossing roads. Home range (AKDE) varied considerably between the sexes and among study animals. Our results indicate tortoises cross roads to utilize resources on both sides and using tortoise exclusion fencing, necessary for high-trafficked roads, may not be necessary on land removed from public access with low to moderate traffic volume and a work force routinely educated in tortoise awareness.

Desert Tortoise Council Activities – 2022

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The Board of Directors (BOD) of the Desert Tortoise Council (Council) managed to navigate the COVID situation and continued to do business by holding seven online BOD meetings in 2022. We had a 14-member BOD until the last quarter of 2022 when we added Max Havelka and John Kalish. Cristina Jones just completed her term and will be stepping down, so we are currently a 15-member BOD with five open Member-At-Large positions. The membership of the Council includes approximately 325 active members with over 2,000 people in our contact list. As of December 31, 2022, the assets of the Council were $292,199. Our Ecosystem Advisory Committee (EAC), which is our most active committee, commented on 77 (96%) of the 80 notices received for projects or actions potentially affecting tortoises and their habitats in CA, NV, UT, and AZ and for interstate or national issues. In coordination with our agency partners and Turtle Survival Alliance (TSA), we held the Introductory Course/Workshop with the lecture conducted by Zoom followed by a field workshop and we had a total of 148 attendees. Our 2022 Symposium, which was held virtually with the assistance of TSA, was very well attended, and even included plenary speakers from Australia and Spain. The David J. Morafka Award went to a student studying disease in Texas Tortoises and two new annual awards were given to honor people who made a difference in 2022. These new awards included the Implementation of Conservation Actions Award and the Power of Persistence Award. In late 2022, the BOD developed a new award, the Linda J. Allison Memorial Grant Award to honor the late Linda Allison who was an invaluable researcher at the Desert Tortoise Recovery Office of the U.S. Fish and Wildlife Service. The Council's social media committee, which is made up of board members and volunteers, have been very active posting on various platforms. Due to COVID, the Mexican Tortoise Conservation Committee did not conduct in-person activities, but three Mexican scientists were able to virtually attend the 2022 Symposium. COVID also curtailed the in-person activities associated with the Agency Coordination Committee and the Advanced Training Courses, but we hope to re-energize these committees and courses in 2023. Representatives from our Education and Outreach Committee attended The Wildlife Society Western Section conference to educate attendees about the mission of Council, to sign up new members, and to sell SWAG as a fundraiser. Our Fundraising Committee sold SWAG and brought in funding through the Amazon Smile program. In addition, the Fundraising Committee is finalizing a job description for a professional fundraiser position that can help the Council increase our fundraising capabilities. The Council also finalized the plans for a "Drink Beer Save Tortoises" fundraising event on May 20, 2023 at the Escape Brewery in Redlands, California. And finally, the Council started a new Ad Hoc Committee for Illegal Cannabis Grow Farms in Southwestern Deserts in 2022 with the goal of understanding the regulatory framework and the impacts of these facilities on tortoises and their habitats. The Council had a very busy 2022 and we look forward to an even busier 2023.

Application of Thermography and Time-lapse Thermal Imaging in Studies of Juvenile Desert Tortoise Ecology

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Temperature is important to desert reptiles as it affects many aspects of their lives, including their ability to digest food, avoid overheating, and conserve water. Climate change creates increased urgency to understand the thermal ecology of desert reptiles and to develop tools for advancing such efforts. For decades, biologists have measured reptile internal body temperatures (Tb) using fine-gauge thermocouples inserted into the cloaca. Recent studies demonstrate that new tools such as infrared pyrometry and thermography may offer non-invasive means to estimate internal Tb in small lizards. We investigated the efficacy of thermography to estimate internal Tb in hatchling desert tortoises (n=39) in a controlled laboratory setting as part of a larger headstart program. We exposed hatchlings to one of two experimental thermal gradients (~22–40 or 22–60 °C) for 3 hours and compared paired surface (thermal camera) and cloacal (thermocouple) temperatures under warming (0.5 h), elevated (2.5 h), and cooling (2.5 h) temperature conditions. We then compared surface and internal Tb of hatchlings (n = 69) during normal activity within their home enclosures. We present findings from these analyses, along with additional time-lapse thermal video observations, that highlight limitations and strengths of thermography in juvenile tortoise research and conservation.

System-Wide Habitat Restoration Approach to Benefit Desert Tortoises

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The Orocopia Mountains in the Sonoran Desert have one of the few desert tortoise populations that have not decreased. Decreased rainfall in the area, leading to loss of those plant species that are susceptible to drought, has lead to simplifications in the plant community. Coupled with significant erosion due to off-highway vehicles and human created levee systems for flood control, the drought has reduced the value of this large land parcel for the desert tortoise. We sought to mitigate these increasing system-wide challenges using three strategies. First, we aimed to directly increase the number of perennial species available that are priority browse plants of desert tortoises during critical times. Out-planting may be directed to those perennial species that are drought-resistant and which have nutritional value for tortoises. In this way, limited restoration resources could be directed to specific perennial species. During prolonged dry seasons, desert tortoises can switch diets from annual and herbaceous perennials to other perennial species such as beavertail cactus, our focus in this approach. Second, most plant restoration successes are highly dependent on the seed bank in the area to be able to respond to the intermittent and unpredictable precipitation

in Southern California. Increasing seed banks will give a better opportunity for the annual species that are key tortoise food sources to wait for adequate conditions during winter and potentially summer precipitation. Last, we are aiming to improve key ecological processes related to hydrology and topsoil retention. By repairing or enhancing key ecosystem processes, we may increase the window of adequate conditions for native species to endure weather variability. Slowing and spreading water movement across the catchment using small check dams and enhancing resident rock barriers will allow greater water availability. As water movement slows, its erosion capacity decrease, and topsoil loss are minimized.

Application of Computer Vision for OHV Route Detection in Mojave Desert Tortoise Habitat

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Habitat degradation and direct mortality from expanding roads and off-highway vehicle (OHV) networks have been identified as direct stressors to desert tortoise populations. In order to ascertain a greater understanding of the effect OHVs have on *Gopherus agassizii* (Mojave Desert tortoise), we developed a computer vision model to identify spatially explicit estimates of OHV route density. For our purposes, OHV routes consist of non-paved linear disturbances across the desert landscape, including, but not limited to, designated routes. Utilizing NAIP (National Agriculture Imagery Program) geospatial data (n = 1,732 image chips), we trained a Convolutional Neural Network (CNN) using a Resnet101, in Fastai. When tested against a validation set (n = 343 image chips), the model benchmarked at 85% accurate (n = 290 correctly-classified images). Model classifications were then compiled and used to generate a heatmap raster for 23 Open-Use Off-Highway Vehicle Areas in Southern California. Across all image chips in the sample area (n = 100,581) we estimate ~19,000 linear km of OHV routes exist. Approximately 55% of the study area was classified as containing no OHV routes. However, a quarter of the study area had four or more OHV routes present within one chip (~150 m area). Single OHV routes were present in 16% of the study area, and 2-3 OHV routes were present in the remaining 4%. Outputs from our model provide a spatially explicit estimate of OHV route density. Estimates from such a tool can inform a framework upon which future studies and stakeholders can evaluate the impact of OHV use on Mojave Desert Tortoises and other desert wildlife.

Camera Traps at Road Crossing Structures and other Updates from the Upper Virgin River Recovery Unit

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This paper summarizes several projects and studies contributing to desert tortoise recovery in the Upper Virgin River Recovery Unit (UVRRU). A 2022 study utilizing camera traps at 6 different

crossing structures along Red Hills Parkway (Red Cliffs Desert Reserve) revealed greater than expected usage by tortoises, and potential design preferences between several different types of crossings. We observed a total of 38 road crossings by 21 different tortoises from May 24 – October 19, 2022. Our initial results show how tortoise passages can help maintain or improve linkages across busy roadways when adequately maintained and will inform future passage design in Utah.

Washington County HCP with assistance from the BLM, Snow Canyon State Park, and volunteers, recently conducted over 100 raven point-count surveys throughout a 200,000-acre area within UVRRU. Nineteen 'Techno Tortoise' decoy stations were also deployed in the study area. Preliminary data reveals areas of raven 'hot spots' and ongoing predation threats. Analysis of raven densities and predation rates will guide future management recommendations.

Wildfire impacts fueled by invasive plant proliferation continues to be a significant threat to tortoise habitat in UVRRU. Recent herbicide treatments with Esplanade (Indaziflam) and Plateau (Imazapic) have been successful in reducing invasive grasses along roads and utility right-of-ways, providing additional protection to unburned habitat in the Reserve.

The newly-designated 'Zone 6' of the Red Cliffs Desert Reserve has required extensive management efforts to reduce habitat impacts associated with OHV-usage, shooting, camping, and garbage dumping. In the past two years, significant progress has been made to reduce threats and protect this high density tortoise population. Zone 6 management actions have included increased law enforcement patrols, installation of fencing and signage, large clean-up projects, and ongoing recreation management planning.

West Mojave Desert Tortoise Hotspots: Management Options and Implications

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Starting in 2015 Hardshell Labs has conducted extensive desert tortoise sign searches on parcels owned by Transition Habitat Conservancy (THC) around Fremont Peak. The modest annual budget was initially used to survey a representative sample of the over 160 THC parcels using 10m standard tortoise sign search methodology. The majority of parcels lack sign of current occupation by desert tortoises but a small number have relatively high tortoise density. The difference between these two sets of parcels is striking and points to the existence of tortoise "hotspots" set in a landscape now largely depopulated. Importantly, many of the now depopulated parcels contained very old tortoise remains, pointing to formerly much higher overall numbers of tortoises and more homogenous distribution. Since 2017 our focus has shifted to examining three of these hotspots. Work has included 5-meter interval transects on two of the hotspots with a view to discerning demographics and distribution of juvenile tortoises within them. In the last few years we have experimented with integrating raven management actions (thorough nest mapping and comprehensive remote egg oiling) in the area with selected habitat enhancements to improve hydration and feeding opportunities for tortoises. This talk covers results of tortoise searches and posits reasons for the observed distribution patterns; presents demographic data on the best studied

hotspot; reviews past, current and possible future conservation actions; and suggests approaches for wider research and management decisions based on the findings.

Formation of a New Non-Profit for Mohave Ground Squirrel Conservation

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The Mohave ground squirrel is a state listed threatened species that has been petitioned for federal listing twice, in 1993 and 2005 and is not currently federally listed. In March 2022, we had the "Mohave Ground Squirrel (MGS) Week of Happiness" in Ridgecrest, CA that included a training workshop coordinated by The Wildlife Society, followed by scientific meetings hosted by BLM and led by the US Geological Survey. These meetings resulted in the completion of four draft proposals directed at what the group determined were the most critical research questions for this species. There is currently a Technical Advisory Group (TAG) for MGS that is led by the California Department of Fish and Wildlife and this group has been active since at least 2008 to support this species. The TAG acts as an advisory group to the Department but does not include functions that could actively support funding these research proposals or training opportunities for this species. To support these functions as well as coordinating the active MGS volunteer corps, a new non-profit has been formed.

PLENARY ADDRESS

Dust Storms Ahead: Climate Change, Green Energy Development and Endangered Species in the Mojave Desert

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The Mojave Desert contains the hottest, driest regions in North America and is also one of the most ecologically intact regions in the contiguous United States. However, a confluence of factors including urbanization, climate change, and energy development are rapidly transforming this ecoregion. As a result of these growing threats, even common, widespread Mojave Desert endemics are at risk of being driven to extinction by the end of the 21st century. Ironically,

renewable energy development that could delay or even reverse the effects of climate change in the region is also a potentially significant source of habitat loss for these same organisms. Protecting the Mojave therefore presents difficult choices about how to select among different conservation priorities. We argue that these choices will necessarily involve compromises in which protections for some habitats will have to be prioritized while allowing development in other areas. We review the state of conservation in the Mojave and use the Mojave Desert's iconic Joshua trees (*Yucca brevifolia* and *Y. jaegeriana*) as a case study to describe a frame-work for identifying habitats that should be given the highest levels of protection to ensure climate change resilience. Finally, using existing spatial data, we evaluate land use and conservation status in the Mojave. The result identifies considerable scope for compromise between conservation and renewable energy development. Although our examples are specific to the Mojave, we argue that these recommendations apply broadly to many biological communities threatened by climate change.

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STUDENT PAPER

Selection on the Move: Landscape characteristics influence resource selection and Movement Behavior of Sonoran Desert Tortoises

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Estimates of landscape resistance can be used to predict where movement should be facilitated or restricted among resources or populations. This can provide spatially explicit information to resource managers tasked with preserving or restoring areas that promote landscape connectivity. However, deriving meaningful estimates of landscape resistance requires knowledge of a species' resource needs and movement patterns. Step selection analyses are a powerful option for estimating landscape resistance and can help elucidate how landscape characteristics influence movement. We aimed to identify areas that facilitate connectivity for Sonoran desert tortoises (*Gopherus morafkai*) in southern Arizona, and to examine how tortoises interact with the physical landscape. To do so, we used tortoise movements in integrated step selection analyses to ultimately derive values of landscape resistance and then map functional landscape connectivity throughout the study area.
To document tortoise movements, we outfitted adult tortoises with GPS loggers recording positions at 30-minute intervals. We used hidden Markov models to characterize movements into either sedentary or moving behavioral states. We fit step selection functions to the movement behavioral state and used the best-fit model to predict the relative probability of movement through the landscape and derive a resistance surface. Using this resistance surface, we mapped functional landscape connectivity through the study area and identified areas where the landscape best facilitates tortoise movement and where movements may be constrained or blocked. Tortoises

selected to move through sloped areas near incised desert washes and rocky slopes that offer them shelter. They avoided extreme slopes and areas of open desert that lack these topographic features and resources. Our results suggest that topographic landscape features best explain how tortoises select habitat when moving through the landscape and should be incorporated in designing effective corridors for the species.

Citizen Science and Indigenous Partners Expand Tortoise Outreach in Southern Utah

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In the past five years, Washington County HCP has significantly improved its public outreach and elevated tortoise conservation in the local area by strengthening ties with the Shivwits Band of Paiutes and launching a citizen science program to gather desert tortoise (*Gopherus agassizii)* observations.

The Pika'aya Tooveep (*Tortoise Country*) project was the culmination of these efforts: combining Indigenous perspectives on conservation with contributions from government agencies, non-profit partners and local universities. With the support of Shivwits elders and youth, approximately 28% of the reservation was surveyed for desert tortoise. As the first comprehensive study in that area, the survey revealed valuable information about connectivity between the Upper Virgin River and Northeast Mojave recovery units and tortoise abundance in the transition area. The Pika'aya Tooveep collaboration also gathered oral histories from Shivwits elders to preserve traditional ecological knowledge.

Citizen science is the second major success story for tortoise outreach in Southern Utah. Since 2017, local residents and visitors have reported 280 tortoise observations throughout Washington County using an online survey form. Reports from citizen science informed relative tortoise abundance and distribution in the BLM's Red Bluffs ACEC — where sensitive soils and endangered plant species made traditional surveys potentially harmful. The high number of observations recorded along designated trails within the ACEC made it an ideal candidate for addition to the Red Cliffs Desert Reserve. In 2021, a portion of the ACEC and other adjacent lands were formally added to the Reserve. Citizen science played a major role in protecting some of the most densely-populated habitat known in the UVRRU. The benefits of citizen science are three-fold: HCP staff obtain data on tortoise distribution and abundance, observers receive education on tortoise conservation through the reporting app and the public becomes a partner in ongoing conservation work.

POSTER

Keep the Wild Wild, and Pets as Pets: A History of Collaborating to Keep Pet Tortoises as Pets

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Pet desert tortoises (*Gopherus agassizii*) are frequently kept in more moist habitats and fed food that is lacking in key nutrients. As such, they regularly are infected by *Mycoplasma agassizii*, a causative agent of upper respiratory tract disease (URTD) common in pet desert tortoises. Pet tortoises are more likely to be seropositive for *Mycoplasma agassizii* and typically exhibit much more severe URTD symptoms than do wild populations. Because they are so long-lived (typically 50-80 years in human care) and that movement of the tortoises in California is restricted by the state registration requirements, pet tortoises will usually need to be rehomed during their lifetime. We discuss a model collaboration between The Living Desert Zoo and Gardens (TLD) and the California Turtle and Tortoise Club (CTTC) that has successfully rehomed several hundred tortoises in the Coachella Valley over the last decade. TLD is the public face of the program and does all the animal care, while CTTC manages the rehoming process and permitting. TLD also provides the complimentary veterinary care and triages animals after the public surrenders the tortoises. Although it has required some modest investment in staffing, resources, and space by TLD and requires volunteer time and effort by CTTC, it directly meets the Zoo's core mission of protecting and restoring natural desert habitats and populations by keeping infectious pets from being released into the wild. This approach can be easily repurposed for local animal rescues, zoos, and similar mission-driven organizations that have a prominent social presence for relatively low cost.

STUDENT POSTER

Texas Tortoise Task Force: Collaborative networks to increase surveillance of disease in tortoises

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Texas tortoises are one of two North American tortoises not receiving federal protection, and due to features of life history, they are particularly susceptible to anthropogenically-mediated decline such as industrial development throughout their range. Not only do these disturbances fragment the habitat of the Texas tortoise and restrict their range, but they may also affect immune function leading to increased susceptibility to disease. Upper respiratory tract disease (URTD) has been detected in closely related desert tortoises and may cause morbidity and mortality in infected individuals. However, there is limited data on the presence of URTD-causing pathogens in Texas tortoises and whether anthropogenic stressors or biological factors influence disease dynamics, hindering proper management actions. Therefore, we propose to 1) test for presence of two URTD-causing pathogens across the range of the Texas tortoise in the U.S.A. and 2) assess whether tortoises are more susceptible to these URTD-causing pathogens based on biological characteristics and anthropogenic stressors. To ensure our survey efforts are as widely representative as possible, we have established a network of biologists and citizen scientists to aid in our efforts. We will collect blood samples from Texas tortoises throughout their range in the United States test for the two URTD causal pathogens (*Mycoplasma agassizzi* and *M. testudineum*). We will further collect geographic variables, such as distances to regions of development and distance to roads, biological data (age, sex, size, any clinical URTD signs) to understand if certain anthropogenic stressors are associated with URTD, if observed. This knowledge will aid in relocation efforts of Texas tortoises in proximity to oil/gas operations and increase our understanding of disease incidence.

Synthesis of Efforts to Optimize Desert Tortoise Head-starting in Mojave National Preserve: 2011 – 2022 Results and Future Directions

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Head-starting is the process of rearing juveniles to a life stage less prone to mortality once released into the wild. Developing optimal and most efficient husbandry and release practices for head-starting Mojave Desert tortoises (*Gopherus agassizii*) has been an ongoing effort to recover the species in Mojave National Preserve, CA. Since 2011, we have released and radio-tracked 324 juveniles. Released juveniles were reared under five husbandry treatments: directly-released hatchlings (n=42), outdoor rearing for 1-2 years (n=92), outdoor rearing for 6-7 years (n=54), indoor rearing for 8 mo – 1 yr (n=58), and combo-rearing (1 yr indoor-rearing followed by 1 yr outdoor-rearing; n=78). Based on radio-telemetry monitoring of post-release movement and survival data collected from 2012 – 2022, we will summarize the major findings to date, with a focus on detailing the evolution of our head-starting and release protocols and our recommendations for best management practices for using head-starting as one of the recovery tools for desert tortoises.

Desert Tortoise Management and Research in Joshua Tree National Park

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Joshua Tree National Park protects nearly 800,000 acres of public land of which 240,000 is considered high quality desert tortoise habitat. Park managers have supported the recovery of the tortoise through participation of region-wide planning efforts, management of habitat, educational outreach, and scientific research. Educational specialists provide desert tortoise educational presentations to visitors (e.g., Desert Tortoise Week) and local school groups. The Park also has an active habitat restoration program that removes exotic plants and outplants native species. Desert tortoise awareness trainings are given to all NPS employees, construction workers and even researchers that may affect the desert tortoise. The Park continues its long-running telemetry project where some tortoises have been tracked for over 15 years near roads. This study to understand the effect of roads on tortoise movement patterns has resulted in some interesting results and soon will be analyzed. Additionally, the Park continues to work with the USFWS and other partners to reduce common ravens with some indication that the action is working to reduce predation on juvenile tortoises.

Effects of Herbicide and Drought on Desert Tortoise Habitat Restoration

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Non-native grasses (e.g., red brome (*Bromus rubens*) and Mediterranean grass (*Schismus* spp.)) are prolific throughout the Mojave Desert and have severe consequences for native flora and wildlife, including Mojave desert tortoises. Effects of non-native annual grasses in the Mojave Desert include altered fire cycles, degraded wildlife habitat, and losses in biodiversity. Generally, attempts to control the spread of invasive grasses have been reactive, focusing on degraded habitats with a prior disturbance history (fire, mining, etc.). We investigated the efficacy of proactive herbicide treatments to reduce non-native, annual grass in otherwise intact plant communities. We used a split-plot design to investigate how single or repeat herbicide treatments affected native and non-native plant communities. Pre-emergent herbicide (imazapic) treatments were aerially applied to four 220 x 220 m plots at four sites in Gold Butte National Monument in the fall of 2019. An additional application occurred in fall 2020 on one third of each plot so that each plot had a once- and twice-treated section. We assessed the vegetation community for changes in non-native annual grass and annual forb cover during the growing seasons of 2020, 2021, and 2022. While 2019-2020 winter precipitation was average, extreme drought began summer 2020 and continued through summer 2022. We found small reductions of red brome cover and annual species richness in once-treated plots in spring 2020. No effects of herbicide were found after once- and twice-applied treatments in 2021 and 2022 on red brome cover or annual forb cover; however, these years experienced severe drought which reduced annual plant occurrence in all plots. While herbicide reduced red brome cover in 2020, subsequent drought potentially negated any benefit of using herbicide by negatively affecting all annual emergence. This emphasizes the importance of timing herbicide treatments during years with adequate precipitation to increase efficacy when restoring Desert tortoise habitat.