ABSTRACTS

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THE DESERT TORTOISE COUNCIL

TUCSON, AZ
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ABSTRACTS OF PAPERS AND POSTERS

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

Long-term Data Collection and Trends of a 130-Acre High Desert Riparian and Upland Preserve in Northwestern Mohave County, Arizona

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The Willow Creek Riparian Preserve (Preserve) is a privately owned 130-acre site located 30 miles east of Kingman, Arizona. The Preserve was formally established in 2007 with the purchase of 10-acres and an agreement with the eastern adjoining private landowner to add an additional 120-acres. The Preserve location was unfenced and wholly accessible by livestock, off-road vehicle use, and hunting. In October of 2008 the Preserve was fenced with volunteer efforts from the local Rotary Club and Boy Scout Troop 66. Additional financial assistance came through a large discount in the cost of fencing materials from Kingman Ace Hardware. A total of 0.5-linear mile of new wildlife friendly fencing (barbless top wire and 18-inches above-ground bottom wire) was installed along the south and west sides and connected to existing Arizona State Lands cattle allotment fencing. Baseline and on-going studies and data collection have occurred since 2004. These have included small mammal live trapping; chiropteran surveys with the use of Anabat; migratory, breeding, and winter avian surveys; amphibian and reptile surveys; deployment of game cameras; animal track and sign identification and movement patterns; vegetation and plant surveys; and a wetland delineation. Results and trends over a 10-year period have demonstrated not only an increase in wildlife and plant diversity, but an increase in overall abundance and use as well as additional habitat use beyond the Preserve boundaries. Habitat changes have resulted in some species no longer being present but subsequently replaced with a suite of other species dependent upon an increase of cover, structure, forage availability, nesting or burrowing opportunities, water availability, and other factors. Opportunities for additional on-going or new studies and data collection exist and volunteers are always welcome.

Desert Tortoise: Still Protected but Still Declining…

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The Center for Biological Diversity continues our conservation and recovery campaign for the desert tortoise and its habitat in California, Nevada, Arizona, and Utah through science-based advocacy, participation in administrative processes, public information and litigation. For over two decades, the Center has consistently supported increased protections for the desert tortoise as the path to desperately needed recovery. Some challenges that the Center focused on in the past year include protecting and supporting current safeguards and programs that protect desert tortoise and other desert plants and animals from an environmentally hostile federal administration. In coalition with others, we have increased the drumbeat of support for desert national monuments in California and Nevada which add a higher level of protection for desert tortoise. We've engaged in the implementation of the Desert Renewable Energy Conservation Plan (DRECP) in California to help assure its proper implementation while defending it from any proposed rollbacks. We continue to engage on poorly sited "grandfathered" solar projects that are not subject to the DRECP. We continue the struggle to limit ORV impacts in tortoise habitat from both authorized and unauthorized use and are anticipating a new West Mojave Plan release in early 2019. We are engaged in the Piute-El Dorado ACEC plan because it is key in mitigating impacts from the Dry Lake SEZ and protecting and enhancing populations of desert tortoise in that area. We have had some recent success in our ongoing legal challenges to the Southern Nevada Water Authority's pipeline water grab. We have been challenging BLM oil and gas leasing within desert tortoise critical habitat in eastern Nevada. We are pushing back on proposals to amend Clark County's desert tortoise HCP and expand the Las Vegas disposal boundary to undisturbed areas outside of the valley. We are fighting back against a massive military land grab, as the Nevada Test and Training Range seeks to expand into Desert National Wildlife Refuge.

Future Directions of the Large-Scale Translocation Site, Nevada

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The Large-Scale Translocation Site (LSTS) is a 100-km^2 (approx. 24,700-ac) fenced enclosure in southern Nevada that was used between 1997 and 2014 to translocate Mojave Desert Tortoises displaced from development or formerly kept as pets in the greater Las Vegas metropolitan area. The LSTS lies within the Ivanpah Valley, which is near an area of genetic admixture between genetic clades and is a major linkage between tortoise populations in California and Nevada. However, fragmentation of tortoise habitat in the Ivanpah Valley recently increased dramatically. In addition to the long-standing inter-state highway, golf course, two gambling resorts, and the enclosed LSTS, three utility-scale solar developments totaling 33.9 km^2 (8,379 ac) were constructed mostly between 2011 and 2015. As part of mitigation for solar development, the Bureau of Land Management secured funding to evaluate risks of reconnecting the LSTS to the surrounding Ivanpah Valley. Separate presentations in this session summarize the population status within the LSTS (Allison), health status of desert tortoises inside and outside the LSTS (Braun et al.), and genetic origins of desert tortoises in the LSTS (Scott and Shaffer). The results of these studies suggest that, while increased infection incidence is possible when reconnecting the LSTS to the surrounding population and some individuals originate from distant populations, the overall benefits of reconnecting the LSTS population to the greater Ivanpah Valley may outweigh any potential risks. Further studies are necessary for more conclusive long-term population viability estimation, and impact monitoring is recommended if populations are reconnected. The Fish and Wildlife Service is working with the relevant land management and wildlife agencies to determine the next course of action.

Translocations, Changes in Density, and Survivorship in the Large Scale Translocation Site, Nevada, 1997-2015

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The Desert Tortoise Conservation Center (DTCC) facilities were gifted in 1990 to the BLM in part to hold tortoises displaced by development before resettlement. In 1996, an environmental assessment was developed for a translocation program on BLM lands now referred to as the Large-Scale Translocation Study (LSTS) site near Jean, Nevada. In 1996, 1-hectare plot surveys estimated there were 1449 tortoises larger than 180 mm midline carapace length (MCL) at the LSTS. The DTCC is now permanently closed but between 1997 and 2014 approximately 9150 tortoises, including 4400 that were larger than 180 mm MCL ("adults"), were translocated from the facility. Line distance surveys were conducted at the LSTS starting in 2001 as a training module for other projects, allowing me to estimate annually the number of tortoises in the LSTS. Surveys from 2001 through 2007 mostly estimated abundances of over 1000 adult tortoises and include translocatees released right before spring surveys. Since 2008, coinciding with surveys before the annual release of translocatees, estimates of adult abundance have been less than 550. Since translocations ceased altogether, two surveys in 2015 indicated abundance of approximately 320 adults. Resightings of marked translocated animals provide an independent opportunity to estimate abundance and survivorship over time at the site. I compare the abundance estimates from distance sampling and from mark-recapture and examine survivorship in light of changing densities and translocation protocols over time. This approach also allows me to describe representation of resident tortoises and of each translocated cohort in the current adult tortoise population.

STUDENT PAPER

Ticks and Mojave Desert Tortoise Health Assessments

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Health assessments required by the United States Fish and Wildlife Service are conducted on the threatened Mojave desert tortoise to help monitor tortoise populations. *Ornithodoros* ticks, which carry the causative agent of tick-borne relapsing fever (TBRF) and occur throughout Mojave desert tortoise habitat, are observed on tortoises for these health assessments. Although ticks are often found attached to desert tortoises, for these assessments ticks are only noted as present on tortoises and are not analyzed further. This study analyzed ticks noted on health assessments as a function of season, location, sex, clinical signs and morphometrics. Our results show that ticks were more likely to be present on females than males and on tortoises with shell abnormalities. Ticks were also more likely to be found on tortoises residing at the Great Basin Field Institute (formerly, the Desert Tortoise Conservation Center or DTCC). Our analyses shed light on the understudied relationship between ticks and its common host, the desert tortoise. Information from this study can be used to help better understand potential tick-borne disease dynamics in the Mojave desert in relation to the tick-vector and its host, the desert tortoise.

POSTER

Ticks and Tick-borne Pathogens of Mojave Desert Tortoises

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Soft-ticks in the genus *Ornithodoros* (*O. parkeri* and *O. turicata*) occur throughout the Mojave and have been documented to frequently parasitize Mojave desert tortoises. These ticks (commonly called “tortoise ticks”) often are not identified to species nor life stage when collected. These tick species carry the pathogen *Borrelia*, which is responsible for Tick-borne relapsing fever (TBRF). The potential for ticks to transmit disease to desert tortoises, however, has not been well documented. This study aims to identify tortoise ticks to species and to determine the pathogen prevalence in ticks collected in the Mojave desert. Thus far, we identified 223 ticks collected from desert tortoises using microscopy and morphological characteristics. Sixty-one percent were identified as *Ornithodoros parkeri*, 18% were *O. turicata* and the remaining 18% were not identifiable. Of the 223 ticks collected from tortoises 170 were analyzed for *Borrelia*, and all tested

negative for the pathogen. We hypothesize that an enzyme found in tortoise blood (similar to that found in western fence lizard blood) has a borreliacidal (*Borrelia* killing) effect. In order to address this hypothesis and learn more about tortoise ticks, we are asking tortoise biologists to send ticks collected from tortoises to Northern Arizona University for analyses. This work will contribute to the large gap of knowledge in relation to ticks and desert tortoises in the desert southwest and how conservation of this iconic animal may also lead to better public health.

INVITED SPEAKER

Warming Up with *Heloderma*, from the Desert to the Tropical Dry Forest

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Just over ten years ago when a panel on *Heloderma suspectum* was convened at the Desert Tortoise Council, the Gila monster was still regarded an elusive and poorly-understood icon of the American Southwest. Things have changed since then, largely thanks to members of this second "HESU" panel. Recent advances in our understanding of Gila monster biology provide a catalyst for exploring the deep connections among helodermatid lizards, desert tortoises, and the habitats these iconic creatures share. Seasonally dry tropical forest, an ancestral habitat for both *Heloderma* and *Gopherus*, has been called the "grandmother of the Sonoran Desert." *Heloderma* first appeared in similar tropical environments over 23 mya, and later colonized the warm Sonoran, Mojave, and Chihuahuan Deserts. The molecular diversity of beaded lizards and their current geographic distribution aligns with the deep evolutionary history of neotropical dry forests of North America. The more recent divergence of *Heloderma suspectum* in desert habitats is reflected in their lower molecular diversity. The thermal biology of *Heloderma*, along with latitudinal and local patterns of variation in the thermal landscape – from the Mojave desert to the tropical dry forests of Mexico – may provide additional insight for conservation issues today. Significant environmental changes associated with humans, such as more extreme drought conditions in desert habitats and stronger hurricanes in tropical dry forests, have important consequences for tortoise and *Heloderma* habitats. As our planet continues to warm, a broader perspective regarding evolution, habitats and thermal biology will be crucial for charting a conservation strategy for the future.

Land Acquisition, Protection, Restoration, Education, and Research

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The original and continuing goals of the Desert Tortoise Preserve Committee, Inc., formed in 1974, were and are to establish protected areas for the desert tortoise in representative ecosystems, to promote education and research, and to recover tortoise populations. Over the last 45 years we have focused on land acquisition, protection, restoration, education, and research. Our best known and signature success, the Desert Tortoise Research Natural Area, grew from a couple of square miles in 1972 to 39.5 mi^2 (102 km^2) in 1976. In 1976, the U.S. Bureau of Land Management (BLM) held 65% of the land and 35% was in small, privately-held parcels. The majority of private lands have been acquired through funds and grants raised by the Desert Tortoise Preserve Committee, cooperative efforts with BLM, The Nature Conservancy, Wildlife Conservation Board, Land and Water Conservation fund, tax sales, land exchanges, mitigation agreements, and donations of parcels from private land owners. Dozens of small parcels remain, a slow process. The success of protecting tortoises and other wildlife such as the rare and endemic Mohave ground squirrel and burrowing owl, can be attributed to protection—the fenced perimeter, constructed in the late 1970s. This fence, raised several inches off the ground to permit movement of animals, keeps out vehicles and grazing animals. Since the early 2000s, the original size of the Natural Area has expanded by 5,510 acres (8.6 mi^2) and has been fenced or is in the process of being fenced, the first of many stages in restoring degraded habitat. Over the years, the Desert Tortoise Research Natural Area has become a major site for research on tortoises and other species and education of the public. Since 1990, the BLM and the Desert Tortoise Preserve Committee have hosted a Naturalist at the interpretive center each spring.

Another important acquisition of land was undertaken in 1995 in partnership with the Wildlands Conservancy. Together, at the behest and support of BLM, we acquired the Pilot Knob grazing allotment, base properties, and water rights encompassing 49,000 acres in the central Mojave Desert. This land is now in critical habitat for the tortoise. Other acquisitions are in the Colorado Desert and Chuckwalla critical habitat and in the Mojave National Preserve.

These protected lands are ideal sites for research and studies on a wide variety of topics and have contributed significantly to our knowledge of the tortoise, Mohave ground squirrel, and other species. The first discoveries of hyper-predation by the common raven on juvenile tortoises, upper respiratory tract disease (mycoplasmosis), sheep trampling, baseline health and physiology of tortoises, and selective choices of plant foods occurred at the Research Natural Area. At the Pilot Knob allotment, studies of piospheres (the degraded areas around water sources) added to the collective knowledge of impacts of cattle grazing and the relationships between land disturbance by domestic grazers and non-native, invasive grasses.

Variables Affecting Survival of Juvenile Desert Tortoises after Release from Headstart Pens at Edwards Air Force Base, a Preliminary Report. Part 1. Size and Growth

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In 2013 and 2014, we released 119 juvenile tortoises from eight cohorts hatched between 2003 and 2010 in headstart pens at Edwards Air Force Base (AFB), California. We previously described growth, health condition indices, and behaviors of the juveniles while in headstart pens (Mack et al. 2018. Crowding affects health, growth, and behavior in headstart pens for Agassiz's desert tortoise. Chelonian Conservation and Biology.17:14–26). The 119 tortoises were released in three groups (Fall 2013, Spring 2014, and Fall 2014) on two sites within Edwards AFB. The composition of each release group varied; in general, the larger tortoises were released first. Here we provide a preliminary report on selected variables affecting survival of tortoises 4–5 years after release at the two sites, one in Joshua tree woodland and the second in a diverse creosote bush scrub. When released, the tortoises were from 3 to 10 years old. Tortoises were placed in 4 groups by size (< 60, 60.0–69.9, 70.0–99.9, ≥100.00 mm MCL). We evaluated the effect of release site by comparing the 60.0–69.9 mm size groups from each site. Mean growth rates (increase in mm/year) ranged between 4.4 mm to 7.9 mm/year, with no significant differences between groups. We found strong, positive correlations between precipitation and growth rates for all size categories. We found no significant differences between groups with respect to their mean spring and mean fall condition indices. We evaluated differences in survival using Kaplan-Meier survival curves followed by log rank tests and found significant differences between the < 60.0 mm and 70.0–99.9 mm size categories and the < 60.0 mm and ≥ 100.0 mm size categories at the Joshua Tree site. Survival appeared to be a function of body size; in the coming months we will model additional variables to determine their effects on survival.

POSTER

Sky Islands High School Desert Tortoise Habitat Project

**Lucas Bogard, Science Teacher; Shari Popen, Director; and Student Tristan Speagle, Anthony Adkins, James Alter, Keenan Hart, Vanessa Navarro*

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Sky Islands' students in the Projects, Research, and Design class wrote a grant to the AZ Game and Fish Dept. Heritage Fund to build a desert tortoise habitat in the school's courtyard. They received the grant, but actually constructing the habitat became the work of the next year's Ecobiology students. After spending much time in the classroom learning about desert tortoise physiology, anatomy, behavior, adaptations and ecological relationships, as well as captive care, the students got to work on building the habitat.

The enclosure was built with the help of master sustainable builder Bert Scott, along with much assistance from Sky Islands' parent, neighbor, Danny Clark. The walls were built using polypropylene bags filled with a mixture of soil and cement, which was then plastered using a hydraulic lime plaster. This type of plaster, which is much safe and environmentally friendly compared to standard lime plaster, was provided by Natasha Winnik at Originate Natural Building Materials. To complete this massive undertaking, several all-day Saturday workdays were required, where a massive outpouring of students, family, friends, and neighbors showed up to lend a hand and leave their mark on this incredible experience.

After building the enclosure, the students constructed a burrow, researched and developed a list of native food plants for the tortoise, and then traveled to Desert Survivors Nursery where Sky Islands' good friend Jim Verrier helped the students select the right plants, as well as impart some of his vast knowledge of all things botanical. After the irrigation was installed and the plants were put in the ground, it was off to the Desert Museum, where Renée Lizotte, the Tortoise Adoption Coordinator, led the students behind the scenes and helped them find the perfect tortoise.

After much dedication and hard work on the part of Sky Islands' staff, students, friends, family, and neighbors, as well as tremendous support from all the stakeholders involved in the project, Sky Islands welcomes Abuelo, our new tortoise, in his beautiful habitat!
Watch the Making of the Tortoise Habitat on Sky Islands' YouTube Channel

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Assessment of Mojave Desert Tortoise Health Inside and Outside the Large Scale Translocation Site

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Desert tortoises inside and outside the Large Scale Translocation Site (LSTS) were evaluated to estimate the association between infection and clinical signs and determine whether there is a difference in this relationship inside compared with outside of the LSTS. The study population included 426 tortoises from four study sites evaluated in 2016 (T2), with a subset (n=196) also evaluated at an earlier time between 2011 and 2014 (T1). Prevalence of clinical signs of mycoplasmosis was measured at field health assessments. Individual infection status and prevalence of *Mycoplasma agassizii* and *M. testudineum* infection was determined by qPCR and ELISA performed on biological samples. Multiple logistic regression was used to estimate the association between infection and health, while controlling for other covariates. In 2016, the LSTS had the highest prevalence of *M. agassizii* (28%), *M. testudineum* (3.4%), and of clinical signs (18.1%); significant differences in prevalence were found across study sites ($p<0.05$). Presence of any clinical sign(s) was positively associated with *M. agassizii* infection (OR=7.7, $p=0.001$), but not with study site ($p\geq 0.127$). There was no such association with *M. testudineum* status ($p=0.360$). An estimated 3.1% of tortoises converted from *M. agassizii*-negative to -positive between T1 and T2, and incidence of conversion was greater within the LSTS ($p=0.002$). There was no association between infection status at T1 and presence of clinical signs at T2 ($p=0.18$), but conversion of *M. agassizii* status from negative to positive was associated with increased prevalence of clinical signs at T2 (OR=11.1, $p=0.018$). While *M. agassizii* infection and associated clinical signs of mycoplasmosis are present both inside and outside the LSTS, there is a possibility that incidence of *M. agassizii* infection and associated clinical signs would increase outside of LSTS if the two populations were to reconnect.

STUDENT PAPER

Development of Multilocus Sequencing Typing (MLST) for *Mycoplasma agassizii* to assess genetic variability

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Mycoplasma. agassizii has been experimentally confirmed as the causative agent of upper respiratory tract disease (URTD) in free-ranging Desert and Gopher tortoises. With the use of serological and molecularly validated diagnostic methods, *M. agassizii* was shown to colonize a wide host range. Understanding the epidemiology of this pathogen is important for maintaining wild and captive population health. 16S rRNA gene sequencing has been useful for determining taxonomy at the species level, but this approach lacks strain-level resolution. Multilocus sequence typing (MLST) is a molecular typing method that uses polymorphisms within housekeeping genes to categorize related isolates into clonal lineages. To assess the genetic diversity of *M. agasizii* isolates, 11 core genes and 14 isolates from various Chelonian species were selected. All isolates were previously confirmed through 16S sequencing to be *M. agassizii*. Core housekeeping genes were selected by reviewing literature of previously performed MLST on *Mycoplasma* species. Strains/isolates were selected to incorporate type strain(s), and host and geographical distribution of the pathogen. Primers for housekeeping genes were developed based on sequences obtained from the type strain *M. agassizii* PS6 genome. PS6 was used as an initial control to ensure primers were viable. Six *M. agassizii* isolates from native tortoises and seven isolates from exotic/non-native tortoises were amplified via polymerase chain reaction (PCR) and sequenced. Reads from isolates were aligned to determine if SNPs were present. Phylogenetic analyses were done on viable reads to determine relationship(s) between strains/isolates. MLST has been a powerful tool to study the epidemiology and genetic variation of major *Mycoplasma* strains. Although MLST cannot determine difference in virulence among isolates, we propose that it may be useful in retrospective and future transmission studies to study *M. agassizii* epidemiology in wild-caught and captive Chelonian populations.

Population Viability of Sonoran Desert Tortoises

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The distribution of the Sonoran Desert Tortoise (*Gopherus morafkai*) encompasses a broad range across Arizona and Sonora, Mexico. In Arizona, this range includes diverse ecosystems from the Lower Colorado River and Arizona Upland subdivisions of the Sonoran Desert, Mojave desert scrub, interior chapparal, and desert grassland. Accordingly, tortoise demography is likely to vary across the range, which has consequences for population viability. However, population viability analyses (PVAs) rarely account explicitly for spatial variation. We used capture–recapture data from multiple populations in Arizona to model spatially explicit estimates of adult survival (ϕ_{ad}), juvenile survival (ϕ_{juv}), and juvenile-to-adult transition rates (ψ). We combined local estimates of these demographic rates in population models to estimate the rate of population change (λ), then used estimates of λ to produce spatially explicit estimates of probability of extirpation (P_{ex}). There was modest spatial variation in $\hat{\lambda}$ (0.94–1.03), reflecting variation in $\hat{\phi}_{ad}$ (0.85–0.95), $\hat{\phi}_{juv}$ (0.70–0.89), and $\hat{\psi}$ (0.07–0.13). Sparse recruitment data forced us to use a range-wide estimate ($\hat{R}$ = 0.32 1-yr-old females per female per year). $\hat{\phi}_{ad}$, $\hat{\phi}_{juv}$, and $\hat{\lambda}$ tended to be lower and $\hat{\psi}$ higher in the northwestern portion of the range. For local abundances >500, P_{ex} was near zero (<0.05) across most of the range after 100 yr; as abundances decreased, however, P_{ex} approached 1 in the northwestern portion of the range and remained low elsewhere. When local abundances were <50, western and southern populations were vulnerable (P_{ex} > 0.25). This approach to PVA reveals spatial patterns in demography and viability of Sonoran Desert Tortoise populations that can inform conservation and management at multiple spatial scales. Comparable analysis of historical Mojave Desert Tortoise (*Gopherus agassizii*) population data would provide similar information and could provide a better understanding of recent population trends across the range of this Threatened species.

The Enduring Influence of Early Growth on the Life-History Trait Values of Turtles: Relationships to Conservation

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Data from three decades of study on the University of Michigan E. S. George Reserve provided answers to the following questions. (1) How do juvenile growth rates of three species of freshwater turtles (Painted Turtles, *Chrysemys picta marginata;* Blanding's Turtles, *Emydoidea*

blandingii); and Snapping Turtles, *Chelydra serpentina*) influence age and size at maturity? (2) Are the influences of juvenile growth on age and body size of females primarily due to phenotypic plasticity? (3) What are the reproductive traits (i.e. clutch size and egg size) of primiparous females (first lifetime reproduction)? (4) Is there evidence that adult growth rates subsequently reduce the initial differences in the body size and reproductive traits of primiparous females?

Fast-growing juveniles of all three species matured earlier and at larger (or similar) body size than slow-growing juveniles. The relationships between juvenile growth rates and age and size at maturity in Painted Turtles was established by age 4 years. Variation in indeterminate (post-maturation) growth was insufficient to reduce differences in reproductive traits within cohorts of females on the E. S. George Reserve. Similar results from all three turtle species of freshwater turtle (families Emydidae and Chelydridae) and Green Sea Turtles (Bjorndal *et al.*, 2013) indicate that: 1) juvenile growth rate is one of the most influential traits shaping fundamental and long lasting variation in the suites of life-history trait values within cohorts of long-lived female turtles, 2) patterns of relationships between early growth and traits of primiparous females (i.e., first lifetime reproduction) are not primarily due to phenotpic plasticty, and 3) relationships between juvenile growth rates and age and size at maturity were established in a common ancestor early in the evolutionary history of turtles (i.e. an evolutionary constraint) that has become a common evolutionary tactic for millions of years. Overall improvement of conditions that increase juvenile growth rates has the potential to reduce cohort generation time and increase reproductive output and parental investment of primiparous and older females. Therefore, the value of conservation plans that target early life stages (i.e., head starting) may have more influence on populations than previously thought based on relative survivorships of juveniles and adults. Although follow up studies of head started individuals have shown some promise, more studies of potential life-history tradeoffs in later life are needed.

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

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The Bureau of Land Management (BLM) manages habitat for both the Mojave desert tortoise (*Gopherus agassizii*) and Sonoran desert tortoise (*Gopherus morafkai*). Mojave desert tortoise habitat is managed by the Arizona Strip Field Office north of the Colorado River, and west of the Colorado River, in California, by the Lake Havasu and Yuma Field Offices. Sonoran desert tortoise habitat is located south and east of the Colorado River, in Arizona, and managed by the Kingman, Lake Havasu, Yuma, Hassayampa, Lower Sonoran, Safford, and Tucson Field Offices. BLM Arizona continues to implement strategies outlined in individual field office land use plans, Mojave desert recovery plan, and Sonoran desert tortoise candidate conservation agreement to minimize/eliminate impacts to desert tortoise from authorized activities and proactively to protect habitat and prevent impacts to tortoise. The Arizona Strip Field Office continues to patrol sensitive desert tortoise habitat to discourage off-road vehicle activity that can damage habitat or directly impact tortoise; and coordinates with U.S. Fish and Wildlife Service on annual line distance monitoring. BLM Arizona continues to partner with Arizona Game and Fish Department to continue the long-term monitoring program initiated in 1987 for Sonoran desert tortoise. This monitoring program consists of 25 long term monitoring plots throughout the species' range in Arizona.

POSTER

A Desert Tortoise Tale of Burrows at Two Sites: It was the Best of Times and the Worst of Times

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Morafka's desert tortoises (*Gopherus morafkai*) typically prefer rocky slopes and deep arroyo habitats for their burrow locations in the Sonoran Desert and generally avoid the surrounding flatlands. The opposite is often, but not always, true for Agassiz's desert tortoises (*G. agassizii*) in the Mojave Desert. Little has been published regarding the burrowing microhabitats of *G. agassizii* that occupy the Sonoran Desert ecosystem of California. We asynchronously monitored the ecology of two populations of Agassiz's desert tortoises at two field sites (Cottonwood and Orocopia) at the southern tip of Joshua Tree National Park. The two sites, separated by Interstate 10, varied in topography, and experienced years of varied rainfall and annual plant productivity from 2015-2018. Cottonwood was monitored from 2015 through 2016 and Orocopia was monitored from 2017 through 2018. We were interested in how topography, soil type, and plant productivity influenced tortoise burrow selection between the two sites during annual cycles, including hibernation. Tortoises occupied burrows in widely varied terrain, with burrow types being strongly dependent on local topography. Tortoises used estimated means of 0.49 burrows per 30 days at the Orocopia site and 0.85 burrows per 30 days at the Cottonwood site. Tortoises used burrows 1-4 times during the 19 and 16-month study periods and occasionally cohabitated. The timing of hibernation (November to February) was similar to other records for *G. agassizii* overall (with a few exceptions), and hibernacula burrow openings tended to have a southerly aspect. The drought following the winter of 2017–2018 resulted in very little rain causing a complete failure of annual food plants to germinate at the Orocopia site. Surprisingly, there was no difference in the number of burrows per 30 days used between the active seasons of 2017 and 2018 at the Orocopia site, despite the wide differences in precipitation and plant productivity.

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

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Major activities within the Desert Tortoise Recovery Program in 2018 included: 1) Range-wide monitoring surveys were conducted in five of ten strata in California and three of six strata in Nevada/Arizona/Utah; 2) Coordination with the Desert Tortoise Recovery Implementation Teams to fund and implement projects, such as habitat restoration, raven monitoring, reduction of predator subsidies, desert tortoise fencing installation, research, and public outreach/education, to address recovery priorities determined by the Desert Tortoise Management Oversight Group; 3)

The Southern Nevada and Palm Springs field offices, along with other state and federal agencies, are in the process of finalizing the prioritization of areas for installation of desert tortoise fencing and passage culverts to reduce mortality and increase connectivity; and, 4) We continue to collaborate with our Federal, state, and local agencies, and NGO partners to increase efforts that benefit desert tortoise recovery.

Issues Facing Desert Tortoises Ten Years After Translocation in an Urbanizing Area

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Copper Mountain College (CMC) in Joshua Tree, California, established a preserve in 2008 to serve as a translocation area for tortoises (*Gopherus agassizii*) displaced by campus expansion. Ten annual surveys used complete coverage transects and mark-recapture techniques to monitor 28 marked tortoises in an enclosed 85 acre plot from 2008-2017. There was no statistically significant difference in tortoise abundance after seven years, suggesting successful translocation at that point (*RM one-way ANOVA*, $p > 0.05$). Between years 8-10, three adult tortoises ($\geq$ 180 mm MCL, midline carapace length) died from a combination of disease and predation. Annualized mortality over ten years of all marked tortoises was 2.5%. Juvenile and immature tortoises (< 180 mm MCL) experienced a higher number of mortalities due to predation by ravens and mammals. Performing two independent surveys on consecutive days detected an average 89% of adults and 27% of juvenile and immature tortoises, which were significantly less detectable than adults. Re-detection on consecutive days averaged 34% for adults, versus 13% of juvenile and immature tortoises. Density of adult tortoises at this site (extrapolated to 8.72/km^2) exceeded the average density (2.8/km^2) cited for the Western Mojave Recovery Unit (USFWS 2017). Tortoise activity varied significantly between months and years (*ANOVA*, $p < 0.01$), and correlated positively with environmental temperature and prior winter precipitation (*Spearman's r*, $p < 0.01$). Activity was significantly lower along the fence bordering Highway 62, possibly indicating a road effect. Management successes included no mortality of adult tortoises for seven years, good compliance with mitigation requirements, removal of invasive plants, educational outreach, and student research opportunities. Persisting management issues included predation by ravens and canids, drought, introduced pet tortoises with upper respiratory tract disease and *Mycoplasma*, ectoparasitic ticks (*Ornithodorus)*, recurrent litter, and fence breaches from storms or vehicles. This translocation scenario may be repeated when tortoises are displaced from other urban areas.

INVITED SPEAKER

The Influences of Energy and Water Balances on Foraging Effort in Gila Monsters

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Foraging is influenced not only by environmental factors (e.g., food availability, predation risk) but also by the physiological condition of an organism, which is commonly referred to state-dependent foraging (SDF). While SDF has been well-studied in endotherms, there is a paucity of data for ectotherms, and, in almost all studies, the resource being considered to evaluate the organism's state is energy reserves despite water also being a key resource that must be balanced. To help address these gaps in current knowledge, we examined how energy reserves and hydration state influence foraging activity in Gila monsters, *Heloderma suspectum*. First, we discovered that Gila monsters must separately satisfy energy and water demands with food and free-standing water, respectively. Furthermore, in contrast to what has been observed in a wide variety of taxa with relatively high energy flux, we found that Gila monsters do not use a SDF strategy to manage their energy reserves nor do they defend their energetic assets. In contrast, hydration state follows SDF and asset defense strategies with activity reduced when Gila monsters are dehydrated and when surface water is unavailable. We suspect that the dominance of water state over energy state in driving foraging activity is a result of the differing timescales within which Gila monsters balance their energy and water budgets (supra-annually versus annually, respectively). Given these findings, the impact of anticipated changes in temperature and rainfall patterns in the Sonoran Desert are most likely going to pose their greatest risks to Gila monsters through direct and indirect effects on water balance.

Multi-year Monitoring of Survival Following Mitigation-driven Ttranslocation of Desert Tortoises

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Translocation is a common tool used to mitigate the negative impacts of development on species of conservation concern, but is often unsuccessful. Robust, post-translocation monitoring is important for evaluating effects of translocation on target species and improving success, yet rarely implemented. Here, we evaluate the efficacy of a translocation designed to mitigate the effects of a utility-scale solar energy project on the U.S. federally listed Mojave desert tortoise (*Gopherus agassizii*). The species is a long-lived reptile threatened by a variety of factors, including habitat loss due to renewable energy development in the Mojave, western Colorado, and Sonoran Deserts. We translocated 58 individual tortoises away from the project's construction site and intensively monitored them over five years (2012-2017). We also monitored tortoises that were located within the translocation release area ('resident' tortoises; n = 112), as well as

'control' tortoises (n = 149) located in nearby habitat. We conducted four survival analyses using known-fate survival models, each of which focused on a different suite of biotic or abiotic covariates hypothesized to affect survival. Our results indicated that translocated tortoises in each of two size classes (120 to 160 mm, > 160 mm) did not survive at lower rates than resident and control tortoises over the five-year period we examined, and that annual and cumulative estimates of survival were always > 0.87 and 0.56, respectively. We found some evidence that larger tortoises had higher survival, but translocated tortoises were not differentially affected by the physical and biological factors we used to model variation in survival. Based on these findings, our translocation design and study protocols could inform other translocation projects for desert species. Our case study highlights the benefits of combining rigorous scientific monitoring with well-designed, mitigation-driven management actions to reduce the negative effects of development on species of conservation concern.

Genomic Insights into Speciation of Southwestern Desert Tortoises

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Species evolve largely in response to changes in their environment. Such changes can fragment populations or impose different climatic stressors on some populations relative to others, both of which can result in divergence of the affected populations. Population and species-level divergence is recorded in the genomes of organisms and can be analyzed and interpreted to better understand 1) what makes two species different from one another, and 2) the reason(s) why they may have evolved to be different. Here, we report new analyses that shed light on the genome divergence patterns of *Gopherus agassizii*, the Mojave Desert tortoise, and *G. morafkai*, the Sonoran Desert tortoise, based on whole genome sequences of ten individuals of each species. We interpret these results in light of new work suggesting the Colorado River is a 'leaky' barrier, having allowed episodic cross-river dispersal since its inception ~5.3 million years ago, and an alternative hypothesis that summer rainfall disparity driven by the North America monsoon may have contributed to differential adaptation of these and other sister species in the southwestern United States.

Immune and Sex-biased Gene Expression in the Threatened Mojave Desert Tortoise

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** Presenter

Extensive research has been conducted to better understand how pathogenic bacteria, such as *Mycoplasma agassizii* (Myag) impact the health and immunity of tortoises; however, the global gene expression changes between animals exposed to and infected with Myag remain largely unknown. To evaluate the immunity associated with bacterial infections in Mojave desert tortoises (*Gopherus agassizii*), we used an RNA-Seq approach with next generation sequencing to evaluate targeted genes and molecular pathways. We sampled 25 adult tortoises for whole blood across three experimental groups with varying degrees of Myag infection including individuals with severe infection (SI), individuals showing low

infection (LI), and individuals serving as a control without any known infection (No Infection-NI) in Clark County, Nevada USA. We generated an average of 30 million reads per sample and based on alignment to the version 1.1 annotated genome, we identified a total of 40 unique differentially expressed genes between our Myag infected groups relative to the NI group . Differentially expressed gene patterns were evaluated with respect to venipuncture site, animal location, collection date and time, RNA extraction date and method, animal sex, and experimental group. Both animal sex and experimental group showed similarly strong molecular signals. Males exhibited higher gene expression variance, and LI individuals showed much higher sample variance than NI or SI groups. Despite widely varying health status and physiological conditions among individuals studied (which was the focus and design of the study), there were 1,037 unique differentially expressed genes associated with tortoise sex. Our results reveal changes of multiple signaling pathways involved in immunity to pathogenic bacteria and provide insights into the role that sex-biased genes may play in tortoises. This work provides a useful resource for the design and interpretation of future molecular and immune studies and enhances our understanding of the impacts pathogens play in the health of the threatened Mojave desert tortoise.

STUDENT PAPER

Genes in Space: What Mojave Desert Tortoise Genetics Can Tell Us about Landscape Connectivity in the Ivanpah Valley

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Anthropogenic disturbance in the Mojave Desert has been increasing, which can result in loss of native species from portions of their range, and create barriers to movement and gene flow. For the protected Mojave desert tortoise habitat loss and degradation continues. In the Ivanpah Valley, habitat modifications include linear features (highway, railway, and network of dirt roads), town sites, a golf course, mining operations, and most recently, several large solar facilities. To evaluate the spatial genetic structure of tortoises in an area experiencing rapid habitat loss, we conducted field surveys fall 2015-2017 using mark-recapture methods and genotyped 299 tortoises at 20 loci within and around Ivanpah Valley. We used Bayesian clustering, spatial principal component, isolation by distance, and maximum likelihood pedigree analyses to evaluate the influence of developments and natural features (mountain passes) on population structure. We detected four genetic clusters with some genetic admixture. These genetic clusters generally corresponded to three valleys separated by mountain ranges, and a genetically distinguishable population in one mountain pass. Pedigree analysis shows first order relationships within 1.5 km,

and second order relationships within 60 km, demonstrating recent genetic connectivity at the valley scale is maintained by movement or dispersal that appears to occur over multiple generations (approximately ≥ 15-75 years), and suggests a greater range of interactions between individuals than previously suspected. Our results support historical gene flow with isolation by distance. However, the tightly clustered distribution of most detected first order relatives may also lead to future decreases in genetic connectivity caused by current and projected habitat loss. As habitat decreases, efforts to maintain connectivity could be pursued, as continued losses may reduce viability and create progressively more isolated populations, however, these genetic impacts may not be apparent in population genetic structure for many years.

Efficacy of DNA Sampling from Herbivorous Reptile Scat

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We collected scat samples from two desert tortoise species (*Gopherus agassizii* and *G. morafkai*) and common chuckwalla (*Sauromalus atar*) at multiple field sites. We assessed two different swabbing protocols and DNA extraction methods for DNA yield and quality. We determined efficacy of samples to generate viable genotype results from different molecular markers; mtDNA sequencing (*S. atar*) and microsatellites (*Gopherus spp.*). For both swabbing protocols, <50% of scat samples produced viable results as expected because DNA exhibits greater degradation and fragmentation when extracted from scat. For those samples that did amplify, we did not detect strong patterns of large-allele drop-out or failure of larger amplicons, however, some *S. atar* samples failed generate longer sequences (>400 b.p.). The number of observed alleles and average allelic range derived from desert tortoise scats were less than that of the comparative genetic data derived from blood samples collected at the same locations. In addition, heterozygosity estimates for the desert tortoise scat samples were significantly lower than expected across most loci, relative to comparative datasets. This study demonstrates that viable DNA can successfully be isolated from herbivorous reptile scat collected in the field, although with less amplification success than with DNA derived from tissue-extracted samples. Although a useful tool for sampling in under-represented populations and as a non-invasive sampling approach, our findings indicate that DNA samples derived from scat alone may not yield adequate genetic information for population genetic studies.

Gila monster (*Heloderma suspectum*) population genetics contributes to understanding the biogeography of Sonoran Desert reptiles at Saguaro National Park, Arizona

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Saguaro National Park, Arizona has been the focus of multiple, long-term population genetic studies of desert reptiles, including desert tortoise (*Gopherus morafkai;* Edwards et al. 2004) and tiger rattlesnakes (*Crotalus tigris*; Goode 2015). Our recent assessment of Gila monster (*Heloderma suspectum*) population genetics at the Park allows us to compare and contrast the phylogenetic and biogeographic patterns of these three, characteristic Sonoran Desert reptiles. All three species share habitat and have similar natural histories. Their collective microsatellite and mtDNA data sets allow us to examine shared patterns in their evolutionary history. All three species exhibit healthy, robust populations within the confines of Saguaro National Park but only *C. tigris* exhibits population structure, whereas *G. morafkai* and *H. suspectum* exhibit nearly panmictic distributions within the park. Across the broader Tucson Basin, *C. tigris* and *G. morafkai* exhibit similar levels of population differentiation but the species differ in their correlation between genetic and geographic distances. We hope to expand our study of Gila monster population genetics to include additional sites throughout their range so that broader geographic comparisons can be made. Better understanding the shared biogeography of these and other Sonoran Desert reptiles may be used to infer commonalities in their evolutionary histories and help to inform management decisions that can be applied to conservation of the greater ecosystem.

History of the Large-Scale Translocation Study Site in Nevada

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In 1989, continuing urbanization of desert tortoise habitat in Clark County, Nevada and the Federal listing of the tortoise resulted in a temporary halt in construction. Development was allowed to proceed after a settlement agreement was reached in 1990 that included the construction of the Desert Tortoise Conservation Center (DTCC) as a research facility where tortoises removed from certain projects would be housed. Under a Short-term Habitat Conservation Plan, additional tortoises displaced by development were to be euthanized if they were unhealthy or healthy but not adopted into captivity. In 1991, the Clark County Board of Commissioners directed that alternative outlets, including translocation, be investigated for healthy tortoises. The County constructed additional holding pens at the DTCC and hundreds of tortoises began to accumulate. The 1994 recovery plan for the Mojave desert tortoise contained guidelines for the translocation of desert tortoises, but indicated that translocations needed to be experimental. In 1996, the University of Nevada, Reno and National Biological Service developed a translocation study plan

that included three parts, one of which was a Large-Scale Translocation Study (LSTS) to assess the efficacy of translocating large numbers of tortoises. A 100-km^2 site near Jean, NV in the Ivanpah Valley was selected for the study, fenced in attempt to contain tortoises, and the first tortoises were released in spring 1997. Translocations continued through 2014 with approximately 9150 tortoises of all age-classes being released. Research topics and release protocols at the LSTS site varied. Over the last decade, solar energy projects have impacted much of the surrounding area. With tortoise populations on the continued decline, connectivity has become increasingly important and the Ivanpah Valley historically connected populations to the north and south. Today, we have great interest in restoring those connections through the LSTS, if it is appropriate to do so.

Results and Lessons Learned from the First Year of Pima County's Sonoran Desert Tortoise Monitoring Program

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Pima County has committed to monitoring the status of numerous species of conservation concern as part of its 30-year Multi-species Conservation Plan (MSCP), including the Sonoran desert tortoise. Occupancy monitoring is a cost-effective way to monitor wildlife population dynamics over space and time. We examined occupancy of Sonoran desert tortoise on Pima County open space lands in the Tucson Mountains of eastern Pima County from July – September 2018. All properties monitored have regular recreation use, increasing invasive plant species presence, and are surrounded by urban development. We generally followed the occupancy monitoring framework currently in use by the Arizona Game and Fish Department and set up 20, three hectare plots that we surveyed three times each during the 2018 monsoon season. We located and marked 42 tortoises on these plots yielding an estimated occupancy rate (ψ) of 0.61 (SE = 0.19) and probability of detection (p) of 0.69 (SE = 0.10). We discuss plot- and detection-level covariates that influenced occupancy and detection probability in this system, as well as overall estimates of the percent area used by tortoises. Additionally, we interpret our results in the context of prior occupancy studies of Sonoran desert tortoise, and discuss both lessons learned and future opportunities identified from our first of many years of repeated monitoring.

A Range-wide Model of Omnidirectional Connectivity for the Mojave Desert Tortoise (*Gopherus agassizii*)

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As habitat for the Mojave desert tortoise (*Gopherus agassizii*) becomes more fragmented, conservation planning that accounts for population-level connectivity and gene flow is an urgent priority, particularly as renewable energy development continues to increase throughout the Mojave Desert ecoregion. Models that only approximate habitat quality are incomplete because areas of high quality habitat may be isolated, whereas intermixed areas of lower quality habitat may still be critical for maintaining connectivity between and among populations. We developed a range-wide, omnidirectional ('coreless') connectivity model and map for the Mojave desert tortoise at a high spatial resolution (30 m), based on empirical movement data and a circuit-theoretic approach to estimating connectivity. We first estimated habitat quality for tortoise movement (as distinct from habitat quality, more generally) across its range using hypotheses derived in consultation with experts and based on the published literature, generalized linear mixed models, multiple environmental factors derived from remotely sensed data, and recent development footprints. We used the resultant raster output to represent landscape conductance in a circuit-based model of connectivity, which relates the flow of electrical current through a circuit to the potential movement patterns of tortoises. We then modeled potential, omnidirectional connectivity across the range of the tortoise using *Circuitscape* software and the Julia numerical programming language. Intermediate distances from minor roads, intermediate values of annual average maximum temperature, and increasing density of desert washes were among the strongest predictors of movement habitat quality. There was also strong evidence for increased habitat quality for movement with increasing amounts of vegetation cover. The conductance and resulting connectivity models were vetted through consultation with experts and determined to accurately reflect important areas for tortoise movement. Our maps can inform management decisions that have the potential to influence the conservation of well-connected tortoise populations throughout their range.

Private Land Conservation in the Foothills Thornscrub of Sonora, Mexico
Northern Jaguar Project

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The Northern Jaguar Project operates and manages a 55,000-acre private reserve in the foothills of the Sierra Madre in the *municipio* of Sahuaipra, Sonora, under a contract with the Mexican nonprofit landowner *Asociación Conservación del Norte*. The reserve is located on a peninsula of land formed by the confluence of the Aros and Bavispe rivers, which join to form the Rio Yaqui, the largest river in northwest Mexico. The reserve's extremely remote and rugged location, complex topography, extreme elevational variations, difficult access, and encompassing river systems provide protection for the area's exceptional biodiversity and endangered wildlife species, including the northernmost breeding population of endangered jaguars, and many threatened species.

In order to create a buffer zone of protection surrounding the reserve, the Northern Jaguar Project initiated the *Viviendo con Felinos* program, which provides economic rewards and restoration assistance to owners of nearby working cattle ranches in exchange for motion-triggered photos of felines on their ranches. Ranch owners sign contracts that they will not harm or kill any of the area's four felines (jaguars, ocelots, pumas, and bobcats) or their prey species, and will permit unannounced visitation from NJP personnel. Currently the incentive program has 14 enrolled ranches, adding 75,000 acres to the protected buffer zone. There is a waiting list to join.
The reserve engages in outreach throughout the surrounding communities, provides educational programs for local students, and conducts scientific research. Among the many species documented to date on the reserve is Moraka's desert tortoise (*Gopherus morafkai*) and quite possibly the northernmost reaches of the Goode's thronscrub tortoise (*Gopherus evgoodei*) making this an exciting area for studying if or how these two species use the landscape differently.

Adaptive Conservation in a Checkerboard Landscape– Hot Spots, Holistic Management, and Thinking Outside the Shell

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Transition Habitat Conservancy (THC) owns nearly 4,500 acres of land within the West Mojave's Fremont-Kramer and Superior-Cronese Critical Habitat Units. This region is largely defined by the complex checkerboard of private lands and conservation inholdings within a larger BLM public land management framework that is popular for off-highway vehicle (OHV) recreation. It also contains some of the lowest desert tortoise (*Gopherus agassizii*) population densities among the desert's recovery units. But there is still hope for tortoises here. THC leveraged its regional stakeholder status to partner with state and federal agencies in order to help steward the roughly 400,000 acres that surround their 132 dispersed parcels. By employing a polygon restoration management approach, starting an interagency working group, and maintaining a consistent ranger presence, this region has appreciated a recent uplift of conservation management and attention. Now, the identification of three densely populated tortoise “hot spots” has shifted THC’s conservation strategy toward a focused nexus of raven management, tortoise habitat enhancement, OHV route reduction, and private land acquisition.

Evaluating the Utility of Supplemental Data to Improve Estimation of Post-translocation Survival of Mojave Desert Tortoises

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Obtaining robust survival estimates is critical to management and recovery of Mojave desert tortoises (*Gopherus agassizii*), but sample size limitations can result in imprecise estimates or the failure to obtain estimates for geographic or demographic subgroups. Concurrently, data are often recorded on incidental re-encounters of marked individuals, but these incidental data are often unused in survival analyses. We evaluated the utility of supplementing a traditional survival dataset with incidental data on marked individuals that was collected ad-hoc. We used a continuous time-to-event exponential survival model to leverage the matching information contained in both datasets and assessed differences in survival among adult and juvenile and resident and translocated Mojave desert tortoises. Incorporation of the incidental mark-encounter data improved precision of all annual survival point estimates, ranging from a 3.4% to 37.5% reduction in the spread of 95% Bayesian credible intervals. Using the supplemental data we were able to estimate annual survival for three age, residency, and geographic subgroup combinations that were previously inestimable when using only the traditional radio-telemetry dataset. Point estimates between the radio-telemetry and combined datasets were within -0.4% to 3.0% of each other, suggesting minimal to no bias induced by the incidental data. Using exponential survival models to leverage matching information among traditional survival studies and incidental data on marked individuals may serve as a useful tool to improve the precision and estimability of survival rates.

INVITED SPEAKER

The Big Turtle Year: Celebrating Wild Turtles Across the United States

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Turtles play significant ecological roles and are visible elements in many habitats. A long list of diverse threats to species globally has contributed to ~59% of all turtles being threatened with extinction. Working in synergy, these threats present broad and immediate conservation challenges for one of the most endangered wildlife taxa in the world. Despite the urgency of the situation, opportunities for conservation are abundant and the charismatic attraction of turtles makes them an excellent group for education and outreach efforts to enhance ecological, conservation, and environmental awareness. The United States is the most turtle-rich country (62 species and 89 terminal taxa), with many taxa of conservation concern. While species from areas such as Asia, South America, and Madagascar often receive the majority of conservation attention, the plight of species within the U.S. quietly goes unnoticed. The goal of The Big Turtle Year initiative is to increase awareness regarding the status of these often overlooked species and to emphasize their rich diversity, natural history, and conservation. Throughout 2017, Florida Turtle Conservation Trust researchers visited numerous sites accompanied by other biologists and conservationists in an effort to see as many species as possible during a single year, while examining threats and conservation actions needed. In addition, a national lecture series will disseminate the information gathered to a wide range of audiences, including stakeholders. For more information, please visit www.thebigturtleyear.org.

The 2017-2018 Tortoise Translocation by the Marine Corps Air Ground Combat Center (Combat Center)

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In April 2018, the Combat Center translocated an additional 189 *Gopherus agassizii*, 107 large (>159mm) and 82 small (<160mm), from base expansion areas to nearby lands on the Combat Center and nearby lands of the Bureau of Land Management. Combined with 2017 efforts, 1232 tortoises (978 large, 254 small) have been translocated. We radiotracked 224 translocatees, 211 residents, and 263 controls, with 2018 mortality of 4.6%, which was similar to post-translocation mortality in 2017 (5.0%). In 2018, 32 radiotracked animals (5 residents, 13 translocatees, and 14 controls) were found dead. The majority of these were depredated (17 canid, 5 badger), 4 died of overheating, and 1 was egg bound; we do not know the cause of death for the remaining 5. The radiotelemetry monitoring will continue for at least five years on the three groups, through 10 years on 150 animals (50 per group). We will continue population level monitoring for 30 years. Monitoring is facilitating evaluations of health and disease status, and will facilitate evaluations of population assimilation, and effects of post-translocation densities, current and historic livestock grazing, and constrained release methods. We are in the process of implementing affiliated conservation measures, including: establishing special use areas on the Combat Center, installing exclusion fence between training areas and recipient or control areas, monitoring and controlling predators on- and off-base, and conservation measures in the Ord-Rodman Area of Critical Environmental Concern (land use monitoring, installing fencing, and rehabilitating unauthorized routes).

QuadState Local Governments Authority: a Partner in Desert Tortoise Conservation and Recovery in the Mojave and Sonoran Deserts

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The Desert Tortoise Council meeting coincides with the 20th anniversary of the sixth county signing the original Joint Powers Authority agreement which formed QuadState Local Governments Authority. We now include eight. Through the listing of the Mojave Population of desert tortoise process in the late 1980's, and development and adoption of the Recovery Plan in the early 1990's, local governments were neither invited to the table, nor engaged in any of the process, which affected their own interests, plus that of their constituents. With the organization of the Authority, it has played a continuing role on behalf of local governments in the region in habitat and species management, with the review of the 1994 Recovery Plan, and the 2011 Revised Recovery Plan.

Because we existed, the Authority was fully able to represent local government's interests and engage in listing and land management issues related to the Sonoran Population consideration in Arizona, and, the decision by Fish and Wildlife Service not to list that species.

Through participation in the Management Oversight Group and the Arizona Interagency Desert Team, we assure local governments views and concerns are brought forward and addressed by the land and wildlife management agencies.

The Authority is engaged, too, with the HCP development, and participates for its member counties on the Steering Committee of the Lower Colorado River MSCP.

The Authority is fully engaged in the Steering Committee of the Desert Landscape Conservation Cooperative. That organization is formulating data and information related to the East Mojave Conservation Partnership. That effort, one of three pilot efforts by the DLCC, involves three of our member counties, and we participate in the Coordinating Team and workshops.

More recently, the Authority has actively sought passage of legislation to provide an administrative means for counties to confirm their road rights-of-ways on federal land. This may strike some as a strange role and workload, but many of the county roads in the region are not recorded on official records of the United States. Many of these roads are in the tortoise resident region. Many environmental groups have opposed this legislation, for inexplicable reasons. The current process requires Federal District Court action, a costly and time-consuming process, for which the courts surely have more important work to undertake.

Strategic Minimization of Road Effects

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Road mortality and other indirect road associated effects (aka, road effects or road-effects) threaten the continued survival and recovery of the Mojave desert tortoise (*Gopherus agassizii*). Fortunately, well maintained exclusionary fencing paired with adequately spaced shade structures and tortoise underpasses has the potential to reduce habitat fragmentation and road mortality, as well as enable the repopulation of thousands of acres of density depleted roadside Mojave desert tortoise habitat. Unfortunately, cost and logistics prohibit efforts to fence all (55,312 km of roads in tortoise habitat) or even most of the roadways that threaten the Mojave desert tortoise. To make this issue more manageable and to maximize returns on conservation actions, the U.S. Fish and Wildlife Service (Service), in partnership with the National Highways Administration, including their respective state representatives, is developing a Recovery Importance Index (RII), a Feasibility Index (FI), and a composite Desert Tortoise Exclusionary Fence Installation Prioritization Index (DTEFIPI). The composite DTEFIPI (i.e., RII x FI) is intended to identify the 1-km segments of road that most profoundly need fencing from a biological need as well as feasibility perspective. In this approach, biological need (aka, RII) is evaluated in terms of road-effect zone (REZ) area, average habitat potential value, and number of overlapping buffered range-wide observations. Feasibility (aka, FI) is evaluated in terms of landownership, road design (at grade or not), and number of local roads or driveways that would perforate the fence. By using information on road-effect zone size, habitat quality, recent occupancy, and logistical feasibly, the Service hopes to optimize the efficiency of future actions intended to minimize the negative impact of roadways on the Mojave desert tortoise and boarder desert ecosystems.

INVITED SPEAKER AND SESSION

Biology and Development of the Chelonian Shell

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The shell of most present-day turtles consists of multilayered β-keratin *scutes* overlying a continuous layer of pseudostratified columnar epithelial cells**.** These cells have a basal surface with thin processes that extend into and interdigitate with the underlying connective tissue. In mature chelonians, most of the dermis is occupied with dermal plates, When chelonians hatch from the egg, they are born with scutes called *embryonic shields*. As chelonians grow, new keratin in the shell is formed in *seams*, areas of the shell where two scutes come together. At the seams the epidermis invaginates into the dermis Differentiation of basal cells into keratin-forming cells occurs in the deepest portion of the invagination. As rings of new keratin are formed around embryonic shields, formerly adjacent embryonic shields become separated**.** There are some aquatic turtles that shed individual outer keratinized layers of older scutes during a discrete period of time.

Scutes overlay a mesodermally derived dermis that is unique in that much of it is ossified. The outer dermis of the chelonian shell consists of collagen fibers, melanophores, vessels and nerves. Underneath the dermal connective tissue is dermal bone**.** Outer and inner layers of the dermal bone plates are compact and "sandwich" a middle layer of trabecular or spongy bone**.** In young growing desert tortoises, osteoid surfaces are devoid of adjacent osteoblasts, the cells that normally deposit the unmineralized matrix of bone. This is in contrast to mammals in which nearly all osteoid surfaces are lined by osteoblasts. The dermal plates are primarily those that are neural and costal, and are derived from vertebrae and ribs that surround the scapula, which in modern turtles are found within the rib cage; with all other amniotes the scapula is outside the ribcage. Ribs of turtles are morphologically shorter than those of other amniotes, because the ribs are arrested in the axial domain and never penetrate into the lateral body wall, unlike those of other amniotes. No ribs extend into the plastron

Nagashima *et al.,* (2009) used the Chinese Soft-shelled Turtle (*Pelodiscus sinensis*) to study embryogenesis of the turtle carapace along with associated musculature. They observed that the second and more posterior ribs grew laterally and anteriorly over the scapula by folding the dorsal part of the lateral body wall inward. Along the folding line, the turtle-specific embryonic structure called the carapacial ridge (CR) developed and later grew anteriorly and posteriorly to form a circle that differentiated into the carapacial margin. The CR, which is an evolutionarily novel structure, is the earliest sign of carapace development and defines the margin of the future carapace. Histologically, it consists of an aggregated mesenchyme with an overlying thickened epidermis. In addition to the positional change of skeletal elements, Nagashima *et al*. (2009) also found that some muscles such as those connecting the trunk and scapula (the *serratus anterior* and *levator scapulae-rhomboid muscle complex*), showed unique turtle-specific positions and attachments in the adult turtle) while the connectivity of other muscles remained unchanged from the amniote plan.

Until recently, the origin of the turtle shell remained a developmental mystery in vertebrate evolution. The fossil record indicates that the plastron evolved before and independent of the carapace. In 2008 a previously unknown fossil, *Odontochelys semitestacea* sp. nov. from the

Late Triassic, was found in China (Li *et al*., 2008*)*. This fossil had the appearance of a transitional fossil in that the animal had an incomplete carapace but a complete plastron. The previous oldest fossil turtle, *Proganochelys quenstedti* from the Late Triassic period Germany, had a complete carapace (Gaffney, 1990). The ribs of *Odontochelys* were arrested axially and did not show a fanned-out pattern. The scapula was situated rostral to the ribs. These morphological features are similar to the morphology of present day turtle embryos before the folding process. The CR may have only developed partially in *Odontochelys* embryos whereas in modern turtles it forms a complete circle. Subsequently, the earliest known stem turtle, the Triassic turtle *Eorhynchochelys sinensis* gen. et sp. nov., from sediments approximately 7.5 m below the horizon that contained the stem turtle *Odontochelys* (Li *et al*., 2018). This turtle had a mixture of derived characters and plesiomorphic features. It had an edentulous beak, teeth on the maxillae, and a rigid puboischiadic plate. The carapace and plastron were absent. These discoveries documented that the carapace and plastron are developmentally separate structures that develop independently (Rieppel, 1993). Below the epidermis, the carapace consists of endochondral skeletal elements and exoskeletal dermal bones, whereas in all extant turtles, the plastron contains only exoskeletal dermal bones. In the Red-Eared Slider (*Trachemys scripta elegans*), the plastron develops at developmental stage 15 when condensates of osteochondrogenic mesenchyme form for each plastron bone at the lateral edges of the ventral mesenchyme (Rice *et al*., 2016). These condensations commit to an osteogenic identity, while at the same time suppressing chondrogenesis. The initiation of the development of bone within the plastron coincides with that of carapacial ridge formation, suggesting that, from the start, the development of dorsal and ventral shells are coordinated. This developmental feature also implies that adoption of an osteogenesis-inducing and chondrogenesis-suppressing fate of cells in the ventral mesenchyme has permitted turtles to develop their characteristic ventral morphology.

A common abnormality of the carapace of mostly tortoises is a condition called pyramiding. Pyramiding is typically first seen in yearling tortoises and involves both the scute and underlying plates. Instead of having a normally smooth carapace, each scute grows in such a way to elevate the embryonic shield above the seam where differentiation occurs. Each scute takes on the appearance of a "pyramid". Rapid growth is thought to be primarily or partially responsible for pyramiding.

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POSTER

An Ecologically Founded Design for a Targeted Non-Lethal Predator Aversion Device to Protect Agassiz Desert Tortoises from Depredation

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Desert tortoises (*Gopherus agassizii*), currently listed as threatened under the Endangered Species Act (ESA), are experiencing depredation at unprecedented and unnatural rates due to the growing presence of human-subsidized predators in desert tortoise habitat, namely ravens (*Corvus corax*) and coyotes (*Canis latrans*). While a multipronged approach addressing the complexities of the issue will likely provide the most comprehensive, sustained solution (i.e. reducing trash, landfills, human food sources, and infrastructure in desert tortoise habitat), one smaller-scoped solution with the potential for immediate impact is training predators to stop preying on desert tortoises through highly targeted, non-toxic, and non-lethal aversion strategies. Charles River Analytics seeks to develop a scalable, low cost, modular device that can effectively identify predators and dynamically deploy repeatable, extensible, and diverse predator-specific aversion tactics to protect a variety of at-risk species without disrupting healthy predator-prey cycles. To this end, Charles River Analytics has defined initial designs and will be prototyping an animatronic desert tortoise decoy device equipped with a variety of non-lethal and non-toxic aversion stimuli (i.e. light, sound, vibration) to enable context-aware predator aversion strategies upon attack, initially targeting ravens and coyotes. For example, ravens identify juvenile desert tortoises on the desert floor through visual cues and fly down to attack by flipping the juveniles over and pecking through their softer plastrons. A visually-accurate decoy device could bait and detect this interaction and trigger a green laser towards the raven, a tactic shown to deter ravens. This effort will employ a hybrid approach of empirically- and ecologically-founded aversion strategies and iterative testing. This presentation will provide early design foundations and their links to desert tortoise ecology, as well as key considerations for this effort; effectively baiting predators, intelligently identifying interactions and selectively deploying tactics, avoiding habituation to aversion strategies, and maintaining healthy balances within the natural environment.

POSTER

Extensive Community Partnerships Lead to a Successful Wildlife Overpass and Underpass on the Edge of the Highly Urbanized Tucson, Arizona Region

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The wildlife linkage between the Santa Catalina and Tortolita Mountains on the northwest side of Tucson, Arizona, is highly threatened by a growing network of roads and new development. To protect this linkage, a wildlife overpass and underpass were completed across State Route 77 in March 2016. With partners, the Coalition for Sonoran Desert Protection has provided outreach and wildlife camera monitoring using community science for these wildlife crossings, pre- and post-construction. We have collected nearly73,000 wildlife photos in six years, representing more than 60 different species, including occurrences of bighorn sheep, mountain lion, white-nose coati, badger, and desert tortoise. We continue to work with partners to finalize tortoise and deer exclusion fencing in key wildlife-funnel fencing gaps near the crossings.

The Use of Drones as a Conservation Management Tool and Burrow Mapping for the Bolson Tortoise (*Gopherus flavomarginatus*)

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Fixed-wing aerial vehicles have routinely been used for aerial photogrammetry and conservation management/strategy for endangered species. Advancement in camera and battery technology have now enabled costly airplane-based tool to be utilized in the form of lightweight fixed-wing drones. The use of the unmanned aerial vehicles (UAVs) in wildlife conservation has taken on many forms, from anti-poaching patrols to habitat mapping and evaluation. The Turtle Conservancy is using drone photogrammetry to map their 17,000 hectare preserve in the Chihuahuan Desert, the last stronghold for the Critically Endangered Bolson tortoise (*Gopherus flavomarginatus*). The distinct, large burrow mound created by the Bolson tortoise allows for aerial recognition. The implication of large scale implementation in areas of critical habitat of the desert tortoise has the potential to allow recovery and recruitment of the species to occur in areas where senescent tortoise populations are now being observed. Conducting more large-scale, comprehensive surveys than are otherwise feasible on foot allows for mapping the distribution, identify conservation challenges (poachers, cattle, food sources), and ultimately developing a management plan for conservation of the species.

Where Has Turtle Ecology Been, and Where Is It Going?

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Over 9,000 articles have been published on turtles and tortoises (excluding sea turtles) since 1950 according to the Web of Science. This includes over 8,000 contained in a personal bibliography that we discuss and analyze in a paper published in the 2019 volume of Herpetologica. Research on freshwater turtles and tortoises (henceforth "turtles") had a slow start from 1900–1950, with mostly anecdotal additions to our knowledge until the contributions of Fred Cagle and Archie Carr elevated turtle research to new levels as the co-fathers of turtle ecology in the middle of the last century. Books written in 1939, 1952, and 1972 that compiled existing literature on turtles in the United States and Canada set the stage for growing interest in turtles. The first global compilation of turtle species was published in 1961, and others followed. Publication numbers skyrocketed in the 1960s and especially the 1970s as interest in turtles grew, and a wave of turtle biologists emerged from doctoral degree programs. We briefly review the contributions of scientists who published extensively on turtle ecology in those and later decades up to the present. We also review advances in our knowledge of various topics, including: the global distribution of turtle research efforts; changes in our perceptions of turtle species diversity over time; advances in our understanding of turtle community ecology; sex ratios, sex-determination and climate change; overwintering behavior; sexual size dimorphism and sexual dichromatism; advances in genetic analyses; turtles and vocalization; and the emergence of turtle conservation biology efforts. We conclude with a discussion of future opportunities and challenges for working with turtles.

Strategies for Private Land Conservation in the Tropical Deciduous Forest of Alamos, Sonora, Mexico

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Private land conservation in Mexico has been proven to be the most effective way of ensuring protection of critically endangered ecosystems. The reason for this is that even within the federally protected areas, all land is privately owned. These lands sustain pressure of livestock over-grazing, agriculture, harvesting of natural resources and overall habitat degradation. Nature and Culture International is one of the few organizations in México that specializes in private and public land conservation. We started working in the Sierra Madre Occidental region of Álamos,

Sonora 14 years ago with the vision of creating a 25,000-acre reserve to protect the watershed of the Cuchujaqui River and the biodiversity within it. NCI has purchased 14 contiguous pieces of land, Reserva Monte Mojino (ReMM). So far, we are working to protect 16,800 acres of Tropical Dry Forest (TDF) and Pine-oak ecosystems. Of the less than 15% of the TDF remaining only 5% is legally protected. In Álamos TDF there are over 1200 plant species, 48 different species of orchids, 330 different bird species (migratory and residents) 5 out of the 6 different species of big cats known in México and 6 species of chelonians. Amongst these chelonians is the Goode´s thornscrub tortoise (*Gopherus evgoodei*). This recent significant discovery of a new tortoise species is evidence that there is still so much that is unknown about the TDF in this region.

Long term conservation and protection of ReMM relies on how effective we are as an organization to engage and work alongside local, regional, and federal governments, especially with the agencies that could support our research and conservation work, but more importantly is working with the people and communities that surround the reserve. NCI's *bottom up* conservation model is to not only protect habitat but to engage the communities where we work to support conservation through different programs such as guardabosques (forest guardians) of ReMM, environmental education, compatible cattle grazing management with neighbors, and as assistants to researchers that visit ReMM.

Genetic Origins and Population Status of Desert Tortoises in Anza-Borrego Desert State Park, California

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Anza-Borrego Desert State Park (ABDSP) has long been viewed as occurring outside the native range of desert tortoises due to its geographic isolation and complex history of releases. To investigate the genetic origins of tortoises in ABDSP, we reviewed historical records and collected DNA samples from 36 live tortoises (9F, 7M, 20J) and 48 scats at 3 known occupied sites inside the park in 2018. We genotyped samples at 25 microsatellite loci, used assignment tests to identify species and genetic relatedness to previously studied populations, and constructed a pedigree of first-degree family relationships to test for evidence of successful reproduction. ABDSP supports nearly 1,000 mi^2 of suitable habitat, and historical records indicated that desert tortoises were present before and after its establishment in 1933, with documented releases occurring from 1958-1972. All genotypes from this study were determined to be *Gopherus agassizii*, with all samples consistent with originating from geographically close populations across the southwestern Mojave, as would be expected from either local introduction or natural colonization. Pedigree analysis indicated ≥7 successful reproductive events from wild individuals within the 3 sites. Additionally, we observed multiple size classes, mating, and egg fragments in the field. We found no evidence of intra-full-sibling group fragmentation occurring among sampling sites, consistent with a naturally sub-structured population. These data confirm that tortoises in ABDSP are a naturally reproducing population with origins from historical human-mediated and/or natural colonization.

Ongoing work includes investigating cause-specific mortality, reproductive success, population size and viability, and resource selection.

STUDENT PAPER

Post-release Movement and Survival until Dormancy of Hybrid Head-started Mojave Desert Tortoises (*Gopherus agassizii*)

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Head-starting—the captive rearing of offspring through their most vulnerable early life stages—is increasingly being explored as a recovery tool for the Mojave desert tortoise. Most desert tortoise head-starting programs have focused on solely outdoor rearing; however, growth is slow and juveniles require 5-9 years in captivity to reach predator-resistant sizes (~105 mm MCL). A recent study investigated the use of indoor rearing to decrease time in captivity, yet, despite 7 months of enhanced growth, indoor head-starts showed no difference in survival when compared to their solely outdoor reared siblings one-year post-release. Here, we explore using a combination of indoor and outdoor captive rearing to maximize post-release success. We assigned 48 neonates (2016 cohort) to one of two treatments: 1) 'Outdoor-only', where neonates (n=24) were reared exclusively in outdoor predator-proof enclosures; 2) 'Hybrid', where neonates (n=24) were reared indoors for 1 year followed by outdoor rearing the 2nd year. A cohort of 6-7yr animals reared exclusively outdoors (n = 30) constituted a third treatment group. All animals were released in the Mojave National Preserve, CA on 25 Sep 2018. We compare pre-release shell hardness and body condition as well as post-release movement and survival to dormancy (31 Oct 2018) among these treatment groups. Pre-release body condition was not significantly different among groups, however, 2yr 'Outdoor-only' head-starts had significantly softer shells relative to the other two treatments. Released juveniles experienced 96% survival to dormancy with all mortalities attributed to mammal predation. Hybrid head-starts moved significantly less than either solely outdoor reared treatment group, both in maximum distance from release site and total distance moved. Final distance from release site at dormancy ranged from 0 - 3118 m. We will monitor post-release survival and movement through Fall 2019 and use results to elucidate the effects of hybrid rearing and size on survivorship.

Status of Translocated Tortoises in Southwest Utah:
A Summary of Growth, Movement and Survival

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The Division of Wildlife Resources has been monitoring tortoises within the Red Cliffs Desert Reserve as an ongoing effort to track the effectiveness of the Washington County HCP translocation program. Displaced tortoises from incidental take areas within Washington County were translocated into the Babylon, East Reef and Sand Cove areas within Zone 4. Prior to translocation, tortoises were measured, uniquely filed on the marginal scutes, and a unique tag number was epoxied on the third right costal. In addition, passive integrated transponder (PIT) tags were injected subcutaneously into the shoulder of tortoises with a carapace length ≥ 140 mm. All tortoises (CL ≥ 80 mm) were blood tested prior to translocation to determine their level of exposure to URTD. Tortoises that were ELISA negative (titer < 32) for URTD were translocated into Zone 4 in the spring (March 15 to May 30) or fall (August 20 to September 30) using a hard release strategy (e.g., no supplemental food or water) and placed near a natural shelter within or near a creosote-bursage plant community. To maintain the genetic integrity of the Upper Virgin Recovery Unit, only tortoises of local origin were translocated into Zone 4.

We present the report on the overall status of translocated tortoises in the Reserve, evaluate the effectiveness of the translocation program, and present a summary of monitoring efforts from 2003 to 2018. Translocation within Zone 4 is successful based on long term survival of adult tortoises, growth of released individuals, evidence of reproduction, and an increasing trend in adult population size. Tortoises are well established as evidenced by their limited movements, high site fidelity, and established shelters. Since monitoring began in 2003, there have been observations of juvenile and immature tortoises annually, indicating that adult tortoises are reproducing. We hope to continue to monitor tortoise populations to assess the population structure and spatial distribution of tortoises within Zone 4.

STUDENT POSTER

Mining Genomes to Reveal the Evolution of Gene Families in Reptiles Relevant to Tortoise Health

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The class Reptilia is a diverse group of vertebrates that vary in habitat use, body plans, developmental patterns, and behaviors. Despite this diversity, non-avian reptiles are underrepresented among species with genomic and functional resources. Due to this absence of data, relatively little is known about reptilian gene families critical to health and how those genes have evolved evolutionarily. Better understanding such gene evolution could elucidate how species are adapted to their environments and how they may respond to environmental threats. One such challenge faced by the Mojave Desert tortoise, *Gopherus agassizii*, is Upper Respiratory Tract Disease (URTD), which is associated with declines in populations throughout much of its range. To improve our understanding of gene evolution and adaptation within reptiles, we used a comparative bioinformatic approach to mine existing genomic data for three gene families, Heat Shock Factors (HSFs), Aquaporins (AQPs), and Toll-like Receptors (TLRs)—which contribute to heat regulation, water regulation, and the immune response, respectively. We phylogenetically reconstructed these gene families for 21 species: fourteen non-avian reptiles and seven representative species from mammals, birds, and amphibians. Preliminary results combined with microsyntenic data suggest TLR1 and TLR6 within *Gopherus agassizii* heterodimerize together, reflecting a pathogen recognition system more similar to chicken than mammals. This subfamily of TLRs plays a role in immune system recognition of gram-positive bacteria, a group that includes *Mycoplasma agassizii*, which is the causal agent for URTD. Genome-enabled discoveries about the evolution of genes essential for health will provide insight into how tortoises respond to their environments and aid in wildlife conservation.

Captive Desert Tortoise Population Survey in Greater Las Vegas Area

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Prior to their federal listing under the Endangered Species Act in 1990, desert tortoises were collected as pets (“captives”) and individuals were grandfathered in to legally to keep them as pets, as well as their progeny. The release of captive tortoises into the desert can result in the spread of diseases picked up in captivity, competition of resources, and disrupt the genetic nature of the native wild population. Estimations of how many tortoises exist in captivity have been made but no official studies have been done to examine the potential of this issue, until 2018. UNLV’s Center for Business and Economic Research partnered with Tortoise Group in order to scientifically quantify an estimate of desert tortoises in Clark County. To estimate the captive population in the Greater Las Vegas area, the study employed a mail survey in English and Spanish, using a stratified (by ZIP Code) random sample of households. The total count estimate of the desert tortoise population in Greater Las Vegas varies from 137,172 (standard deviation 23,486) in WS1, to 137,331 (standard deviation 22,424) in WS2, and 153,783 (standard deviation 44,755) in WS3. Using three weighing schemes, the estimates also vary by ZIP Codes. As a sub-product of the survey, we also obtained the estimates of the total domestic ownership of the cat and dog populations. Given these results, we will explore various working solutions to the pet-overpopulation problem and explore research possibilities in order to protect the wild population.

The Application of New Models for the Conservation of the Mojave Desert Tortoise

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Defenders of Wildlife has sought to evaluate potential impacts of development projects on the Mojave desert tortoise throughout their range to inform least conflict siting. To facilitate meaningful evaluation based on best available science, we developed a range-wide high-resolution species distribution model that would allow us to assess the likely impacts of development on desert tortoise habitat. We collaborated with NatureServe to create such a model, which incorporated US Fish and Wildlife Service and natural heritage presence data. In addition there is increasing evidence that tortoise populations exist in metapopulations, which require corridors between subpopulations to maintain genetic connectivity. To evaluate the how important areas are to desert tortoise connectivity, we collaborated with Conservation Science Partners to create a high-resolution connectivity model for the desert tortoise across its entire range. This model used data from tracked tortoises to create the resistance layer that was ultimately used to model connectivity. We are now working to combine these two models to evaluate key areas for desert tortoise conservation (and development project avoidance), based on habitat quality and important corridors across their range. Additionally, we plan to create a prioritization model for the tortoise that incorporates these layers, in addition to a human impact layer. This output will provide information about the relative importance of different parts of the landscape for the tortoise, thereby allowing us to more comprehensively evaluate and compare alternative areas for development.

The Herpetofauna of the Santa Rita Experimental Range and Adjacent Urbanized Areas

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The 21,500 ha Santa Rita Experimental Range (SRER) is located on the alluvial fan west of the Santa Rita Mountains. To the east and north of the SRER are landscapes shaped by urban sprawl and agriculture. This study focuses on the herpetofauna of the SRER and adjacent areas with the idea of comparing the species diversity on the SRER to that found in the nearby urbanized areas. Vegetational changes have been studied on the Santa Rita Experimental Range since 1903 as have the mammal and bird communities. However, relatively few studies involved amphibians and reptiles, and no overall inventory of the herpetofauna has been done. Here I examine the ecological organization of the herpetofauna in a heterogeneous Sonoran semidesert-grassland. The vegetation is a mosaic of grazed vegetation closely resembling the mesquite-grass association, that is savanna-like in some places. The urbanized area includes low density housing and golf courses. The literature and museum records suggested five families of anurans, two families of chelonians, and eleven families of squamates were present and represented by 53 species. Of nine species of amphibians expected to be present in the area six have been located, five species in the urbanized area and five species in the non-urbanized areas. Of 48 reptile species expected to be present 34 have been located, 24 species in the urbanized area and 26 in the non-urbanized area. Arizona has approximately 164 species of amphibians and reptiles (including introduced species), thus the SRER and surrounding areas support about 20.7% of the State's herpetofauna based on field results to date. Two years into this project some species expected to be present have not yet been discovered, while other, unexpected species have been confirmed as present. The Gila Monster and the Sonoran Desert Tortoise are present in the study area.

An Inside Look into the Construction of Pima County's Sonoran Desert Tortoise Monitoring Program

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Pima County's Section 10 Incidental Take Permit from the U.S. Fish and Wildlife Service and its associated Multi-species Conservation Plan (MSCP) ensures that the County remains in compliance with the federal Endangered Species Act. Implementation of an ecological monitoring program is a key requirement of the MSCP, and monitoring populations of Sonoran desert tortoises on County open space lands is a critical component of this program. The County's tortoise monitoring objective is to detect biologically meaningful changes in tortoise populations and where possible, support other tortoise monitoring efforts at spatial scales beyond Pima County lands. Here we outline the process that staff used to structure Pima County's tortoise monitoring program, including decisions related to what tortoise population parameter to use (density vs. occupancy) and how to inform the spatial construct of the tortoise monitoring sampling frame across County lands from which we chose tortoise monitoring sites. We also discuss the process through which we reconciled the tradeoffs between the resources devoted to plot numbers and field visits, with a trend-detection power analysis to establish a robust but realistic monitoring strategy.

STUDENT POSTER

Virus Discovery in Mojave and Sonoran Desert Tortoises

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Species evolve in response to pathogens they encounter in their environment. Endangered species are often at increased susceptibility to pathogenic threats due to low genetic diversity. The threatened Mojave Desert tortoise, *Gopherus agassizii*, has experienced large population declines in part due to Upper Respiratory Tract Disease (URTD) caused by a bacterium, *Mycoplasma agassizii*. While there has been work into this pathogen, considerably less is known about the viral assemblage carried by the Mojave Desert tortoise, or its sister species, the Sonoran Desert tortoise, *G. morafkai*. Tortoises are interesting candidates for virus discovery because they are long-lived animals that closely interact with desert soils, eat a wide range of native flora, and interact with other desert fauna through use of burrows and shelters. These reasons suggest that they may be exposed to a diverse array of virus communities. Previous studies have shown multiple virus families present within members of the Testudines family. In this project, we aimed to catalog viruses found within wild tortoises. We performed viral metagenomics on 33 scat samples of the Sonoran Desert tortoise and mined existing transcriptomic and genomic data for *G. agassizii*. Using bioinformatic approaches, we identified 119 novel microviruses which are likely associated with their gut flora, 27 genomoviruses and 16 novel circular DNA viruses. The scat samples collected from Sonoran Desert tortoises had particularly diverse virus assemblages.

Impact of Solar and Wind Development on Conservation Values in the Mojave Desert of California

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In 2010, The Nature Conservancy completed the Mojave Desert Ecoregional Assessment, which characterizes conservation values across nearly 130,000 km^2 of the desert Southwest. Since this assessment was completed, several renewable energy facilities have been built in the Mojave Desert, thereby changing the conservation value of these lands. We have completed a new analysis of land use to reassess the conservation value of lands in two locations in the Mojave Desert where renewable energy development has been most intense: Ivanpah Valley, and the Western Mojave. We found that 99 of our 2.59-km^2 planning units were impacted by development such that they would now be categorized as having lower conservation value, and most of these downgrades in conservation value were due to solar and wind development. Solar development alone was responsible for a direct development footprint 86.79 km^2: 25.81 km^2 of this was primarily high conservation value Bureau of Land Management lands in the Ivanpah Valley, and 60.99 km^2 was privately owned lands, mostly of lower conservation value, in the Western Mojave. Our analyses allow us to understand patterns in renewable energy development in the mostly rapidly changing regions of the Mojave Desert. Our analyses also provide a baseline that will allow us to assess the effectiveness of the Desert Renewable Energy Conservation Plan in preventing development on lands of high conservation value over the coming decades.

Modeling the Impacts of Roads and Mitigation Efforts on the Viability of Desert Tortoise (*Gopherus agassizii*) Populations

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Effective species conservation requires identifying threats to populations and possible mitigation measures to ameliorate those threats. Infrastructure, such as roads, pose both direct and indirect threats to wildlife, particularly the Mojave desert tortoise. To reduce road mortality,

conservation managers have installed fencing along roadways. However, the extent to which tortoise populations may benefit from roadside fencing remains unknown due to long generation times and cryptic behavior of desert tortoises. To understand how local populations may respond to recovery actions such as roadside fencing, we developed a spatially explicit, individual-based model. Empirical data from long term datasets – including reproduction rates, age-classes, movement and behavior of desert tortoises – were used to investigate population trends along roads of varying traffic volume. Using these models, we investigated how populations may respond to two recovery tools: 1) roadside fencing and 2) release of head-started tortoises. We found that nearly all roads pose a significant threat to the long-term persistence of local tortoise populations, with roads of high traffic volume leading to severe population declines. While the installation of mitigation fencing effectively stops further population decline, local populations are slow to recover with less than 3% population recovery over 50 years. As a potential tool to assist recovery of these local populations, the release of head-started tortoises to "jump-start" the depleted population was next explored. We simulated releasing juvenile tortoises, aged 5-7 years–old within the landscape post-fencing installation. With the amalgamation of roadside fencing and the release of head-started tortoises, the simulated population increased to near pre-road installation conditions. Our work highlights the priority of mitigation fencing to prevent further desert tortoise population declines while alternative recovery actions can be taken to ensure species recovery.

Private Land Conservation in Southern Arizona
Arizona Land and Water Trust

Liz Petterson, Executive Director
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Arizona Land and Water Trust (Trust) has been a trusted partner to private landowners, ranchers and farmers in Southern Arizona for over 40 years. The Trust achieves its mission of protecting farms and ranches, wildlife habitat, and the waters that sustain them by working with landowners who are interested in voluntarily conserving their lands. With expertise in land protection transactions, tools such as conservation easements or identifying conservation buyers to permanently protect landscapes are often utilized. The Trust works closely with federal, state, county and local entities, along with private foundations and their base of individual supporters, to secure funding sources for transactions, serving as a bridge between public entities and private landowners. The Trust has protected over 50,000 acres to date and currently holds over 12,000 acres in conservation easements in Southern Arizona. The Trust is also Arizona's only water trust, launching our Desert Rivers Program in 2007. Through the use of short-term water lease agreements, we are addressing both the needs of local agricultural producers and needs of river systems by compensating farms and ranchers who put water back instream to support healthy habitat and hydrologic function.

The organization played a significant role in Pima County's 1997 and 2004 bond programs, acting as a facilitator to bring the County and willing sellers together to assist in protecting over 30,000 acres as part of the Sonoran Desert Conservation Plan (SDCP). Habitat for the Sonoran Desert tortoise (*Gopherus morafkai*) is substantially included within specific areas of desertscrub, thornscrub, and semi-desert grassland in these protected landscapes. Most of these lands are near the Tucson metropolitan area, and some are at intermediate elevation that would likely become more suitable for tortoises as climate warms.

Birds not in Flight: Using Camera Traps at Desert Tortoise (*Gopherus agassizii*) Burrows to Study Avian Behavior at a Wind Farm

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Wind energy facilities are dangerous landscapes for many bird species. The increasing establishment of wind farms worldwide in recent years is a significant concern for bird conservation efforts. However, it can be difficult and time-consuming to study birds in a wind farm. We implemented a passive ground-based technique using camera traps installed at the burrows of desert tortoises (*Gopherus agassizii*) at a wind farm near Palm Springs, California to study and quantify avian species presence, behavior, and use. Birds utilize these burrows for nesting, resources (e.g. food and nesting material), hibernacula, and as thermal refugia. We observed a total of 12 avian species in the photos taken by our camera traps. Mortality from turbine strikes has been documented in the literature for 10 of these species, although all of the species are considered vulnerable. We collected over 13,000 photos (a total of 1,968 ‘events’, or photosets of the same individual bird triggering a camera within a five-minute period) distributed across 45 tortoise burrows from 1 June–14 November 2013. We observed birds using the burrows to collect nesting material and food, displaying hunting and defensive behaviors, dust bathing, and entering and/or exiting the burrows. Bird counts increased with the minimum estimated age of desert tortoise burrows, possibly indicative of older burrows being known resources to individual birds. Estimated bird counts at burrows exhibited a non-linear relationship with distance from wind turbines, displaying a distance threshold of around 150 m from wind turbines in which avian presence increased at desert tortoise burrows, in contrast to expectations of avoidance. Passive observation of avian use and behavior at wind farms through ground-based camera trapping allows for species identification, determination of activity patterns and behavior, and habitat preference, all of which can provide useful knowledge for wildlife managers.

More Luck Than Brains: The Opportunistic Discovery of Hatchling Gila Monsters in a Semi-Urban Nest

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Despite the iconic status that the Gila Monster *(Heloderma suspectum)* maintains as an inhabitant of the Sonoran Desert, very little is understood about its reproductive and nesting behaviors. In late October of 2016, a construction crew digging a footing for a house addition accidently uncovered five hatchlings that were either still in the egg or had just emerged. The author was blessed to receive the phone call from the crew, and was on scene within forty minutes. The author's close relationship with the DeNardo lab at Arizona State University allowed for collaboration between what they learned through radio telemetry at their discovered nesting sites, and the information that was acquired at the dig site. Preliminary findings indicate that *Heloderma suspectum* may be the only lizard species in the world to lay their eggs in early summer, hatch in mid fall, overwinter out of the egg, and emerge to become surface active in the spring. The nest found in October 2016 is the first ever to be documented in the history of mankind, and we continue to learn from the hatchlings, which are being kept by the DeNardo lab. The color change of the young from whitish-yellow to orange has already been documented, and a watchful eye for pattern change is being applied. The metrics of the hatchlings will be discussed, as will the physical aspects of the nest itself.

INVITED SPEAKER

Global Conservation Status of Turtles and Tortoises (Order Testudines), with an Emphasis on Testudinidae and *Gopherus*

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We present a review and analysis of the conservation status and IUCN threat categories of all 360 currently recognized species of extant and recently extinct turtles and tortoises (Order Testudines). Our analysis is based on the 2018 IUCN Red List status of 251 listed species augmented by provisional Red List assessments by the IUCN Tortoise and Freshwater Turtle Specialist Group (TFTSG) of 109 currently unlisted species of tortoises and freshwater turtles as well as re-assessments of several outdated IUCN Red List assessments. Of all recognized species of turtles and tortoises, this combined analysis indicates that 20.0% are Critically Endangered (CR), 35.3% are Critically Endangered or Endangered (CR+EN), and 51.9% are Threatened

(CR+EN+Vulnerable). Adjusting for the potential threat levels of Data Deficient (DD) species indicates that 56.3% of all data-sufficient species are Threatened. We calculated percentages of imperiled species and modified Average Threat Levels (ATL; ranging from Least Concern = 1 to Extinct = 8) for various taxonomic and geographic groupings. Proportionally more species in the subfamily Geoemydinae (Asian members of the family Geoemydidae) are imperiled (74.2% CR+EN, 79.0% Threatened, 3.89 ATL) compared to other taxonomic groupings, but the families Podocnemididae, Testudinidae, and Trionychidae and the superfamily Chelonioidea (marine turtles of the families Cheloniidae and Dermochelyidae) also have high percentages of imperiled species and ATLs (42.9–50.0% CR+EN, 73.8–100.0% Threatened, 3.44–4.06 ATL). The subfamily Rhinoclemmydinae (Neotropical turtles of the family Geoemydidae) and the families Kinosternidae and Pelomedusidae have the lowest percentages of imperiled species and ATLs (0–7.4% CR+EN, 7.4–13.3% Threatened, 1.65–1.87 ATL). Turtles from Asia have the highest percentages of imperiled species (75.0% CR+EN, 83.0% Threatened, 3.98 ATL), significantly higher than predicted based on the regional species richness, due to much higher levels of exploitation in that geographic region. The family Testudinidae has the highest ATL (4.06) of all Testudines, due to the extinction of several species of giant tortoises from Indian and Pacific Ocean islands since 1500 CE. The family Testudinidae also has an ATL higher than all other larger polytypic families (≥ 5 species) of Reptilia or Amphibia. The Order Testudines is, on average, more imperiled than all other larger Orders (≥ 20 species) of Reptilia, Amphibia, Mammalia, or Aves, but has percentages of CR+EN and Threatened species and an ATL (2.96) similar to those of Primates and Caudata (salamanders).

INVITED SPEAKER

Growth Studies in Hatchling and Juvenile Gopher Tortoises (*Gopherus polyphemus*)

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Multiple factors influence early growth in gopher tortoises. Growth has proven to be challenging to study. Difficulty finding and following hatchling and juvenile gopher tortoises in the field has received limited study across much of its range. Separating out factors that influence early growth have also proven challenging. The results of four studies will be presented which address population, diet, genetics (clutch effect), sex, thermoregulation and social context. Gopher tortoises live in varied habitats ranging from scrub to flatwoods to sandhill habitats. Management practices can influence habitat quality and food availability. This food availability can influence mother's condition and size as well as subsequent egg and hatchling quality. Subsequent growth rates of hatchlings may further be influenced by other factors such as sex, genetics (clutch effect), temperature and density (social interaction). We studied growth in the lab where we could control variables. Sex, access to supplemental heat, and density did not strongly influence growth rates. Genetics (clutch effects) and diet had the greatest influence on growth rates and size

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Sonoran Desert Tortoises in Arizona: an overview of recent and ongoing projects of the Wildlife Contracts Branch of the Arizona Game and Fish Department

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The Sonoran Desert Tortoise is a Species of Greatest Conservation Need in Arizona and designated a tier 1A species by the state's wildlife action plan. With this designation, coordinated efforts with partner agencies have been made to ensure geographically and ecologically broad coverage of Sonoran Desert Tortoises in Arizona. The Arizona Game and Fish Department (AGFD) has actively managed the Sonoran Desert Tortoise since the mid-1980s. In cooperation with partners such as the Arizona Army National Guard, Department of Defense, Arizona Department of Transportation, and the Bureau of Land Management, AGFD has conducted monitoring of tortoise populations and their habitat across the state. These monitoring strategies have provided AGFD with important data related to population levels, species distribution, habitat selection, and the prevalence of disease for tortoises in Arizona. With a greater understanding of tortoise ecology, land managers and natural resource managers are able to make better informed decisions that reduce conflicts with this species while still maintaining their respective agency's goals. Here we will provide an overview of recent and ongoing monitoring projects conducted by the Wildlife Contracts Branch of the AGFD. We will highlight the outcomes of our occupancy, demographic, and telemetry projects, and provide recommendations regarding the monitoring strategy for Sonoran Desert Tortoises.

Leveraging Public-Private Partnerships in Private Land Conservation

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Mojave Desert Land Trust (MDLT) is a non-profit conservation organization dedicated to conserving the ecological, cultural, and scenic resource values of the Mojave Desert in California. Since its founding in 2006, it has conserved over 90,000 acres of desert land through fee title acquisition, and has conveyed approximately 60,000 of those acres to public land management agencies, allowing for landscape scale conservation practices across the California desert. A significant portion of MDLT's acquisition strategy is to purchase lands in critical habitat for desert tortoise, as determined by the US Fish and Wildlife Service. To date, MDLT has acquired about 15,000 acres of desert tortoise habitat in the Chuckwalla Bench, a further 2,000 acres in the Chemehuevi Valley, and some 3,000 acres in the Cady Mountains Wilderness Study Area by leveraging a combination of public and private funding sources. While some of this acreage is intended for conveyance to the Bureau of Land Management, much of it will be managed by MDLT in perpetuity, which has allowed MDLT to initiate partnerships with a variety of federal, state, and private entities. These partnerships have been instrumental in MDLT's work to maintain or improve tortoise habitat across the Mojave.

Harnessing Genomics to Provide Probable Geographic Origins for Tortoises in the Large-Scale Translocation Site, Nevada

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Between 1997 and 2014 approximately 9,150 Mojave Desert Tortoises that were surrendered pets or displaced from development were moved to the Large-Scale Translocation Site (LSTS) in the Ivanpah Valley, Nevada. These animals had diverse histories of captive containment and unknown geographic and genetic origins, making their genetic effects on native Ivanpah tortoises impossible to evaluate. Given that the fences surrounding the LSTS are being considered for removal, we sought to provide probable geographic origins for LSTS transplants to determine the potential genomic risks of reconnecting surviving animals within the LSTS to surrounding natural populations of Mojave Desert Tortoises. We harnessed an available dataset of 270 low coverage (~1.7x) tortoise genomes that span the species' distribution and have known locality data, combined with new RAD sequencing of most of the remaining individuals in the LSTS, to determine the geographic origins for tortoises contained within the LSTS. In total, we sequenced 79 surviving LSTS transplants, demographically similar set of LSTS transplants that are known or presumed to have died, and all available samples for tortoises believed to be native to the LSTS. We found that approximately 15% of LSTS transplant survivors are distant transplants with a genomic make-up that is drastically different from the Ivanpah Valley and nearby Las Vegas metro area. We also found that the original source of transplanted tortoises had no impact on the proportion of individuals surviving in the LSTS (χ^2 p-value= 0.11) indicating that translocation to the LSTS did not act as a selective filter for either native or foreign genotypes. We suggest that the low number of LSTS survivors with extra-native genotypes (about 26 tortoises) will likely not be detrimental to the overall health of tortoises in the region and may even be advantageous in light of current and predicted warming trends associated with climate change.

POSTER

Community Solar Project Environmental Monitoring and Research

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HDR environmental services recently assisted a large power and energy client in southern Nevada move a solar project forward to production inside desert tortoise habitat. This 80 acre solar project included innovative research designs outside of the standard operating procedures for solar facility construction. Most solar farms constructed in desert tortoise habitat require capturing tortoises found inside the construction footprint and permanently moving them to designated areas outside of project impacts for their safety. This project was designed to allow the release of

tortoises back to where they were originally located, inside a complete and fully operating solar energy plant. The tortoises were located, removed, cared for, and then released by HDR USFWS authorized desert tortoise biologists. Research and monitoring of the vegetation, desert tortoises, and avian and bat mortality in response to modified construction is being conducted and innovative construction design features and research results will be presented.

The Use of Emerging Drone Technology for Management of the Common Raven (*Corvus corax*) for Conservation of the Mojave Desert Tortoise (*Gopherus agassizii*)

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Unmanned aerial systems (UAS- drones plus control programs) have been around for nearly a century, however, only in the past decade have they become readily available for commercial use. The use of the UAS in wildlife conservation has taken many forms, from anti-poaching patrols to habitat mapping and evaluation. We have pioneered an innovative adaptation of a quad-copter drone for predator control to benefit Mojave Desert Tortoise conservation and implemented the use of a fix-winged drone with mapping GIS capabilities to assist in locating raven nests. The common raven (*Corvus corax*) is a voracious, human-subsidized predator of juvenile desert tortoises. Raven numbers have increased in the Mojave Desert by over one thousand percent in the past three decades. We have engineered, tested and deployed a drone to apply non-toxic oil to common raven nests to induce egg-mortality, a method we call remote egg oiling (REO). The implementation of large-scale REO in critical habitat of the desert tortoise has the potential to promote recovery of the species in areas where senescent tortoise populations, the result, in part, of long-term raven hyper-predation, are now being observed.

Acquisition and Protection of Critical Habitat for the Bolson Tortoise (*Gopherus flavomarginatus*) in the Bolsón de Mapimí Biosphere Reserve, Durango, Mexico

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The Turtle Conservancy protects and manages a relatively small number of reserves around the world that provide critical habitat for highly endangered turtles and other biodiversity. We invest heavily in those sites, in partnership with local NGOs. This vertical strategy has allowed us to acquire core habitat for chelonian species in Mexico and South Africa, and to partner with local NGOs to purchase critical habitat elsewhere. In this paper we discuss issues of land acquisition and management in the Bolsón de Mapimí Biosphere Reserve in Durango, Chihuahua, and Coahuila, Mexico. The Turtle Conservancy has purchased 17,300 hectares of prime habitat for the Bolson Tortoise (Gopherus flavomarginatus) in the Mapimí ecosystem, and has begun implementing a conservation management strategy involving protection of tortoises and their burrows, mitigation of damage from livestock from neighboring properties, infrastructure maintenance, and tortoise and habitat surveys and monitoring. Land acquisition can be a highly effective conservation strategy, but it is not for the faint-hearted. Mexico's Biosphere Reserves may allow for land uses not compatible with conservation of certain species, making private conservation the only path for preserving these fauna. Additionally, the communal land ownership system of rural Mexico makes land acquisition difficult, and cultivating long-term relationships with local land owners, government agencies and NGOs is critically important.

Sonoran Desert Tortoises (*Gopherus morafkai*): Some Observations on Seasonal Variation in Behavior

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Since 2011 we have been using radio-telemetry to study the spatial ecology of *Gopherus morafkai* on the northern edge of Phoenix metropolitan region along the eastern edge of the Union Hills. Results from over 96 months of radio-telemetry provide insights on: 1) consistency in refuge use and movement patterns each year, 2) inactivity during drought, and 3) consumption of caliche fragments by females during the hot/dry season. Our findings document some activity in every month of the year for SDTs. We hypothesize that activity and reproductive recruitment were impacted by short-term drought during 2017-2018. Drought during the monsoon dramatically reduced activity in SDTs. Although SDTs appeared to successfully reproduce following a dry monsoon, a dry winter may have resulted in mortality of all young "hatchling" (1-3 yrs) SDTs under visual observation from October to April. Over eight years of study, we observed female *G. morafkai* consuming small white fragments of calcium-rich and phosphorus-poor caliche but only during late May and June and in close proximity to their deep caliche refuge. The temporal restriction of caliche consumption coincides with clutch development and egg deposition. In contrast to females, males have largely non-overlapping home ranges, and exhibit a pattern of movement in which they visit females on the periphery of their home range at the same refuge year after year.

Desert Tortoise Council Activities — 2018

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The Desert Tortoise Council's (Council) Board of Directors (Board) continued to pursue and implement strategies outlined in its 2015 5-year strategic plan, with our committees fulfilling specific roles in carrying out the plan in 2018. Our Ecosystems Advisory Committee (EAC) received 95 notices, commented on 39, cosigned an additional 10 letters, attended 3 public meetings, and met with policy makers in Washington D.C. The Council's Grants Committee funded a total of $25,000 in Grant Requests for conservation activities and land acquisition efforts, and $2,000 for the Lockheed Martin Diversity Grant, in 2018. The Council received a generous donation of $4,000 from the California Turtle and Tortoise Club and donated $10,000 to the Springs Preserve in Las Vegas. The 2018 Symposium featured 53 papers and posters from biologists, conservationists, and resource managers and was attended by more than 290 registrants. The Introductory and Advanced Training Committees provided training opportunities in 2018 through offering one Introductory Course and a refresher course for the 2017 Authorized Desert Tortoise Biologist Training attendees. The Media Committee published one Newsletter, increased the frequency and visibility of social media posts, and updated the website. The Board established new committees in 2018, including the Education & Outreach Committee and the Mexico Coordination Committee. By the end of 2018, total assets of the Council were $217,450, our active membership reached 368, and we implemented new membership categories and membership terms on a calendar year basis.

Variables Affecting Survival of Juvenile Desert Tortoises after Release from Headstart Pens at Edwards Air Force Base, a Preliminary Report. Part 2. Behaviors, Home Range

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When released from headstart pens at Edwards Air Force Base, the juvenile tortoises were placed 200 m apart, and in the 3 to 5 years after release, most remained near release sites. We tracked tortoises monthly, recording their location, behavior, and habitat, and determined post-release home range sizes and movement parameters for 105 of 119 tortoises, for which we collected 4 to 50 months of data. Home range sizes (minimum convex polygon) were significantly larger for tortoises in the ≥100.0 mm size category (4.9 ha) than for the other size categories (0.93 ha, 0.49 ha, and 0.18 ha for the 70.0–99.9 mm, 60.0–69.9 mm, and < 60.0 mm size categories, respectively). Similarly, mean distances moved by tortoises between subsequent locations were significantly greater for tortoises in the ≥ 100.0 mm size category (mean = 68.9 m) than the other size groups (34.2, 35.8, and 34.0 m for 70.0–99.9 mm, 60.0–69.9 mm, and < 60.0 mm size categories, respectively). The mean number of burrows used by tortoises in different size categories was 3.9 (< 60.0 mm) to 6.5 (60.0–69.9 mm), 8.7 (70.0–99.9 mm), and 12.4 (≥ 100 mm). Total displacement distances between release points and last known location was greatest for the ≥ 100.0 mm size category (271.4 m), followed in descending order by the 70.0–99.9 mm category (117.1 m), the 60.0–69.9 category (80.5 m), and the < 60.0 mm category (77.9 m), with significant

differences between the largest size category compared to all others. The tortoises were solitary, did not share burrows, and exhibited very little overlap in home range areas.

Desert Tortoise Management and Research in Joshua Tree National Park

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Joshua Tree National Park (JOTR) protects nearly 800,000 acres of public land of which 240,000 is considered high quality desert tortoise habitat. Annual visitation grew from just over 2.5M in 2016 to 2,853,619 this past year. That is an increase of over 338,000 visitors to Joshua Tree National Park in 2017 and the continuation of four consecutive years of record visitation numbers.

The park has supported the recovery of the tortoise through participation of region wide planning efforts, management of habitat, educational outreach and scientific research. The park is also an active participant in the Colorado Desert workgroup under the California Mojave RIT to guide future recovery efforts in the region. Within the park, educational specialists provide desert tortoise educational presentations to many local schools. The park also has an active habitat restoration program that works to return degraded habitats to functional ecosystems for tortoises and other animals. Desert tortoise awareness talks are given to all NPS employees, construction workers and even researchers doing work in the park that may affect the desert tortoise. Since 2007, the park's wildlife staff has been tracking desert tortoises near roads as part of a study to understand the effect of roads on tortoise movement patterns. Currently, the park is analyzing the data with some interesting preliminary results.The park is heading into its fourth year of removing offending common ravens with some promise that the action is working to reduce predation on juvenile tortoises.

The Large Mechanosensitive Channel Protein of *Mycoplasma agassizii*: Are Differences Reflective of Host Evolutionary Pressures?

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Mechanosensitive channels (MscL) are found in a wide variety organisms, including eukaryotes, eubacteria, and archaebacteria. In silico analysis identified mscL in over 40 Mycoplasma species as well as multiple Phytoplasma and Acholeplasma species. Analysis of the predicted MscL amino acid sequence as well as protein size showed clear differences among species. Given these differences as well as the differences in genomic context, it is likely that Mollicutes acquired mscL independently. Regardless of the evolutionary origin of *mscl* in Mollicutes, it appeared that once the gene was present in a species, both the amino acid sequence and genomic context is highly conserved. Within multiple isolates of a single species, the MscL amino acid sequence is virtually identical. Mycoplasma agassizii is a primary etiologic agent of a well-characterized upper respiratory tract disease (URTD) in free-ranging desert and gopher tortoises in the U.S. Genome sequence data from isolates of the gopher and desert tortoises revealed the presence of the mscL gene. Although narrow host specificity traditionally is considered a feature of mycoplasmal species, we have isolated *M. agassizzi* from 9 tortoise species representing 6 genera in the family Testudinidae. We amplified and sequenced the mscL gene from these isolates. MscL was detected by PCR in clinical isolates from the other tortoise species, suggesting that the gene was derived from a common ancestor. Unlike other mycoplasma isolates of the same species (for example different isolates of *M. bovis, M. galllisepticum, M. canis, M. hominis*), the MscL protein in *M. agassizii* was not conserved and showed significant amino acid variation, especially in the extracellular loop. Members of the *Gopherus* species in the U.S. arose ~35 million years ago; the three major *Gopherus* species occupy dramatically different habitats: the Mojave/Sonoran desert; dry scrub and grasslands in Texas; and dry, sandy uplands and coastal dunes in Florida and the Southeast. Each species has developed different biological strategies and life history, including reproductive and burrowing traits, in response to these different habitats. We hypothesize that the mscL gene was acquired by a common ancestor and then may have undergone substantial alterations and modifications of the protein structure as a result of the specific environmental pressures unique to the host:pathogen interactions.

Sequencing the Gila monster (*Heloderma suspectum*) Genome to Unravel Mysteries of Squamate Adaptation and Evolution

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The Gila monster (*Heloderma suspectum*) is one of the Desert Southwest's most iconic animals. In coping with the environmental extremes of the desert environment, Gila monsters use a unique suite of adaptations. This makes Gila monsters particularly valuable for understanding evolutionary processes. Unfortunately, potential work has been limited by the lack of an available genome for Gila monsters. Here we escribe our efforts to generate a draft reference genome for the Gila monster and undertake population and comparative genomic analyses. By sequencing and analyzing the Gila monster genome, we will contribute critical knowledge and resources that will not only promote the conservation of the species, but enable the Gila monster to become an effective study system for addressing broad questions regarding evolutionary processes associated with adapting to challenging environments. As an example of our ongoing work, we highlight a detailed assessment of Gila monster sex chromosomes. Both XX/XY and Z/ZW sex determination is present within the squamate (lizards and snakes) clade, and phylogenetically Gila monsters are ideally located to aid in our understanding of the evolution of squamate sex determination. Our results give insight into the evolutionary history of sex chromosomes and sex determination not only in Gila monsters but across squamates as well.