ABSTRACTS

47th Annual Meeting and Symposium

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FORTY-SEVENTH ANNUAL MEETING AND SYMPOSIUM
THE DESERT TORTOISE COUNCIL
Virtual by Zoom
Tuesday and Thursday Mornings, February 15, 17, 22, and 24; and
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ABSTRACTS OF PAPERS AND POSTERS

(Abstracts arranged alphabetically by last name of first author)
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Restoration of Desert Tortoise Habitat: Indicators, Techniques, Effectiveness, and Costs

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Habitat restoration has potential for contributing to Agassiz's desert tortoise (*Gopherus agassizii*) recovery actions by reversing habitat degradation, replenishing or enhancing habitat resources utilized by tortoises, and limiting further habitat deterioration. This project reviewed desert tortoise habitat restoration techniques and had the following objectives: 1) summarizing desert tortoise habitat requirements and indicators of habitat quality, such as availability of protective cover and forage; 2) synthesizing restoration practices and their effectiveness in the Mojave and western Sonoran deserts; 3) providing estimated costs of candidate restoration treatments; and 4) anticipating future restoration and research needs for effective restoration in changing climates and environments. Over 50 published restoration studies in the Mojave and western Sonoran deserts collectively demonstrate that restoration can increase perennial plant cover and native annual plants, improve soil conditions (e.g., biocrusts), enhance native seed retention and seed banks, and reduce fire risk. All these outcomes would be anticipated to improve habitat conditions for desert tortoises based on tortoise habitat requirements. The review details 11 major restoration treatments (and their numerous variations) evaluated in at least one study and ranging from active revegetation (e.g., outplanting, seeding) to abiotic structural restoration (e.g., vertical mulching) and protection treatments. For example, 16 outplanting studies assessed performance of 46 species and began identifying top-performing species, associated treatments (e.g., protection from herbivory) required to aid plant survival, and potential for outplants to form self-sustaining populations. As an example, creosote bush (*Larrea tridentata*), a major shrub tortoises utilize for cover, has achieved at least 50% survival in five of eight studies in which it was outplanted. Cost estimates and logistics are also presented for the range of restoration treatment options along with ideas for further research to advance habitat restoration practices.

The Desert Tortoise Recovery Office: A 17-Year Review

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In the early 2000s, reviews of the recovery program for the Mojave Desert Tortoise (*Gopherus agassizii*) and its 1994 recovery plan concluded that *a*) a coordinated research strategy was needed to link land management decisions with research results and that *b*) the U.S. Fish and Wildlife Service (Service) should establish a Desert Tortoise Recovery Office (DTRO) to facilitate such coordination. As a result, the Service established the DTRO in 2005 with the initial charge to revise the recovery plan. In 2011 the Service published a revised recovery plan that described a structured approach for recovery along six strategic elements, and this presentation will describe substantial progress the DTRO helped facilitate among many partners under each element. However, desired progress toward recovery has not been achieved as indicated by recent negative population trends across much of the range. Discretionary recovery investments and reactive regulatory processes have been insufficient to match the magnitude and scale of threats across the tortoise's range. Therefore, we need new approaches for recovery along with renewed emphasis on existing priorities.

We suggest identifying collaborative, focal project areas for the Mojave Desert Tortoise across its range within which multi-partner recovery resources can be concentrated to meaningfully reduce or eliminate threats within ~5 years. The goal would be to rapidly stabilize or augment existing local tortoise populations, thereby creating strongholds from which longer-term, range-wide recovery criteria can be approached. At the same time, improved application of regulatory processes should maintain connectivity and occupied habitat between focal project areas and Tortoise Conservation Areas. Other actions such as tortoise-exclusion fencing along highways and raven management should also continue range-wide. Finally, managers need to begin thinking about how to apply Resist-Adapt-Direct approaches at local and landscape scales to deal with impacts from climate change. It is important to recognize progress that has been made to support desert tortoise recovery while still soberly continuing down the long road that lies ahead.

Road Density and Mojave Desert Tortoise Population Trends

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Wildlife management agencies regularly work with land managers to achieve desired abundance and productivity for game species, resulting in motorized access plans that are in widespread use to address harmful effects of roads to these species. Motorized access plans may restrict seasonal use of roads to reduce mortality, or if data demonstrate a correlation with population-level impacts, thresholds may be set for road density. However, these approaches have not been applied substantially within the range of the Mojave Desert Tortoise. Across tortoise conservation areas, we show a negative relationship between road density and published trends in adult tortoise

density. We found that all tortoise populations declined in tortoise conservation areas with route densities above 0.75 kilometers of roads (paved and unpaved) per square kilometer.

Roads are ubiquitous throughout the range of the tortoise, so it is not surprising that we detected this correlation. Roads and road densities are known to have negative impacts on desert tortoises through highly disparate direct and indirect effects including poaching, death through crushing, facilitation of invasion of plants with poor nutritional quality and which increase fire risk, and fragmentation that reduces individual tortoise movement and thereby reduces both population persistence and ability to be rescued by immigration from nearby areas. Land managers currently set upper speed limits in tortoise conservation areas and limit location and season of some off-highway vehicle races, but on a case-by-case basis and with the goal of reducing known mortality risk to tortoises. With this additional information about negative population effects of dense road networks, more generalized and widespread road management planning has the potential to change the trajectory of declining tortoise populations.

AI-Assisted Drone Surveys Detect Desert Tortoises and Soil Burrows at Rates Comparable to Human Observers

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Small unmanned aerial vehicles (sUAS, or "drones") are becoming an indispensable tool in ecology and wildlife studies. Low altitude aerial photography enables rapid coverage of large areas and computer vision technology can reduce the effort required to identify target resources in large photographic datasets. We report on two tests of this method that 1) evaluate the effect of flight elevation on detection rates, and 2) explicitly compare the effectiveness of the method to traditional pedestrian transect surveys. We find that AI-assisted drone surveys are most effective at locating desert tortoises when flown at a 20 meter elevation and that observed detection rates for tortoises (mean P_d=0.67) and burrows (mean P_d=0.71) are comparable to or even slightly superior to pedestrian surveys (tortoise mean P_d=0.63, burrow mean P_d=). We also report that AI-assisted drone surveys are approximately 12 times faster (100 acres/hour) than pedestrian surveys (< 8 acres/hour). Finally, we consider the detection curve of the AI-assisted drone survey method and compare it to the detection curve of pedestrian transect surveys.

OHV Restoration: Factors of Success

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Efficacy of OHV route restoration varies across the California desert. Some project areas enjoy greater durability than others, including Friends of Jawbone project areas that have a higher- than-average OHV compliance rate. This discussion identifies and shares factors for this success using before and after photos of project sites along with descriptive statistics about the acres and miles restored. Challenges to success will also be discussed including keeping costs down through vehicle maintenance and staffing in the face of the harsh desert conditions. Other challenges include vandalism and continued motorized use of non-designated routes and discovering travel management defects. I provide a list of 10 basic restoration success factors I have found to be useful including: 1) dependable long-term funding; 2) availability of local project resources; 3) strong training program for dedicated staff; 4) equipment availability; 5) a good base for operations; 6) working locally; 7) project monitoring, data collection, and analysis; 8) land manager cooperation; 9) community partnerships; as well as 10) organizational, administrative, and field team leadership. It is not always possible to enjoy all of the 10 factors to success that we discuss with the regularity necessary for a high probability of success.

Advancing Tortoise Protection and Recovery Across the Country

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The Center for Biological Diversity continues to protect and aid in the recovery of the desert tortoise and its habitat in California, Nevada, Arizona, and Utah, using science-based advocacy, administrative processes, public information and litigation. In California, the Center in coalition with groups including the Council, filed litigation challenging the BLM's West Mojave Plan for failure to comply with NEPA, FLPMA and the ESA in September 2021; with Western Watershed Project, we successfully challenged a BLM cattle trailing permit over a permanently retired grazing allotment within the West Mojave Recovery Unit; and we continued to ensure that BLM's implementation of the Desert Renewable Energy Conservation Plan (DRECP) provides critically needed conservation for tortoise and other species. In southwestern Utah, a conservation coalition including the Center filed litigation in June 2021 challenging the Department of Interior's decisions on the Northern Corridor which allowed a new 4-lane highway through the Red Cliffs National Conservation Area established for desert tortoise conservation in the Washington County HCP. In Nevada, the Center continues to fight against development in tortoise habitat: pushing back against the Clark County lands bill, which would open up tens of thousands of acres of pristine tortoise habitat to development; successfully keeping the new Interstate 11 in southern

Nevada out of Lake Mead National Recreation Area and Rainbow Gardens ACEC; advocating for Nevada to adopt a DRECP-like model for renewable energy, steering development to lower conflict areas and protecting the remaining tortoise habitat; and fighting new mining proposals in Beatty on the northern edge of the tortoise's habitat needed for connectivity as climate change progresses. To protect the eastern gopher tortoise in Florida, the Center is fighting an order from the Florida Fish and Wildlife Conservation Commission that accelerates development, and in April 2021 filed a lawsuit against the U.S. Fish and Wildlife Service for failing to list the species.

Fences and Barriers Work for Managing Unauthorized Uses: A Valuable Tool

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Most populations of desert tortoises (*Gopherus agassizii*) in critical habit across the geographic range are in steep decline. Many populations are no longer viable and the IUCN has placed the species on its Red List as critically endangered in September 2021. Although many anthropogenic uses have negative impacts on tortoises and their habitats, two stand out as being pervasive threats in much of the range: livestock grazing and unauthorized off-highway or off-road vehicle use. Two preserves, both small, have been fenced to protect populations from incursions by damaging uses: the Desert Tortoise Research Natural Area in the western Mojave Desert and the Red Cliffs Desert Reserve in an ecotone with the northeastern Mojave and Great Basin deserts. Both places have the highest remaining densities of adults documented in the geographic range. The Desert Tortoise Research Natural Area was fenced with hogwire fencing in 1978–1979 and with mesh fencing extending to the ground along sites with high vehicle traffic in 2011 to protect from sheep and vehicles. The Red Cliffs Desert Reserve has both block wall and wire fencing, including fencing to the ground in some areas. We discuss the demonstrated ineffectiveness of using only signs to prevent unauthorized uses, the effectiveness and economic value of high-quality fencing and other barriers in protecting habitat and populations, limitations of fences, and the challenges of protecting fenced sites from unauthorized grazing and vehicle access, invasive plants, and fires.

PLENARY SPEAKER, TRANSLOCATION

Chelonian Translocations in Catalonia: A 30-year Overview

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Translocation (following IUCN definition) can be a good tool to improve the conservation status of depleted chelonian species or populations. Although it is a conservation strategy, it has not been without criticism and has even been considered to lack evidence that it really works. Part of this

concern is due to the fact that chelonian life cycle is long and therefore it is difficult to evaluate the results of translocations during the working life of researchers or managers. Thus, translocations are slow projects that may take several years to achieve their objective: recover chelonian species or populations. Assessing the results of the translocation is only possible by long-term monitoring of released chelonians and their progeny. However, it is also possible to assess results in the short-term (establishment phase), medium-term (growth phase) and the long-term (regulation phase).

Since 1987 several chelonian translocation projects have started in Catalonia. In particular, since 1991 I have been involved in projects on Hermann's tortoises *Testudo hermanni*, European pond turtles *Emys orbicularis* and Mediterranean pond turtles *Mauremys leprosa* at the Ebro Delta Natural Park. Here I present the main results of the *T. hermanni* project, started in 1987 and with an annual monitoring carried out since 1991. Despite being a project in which few tortoises were released at the beginning (44 adults, 16 still alive in 2021), it is the one that has been working successfully. Tortoises began to reproduce the following year after release and reproduction was regular. From the beginning, 1012 wild born hatchling has been marked and at least 228 of them have reached the subadult or adult class. Tortoises occupy a patchy habitat, where "islets" of favorable habitat are in the middle of an unfavorable zone. Movements between patches allow colonization of islets and currently more reproduction is found in the colonization front. This colonization process is mainly carried out by the descendants of released tortoises. Annual survival rate was very high for released and wild born adult tortoises (0.978 ± 0.004), but successive batches of released adults showed poor survival during the establishment phase (1 to 3 years) if residents tortoises were present. Mammal predators are infrequent in the area, but the incursion of one badger *Meles meles* in only one year (1994) reduced the adult survival rate (0.819 ± 0.073). However, the most common predators are Norwegian rats *Rattus norvegicus* and yellow legged gulls *Larus michahellis* that preyed on hatchlings and juveniles. Population projections showed that it has achieved a growing and self-sustainable population, where the most important demographic parameter was the survival rate of wild born female adults (descendants of released tortoises). Finally, the project is still ongoing focused on the colonization process and movement ecology, comparing movements between batches of tortoises released more than 25 years ago, tortoises released less than 4 years ago and wild born tortoises.

The Techno-Tort™: An Active Predator Aversion Training Device

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Predator aversion training is a method of altering behavior patterns of predacious animals to mitigate the harm done to valuable resources. Examples include the use of lithium chloride to discourage lion predation on cattle in Africa and several attempts to reduce avian predation on the eggs of threatened and endangered birds. In the latter case, eggs treated with aversive chemicals were placed in nests to be eaten by ravens. However, in many cases the eggs used were of other

species than the sensitive species in question. The record of such efforts is mixed and this may be due to the mismatch between the model used and the eggs of the species of interest.

Hardshell Labs has developed a highly realistic juvenile tortoise model, the Techno-Tort™ and passive versions of these, paired with motion capture cameras, have been used in the past several years to systematically measure raven predation pressure across wide areas of the Mojave Desert. In 2021, working with Cornerstone Research Group on a Department of Defense funded Small Business Innovation Research grant, we developed and ran initial field tests of a "weaponized" version of the device whereby methylanthranilate was sprayed from the shell whenever a raven tapped at or tried to tip it over. We report on initial results and include video clips of raven attacks on the models, describe their design and field deployment and discuss next steps in the process of readying this example of a Predator Aversion Training System (PATS) for use in the field. We also sketch the potential for use of the similar PATS devices more broadly in tortoise and threatened and endangered species conservation.

Recovery Progress at Mojave National Preserve

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Recovery efforts for the desert tortoise (*Gopherus agassizii*) at Mojave National Preserve in 2021 included planning tortoise mitigation measures for proposed road projects, ongoing invasive weed control, raven management, monitoring of road maintenance projects, ongoing pre-project surveys for soils mapping, and habitat acquisition. Collaborating with the Federal Highways Administration and USFWS to incorporate strategic tortoise fencing and traffic calming measures as part of proposed improvement projects on Kelbaker, Kelso-Cima, Morning Star and Ivanpah roads. Three tortoise mortalities from visitor vehicle collisions were documented this past year. Drought conditions precluded the need for Sahara mustard control as only one basal rosette was found. Permitting issues prevented raven monitoring and control efforts, but a programmatic permit was signed to eliminate future delays. About 20 hours of tortoise monitoring to protect tortoises and their habitat from harm occurred on multiple road maintenance projects. In conjunction with the BLM, worked with Southern California Edison to ensure adequate monitoring was done for their major powerline retrofit projects in the Preserve. As part of the USDA-NRCS soils surveys for Mojave, some 100 locations, approximately 50 m X 50 m, have had pre-project surveys this past year. We continue to support ongoing research in head starting at the Ivanpah Desert Tortoise Research Facility. Land acquisitions have occurred this past year and total approximately 2,600 acres including significant parcels in Ivanpah Valley.

Reconciling Genetic and Field Estimates of Dispersal and Gene Flow in the Mojave Desert Tortoise

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Animal dispersal – defined as the movement of animals from one portion of suitable habitat to another - is critical for population persistence, particularly in landscapes fragmented by human activities. Although historically studied using field methods, such as radio telemetry and long-term mark-recapture studies, the increased availability of next-generation sequencing datasets now facilitates the application of landscape genetic tools to estimate rates of gene flow and dispersal. Although landscape genetic approaches may be profitably applied in tandem with field techniques to estimate dispersal rates, doing so is often difficult due to differences in study design and scale between field ecological and landscape genetic studies. Herein, we compare previously-reported dispersal rate estimates for the Mojave desert tortoise (*Gopherus agassizii*) – largely derived from field studies – to more recent estimates derived from landscape genetic studies. Using a dataset of 25,200 SNPs from more than 500 individual Mojave Desert Tortoises, we demonstrate the application of a variety of approaches – ranging from kinship-based dispersal inference to landscape resistance surface optimization – that provide insights into both the spatial scales involved in dispersal inference and quantitative estimates of dispersal probability. While within the ranges of previously-reported field-based estimates of dispersal, these landscape genetic approaches suggested complex and scale-specific landscape effects on dispersal. We argue that the integration of landscape genetic and field methodologies for estimating dispersal holds promise for improving our understanding of the impacts of past, present, and future environmental change on movement and population persistence for the Mojave desert tortoise and other sensitive taxa.

Clark County Multiple Species Habitat Conservation Plan Update

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The Clark County Desert Conservation Program (DCP) continues to administer the Multiple Species Habitat Conservation Plan (MSHCP) on behalf of the Cities, Clark County, and Nevada Department of Transportation as mitigation for an Endangered Species Act Section 10 incidental take permit for desert tortoise and 77 other species of plants and animals. The DCP has collected mitigation fees for 3,411 acres of take during the period of January to November 2021, leaving 50,960 acres of take authorization remaining under the current permit. The 2021-2023 Implementation Plan and Budget allocated up to $19,617,877.05 for the funding of staff and projects starting in July 2021. Highlights of desert tortoise-related work conducted over the past year include: occupancy surveys on the Boulder City Conservation Easement (BCCE); commenced year 8 of post-translocation monitoring of desert tortoises on the BCCE; completed

models to determine ways to maintain and/or increase connectivity in areas where connectivity is expected to decline in the future; collected mark-recapture data around 18 culverts along US 93 and US 95; and completed a nesting study for desert tortoise on the BCCE.

PLENARY ADDRESS

Acting on Internal Climate Migration: Findings from the Latest Groundswell Report

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This sequel to the Groundswell report includes projections and analysis of internal climate migration for three new regions: East Asia and the Pacific, North Africa, and Eastern Europe and Central Asia. Qualitative analyses of climate-related mobility in countries of the Mashreq and in Small Island Developing States (SIDS) are also provided. This new report builds on the scenario-based modeling approach of the previous Groundswell report from 2018, which covered Sub-Saharan Africa, South Asia, and Latin America. The two reports' combined findings provide, for the first time, a global picture of the potential scale of internal climate migration across the six regions, allowing for a better understanding of how slow-onset climate change impacts, population dynamics, and development contexts shape mobility trends. They also highlight the far-sighted planning needed to meet this challenge and ensure positive and sustainable development outcomes. The combined results across the six regions show that without early and concerted climate and development action, as many as 216 million people could move within their own countries due to slow-onset climate change impacts by 2050. They will migrate from areas with lower water availability and crop productivity and from areas affected by sea-level rise and storm surges. Hotspots of internal climate migration could emerge as early as 2030 and continue to spread and intensify by 2050. The reports also finds that rapid and concerted action to reduce global emissions, and support green, inclusive, and resilient development, could significantly reduce the scale of internal climate migration.

(https://www.worldbank.org/en/news/feature/2021).
See also: openknowledge.worldbank.org/handle/10986/36248, and worldbank.org/en/news/infographic/2021/09/13/groundswell-acting-on-internal-climate-migration

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Mojave Desert Grasslands: 40 Years of Collecting Historical Ecological Evidence of Past and Present Native Plant Community Diversity

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Through extensive examination of reference sites across the Mojave Desert of California and Nevada since the 1980s, supplemented with historical record searches, and the study of herbaria

collections, a diversity of native arid grassland components can be reconstructed among current native plant communities. Grassland communities may have been a more common part of deserts, intermixing with Mojave desert scrub, Joshua tree savannas, and wetlands. Distinct desert grassland communities are evidenced in the West Mojave Desert region, southern Mojave lowland and upland areas, uplands in the Mojave National Preserve and southern Nevada ranges, and a distinctive desert grassland type in the northern Mojave. Details of the native grass species diversity in these geographic regions are reviewed. Cool season grasses dominate western Mojave Desert regions, transitioning to warm season grasses in eastern Mojave regions. Warm-season grasses are known as C4 plants, as they use the four-carbon compound PEP carboxylase in photosynthesis. PEP carboxylase is a photosynthetic enzyme that can "attract" CO2 more efficiently than C3 plants, and allows the stomates of the plant to be closed more often—an adaptation to drought. Historic and ongoing impacts such as livestock grazing, invasive non-native grasses and forbs, habitat development and disturbance, and climate change have greatly reduced native grasses. Given the importance of cover from predation to Agassiz desert tortoise (*Gopherus agassizii*), a better understanding of this component of Mojave Desert plant communities is recommended, especially when considering mitigation measures and restoration activities of desert habitats.

Identifying Population Management Strategies for Avian Predators: A Decision Tool

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Some avian species have developed the capacity to leverage resource subsidies associated with human manipulated landscapes to increase population densities in habitats with naturally low carrying capacities. Elevated corvid density in many areas has led to an unsustainable increase in crop damage as well as depredation pressure on sympatric native wildlife prey populations, including tortoises. We developed decision support software that leverages stage structured population models to compare and identify treatment strategies that reduce common ravens (*Corvus corax*) density most efficiently, in terms of limiting both cost and take levels. Nevertheless, removal programs are only prudent if conducted in addition to subsidy control as well as habitat management programs, and in tandem with a robust effectiveness monitoring program. The StallPOPd (Version 3; freely available at *https://doi.org/10.7298/sk2e-0c38.3*) software enables managers to enter the areal extent of their management stratum and the demographic properties (vital rates) of raven population(s) of interest to evaluate strategies to decrease or curtail further population growth. Strategies explicitly include the reduction in fertility (i.e., eggs hatched) and/or the culling of hatchlings, non-breeders and/or breeders, but implicitly

comprise reduction in survival or reproduction through subsidy denial. We will illustrate the utilities of the software with examples from the Mojave and Colorado Deserts of California where ravens negatively impact populations of Desert Tortoises (*Gopherus agassizii*). Because the software leverages a life history representation that is known to characterize hundreds of wildlife species in addition to ravens, the work expands the suite of tools available to wildlife managers and agricultural industry specialists to abate bird damage in habitats with persistent human subsidies.

POSTER

BurrowFinder: Increasing Survey Efficiency with Offline Imagery Processing and Machine Learning

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Desert tortoises (*Gopherus agassizii*) frequent burrows during most of the day, making it difficult to find and count them during surveys. Burrows are conspicuous from aerial surveys, even when tortoises are underground. Traditional pedestrian surveys are time consuming and require more resources than drone-based surveys. Drones can cover the same survey areas faster and imagery can be scanned with a machine learning model to detect active burrows. SWCA has developed an object detection model trained on tortoise burrows in drone imagery collected at 30 feet above ground. The keystone of this technique is a progressive web application that can be used offline in remote field situations to scan imagery, conduct desktop review of detections, and output geographic coordinates of validated burrows. After detection, field crews can physically verify burrows or above-ground tortoises. The application can also be used online, and all offline data will sync to a remote host. This system allows flexibility for regular monitoring efforts or more time-sensitive projects where active burrows or tortoises need to be detected, sampled, or relocated.

POSTER

Detecting Desert Tortoises in Highway Culverts with Wildlife Cameras and Machine Learning

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Vehicle-induced fatalities pose a considerable risk to desert tortoise (*Gopherus agassizii*) populations near Nevada highways. Fences prevent tortoises from crossing roads, but also

reduce connectivity and gene flow. Water culverts under highways offer an alternative crossing method, though the extent of their use by tortoises is unknown. Wildlife cameras offer an affordable way to monitor wildlife use of culverts. For this project, we used one million wildlife camera images from 18 different culverts to identify desert tortoise occurrences under Highways 93 and 95 near Las Vegas, Nevada. With a custom annotation software, we manually labeled 231 tortoise images from the project and an additional 393 desert tortoise images from the iNaturalist and GBIF databases. We fine-tuned Google's Inception v3 image classification model to detect tortoises and enhanced the training with data augmentations to simulate different travel directions and lighting conditions. We also developed a workflow to manage image metadata and added camera-reported temperatures with automated optical character recognition. The fine-tuned model classified 430 images containing desert tortoises, and all results were combined with metadata for all one million images in a PostgreSQL database. This approach allowed the Clark County Desert Conservation Program to analyze the biological importance of tortoise occurrences in the data set and saved a significant amount of time and resources over manual inspection of the image set.

Monitoring Restoration Effectiveness in the Fremont-Kramer Desert Wildlife Management Area

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Transition Habitat Conservancy (THC) owns and manages approximately 4,260 acres of land in the Fremont-Kramer Desert Wildlife Management Area (DWMA). This region is a Bureau of Land Management (BLM) limited-use area which requires Off-Highway Vehicle (OHV) users to travel only on designated open routes. Unfortunately, there are many unauthorized routes in this region that fracture functional habitat "polygons", damaging intact desert. An added complication in this area is the checkerboard land ownership of public and private land that does not easily lend itself to cooperative and comprehensive management. During our time slot, we will discuss an ongoing OHV restoration monitoring effort on THC and BLM land in the Fremont-Kramer critical habitat unit for the desert tortoise. We will cover our methods for collecting data on previous restoration efforts and the knowledge gained from that ongoing survey of approximately 500 sites to date. We will touch on successes and lessons learned from seven years of land management in this area as well as our plan for protecting sensitive habitat moving forward.

Evaluating Use of Restored Unauthorized Incursions on BLM lands in California's Mojave Desert

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Ecologically functional landscapes are essential to the health of wildlife populations, and this is especially true for the Mojave desert tortoise. Yet the connectivity of desert habitats is severely diminished by unauthorized vehicle incursions leading to fragmentation and reducing habitat

functionality. In 2015, the Desert Renewable Energy Conservation Plan's Land Use Plan Amendment set new goals for habitat quality in California's Mojave Desert: the Plan requires that the Bureau of Land Management (BLM) meet standards of habitat function, in part, by restoring unauthorized vehicle incursions across the region. To quantify the amount of intact lands versus those requiring restoration, we developed a protocol to define ecological restoration, identify methods and standards to monitor unauthorized incursions at the landscape scale, and measure the restoration status and reuse of restored incursions through time using BLM's defensible space concept. Using our protocol, we conducted rapid assessments of nearly 1,000 restored incursions near Barstow and Ridgecrest to understand the level of reuse of restored incursions. We found less than 15% of restored incursions still had evidence of the original restoration in some areas, while other areas had greater compliance. Our rapid assessment suggests people are less likely to reuse restored incursions when they are harder to detect (such as when hidden by vertical mulch), but more visible actions (such as carsonite signs at roadheads) may not be as effective under some circumstances. We also found that the initial treatments of ~50% of restored incursions were still intact after 15 years. While some progress has been made, there is a lot of room for improvement. This information can inform multiple parties, including BLM and the general public, whose actions may be key to successful restoration in the future.

A Challenge of Managing Desert Tortoise Conservation – Unauthorized Motorized Travel

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The California Desert Conservation Area (CDCA) was created by the Federal Land Policy and Management Act of 1976 which provides for conservation of resources and human use, including recreation (*see* 43 U.S.C. 1781). The CDCA Land Use Plan was established in 1980 to provide guidance for the management of the CDCA and included direction for recreation; wildlife, plant, and habitat conservation; and human development activities. The desert tortoise (*Gopherus agassizii*) and its habitat are central to the West Mojave Route Network Project and the Desert Renewable Energy Conservation Plan, both of which are amendments to the CDCA plan. The desert tortoise is the focus species for the CDCA. BLM administered lands play a critically important role for desert tortoise conservation. In addition to the authorized route network for motorized vehicle travel throughout the California Desert District lands, there are numerous unauthorized incursions into wildlife habitat. Habitat degradation from, among others, unauthorized incursions has been identified as a stressor of interest and the species remains in decline across much of its range. Annually, BLM makes substantial investment of staff, time, and funding to the restoration of tortoise habitat, mostly focused on blocking access to unauthorized incursions. BLM's efforts to restore tortoise habitat and the challenges of motorized travel off designated routes including OHV recreation within listed species habitat will be presented.

Estimating Trends of Common Raven Populations in North America 1966—2018

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Over the last half-century, common raven (*Corvus corax;* raven, hereafter) populations have increased in abundance across much of North America. Ravens are generalist predators known to depredate the eggs and young of several sensitive species, including Mojave desert tortoises (*Gopherus agassizii*). Quantifying raven population increases at multiple spatial scales across North America will help wildlife resource managers identify areas where population increases present the greatest risk to species conservation. We used a hierarchical Bayesian modeling approach to analyze trends of standardized raven counts from 1966 to 2018 using Breeding Bird Survey (BBS) data within each Level I and II ecoregion of the United States and Canada. We also compared raven abundance within and outside the distributions of 9 sensitive or endangered species. We found substantial evidence that raven populations are increased across North America but variation existed in these growth rates and relative abundances among regions. For example, we found 73% of Level I (11/15) and II (25/34) ecoregions demonstrated positive annual population growth rates ranging from 0.2% to 9.4%. Regarding raven abundance within and outside the distributions of sensitive species in 2018, we found higher abundance higher inside 78% of the sensitive species distributions included in our analysis. Raven abundance has increased more rapidly within the range of Mojave desert tortoises than outside of their range, and in 2018 there were more than twice as many ravens counted per BBS route within the range of desert tortoises ($\hat{N}$=6.72) than outside of their range ($\hat{N}$=3.19). Our findings will help wildlife resource managers identify regional trends in abundance of ravens and anticipate which sensitive species are at greatest risk from elevated raven populations. Future research directed at identifying the underlying regional drivers of these trends could help elucidate the most appropriate and responsive management actions and, thereby, direct the development of raven population management plans to mitigate impacts to sensitive species.

Desert Tortoise Translocation of the Marine Corps Air Ground Combat Center (Combat Center) in 2021

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In April 2020, the Combat Center translocated 97 small tortoises, those with carapace lengths < 160 mm. The translocation totals are now 1017 large (carapace length > 159 mm) and 518 small tortoises. Radiotracking in 2021 identified 22 mortalities (9 Controls, 7 Residents & 6 Translocatees), for totals of 50 Controls, 24 Residents and 41 Translocatees (19.7%, 12.4%,

22.5%, respectively), for prior study animals. The annualized mortality rates from April 2017 to December 2021 were 4.51%, 2.74%, 5.23%, respectively (annualized survival: 95.5%, 97.3%, 94.8%, respectively). These rates are comparable to natural survival in wild populations during good rainfall and primary production years. The mortalities were spread among 4 control sites and 4 recipient sites, and resulted from predation (59%: 12 coyote, 1 badger), hyperthermia (overturned, n=1), natural causes (e.g., drought induced dehydration or starvation) and unidentified causes (32%, n=7).

A Desert Tortoise-Common Raven Viable Conflict Threshold: A Generalizable Approach to Corvid Depredation Management

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Since 1966, common raven (*Corvus corax*, raven) abundance has increased throughout much of this species' Holarctic distribution, fueled by anthropogenic resource subsidies (e.g., water, food, shelter, and nesting substrate) to ecoregion specific raven population carrying capacities. Consequently, ravens are implicated in declines of both avian and reptilian species of conservation concern. While ravens are a natural Mojave desert tortoise (*Gopherus agassizii*, tortoise) predator, the inter-generational stability of tortoise populations is compromised as annual juvenile survival is suppressed below 0.77 through a combination of raven depredation and other background sources of mortality. To estimate the extent to which raven depredation suppresses tortoise recruitment within the Mojave Desert of California, we collected data from 274 point counts, 78 tortoise decoys, and 8 decoy controls during the spring of 2020. Additionally, we complied a geodatabase of previously active raven nests (nests), observed between 2013 and 2020. Raven density estimates from four conservation areas ranged between 0.63 (eastern most) and 2.44 (western most) raven km^{-2} (95% CI: 0.35–1.14 and 1.33–4.48, respectively). We then used a Bayesian shared frailty model to estimate the effects of raven density and distance to the nearest nest on the annual "survival" of juvenile tortoise decoys, which were then converted into survival estimates for 0 to 10 year-old tortoises by adjusting exposure to reflect natural activity patterns. At the 1.72 km median distance from the nearest nest, the estimated annual survival of tortoises decreased as raven density increased, ranging among conservation areas from 0.774 (eastern most) to 0.733 (western most). Our model also predicts that tortoise populations exposed to raven densities in excess of 0.89 raven km^{-2}, at a distance <1.72 km from a raven nest are not expected to exhibit inter-generational population stability, because additive juvenile mortality is expected to exceed the natural history limits of these tortoise populations by limiting or eliminating recruitment.

STUDENT PAPER

Movement of Mojave Desert Tortoises is Altered by Landscape and Small-scale Disturbances

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Describing how animal movements are influenced by landscape features is important to understanding a species ecology and how disturbance may alter species movements, dispersal, and ultimately connectivity among populations. If an animal takes longer movements near a feature or in a disturbed area it could indicate reduced habitat quality while smaller movements may indicate higher availability of resources. The Mojave desert tortoise is a threatened species that often interacts with disturbances, both anthropogenic and natural, within its habitat. We studied tortoise movements using GPS loggers at multiple sites in the Mojave Desert of Nevada and California. Tortoises at our sites interacted with a variety of human infrastructure including paved roads, dirt roads and fences, as well as landscape-scale disturbances (wildfire scar and an open OHV use area). We fit two-state hidden Markov models to our GPS logger data to make inference on how tortoise movement behavior relates to anthropogenic and natural features. We found that temporal covariates, individual level random intercepts, and slope best explained state transition probability; tortoises were more likely to transition from moving to resting in areas of higher slope. We also demonstrated a relationship between tortoise movement behavior and environmental covariates. Tortoises took longer movements in burned habitat, the open OHV area, and near dirt roads, indicating that these disturbances may reduce habitat quality. Conversely, tortoises took shorter movements in areas of higher slope and near paved roads suggesting that these features may restrict movement or provide resources (e.g., drinking locations, forage). Tortoises that interacted with fences around utility-scale solar installations took smaller, less variable movements indicative of pacing behavior. These results provide insight into how different disturbances alter tortoise movement behavior and modify tortoise habitat.

INVITED PAPER

Discovery of a New Reproductive Strategy for the Order Testudines: Beating the Heat through Facultative Viviparity in the South African Tortoise *Chersina angulata*

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Chersina angulata has an unusual reproductive pattern for a tortoise inhabiting climatic zones ranging from winter rainfall with extreme aridity in the northwest (south-western Namibia) to Mediterranean in the southwest (Western Cape) to temperate with all-year rainfall in southern South Africa: females usually produce single egg clutches nearly year-round (March to December) and lay up to six clutches per year in underground nests. Hatching occurs March to April, just before or at the start of the rainy season in autumn. While ultrasound scanning female *C. anulata* on Dassen Island in the Atlantic Ocean we found a freshly laid egg dropped on the surface (no sign of a nest) on 20 March 1999. We stored it in a glass flask in the laboratory, to find the next morning that the egg had hatched overnight. The hatchling appeared to have a bilateral microphthalmic condition. Summer drought conditions appeared to occur at Dassen Island in 1998/99, but retrospectively we could not reconstruct details of the climatic conditions. The next observation of egg retention inside the female until the hatching stage – conforming to the generally accepted definition of viviparity – took place in a captive colony of *Chersina angulata* in Cape Town in 2015/16. Retrospective climatic analysis indicates egg retention until the hatching stage in 2015/16 co-occurred with unusually hot summer weather: the average air temperatures in December 2015 and January and February 2016 were higher than during the preceding five and the following five years when facultative viviparity could not be observed. Late December and January appears to be the critical period for females to either deposit their last clutch of the nesting season into a nest, or to retain the last clutch for embryonic development inside the female. Over the 28 December to 24 January period the minimum, average and maximum air temperatures in 2015-16 were about 3°C higher than in the five following years. This association of facultative viviparity with unusual summer heat suggests that hot ambient temperatures at the end of the nesting season may cue females to switch from oviposition to facultative viviparity. Compared to incubation in a nest this phenotypic plasticity of the reproductive mode - to retain during hot summers the season's last clutch inside the female - may buffer the developing embryos from excessive heat exposure: females can thermo-regulate by moving among microhabitats whereas sun exposed shallow nests cannot escape high ground temperatures. This novel reproductive strategy for the order Testudines can easily be overlooked in the wild and may be a rare event in captivity where environmental extremes are generally buffered. Facultative viviparity in *C. angulata* warrants further investigation: it may have the potential to enhance the resilience of the species to heat waves, droughts and human induced climate change.

Genomic Insights into the Evolution and Conservation of Threatened *Gopherus* Tortoise Species

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There are currently 6 identified species of North American tortoises in the genus *Gopherus,* which have adapted to environments ranging from the Mojave and Sonoran deserts of the southwest United States to the longleaf pine savannahs of the southeast. The genomes of these species contain a historical record of genetic changes underlying the adaptation to these environments. Towards uncovering these genetic signatures of adaptation, we have generated genome references for two species and have launched a project on a third species for comparative analysis to identify divergent genes. This growing genomic library also provides a reference framework for population genomic studies, to develop a catalog of both interspecific and intraspecific polymorphic loci.

For the Mojave desert tortoise (*Gopherus agassizii*), we previously generated first generation (Tollis et al., 2008) and second generation large-scaffold (Dolby et al., 2020) genome assemblies from a male specimen from Clark County, Nevada, with N50 = 28.4 Mega-basepairs (Mbp) and 25,469 protein-coding genes. For the Sonoran desert tortoise (*G. morafkai*), we generated a large scaffold genome from male specimen from Pima County, Arizona, with N50 = 141 Mbp and 22,130 protein-coding genes (Dolby et al., in preparation). Comparative genomic analysis of the top 1% most divergent regions between the Mojave and Sonoran desert tortoise genomes identified genes regulating the immune system, DNA stability and longevity, chemosensory function, and kidney development and water regulation. We are expanding our genomic analysis to the Texas tortoise (*G. berlandieri*), which is categorized in the same clade as the gopher tortoise (*G. polyphemus*) and divergent from both the Mojave and Sonoran desert tortoises. For the Texas tortoise, we are generating a large-scaffold genome assembly from a male specimen from Cameron County, Texas. Together with the publicly available genome for Goode's thornscrub tortoise (*G. evgoodei*), we are making progress towards availability of genomes for all *Gopherus* species, which would advance our understanding of the genetic basis of adaptation of these animals to their environment and together with populational sampling would uncover the polymorphisms within each species that likely play a key role in their long-term survival.

Route Proliferation Challenges at the Urban Interface in the Eastern Mojave

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Route proliferation is a challenge for tortoise habitat restoration throughout the Mojave Desert, particularly on many multi-use BLM lands managed by the Southern Nevada District Office

(SNDO). SNDO's Resource Management Plan (RMP) only includes route designations for the Areas of Critical Environmental Concern (ACECs) that overlap Mojave desert tortoise Critical Habitat Units (CHUs). Most other areas (with the exception of Red Rock and Sloan Field Offices, and Gold Butte National Monument) are "limited to existing" roads, trails, and dry washes. This is problematic as once a new route has been driven once, continued use on it is technically permitted as described in the RMP. SNDO has started to initiate travel management planning for certain recreation areas (Logandale Trails), but some areas are so heavily trafficked that implementation of route designations would be incredibly difficult given historic use, number of routes, and the scale of enforcement that would be necessary. Updated landscape-level planning should address this, especially given increased large-scale land uses (proposed disposal boundary expansions, utility-scale solar) that will further concentrate recreational use closer or into ACECs/CHUs. Past successes with route closures have come from clear and concise signage, prioritization of areas where restoration and compliance will be the most successful, and monitoring for new or recurring incursions in high resource value areas. Immediate response to new incursions, outreach and physical barriers are also important tools for preventing additional route proliferation.

Challenges Facing Route Restoration in the West Mojave

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In recent years, the Desert Tortoise Council (Council) has provided extensive input to land managers concerning administrative, programmatic recommendations governing route designation and restoration in the West Mojave Desert including the West Mojave Route Network Project (2011, 2015, 2018, 2021); route designation on the Arizona Strip (2013); the Desert Renewable Energy Conservation Plan (DRECP 2015); dual sport events (2019, 2021); route restoration through the Bureau of Land Management's (BLM) Preliminary Grant Application process (2018, 2021) and analogous National Park Service process (2020); Travel Management Plans on BLM lands (2018, 2019) and Red Rock Canyon General Plan (2019); and miscellaneous recreational events (two in 2021).

Despite substantive comments, thousands of acres of critical habitat were designated by the BLM as Special and Extensive Recreation Management Areas in 2015 under the DRECP; both the El Mirage and Spangler Hills BLM-designated open areas were expanded into tortoise critical habitats without benefit of public input (2019 Dingell Act, Public Law No: 116-9); BLM has created off-highway vehicle camping areas to curtail cross-country travel in critical habitat, which has had the reverse effect of concentrating impacts in those areas; and in 2019, created de facto open areas on Cuddeback and Coyote dry lakes, both located in critical habitat, reintroduced competitive events into the Ord-Rodman Critical Habitat Unit, and increased the linear distances of designated routes in the West Mojave.

In addition to dozens of comment letters alluded to above, to further inform the BLM, the Council has developed and shared an extensive road impacts bibliography, best management practices for restoring desert habitats, and recommended seven high-density tortoise areas to be proactively

managed through fencing. The Council petitioned the California Fish and Game Commission to upgrade the state listing from Threatened to Endangered in March 2020 and joined four other environmental groups in September 2021 to sue the BLM and U.S. Fish and Wildlife Service to reconsider the West Mojave Route Network Project.

Did More Female Than Male Agassiz's Desert Tortoises Die in the Western Sonoran Desert During California's Epic 2012-2016 Drought?

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We conducted population surveys for Agassiz's desert tortoises (*Gopherus agassizii*) at two nearby sites between the Cottonwood and Orocopia Mountains in the western Sonoran Desert of California beginning in early 2015 and ending in the summer of 2018. This time period included the end of the protracted drought of 2012–2016, described as the worst in central and southern California in 1,200 years. Precipitation, and thus germination and availability of annual tortoise food plants, varied greatly between sites and among years. Thirty-four live tortoises and 18 carcasses were found at the higher, wetter Cottonwood site from 2015-2016 during surveys covering approximately 5.75 km^2 of habitat. The sex ratio of live adult tortoises was strongly biased toward males (22 males: 9 females) and the sex ratio of tortoises estimated to have died during the drought was slightly biased toward males (4 males: 3 females). In contrast, only 22 live tortoises and 60 carcasses were found at the lower, drier Orocopia site from 2017-2018 on transects covering approximately 21 km^2 of habitat surveyed. The sex ratio of live adult tortoises was strongly biased toward males (16 males: 5 females) and the sex ratio of tortoises with estimated times of death during the drought was strongly biased toward females (4 males: 15 females). High female mortality at the Orocopia site may have resulted from the interaction of drought (including increased predation) and the bet-hedging reproductive strategy of tortoises to produce clutches of eggs during both drought and non-drought years. Mean clutch size for tortoises in this region is about four eggs per clutch and up to two clutches per year. Their reproductive output results in an estimated loss of 13.5% of their body mass including over 0.20 liters of water annually. Combined with the other effects of severe droughts, these losses, potentially due to reproductive output in bad years, may compromise their ability to survive droughts lasting more than 2-3 years. The low tortoise density and high mortality, especially of females, observed by us and others in the area may threaten the long-term viability of tortoises in Shavers Valley.

The Year in Review

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The Desert Tortoise Council has had a productive year, despite the restrictions brought by Covid-19. The Board met frequently using Zoom and will continue to do so into the future. The year began with a virtual Annual Meeting and Symposium, aided by Mari Quillman, who pulled together all the necessary elements for virtual meeting. Kristin Berry prepared an outstanding program and David Hedrick, an expert at virtual meetings at the Turtle Survival Alliance, assisted presenters unfamiliar with Zoom. Cristina Jones, who leads the Agency Coordination Committee, was limited in setting up in-person meetings due to the pandemic. The objective of this committee is to provide expertise to agency managers and reduce negative impacts, enhance mitigation, and speed recovery of desert tortoise populations. Plans for 2022 include coordination with Recovery Implementation Teams and the Desert Tortoise Recovery Office.

The Training Committee, led by Dr. Maggie Fusari, held an Introductory Tortoise Workshop for 140 participants; another 112 people benefitted from attending one of two full-day field courses. Peter Woodman continued tracking and assessing tortoises with transmitters at the Large-scale Translocation Site in Nevada. Throughout the year, the Ecosystems Advisory Committee, led by Ed Rue and supported by Judy Hohman, was incredibly busy with reviewing and preparing environmental documents. This committee received 57 notices of NEPA and CEQA documents available for review and commented on 52 (91%).

We acknowledge Dr. Greer Dolby, an outgoing member of the Board of Directors, with gratitude for her service. And we welcome Mari Quillman, the new Chair of the Desert Tortoise Council.

STUDENT PAPER

A Comparison of the Post-release Survival and Behavior of Indoor-reared and Combination-reared Head-started Mojave Desert Tortoises (*Gopherus agassizii*)

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Head-starting is the process of rearing juveniles to a life stage less prone to mortality once released into the wild. Developing the best husbandry and release practices for head-starting Mojave Desert tortoises (*Gopherus agassizii*) has been an ongoing effort to recover the species in Mojave National Preserve, CA. Combo-rearing (rearing tortoises indoors for one year to increase growth and then outdoors for another year to provide natural environmental conditions) has been shown to produce

tortoises with high survival and site fidelity compared to outdoor-only rearing. However, it is unclear to what extent the second rearing year improves release outcome. We compared the post-release survival and behavior of two groups of head-started tortoises with different husbandry treatments: combo-reared two-year olds (2018 cohort, n=30) and indoor-reared one-year olds (2019 cohort, n=30). Tortoises were released in Fall 2020 and tracked using VHF radio telemetry for one year. We will summarize our preliminary results for each treatment, including time to creating their first burrow, surface activity, timing and duration of winter dormancy, and survival. Unfortunately, severe drought occurred at our study site from Fall 2020 to mid-Summer 2021. To account for this, we will also compare our qualitative results during a drought year to previously released cohorts' survival and activity during non-drought years to evaluate the extent to which drought may have affected release outcomes in our study. Our findings will help increase our understanding of the best head-starting practices and reveal the extent to which drought years may affect release outcomes for head-started Mojave Desert tortoises of all ages and rearing treatments.

Desert Apocalypse: A Series About the Assault on Desert Habitats

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Thirty square miles of desert tortoise habitat to be developed in south Pahrump Valley; 70,000 Joshua trees threatened by a 10,000-acre project called Sawtooth Solar adjacent to Death Valley National Park in a basin called Sarcobatus Flat; expanding Lithium mining--Kevin Emmerich and Laura Cunningham of Basin and Range Watch are joined by filmmaker Justin McAffee out in the field examining all the rich biodiversity in these intact habitats that are at stake.

Nevada is moving forward with the GreenLink transmission system, which would enable an unprecedented opening up of 9 million acres of public lands for industrial energy development, mostly solar, with no regard for the fragile but rich ecosystems in the Mojave and Great Basin. Massive utility-scale solar projects are planned or already under construction on desert tortoise habitat. Desert Apocalypse, as the name suggests, is an exposé of this plan to destroy our deserts, by independent Las Vegas filmmaker Justin McAffee.

Importance of Age and Microsite on Habitat Selection and Space Use in Headstarted Juvenile Mojave Desert Tortoises

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Little is known about the juvenile age class in desert tortoises, however the release of neonates following captive rearing, or headstarting, is a recommended recovery tool to mitigate precipitous population declines. Therefore, understanding optimal head start methods as well as what

constitutes ideal habitat for juveniles and the impacts of habitat on post-release growth, movement, and survival will be key for species recovery. We sought to understand how careful selection of microhabitat characteristics at translocation receiver sites may impact post-release movement and habitat selection by juvenile Mojave desert tortoises (*Gopherus agassizii*) of different ages. We released 144 juvenile tortoises that were headstarted for either 1 or 2 years and randomly assigned individuals of both age classes to sites that varied by vegetation community type (yucca woodlands, creosote scrub) and substrate. We tracked juveniles via radio telemetry and recorded microsite habitat characteristics at each telemetry fix and at random locations within each study area. We used habitat data to construct a resource selection function for juvenile tortoises. Juvenile tortoises preferentially selected sites with higher small mammal burrow density and increased shrub and coppice mound coverage compared to what is available to them on the landscape. Post-release movements were greater in 2-year-old juveniles compared to 1 year olds, both in distance moved from release site and home range size. Home range size and post-release movements were also greater in creosote scrub communities compared to yucca woodlands. Our findings have important implications for optimizing release site selection and headstarting methods for juvenile desert tortoises.

PLENARY ADDRESS

Climate Change and the Aridification of North America

Jonathan T. Overpeck
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Many current assessments of future climate and hydrologic change suggest that current drylands around the globe could become drier with continued anthropogenic climate change. In some "early warning" regions, such as the Southwest U.S., there is a clear observed trend in this direction. This is particularly true for the region's rivers, where the nature of drought is shifting to a more temperature-dominated climate extreme. At the same time, however, some recent and influential scientific assessments suggest that temperature-driven drying could be compensated by precipitation increases with little net increase to water supply or ecosystem risk. A new approach integrating the examination of temperature, precipitation and drought risk indicate that Colorado River flows, sustainable water supplies, and ecosystems in the Southwest are already being seriously affected by warming, and that continued warming could result in much larger impacts than widely thought, even if mean precipitation increases. The implications of these results have serious implications for terrestrial systems across North America, including regions with higher average precipitation.

See article (open access): Overpeck, Jonathan T., and Bradley Udall. 2020. Climate change and the aridification of North America. www.pnas.org/cgi/doi/10.1073/pnas.2006323117

STUDENT PAPER

Understanding the Adaptive Potential between Different Regions of the Range for the Mojave Desert Tortoise

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The Mojave Desert Tortoise (*Gopherus agassizii*) is a long-lived species that has suffered population declines yet continues to persist in the fragmented landscape of the Mojave Desert, influenced by changing land use and climate patterns. These stressors have been increasing across its range for decades, but have recently accelerated, with significant change occurring on a shorter time scale than the length of one tortoise generation. While local adaptation and acclimatization may help species like the Desert Tortoise persist under these environmental disturbances, adaptive intraspecific genetic variation has typically been ignored in studies examining extinction risk under forecast models of climate change. The spatial distribution of adaptive genetic variation is a function of historical interactions between genetic drift, natural selection, habitat connectivity, and demography, and so adequately characterizing adaptive genetic variation for sensitive species such as the Desert Tortoise requires the pairing of high-resolution genomic datasets with habitat modelling. We pair landscape genomic analyses of adaptive genetic variation in the Mojave Desert Tortoise with concurrent studies examining landscape level connectivity and habitat suitability across the tortoise's range. We will use a sequencing dataset created for concurrent studies and multiple analyses such as partial redundancy analyses and latent factor mixed models to identify loci associated with climatic gradients. Loci identified using both approaches will be pooled into a single dataset of potentially adaptive SNPs. By understanding the adaptive potential of the tortoise in different regions of its range and the connectivity between these regions, we will be able to delineate areas for conservation action, assist with climate change vulnerability assessments, and identify the evolutionary rescue potential for this species

STUDENT PAPER

Multi-year Space-Use and Survival of Head-started Mojave Desert Tortoises Following Release in Mojave National Preserve, California, USA

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The slow life history of Mojave Desert Tortoises can make it challenging to examine their response to recovery efforts given the length of time needed to observe changes in their populations. Head-starting, the process of raising an animal to a stage less vulnerable to mortality from predators or environmental conditions, is one of the recovery tools currently being studied for desert tortoises. Evaluating long-term head-starting success for desert tortoises involves quantifying survival, time to maturity, and site fidelity. Increased movement shortly after the release of captive tortoises and before settling can be associated with decreased survival and may provide early indications of challenges associated with head-starting. Additionally, little is known about survival and movement after this settling phase. We compared multi-year space use and survival by juvenile tortoises reared under three different head-starting treatments: 1) indoor-reared for 1 year followed by 1 year of outdoor rearing ("Combo HS"); 2) same aged but smaller juveniles reared solely outdoors for 2 years ("SOR"); and 3) same sized but older animals reared solely outdoors ("6-7 years old"). Tortoises were released in Fall 2018 (n=78) and Fall 2019 (n=72) and tracked using VHF radio-telemetry until October, 2021 (for a total of three and two years, respectively). For each individual, we quantified settling date, annual home ranges, and site fidelity and compared these metrics among treatments and across years post-release. We predicted that total movement and yearly displacement from release site would decrease as time since release increased. By implementing a multi-year monitoring period for head-started tortoises and conducting multiple releases with the same experimental design, we can better evaluate post-release movement and fate of head-started individuals, informing recovery efforts for Mojave desert tortoises.

Challenges and Opportunities Managing Private Mitigation Lands in the California Deserts

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I will describe Wildlands experiences in managing private mitigation lands. Challenges for land management and mitigation on private lands in California's deserts include on-going management of legal and illegal routes, coordination with BLM and the other resource agencies on keeping authorized roads and routes open, restoration, fencing and signage techniques for roads and open routes. New and novel encroachments include the expansion of cannabis operations in the Mojave Desert.

Efficacy of Common Raven (*Corvus corax*) Reproduction Manipulations at Conserving Sensitive Prey Species: Three Case Studies

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Expansion of human enterprise has resulted in the availability of anthropogenic subsidies to generalist species and has led to population increases across landscapes that were previously less suitable for generalists' current rates of survival and recruitment. Of particular concern is growing populations of common ravens (*Corvus corax*, raven), because raven predation is linked to depressed vital rates and population declines of several sensitive species. Recent management strategies intended to both limit raven recruitment and decrease predation by ravens on sensitive species are focused on manipulating raven populations during the breeding season. These strategies include oiling raven eggs, which causes embryonic development to fail, and removing raven nests in targeted areas, which prevents or terminates raven reproduction. We present three case studies, each with the objective of examining how manipulation of raven reproduction during the breeding stage influences demographic rates of sensitive prey species. We oiled raven eggs in the Mojave Desert of California, and deployed Mojave desert tortoise (*Gopherus agassizii*, desert tortoise) decoys paired with Passive Infrared (PIR) triggered trail cameras to examine the effects of treatment on raven depredation rates of juvenile desert tortoises. Additionally, we oiled and removed raven nests within greater sage-grouse (*Centrocercus urophasianus*, sage-grouse) nesting habitat at multiple sites across Wyoming, California, and Nevada and measured changes in sage-grouse nest survival within control and treatment sites to determine efficacy of treatments. Results in all three case studies consistently indicated that manipulating the reproductive success of nesting ravens, through egg-oiling or nest removal, reduced predation impacts on sensitive prey. Along with new technologies that can make both techniques more feasible, these findings suggest that egg-oiling and nest removal are viable tools for managing raven predation on desert tortoises and other sensitive prey. Findings are preliminary and provided for timely best science.

Common Raven Subsidy Denial via Laser

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We report preliminary results of a project to deny common ravens (*Corvus corax)* access to a pair of rich subsidy sites near Victorville, CA. The Victor Valley Wastewater Recovery Authority's sewage treatment plant provides a rich caloric resource known as FOG (fats, oils and grease) that floats on the surface of open pools. Ravens perch near the pools and skim the FOG off the surface. American Organics runs an adjacent industrial scale composting facility whose piles of waste provides opportunities for ravens gleaning food waste. We describe the three types of lasers we used in November and December 2021 to provide comprehensive coverage of the two sites, denying ravens access to these food sources. These include both internet-connected and radio-controlled fixed lasers and two different handheld lasers. We used three types of raven counts to document the effect of laser treatment: hourly on-site transect counts; point counts along three 12.5-km radial routes with 360° raven counts at 2.5-km increments; and weekly counts at a large raven roost 5 km south of the facilities at which the entirety of the ravens feeding at the two sites seem to spend their nights. We present the very promising results of these counts and discuss their meaning. The implications of reliable raven subsidy denial for desert tortoise conservation are also examined.

A Citizen Science Raven Research Project: Raven Nest Mapping

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We have developed a prototype project to involve citizen scientists in an effort to greatly increase knowledge of the locations of raven nests and data associated with them. Involving a broader circle of volunteer data collectors promises to not only expand the number of known raven nest locations but to extend manager's knowledge into rural, ex-urban and urban areas. Heretofore the emphasis has been on mapping nests in desert tortoise critical habitat units but, given raven mobility, it is desirable to generate a more comprehensive picture.

The components of the effort include: a brochure serving as a distilled guide to locating and collecting information on raven nests; a website with more detailed information on raven nesting; and a data recording function within the website allowing participants to use cell phones to record nests they find and observe. A completed draft of the brochure will be presented, as will a

demonstration of the prototype website's functions. This will include navigating through the site and a mock recording of raven nest data.

A test run of the use of the brochure and website is planned for Spring, 2022, in Nevada. This test will yield direct user feedback to guide refinement of the website and its data recording features. We view this as a potentially fruitful effort to massively increase our knowledge of raven nesting at the very low cost of printing brochures and maintaining the website. This sort of efficiency will be needed to facilitate the efficient management of raven control efforts. A further and important benefit will be to give interested citizens ways to make practical contributions to desert tortoise conservation. It will serve as a template for similar efforts for work throughout the range of the tortoise and for application to other sensitive species.

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

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The Desert Tortoise Recovery Program collaborated with numerous partners on several large-scale recovery projects in 2021:

1) We conducted range-wide monitoring surveys of desert tortoises in five strata in California and three strata in Nevada including one that is half in Arizona.
2) We coordinated surveys in the Tonopah BLM field office jurisdiction based on pre-project survey guidelines and found densities in the northern part of the range that were comparable to those observed elsewhere in the Eastern Mojave Recovery Unit.
3) We coordinated on transportation infrastructure-related projects and effects on recovery, including state-specific programmatic NEPA and CESA durability analyses of the installation of tortoise barrier fencing along highways, a transportation ecology webinar series and workshop, and the "Road Warriors" project documenting roadkills and fence maintenance issues in southern Nevada.
4) We continued to expand raven abundance and predation risk monitoring in Nevada and Utah. We also 1) co-developed an updated social science common raven subsidy management program with The Living Desert; 2) completed a final draft of SCE's Programmatic Common Raven Management Plan for California and a portion of southwestern Nevada; and 3) co-developed DoD's draft Raven Management programmatic EA for installations in California's Mojave desert tortoise habitat.
5) We coordinated efforts to change how several utility-scale solar developments will be constructed so that vegetation will remain and allowed to regrow and so that tortoises will be allowed to reoccupy the sites.
6) We led the 3rd Annual Desert Tortoise Week. The event was a combination of virtual experience and socially distance events. The public outreach program covered the entire range of the species, from California to Utah and Arizona.
7) We published nine papers with collaborators on topics including raven management (five papers total, including four papers in a special issue of the Journal of Human Wildlife Interaction), translocation and population augmentation strategy (white paper), post-

translocation disease risk at the Large Scale Translocation Study area, population connectivity management (white paper), and a revision of the IUCN classification of *Gopherus agassizii*..
8) We initiated a five-year review on the status of the species which is expected to be completed early in 2022.
9) We completed a Species Status Assessment for the Sonoran desert tortoise, and our decision of whether to list under the Act will be released in 2022.

PLENARY ADDRESS

Large Contribution from Anthropogenic Warming to an Emerging North American Megadrought

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Severe and persistent 21st-century drought in southwestern North America (SWNA) motivates comparisons to medieval megadroughts and questions about the role of anthropogenic climate change. We use hydrological modeling and new 1200-year tree-ring reconstructions of summer soil moisture to demonstrate that the 2000-2018 SWNA drought was the second driest 19-year period since 800 CE, exceeded only by a late 1500s megadrought. The megadrought-like trajectory of 2000-2018 soil moisture was driven by natural variability superimposed on drying due to anthropogenic warming. Anthropogenic trends in temperature, relative humidity, and precipitation estimated from 31 climate models account for 47% (model interquartiles of 35 to 105%) of the 2000-2018 drought severity, pushing an otherwise moderate drought onto a trajectory comparable to the worst SWNA megadroughts since 800 CE.

Citation: Williams, A.P., E.R. Cook, J.E. Smerdon, B.I. Cook, J.T. Abatzoglou, K. Bolles, S.H. Back, A.M. Badger, and B. Livneh. 2020. Large contribution from anthropogenic warming to an emerging North American megadrought. Science 368, 314-318.

PLENARY ADDRESS

The Tree-ring Record of North American Drought and Pluvial, Including the Precipitation Reconstructions for Southeastern California Over the Past 600-years

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Hundreds of exactly dated and climate sensitive tree-ring chronologies have been developed for North America and have been used for the reconstruction of seasonal precipitation and the Palmer Drought Severity Index (PDSI) on a regular 0.5° latitude/longitude grid across the continent. These seasonal tree-ring estimates skillfully reproduce the interannual to decadal variability of precipitation and PDSI evident in instrumental observations of climate during the 20th century. The tree-ring reconstructions extend for 600-years across the entire continent and for up to 2000-

years over those portions of the West where multi-millennial tree-ring chronologies have been developed. These reconstructions help to place the modern era of anthropogenic climate forcing into a longer perspective of natural climate variability and climate change. The last 120-years have been unusual over the West in terms of both decadal wetness and more recently with the development of severe and sustained drought conditions. For southeastern California, the area including the native range of the desert tortoise, the pluvials of the 20th century and the drought of the early 21st century have been among the most extreme over the past 600-years.

See D.W. Stahle. 2020. Anthropogenic megadrought. Human-driven climate warming worsens an otherwise moderate drought. Science 368, Issue 6488:238-239.

STUDENT PAPER

Evaluating Connectivity Model Predictions using Sonoran Desert Tortoise Movements

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Anthropogenic activities are causing habitat loss and fragmentation and reducing movement potential throughout the range of the Sonoran desert tortoise (*Gopherus morafkai*). Barriers to movement among populations disrupt important natural processes like gene flow and demographic rescue and are considered one of the greatest threats to the long-term persistence of the species. In response to ongoing landcover alteration and development, preserving and restoring landscape connectivity have become foci of conservation efforts for desert tortoises.

Estimating landscape resistance is frequently used to model functional connectivity through the landscape for purposes like identifying potential barriers to movement or predicting areas of high movement potential. We generated functional connectivity models based on resistance estimates derived from two commonly used approaches: an expert knowledge-based approach and an empirical approach incorporating fine-scale movement data. We collected movement data from 14 adult tortoises outfitted with GPS loggers recording positions at 30-minute intervals from July to October, 2021. GPS positions were used in a path selection process to model the relative probability of movement through the landscape, the inverse of which was used as a resistance surface. We then compared the ability of these two approaches to predict tortoise movement and describe their applicability to identifying areas or features that promote or curtail movement through the landscape relative to the cost and effort required to perform each approach. Preliminary results indicate that expert knowledge-based models predicted tortoises to move through areas of moderate to high topographic roughness and vegetation coverage, with actual movements occurring only through areas of moderate roughness and vegetation coverage. Lack of convergence indicates that empirically derived assessments of connectivity are more conservative.

Desert Tortoise Management and Research in Joshua Tree National Park

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Joshua Tree National Park (NP)protects nearly 800,000 acres of public land of which 240,000 is considered high quality desert tortoise habitat. Park managers have supported the recovery of the tortoise through participation of region wide planning efforts, management of habitat, educational outreach, and scientific research. Actions to reduce desert tortoise mortality on roads continue. Educational specialists provide desert tortoise educational presentations (many virtual this past year) to local schools. The Park also has an active habitat restoration program that removes exotic plants and outplants native species. Desert tortoise awareness trainings are given to all NP employees, construction workers and even researchers doing work in the Park that may affect the desert tortoise. Since 2007, wildlife staff have been tracking desert tortoises near roads as part of a study to understand the effect of roads on tortoise movement patterns. Additionally, the Park is heading into its sixth year of reducing common ravens with some indication that the action is working to reduce predation on juvenile tortoises.

STUDENT PAPER

Innate Testosterone Identifies Sex of Hatchling Mojave Desert Tortoises (*Gopherus agassizii*)

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The Mojave desert tortoise (*Gopherus agassizii*) has temperature-dependent sex determination, and individuals are externally sexually monomorphic until sexual maturity. Previous studies have identified sex in juveniles as young as 11 months old using minimally invasive blood sampling for quantification of plasma testosterone concentration. However, to determine the sex ratio of clutches incubated in the wild, a validated method is needed to identify sex of hatchlings at a single encounter. We tested whether plasma testosterone quantified by enzyme-linked immunosorbent

assay (ELISA) differentiated males from females in 0–3 month old captive hatchlings, and validated sex by laparoscopic surgery (visual inspection of the gonads). Female testosterone concentrations ranged from 7.8–20.8 pg/mL ($n = 6$), while male concentrations ranged from 125.4–651.4 pg/mL ($n = 18$). We then fit the testosterone concentrations to lognormal distributions and identified the concentration below which individuals have a greater than 50% probability of being female, and above which individuals have a greater than 50% probability of being male ('50/50 threshold'). Using a parametric bootstrapping procedure, we estimated a 0.01–0.04% misidentification rate when applying this threshold. Quantification of innate blood plasma testosterone concentration from small volume (0.1 mL) blood samples appears to be a viable, accurate method to identify sex of 0–3 month-old hatchlings and could be a valuable tool for headstarting efforts, translocation projects, and investigation of trends and variation in sex ratios for *in situ* wild nests.

Monitoring Results from Pima County's 2021 Sonoran Desert Tortoise Campaign

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The Sonoran desert tortoise (*Gopherus morafkai*) is one of 44 species covered by Pima County's Multi-Species Conservation Plan (MSCP). To fulfill the County's commitments as stated in its Section 10 Permit under the Endangered Species Act, the County's Ecological Monitoring Program (EMP) monitors tortoise occupancy at three County properties in eastern Pima County, Arizona. EMP staff conduct tortoise monitoring every three years. The first year of monitoring was completed in 2018, making 2021 the second round of monitoring since the inception of the MSCP in 2016. The 2021 monitoring season is of special interest because the timing of it spanned climatic extremes; the summer monsoon season was one of the wettest on record, but Pima County was in an exceptional drought the preceding winter, and 2020 was the driest and 2nd hottest on record in the Tucson area. In addition to potentially affecting tortoises directly and via food availability, these dynamics influence the spread of invasive plants that threaten tortoise habitat and increase fire risk. Furthermore, rainfall regimes can impact detection through the production of annual forbs and grasses that obscure lines of sight between surveyors and tortoises. Survey effort in 2021 resulted in the detection of 42 individual tortoises, including 9 recaptures from 2018. In 2018, there were at least 42 detected individuals. Over both years, Pima County surveyors have captured over 75 individuals on the monitoring plots. A multi-season occupancy analysis showed an average occupancy rate (ψ) of 0.61 (95% CI = 0.23 - 0.88) Detection probability (p) was 0.66, 95% CI = 0.50 - 0.80) in 2018 and p = 0.52 (95% CI = 0.34 - 0.69) in 2021. Estimates of colonization (γ) and local extinction (ε) were 0.27 (95% CI = 0.06 - 0.69) and 0.02 (95% CI = 0.00 – 1.00) respectively, indicating a small increase in colonization, or geographic expansion across monitoring years. Across all plots, the area covered by invasive buffelgrass (*Cenchrus ciliaris*) increased 10-fold between 2018 and 2021 to 2,383 meters squared. Overall, tortoise health appeared good with few signs of respiratory illness.