Mojave Desert Tortoises in the Red Cliffs NCA and Upper Virgin River Recovery Unit: Population Trends, Threats to Persistence, and Conservation Significance

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Abstract

Population monitoring studies conducted over the past 20+ years have determined that Mojave Desert tortoise populations in the Red Cliffs National Conservation Area (NCA) are among the most robust and healthy throughout the range of the species. Recent wildfires in the Upper Virgin River Recovery Unit (UVRRU) have likely impacted tortoise populations and the habitat degradation caused by these fires will likely have serious negative implications for tortoise populations for many years to come. Other important threats to tortoise populations and habitats in the UVRRU include invasive plants, roads, off-highway vehicle (OHV) recreation, urbanization, and climate change. The tortoise populations in the UVRRU, due to their high densities and apparent relatively good health prior to the recent wildfires, are an important source of tortoises and genes for populations to the south and west in Nevada and Arizona, as well as an important source for range extensions to the north into the Great Basin, an area where climate change models predict will become an important refugia for Mojave Desert tortoises. To ensure that populations remain healthy in the UVRRU and provide a source of dispersing tortoises to the south and north, populations in the Red Cliffs Desert Reserve and surrounding tortoise habitats will need to be carefully managed. Threats, such as wildfires, invasive plants, human developments, and human activities will need to be very carefully controlled through avoidance and minimization actions. Furthermore, areas that were burned by recent wildfires will need to be restored to ensure that tortoise populations may continue to occupy and grow in these areas.

Status of Mojave Desert Tortoise Populations in the Upper Virgin River Recovery Unit and Red Cliffs Reserve

The Upper Virgin River Recovery Unit (UVRRU) includes all designated Critical Habitat and other suitable habitats for the Mojave Desert tortoise (*Gopherus agassizii*) east of the Beaver Dam Mountains in Washington County, Utah and contiguous habitat in Mohave County, Arizona. This recovery unit is the northeastern-most within the species' range and contains one tortoise conservation area (TCA), the Red Cliffs Desert Reserve (Reserve). In 2020 the Reserve was comprised of 45,311 acres of BLM-administered lands in the Red Cliffs National Conservation Area (NCA); 6,426 acres within the State Trust Institutional Lands Administration (STILA); 6,106 acres of lands administered by the Utah Department of Natural Resources (UDNR); and 2,981 acres of privately owned inholdings. Ecologically, the UVRRU is transitional between the Colorado Plateau, Mojave Desert, and Great Basin Desert. Vegetation communities in the UVRRU are composed mainly of creosote bush-white bursage scrub, blackbrush scrub, desert sand sagebrush scrub, warm desert riparian scrub, and warm season grassland communities (Provencher et al. 2011). Mojave Desert tortoise populations occupy lower elevation landscapes within the UVRRU that include Navajo sandstone outcrops, rocky canyons, creosote-bursage flats, and basalt-capped ridges, and sandy valleys, where they find cover sites in caves, deep fissures, rocky overhangs, and deep sandy burrows (Bury et al. 1994).

One of the management actions conducted within the UVRRU is monitoring of Mojave Desert tortoise population trends through periodic surveys. Since 1999, the U.S. Fish and Wildlife Service (USFWS) and Utah Department of Natural Resources, Division of Wildlife Resources (UDNR) have employed distance sampling (Buckland et al. 2001) for estimating population density within TCAs across the range of the Mojave Desert tortoise, a technique that is considered suitable for assessing population trends at large spatial scales. The distance sampling surveys were conducted in TCAs that generally correspond to designated Critical Habitat. The goal of the monitoring program is to estimate population trends to determine whether recovery actions defined and implemented under the Recovery Plan (USFWS 2011) are having an effect on recovery of Mojave Desert tortoise populations. Within the UVRRU, the Reserve was surveyed in 1999, 2000, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, and 2023 (Allison and McLuckie 2018; McLuckie et al 2024). Sampling transects totaling between 262 to 314 kilometers were sampled each year, primarily on BLM lands in the Red Cliffs NCA within Management Zones 2, 3, 4 and 5, but also in surrounding areas on STILA and UDNR lands.

Across the range of the species, adult Mojave Desert tortoise density estimates derived from distance sampling surveys implemented in TCAs between 1999 and 2023 ranged between 0.2 to 34.3 tortoises per square kilometer (km^2) (Allison and McLuckie 2018; UDNR 2024; USFWS 2009, 2016, 2018, 2019, 2020, 2022a, 2022b; Table 1). The adult tortoise density estimates for the Reserve and the UVRRU have been consistently the highest observed across the range of the Mojave Desert tortoise, underscoring the importance of these relatively healthy populations. However, an annual decline of -3.2% in the UVRRU was detected between 2004 and 2014 (Allison and McLuckie 2018). Declines in density of adult tortoises were particularly evident in the Reserve between 2007 and 2013 (Table 1). Survey data from 2015 through 2023 appear to indicate a slight recovery, but not to a level that matches density observed pre-2007 (Table 1). Abundance estimates also indicate population declines across the range of the species between 2004 and 2014 (Allison and McLuckie 2018). Range-wide, there were an estimated 336,393 adult tortoises in 2004 and 212,343 in 2014, representing a decline of 124,050 (-37%) over this 10-year period. The steepest declines in adult tortoise densities were detected in the Western Mojave (-49%) and Eastern Mojave (-33%) recovery units between 2004 and 2014 (Allison and McLuckie 2018). Within the Reserve in the UVRRU, the estimated abundance of adult tortoises declined from an estimated 3,482 in 1999 to an estimated 2,425 in 2023, an estimated loss of 1,057 (-30%; UDNR 2024).

Threats to Mojave Desert Tortoise Populations and Habitats in the Upper Virgin River Recovery Unit and Red Cliffs Reserve

Mojave Desert tortoise populations and habitats are susceptible to numerous threats across the range of the species, each with differing distributions, severities, and effects (Lovich and Bainbridge 1999; Boarman 2002; USFWS 1994, 2011). Most threats are anthropogenic in origin, including human developments (*e.g.*, urban areas, roads, railroads, and utilities), human activities (*e.g.*, off-highway vehicle [OHV] recreation, livestock grazing, agricultural practices, mineral extraction, military activities, illegal dumping, tortoise poaching, and target shooting), and side-effects of these human developments and activities (*e.g.*, climate change, toxin and pollutant deposition, degradation of air quality, spread of invasive plants, attraction of subsidized predators, introduction of wildfires, spread of disease). These threats contribute to mortality of Mojave Desert tortoises and loss and degradation of their habitats and are more severe in effect when they occur widely over landscapes or constantly through time (Tuma et al. 2016). Each TCA is affected by a unique suite of threats. Within the UVRRU, tortoise populations and their habitats are primarily threatened by wildfires and the spread of invasive plants, but climate change and development of roads, utilities, and other infrastructure associated with urbanization also threaten these populations and their habitats. The presence of multiple threats may produce synergistic effects on tortoise populations and habitat (USFWS 2011).

Wildfires and Invasive Plants

The most significant threats to Mojave Desert tortoises and their habitats in the UVRRU are wildfires and invasive plants, specifically alien, annual brome grasses. These two threats work in tandem, causing a positive feedback loop that amplifies the negative effects of each threat due to the grasses providing fuel for wildfires and burned areas providing conditions that favor the spread of invasive plants. Wildfires in the Mojave Desert typically originate from anthropogenic sources such as roads, urbanized areas, and recreational activities (Swantek et al. 1999, Brooks and Matchett 2006). Wildfires contribute to rapid degradation of desert scrub habitats with both short-term and long-term implications. Short-term post-fire effects include reduced availability of tortoise food plants, loss or reduction of available nutrients and trace elements, and change in seasonal availability of food plants (Nagy et al. 1998). The long-term effects include a change in community structure that includes increases in the biomass of non-native annual grasses, little shrub cover, and a reduction in native annual plant biomass (Brooks and Esque 2002). Because the Mojave Desert is not a fire-adapted ecosystem and few desert plants are adapted to recover from fire disturbance, fire immediately alters vegetation communities and recovery is very slow, resulting in long-term degradation of tortoise habitat (Esque et al. 2003).

Wildfires appear to be a significant source of Mojave Desert tortoise mortality (Brooks and Pyke 2001; Brooks and Esque 2002; Brooks et al. 2004; Brooks and Matchett 2006; Drake et al. 2015). Because wildfires are not a typical ecological feature in the Mojave Desert, tortoises are not well adapted to cope with their effects (Brooks and Esque 2002). Fires contribute to tortoise mortality and injury by producing lethal heat or low oxygen levels, elevating body temperature, and poisoning and asphyxiation by smoke (Brooks et al. 1999; Esque et al. 1994; Whelan 1995). Early season fires are potentially more threatening and detrimental than mid-or late-season fires because tortoises are most active above ground and use relatively shallow cover sites during the spring (Esque et al. 2003) and thus are more vulnerable to the effects of high-intensity fires (Esque at al. 1994).

Areas subject to recurrent wildfires can be converted from native desert scrub to non-native annual grasslands (Brown and Minnich 1986; Duck et al. 1997; Esque et al. 2003), which are in turn prone to additional wildfires because non-native annual grass species often increase in dominance after fire (D'Antonio and Vitousek 1992; Jennings 1997b). Non-native annual grasses alter the fuel structure and fire behavior in the Mojave Desert, making areas more susceptible to frequent fires (Brooks and Esque 2002; Esque and Schwalbe 2002). Abundant fuel loads place Mojave Desert tortoises at increased risk from fire (Brooks and Esque 2002), a situation that is exacerbated by the introduction of invasive plants. Areas that support invasive annual grasses such as cheatgrass, bromes, and Mediterranean grass are characterized by high abundance and cover of standing dead stems that create a continuous fuel bed, facilitating the spread of fires (Duck et al. 1997; Esque et al. 2003). The invasive, alien grasses of concern within the UVRRU include cheatgrass (*Bromus* *tectorum*) and red brome (*Bromus rubens*) (McLuckie et al. 2007). The spread of these invasive plant species degrades otherwise suitable tortoise habitat through changing the character of desert scrub vegetation communities, replacing native forage species, and altering the cycles, frequency, and intensity of wildfires. Additionally, invasive plants impact tortoise nutrition, depleting nitrogen, phosphorus, and water, and causing weight loss, which in turn affects vital rates such as growth, reproduction, and survival (Avery 1998; Nagy et al. 1998; Hazard et al. 2009, 2010; Drake et al. 2016).

Recent wildfires have been documented as one of the most significant threats to Mojave Desert tortoise populations and habitats within the UVRRU. McLuckie et al. (2007) provided an accounting of the effects of the 2005 wildfires on tortoise populations in the Reserve, when a significant number of adult and juveniles were killed in wildfires that encompassed nearly 8,000 acres of their habitat. The authors documented deaths that were attributed to direct contact with flames, exposure to lethal temperatures, and smoke inhalation. During the Plateau Fire in June 2005, which occurred in an area of high tortoise density, many tortoises were likely active on the ground surface when the fire moved through the area, which contributed to the high mortality event. During implementation of line distance sampling transects through the burned areas, the researchers documented 57 tortoise carcasses and estimated that approximately 15% of the population had been killed in burned areas (McLuckie et al. 2007). More recently, researchers documented the effects of the 2020 Cottonwood Trail Fire in the Red Cliffs NCA, where 25 carcasses were detected after the fire and an estimated 16.3% of the population was killed within the 250-hectare burned area (Kellam et al. 2021).

The effects of wildfires and invasive plants on Mojave Desert tortoise populations in the UVRRU are evident in the USFWS line distance sampling data. Kissel et al. (2022) used these data to develop a range-wide dynamic occupancy model to estimate probabilities of occupancy, local extinction, and local colonization for Mojave Desert tortoises. Using monitoring data collected between 2001 and 2018, the model estimated negative trends in occupancy in 26% of tortoise habitat across the range, with occupancy trends in later time periods exhibiting greater declines (27% decline from 2006 to 2018 and 77% decline from 2011 to 2018). Occupancy trends, which are based on the balance of probabilities of local extinctions and local colonization of habitats, were lowest in the northeastern portion of the species' range, indicating a higher probability of extinction than colonization in this area. Importantly, habitat in the UVRRU and Red Cliffs Reserve exhibited the lowest occupancy trends among the TCAs, suggesting that population declines there are more precipitous than in other TCAs. The model identified two variables, high precipitation and high normalized difference vegetation index (NDVI), a measure of vegetation density, as important drivers of occupancy, which the authors attributed to negative effects of invasive plants on Mojave Desert tortoises. The authors also determined that two variables, wildfires and NDVI, contributed to increased extinction probabilities, which the authors attributed to the large number of fires that have affected the UVRRU in the previous two decades. This study underscores the importance of wildfires and invasive plants in causing declines of Mojave Desert tortoise populations in the UVRRU and Red Cliffs Reserve.

Roads

Another critical threat to Mojave Desert tortoise populations and habitats is the proliferation of roads in the Mojave Desert. Roads, including primary roads, secondary roads, local neighborhood roads, rural roads, city streets, vehicular trails (four-wheel drive), ramps, service drives, walkways, stairways, alleys, and private roads, may be particularly problematic in the Red Cliffs Reserve, where road density is 2.49, the highest within any TCA (Averill-Murray and Allison 2023). Roads degrade habitats through soil compaction, erosion, pollutant deposition, introduction of wildfires, and spread of invasive plants. Roads are a significant source of mortality of Mojave Desert tortoises from vehicle strikes and represent significant barriers to tortoise dispersal. Roads facilitate human access into areas supporting tortoises and provide humans with opportunities to poach or collect tortoises. Darst et al. (2013) estimated that road-related threats contributed to approximately 22% of the total adverse impacts to Mojave Desert tortoises.

Vehicle collisions with Mojave Desert tortoises on roads are a major contributor to mortality that result in population declines in the vicinity of roads. Several studies have identified a 'mortality sink' or depression in tortoise population densities up to 4.6 kilometers from roads (Nicholson 1978; Karl 1989; von Seckendorf and Marlow 1997, 2002; Boarman and Sazaki 2006; Nafus et al. 2013; Peaden et al. 2015). The area of influence that roadways have on tortoises varies greatly depending on a variety of factors, including traffic volume, traffic speed, topography, vegetation characteristics, and tortoise densities (Nicholson 1978; Boarman and Sazaki 2006; Nafus et al. 2013; Peaden et al. 2015). Roads also influence the movement behaviors of tortoises, further contributing to the effect of roads as barriers. Hromada et al. (2020) determined that Mojave Desert tortoises generally avoided moving through areas near roads. Furthermore, tortoises made shorter movements near highways, suggesting that roads may restrict tortoise movements (Hromada et al. 2023).

Roads fragment Mojave Desert tortoise habitats and contribute to genetic isolation of tortoise populations by separating continuous habitats and providing substantial barriers to the movement of species (Forman and Alexander 1998). The inability of individuals to cross roads may eventually lead to the isolation of subpopulations, which in turn can promote increased inbreeding and a lack of genetic exchange with other subpopulations (Dobson et al. 1999) or the reduced potential for recolonization when extirpations occur as a result of localized population fluctuations and catastrophic events (Yanes et al. 1995). Ultimately, isolation of populations may lead to declines in the genetic diversity of a population, which is required for adaptation to variable conditions and possible founder effects (Hanski and Simberloff 1997; Hanski 1999). Fragmentation of Mojave Desert tortoise populations is particularly pronounced in areas where unfenced roads with high traffic rates have contributed to local population declines (Nafus et al., 2013; Dutcher et al., 2020). Sutor et al. (2023) determined that road barriers cause significant connectivity issues for tortoise populations by preventing dispersal events that would otherwise allow for recolonizations following localized extinctions and range shifts in response to climate change. Installation of fencing and of wildlife crossing structures along roads has been implemented in recent years (Averill-Murray et al. 2021), but their effect on facilitating movements of individuals and genes between tortoise populations has not yet been evaluated.

Urbanization

Another important threat in the vicinity of the UVRRU and Red Cliffs Reserve is urbanization, particularly in St. George, Utah, which is situated along the southern and western borders of the Reserve. Urbanization results in the permanent loss of tortoise habitat and a network of roads, utility corridors, residential dwellings/commercial structures and associated activities, and undeveloped areas containing nonnative vegetation (*e.g.*, parks, landscaped areas). Other impacts include degradation of habitat from dumping of trash and litter, increased predation rates from subsidized predators, and possibly increased incidence of disease in tortoise populations in the vicinity of human developments. Urbanized localities also serve as staging areas—either for local recreationists or recreational users who originate from urban centers on a region-wide scale—that provide increased human access to desert areas. OHV use is most significant of the recreational uses in tortoise habitat; it can kill tortoises or destroy or degrade habitat and is common adjacent to urban areas. Other recreational activities, including target shooting, camping, picnicking, sightseeing, hiking, bird watching, horse riding, and rock and other mineral collecting that are common in areas adjacent to urban centers can result in degradation of Mojave Desert tortoise habitat. The increased recreational use of desert environments in the vicinity of urbanized areas likely results in the collection, poaching, and killing of tortoises. Other human impacts associated with recreational use of desert environments in the vicinity of urbanized areas include the increased risk of anthropogenic fires. Urbanized areas are major sources of food and water for subsidized predators, and likely contribute substantially to the growth and spread of common raven and coyote populations in adjacent desert environments. These predators are not subsidized only by garbage and litter that scatters from urbanized areas but also by point sources within urban areas, such as landfills, dumpsters, trash cans, and irrigation (Kristan and Boarman 2003). The effects of urbanized areas extend at least one kilometer into adjacent habitats, where tortoises are essentially absent (Carter et al. 2020).

St. George is a rapidly growing metropolitan area, which grew from a population of 13,000 in 1969 to 197,680 in 2022, representing an increase in 1,420.62% over this period. This rate of growth has likely resulted in a tremendous amount of urbanization effects on tortoise populations and habitats in the adjacent Reserve and larger UVRRU and will continue to affect populations there for the foreseeable future. One of the most significant pressures resulting from the growth of St. George is the proposal to construct the Northern Corridor, a highway that would bisect the Reserve on lands that were set aside for tortoise conservation through the 1995 Washington County Habitat Conservation Plan. The construction of the highway would likely facilitate further growth and development of St. George, including lands within the Reserve.

Climate Change and Drought

Droughts are a fairly common and cyclical occurrence in the Southwest region of the United States, particularly within the Mojave Desert (Hereford et al. 2006). The Mojave Desert climate appears to have been fully developed into its modern condition by around 8,700 years ago (Koehler et al. 2005). Therefore, Mojave Desert tortoises have likely faced natural fluctuations in water availability throughout their most recent evolutionary history (Nagy and Medica 1986; Peterson 1994). Dehydration and starvation of tortoises due to drought conditions is known to be a source of mortality (Peterson 1994; Berry et al. 2002), and droughts have been implicated in lowered survivorship and episodic population declines (Turner et al. 1984; Peterson 1994; Berry et al. 2002; Longshore et al. 2003). Climate data indicate that southwestern North American has been experiencing a megadrought since 2000 that is longer and more severe than droughts over the past 1,200 years and is being driven by anthropogenic warming (Overpeck and Udall 2020; Williams et al. 2020; Williams et al. 2022). Drought frequency and severity appears to be increasing due to anthropogenic climate change, and future megadroughts will be substantially warmer and more severe than past events (Cook et al. 2022). Due to the variety of recent anthropogenic threats faced by the Mojave Desert tortoise—particularly those threats that reduce population size or fragment habitat—the ability of populations to recover from stochastic events such as droughts is likely greatly diminished. The effect of droughts in the context of multiple anthropogenic threats thus becomes synergistic (Peterson 1994).

Conservation Significance of Mojave Desert Tortoise Populations in the Upper Virgin River Recovery Unit and Red Cliffs Reserve

Maintaining a robust population of Mojave Desert tortoises in the UVRRU and Red Cliffs Reserve is critical for the long-term survival of the species for the following reasons:

High population density. The Reserve has consistently exhibited the highest population densities detected within a TCA through the USFWS line distance sampling monitoring program. As such, this population should be considered and managed as a core population. The higher densities in the UVRRU likely provide a source of tortoises and genes to the adjacent Northeastern Mojave Recovery Unit (NMRU), which contains four TCAs: Beaver Dam Slope, Gold Butte-Pakoon, Mormon Mesa, and Coyote Springs. Assuming equal rates of dispersal between tortoise populations, populations in the Beaver Dam Slope and Gold Butte-Pakoon TCAs likely receive more dispersing individuals from the UVRRU than emigrate from these areas to the UVRRU, underscoring the importance of populations in the UVRRU. The high population density of Mojave Desert tortoises in the UVRRU also has importance for providing individuals and genes as they disperse northward outside of their current range in response to climate change (see below). It will be very important to maintain core populations within TCAs to ensure long-term survival of the species. USFWS has defined the TCAs, and in doing so has recognized that these areas have supported or support the largest and most dense tortoise populations, or they are capable of supporting large, dense populations due to the occurrence of suitable habitat. These areas should be managed in a way that maintains large, dense, healthy populations to serve as core areas from which tortoises may disperse into adjacent areas of suitable habitat outside of the TCAs.

Genetic diversity. The size and density of the Red Cliffs Reserve tortoise population is an indicator of its genetic diversity. The genetic diversity of this population will allow it to adapt to changing conditions or new conditions encountered under climate change. Maintaining genetic diversity of core populations near the leading edge will allow for more effective and efficient adaptation to new environments. The conservation of peripheral populations maintains rare alleles (Gapare et al. 2005), which may be particularly important for providing adaptations for ecological conditions encountered in range expansion areas. Conversely, reduced genetic diversity would likely limit the potential for populations to respond to climate change.

Leading-edge population under climate change scenarios. The tortoise population in the UVRRU represents the northeastern-most core population in the species' range and a leading-edge population for expansion to the north in response to climate change. Climate change scenarios indicate that Mojave Desert tortoise habitats in the southern and western portions of its range will become unsuitable in the coming decades, and that areas to the north and east of the species' current range will become suitable climate refugia (Sinervo 2014). In particular, the Great Basin deserts will become suitable climate refugia with good habitat for tortoises as the more southerly habitats become unsuitable. Peripheral populations such as those in the UVRRU are critical for species persistence in the face of climate change and shifting geographic ranges (Nielsen et al. 2001; Razgour et al. 2013). The population contains genes that are locally adapted for ecological conditions encountered in the northeastern periphery of the species' range, providing the best source of genes for poleward expansion into new areas.

Because of the likelihood that trailing edge populations, particularly in the western Mojave Desert, face high risk of extinction, tortoise populations in the northern portions of the species' range may be the most important for the long-term persistence of the species in the face of climate change. The UVRRU will likely be an important refugia for the species as climate change progresses and trailing-edge populations contract or decline. Preventing the extirpation of this leading-edge peripheral population will be important for conserving evolutionary processes that may be critical for species response to climate change and facilitating poleward range shifts into habitats outside of their current range (Gibson et al. 2009). The loss of locally adapted range-edge populations through anthropogenic disturbances would reduce the ability of the species to persist under climate change (Rehm et al. 2015).

Recommendations

- Maintain tortoise abundance, population densities, genetic diversity, and habitats within the Reserve and UVRRU.
- Curtail development of roads and urban areas within and directly adjacent to the Reserve.
- Restore habitats that were burned in the UVRRU.
- Provide connectivity to adjacent populations in the NMRU and expansion areas to the north in the Great Basin.
- Develop plans for translocation of tortoises into adjacent Great Basin habitats as part of a strategy of human-assisted migration (*c.f.*, Loss et al. 2010; Butt et al. 2020; Mitchell et al. 2021).

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Table 1. Adult tortoise density (tortoises/km^2) estimates within tortoise conservation areas (TCAs) between 1999 and 2023.

TCA	1999 (a)	2000 (a)	2001 (a,b)	2002 (b)	2003 (a,b)	2004 (a)	2005 (a)	2007 (a)	2008 (a)	2009 (a)	2010 (a)	2011 (a)	2012 (a)	2013 (a)	2014 (a)	2015 (c,d)	2016 (c)	2017 (d,e)	2018 (f)	2019 (d,g)	2020 (h)	2021 (i)	2023 (d)
AG						11.4	13.4	6.5	4.5	7.5	13.8		6.0	7.3	8.4	10.3	8.5	9.4	7.6	7.0	7.1	3.9	
CK			10.1	7.7	4.0	4.9	6.0	4.3	4.2		3.7	3.9	3.9					4.3		1.8	4.6	2.6	
CM			7.2		6.3	6.7	10.3	3.9	4.8	9.4	4.2	4.0	0.8				1.7		2.9		4.0		
FE			15.7	3.7		8.2	13.5	6.2	6.6	8.3	6.9	6.8	0.9				5.5		6.0	2.8		5.3	
JT				3.3	2.7	1.9	2.7	3.0	2.3	2.3	2.8	3.5	3.4				2.6	3.6		3.1	3.9		
PT			6.5	4.0	3.8	2.2	9.9	1.9	3.3	4.3	3.4	3.3	3.7				2.1	2.3		1.7	2.9		
PV						2.9	3.7	4.1	4.1	3.6	3.8	6.6	1.9				4.0	5.9				3.9	
EV						2.6	5.0	4.1	1.8	3.8	1.0	2.8	0.9				2.7	5.6		2.3			
IV			2.8	5.4		4.4	4.4	5.6	5.1	4.1	1.0	4.5	2.8			1.9			3.7	2.6		3.0	
BD			5.6				0.9	1.1	1.1	3.2	3.3	3.3	5.4	2.6			5.6	1.3		2.0			
CS			2.2	3.5	5.5	1.3	3.3	1.4	1.2	2.0	3.6	4.0	2.9				4.2		5.1	3.2			
GB			1.2		1.8	0.6	0.2	1.1		2.2	1.7	1.6	2.3	1.7				1.9	2.3			2.4	
MM			1.8		3.8	2.4	4.9	3.0	1.9	7.3	5.5	6.3	4.3				2.1		3.6			5.2	
RC	34.3	25.7	24.4		14.0		22.5	22.1		15.5		19.3		18.3		15.4		20.6		18.5			20.7
FK			5.5	4.7	3.4	8.4	5.3	3.0	0.5	3.3	2.4	3.5	2.2		4.7	4.5		4.1		2.7	1.7		
OR			10.1	13.1	4.1	7.3	7.7	7.1	5.0	7.2	7.5	3.2	4.6		3.5			3.9	3.4	2.5		2.5	
SC			4.3	8.1	7.8	6.3	6.3	5.9	1.9	4.6	2.6	3.4	4.3		2.5	2.6	3.6	1.7		1.9			

Data sources

a) Allison and McLuckie (2018)
b) USFWS (2009)
c) USFWS (2016)
d) UDNR (2024)
e) USFWS (2018)
f) USFWS (2019)
g) USFWS (2020)
h) USFWS (2022a)
i) USFWS (2022b)

Colorado Desert Recovery Unit
AG = Chocolate Mountain Air Gunnery Range
CK = Chuckwalla
CM = Chemehuevi
FE = Fenner
JT = Joshua Tree National Park
PT = Pinto Mountains

Eastern Mojave Recovery Unit
PV = Piute Valley
EV = Eldorado Valley
IV = Ivanpah Valley

Northeastern Mojave Recovery Unit
BD = Beaver Dam Slope
CS = Coyote Springs Valley
GB = Gold Butte-Pakoon
MM = Mormon Mesa

Upper Virgin River Recovery Unit
RC = Red Cliffs Desert Reserve

Western Mojave Recovery Unit
FK = Fremont-Kramer
OR = Ord-Rodman
SC = Superior-Cronese

Michael W. Tuma

PHD, CWB, RPA

Profile

Dr. Michael Tuma has more than 25 years of experience as a professional scientist in environmental consulting, government agency positions, and academic settings. He has project experience in a diversity of market sectors, including renewable energy, land management, transportation, water infrastructure, gas and mineral extraction, and land development. He has a deep understanding of regulatory processes pertaining to Endangered Species Act, California Endangered Species Act, and California Environmental Quality Act compliance, as well as other environmental laws. Dr. Tuma's technical expertise includes desert ecology, population biology, herpetology, biodiversity, and applied conservation, and he is an expert in desert tortoise biology. Dr. Tuma has additional experience conducting anthropological, archaeological, and paleontological research.

Dr. Tuma is an experienced leader and has supervised and mentored groups of biologists at environmental consulting companies and government agencies. He has directed teams on large, long-term projects and mentored junior staff on issues pertaining to project management, technical studies and documentation, and regulatory processes. He has instructed students, volunteers, and international biologists on advanced data collection techniques and has experience leading a non-profit organization with more than 350 members.

Dr. Tuma is an expert in implementing advanced field data collection techniques for study of tortoises, including head-starting, radio telemetry, protocol health assessments, collection of blood/tissue samples, morphometric measurements, and radiography. He has trained and directed teams of biologists to implement these activities and has been authorized to conduct these activities by the U.S. Fish and Wildlife Service, the Kenya Wildlife Service, and several state agencies, including the California Department of Fish and Wildlife. He has been approved as Designated/Authorized Biologist under several Biological Opinions and Principal Biologist under Section 10(a)1(A) Recovery Permits.

Contact

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Education

- Ph.D. Integrative and Evolutionary Biology, 2016, University of Southern California, Los Angeles, California.

  Dissertation Title: Evolution of Body Size and Sexually Dimorphic Traits in the North American *Gopherus* Tortoises
- M.S., Anthropology, 1998, University of Southern Mississippi, Hattiesburg, Mississippi.

  Thesis Title: Subsistence Patterns at Immokakina'Fa', an Early Colonial Period Chickasaw Village: Change Following European Contact
- M.S., Zoology, 1993, Eastern Illinois University, Charleston, Illinois.

  Thesis Title: Ecology of the State Endangered Yellow Mud Turtle, *Kinosternon flavescens*, in Henry Co., Illinois
- B.S., Zoology, 1991, Truman State University, Kirksville, Missouri

Professional Training

- California Bumble Bee Atlas Training, The Xerces Society for Invertebrate Conservation, 2024
- Mohave Ground Squirrel Workshop, The Western Section of The Wildlife Society, 2024
- Desert Tortoise Council, Desert Tortoise Health Assessments for Translocation Projects, 2015
- USGS, Desert Tortoise Health Assessment and Phlebotomy Training, 2007
- Desert Tortoise Council, Surveying, Monitoring, and Handling Techniques Workshop, 2004

Permits & Authorizations

- Holder of two previous USFWS 10(a)1(A) Recovery Permits for Mojave desert tortoise (Nos. TE-195280-1 and TE-32004C-2)
- Previously authorized under USFWS 10(a)1(A) Recovery Permits for Mojave desert tortoise (Nos. TE-218901-5 [held by Danna Hinderle], TE-210234-0 [held by Edwards AFB], TE-102235-3 [held by Ft. Irwin], TE-85050-2 [held by Dr. Ken Nagy], and TE-006556-13 [held by Dr. Kristin Berry])
- Currently Authorized Biologist under USFWS Biological Opinion (FWS-SB-19B0147-19F1274): Biological Opinion for the Issuance of an Incidental Take Permit for the High Desert Solar Project, San Bernardino County, California
- Previous holder of California Department of Fish and Wildlife Memorandum of Understanding (Mojave desert tortoise)

Certifications

- Certified Wildlife Biologist ®
- Registered Professional Archaeologist
- County of San Bernardino Qualified Biologist
- County of Los Angeles Certified SEATAC Biota Report Consultant
- County of Ventura Qualified Biologist
- County of San Diego Approved CEQA Consultant, Archaeological Resources
- County of Orange Certified Archaeologist

Software/App Skills

- ArcMap/ArcGIS (including Field Maps, Survey123)
- Google Earth Pro
- Microsoft Office (Word, Excel, Access, PowerPoint, Publisher, Teams, SharePoint)

Employment History

- Principal Biologist at FirstCarbon Solutions, Inc. (September 2023 – present; San Bernardino, California)
- Research Scientist at RESI, Inc. (May 2022 – present; Albuquerque, New Mexico)
- Senior Biologist (on-call) at FirstCarbon Solutions, Inc. (April 2020 – September 2023; San Bernardino, California)
- Senior Biologist (on-call) at SWCA, Inc. (February 2021 – May 2022; Pasadena, California)
- Senior Biologist (on-call) at ECORP Consulting, Inc. (April 2020 – present; Redlands, California)
- Principal Biologist/Archaeologist at Bargas Environmental Consulting, LLC (April 2019 – March 2020; Redlands, California)
- Adjunct Professor at University of Southern California (March 2019 – present; Los Angeles, California)
- Ecologist at U.S. Geological Survey (January 2017 – May 2019; Riverside, California)
- Senior Ecologist at Western EcoSystems Technology, Inc. (March 2015 – January 2017; Redlands, California)
- Senior Biological Program Manager at ECORP Consulting, Inc. (October 2013 – March 2015; Redlands, California)
- Senior Biologist & Archaeologist at SWCA Environmental Consultants, Inc. (April 2003 – September 2013; Pasadena, California)

Employment History (continued)

- Archaeologist at Brian F. Smith and Associates, Inc. (October 2000 – April 2003; Poway, California)
- Archaeologist at Cultural Resources Analysts, Inc. (June 1998 – October 2000; Lexington, Kentucky)
- Gopher Tortoise Biologist at Mississippi Museum of Natural Science (April 1994 – May 1996; Hattiesburg, Mississippi)

Selected Consulting Project Experience

Palmdale Warehouse Project; Los Angeles County, California (2021-present with FirstCarbon Solutions, Inc. as Senior Biologist). Served as Senior Biologist, responsible for conducting assessment studies to support California Environmental Quality Act review and regulatory permitting processes. Dr. Tuma led implementation of protocol burrowing owl, desert tortoise, Crotch's bumble bee, and rare plant surveys, as well as inventory and assessments of more than 400 western Joshua trees. Dr. Tuma developed and submitted the Incidental Take Permit application for take of western Joshua tree and Mohave ground squirrel and facilitated the submission of the Lake and Streambed Alteration Agreement application. Dr. Tuma designed on-site mitigation programs for western Joshua tree, burrowing owl, and Mohave ground squirrel, and contributed to studies of off-site mitigation lands. Dr. Tuma is currently serving as Designated Biologist during the construction phase of the project. Client: IDS Real Estate Group

High Desert Solar Project; San Bernardino County, California (2020-present with ECORP Consulting, Inc. as Senior Biologist). Served as Authorized Biologist, responsible for implementing the Desert Tortoise Translocation Plan, American Badger and Desert Kit Fox Management Plan, Burrowing Owl Exclusion Plan, Nesting Bird Management Plan, and Common Raven Management and Control Plan, and monitoring site compliance with permit conditions contained in the CDFW Incidental Take Permit and Streambed Alteration Agreement, USFWS 10(a)1(B) Habitat Conservation Plan and Biological Opinion, and other federal, state, and local permits. Led the translocation effort for tortoises that occupied the project site, including attaching and removing transmitters, conducting protocol health assessments, collecting oral swab and blood samples for *Mycoplasma* testing, translocation of tortoises to the Fremont-Kramer Critical Habitat Unit, radiotelemetric monitoring before and after translocation, and supervision of staff who assisted in these efforts. Monitored construction activities during the construction phase of the project, provided Worker Environmental Awareness training to project personnel, and interacted with construction managers, supervisors, foremen, and crews as Lead Biologist. Client: Middle River Power (through contract with AECOM)

Selected Consulting Project Experience (continued)

AT&T Pole Replacement Project; San Bernardino County, California (2022-2023 with FirstCarbon Solutions, Inc. as Senior Biologist). Served as Senior Biologist, responsible for conducting assessments of damaged pole locations to support their replacement on lands administered by the Bureau of Land Management (BLM). Dr. Tuma surveyed the action area and authored a Biological Evaluation report to support an informal Section Endangered Species Act consultation between the BLM and U.S. Fish and Wildlife Service. As part of the Biological Evaluation, Dr. Tuma designed conservation measures to prevent take of Mojave desert tortoises. Client: Forkert Engineering

Olancha-Cartego U.S. Highway 395 Widening Project; Inyo County, California (2021-2022 with ECORP Consulting, Inc. as Senior Biologist). Served as Senior Biologist, responsible for conducting pre-project clearance surveys, relocation, and monitoring of Mojave desert tortoises prior to and during construction of the project. Dr. Tuma led a team that searched for Mojave desert tortoises on the project site and relocated them to adjacent, off-site habitat. Dr. Tuma additionally conducted compliance monitoring of crews that installed tortoise-proof fencing and utility pole relocations.. Client: Caltrans District 9

Biological and Archaeological On-Call Services Contract; Multiple Counties, California (2019-2020 with Bargas as Principal Biologist/Archaeologist). Served as Project Manager, responsible for client management, QA/QC of data and technical deliverables (biological and cultural resources), and management and mentoring of technical staff. Additional duties included preparation of biological reports for Los Angeles County SEATAC review, development of training program, and desktop reviews for biological and cultural resources. Client: Southern California Edison

Desert Quartzite Solar Energy Project; Riverside County, California (2016; with WEST as Senior Ecologist). Served as project manager, responsible for client management, biological studies, technical report preparation, and CEQA/NEPA documentation for a large-scale solar development in east Riverside County, California. Duties included reviewing studies prepared by prior consultants, conducting updated field surveys (vegetation mapping, rare plant and desert tortoise surveys) and technical reports, preparing EIR/EIS Biological Resources section and appendices (Invasive Weed Management Plan, Raven Management Plan, Desert Tortoise Translocation Plan, Desert Kit Fox & American Badger Management Plan, Rare Plant Management Plan, and Vegetation Restoration Plan). Client: First Solar, Inc.

Selected Consulting Project Experience (continued)

Edom Hills Wind Energy Facility; Riverside County, California (2015-2016; with WEST as Senior Ecologist). Served as project manager responsible for conducting a habitat assessment, eolian dune characterization study, and biomonitoring of project activities in support of minimizing the potential for take of Coachella Valley fringe-toed lizard and Coachella Valley milk-vetch during installation of equipment in two project turbines. Coordinated with the BLM project biologist to gain approval of biologists to monitor the work, and concurrence for the recommended mitigation measures, which included removal of wind-blown sands from portions of the access road and placing the sands in adjacent areas where they could continue transport in the eolian ecosystem. Authored a post-construction memo that detailed the restoration of the eolian sands and avoidance of sensitive microhabitats where fringe-toed lizards typically hibernate during the project activities. Client: BP Wind Energy North America, Inc.

Dune Palms Road Crossing Replacement; Riverside County, California (2014; with ECORP as Senior Biologist). Served as project manager responsible for coordinating natural resources studies and agency consultation in support of the preparation of a Caltrans Natural Environment Study (NES). Project tasks included a general biological survey, focused surveys for burrowing owl and rare plants, trapping efforts for Palm Springs round-tailed ground squirrel and Palm Springs pocket mouse, a jurisdictional waters/ habitats determination, agency consultation, preparation of a Biological Assessment in support of Section 7 consultation, documentation of study results, and preparation of the NES. Client: California Department of Transportation (sub to Parsons Brinckerhoff)

Environmental Generalist Services Task Order Contract – Caltrans District 7; Los Angeles and Ventura Counties, California (2014; with ECORP as Senior Biologist). Served as senior biologist for this two-year, on-call environmental services contract with Caltrans District 7. While serving in this capacity, contributed to two task orders in support of the State Route 138 NW project, which consists of environmental studies on SR-138 between State Route 14 and Interstate 5. Led task order responses that included 1) desert tortoise surveys and 2) an analysis of wildlife crossing and movements. Participated in the fieldwork, planned field and desktop analyses, directed a group of biologists and GIS specialists, and served as primary author of the deliverables produced for these task orders. Client: California Department of Transportation

Dry Lake Solar Energy Zone Desert Tortoise Translocations; Clark County, Nevada (2014; with ECORP Consulting as Senior Biologist). Served as senior wildlife biologist responsible for conducting focused, protocol health assessments and tissue sampling of desert tortoises within the Project site and translocation areas in support of disease testing and

Selected Consulting Project Experience (continued)

assessment. The Project involved translocating desert tortoise from a designated Solar Energy Zone on Bureau of Land Management lands in the vicinity of Dry Lake in Clark County, Nevada, in support of the development of the area for solar energy facilities. Dr. Tuma captured and handled tortoises encountered during surveys of the development area and proposed translocation areas, performed U.S. Fish and Wildlife Service-protocol health assessments, collected blood samples through subcarapacial venipuncture, collected oral swabs, and weighed, measured, photographed, and released the tortoises. Client: First Solar, NV Energy, and Invenergy (subconsultant to Ironwood Consulting, Inc.)

Biological and Archaeological Services On-call Contract; Multiple Counties, California (2013; with SWCA as Senior Biologist). Served as Biological Resources Program Director for SCE's Emergency On-call Natural and Cultural Resources Services Contract. While serving in this capacity, was responsible for leading SWCA's response to task orders involving biological resources. This included managing technical specialists, support staff, and subconsultants in responding to multiple, concurrent emergency and fast-burn task orders. Tasks conducted under this contract included biological assessments of gen-tie line alternatives, pre-construction surveys and monitoring in support of construction of a new substation and associated tie-in with a transmission line and preparing a Biological Assessment in support of Section 7 consultation for a deteriorated pole replacement project in the Angeles National Forest. Client: Southern California Edison

Kramer Junction Solar Energy Center; San Bernardino County, California (2009-2011; with SWCA as Senior Biologist): Served as co-project manager and senior biologist on this project, which included designing and implementing measures to avoid sensitive biological resources, including desert tortoise, in support of development of a solar power project. Consulted with FWS and CDFG for permitting the project, developed a fencing plan to keep desert tortoises from accessing the project site, developed and implemented a desert tortoise monitoring program, and served as senior author of the technical report deliverables. Client: NextEra Energy, Inc.

Boeing’s Santa Susana Field Laboratory; Ventura County, California (2006; with SWCA as Biologist). Designed and conducted field investigations on the extent and size of Braunton’s milk-vetch (*Astragalus brauntonii*) population within an area of USFWS proposed designated Critical Habitat. Led field effort, which included conducting vegetation mapping, delineating the Braunton’s milk-vetch population within the proposed area, estimating the population size with the use of randomized transects and quadrats, conducting a complete vascular plant inventory within the study area, and authoring a technical report detailing the results of the investigation, which were used by

Selected Consulting Project Experience (continued)

the client in commenting on the proposed area of designated Critical Habitat. Client: MWH Americas, Inc.

Los Angeles Department of Water and Power's Stone Canyon Water Quality Improvement Project; Los Angeles, California (2003-2008; with SWCA as Biologist). Served as project manager for this project, which included performing pre-construction surveys for special-status species, establishing buffers around active red-tailed hawk nests, and monitoring active avian nests in the vicinity of construction activities. Provided expertise to Los Angeles Department of Water and Power personnel, construction personnel, and community interest groups regarding red-tailed hawk reproductive biology and the effects of construction activities on actively nesting pairs and their offspring and contributed to the development of construction schedules around sensitive periods of red-tailed hawk nesting. Client: MWH Americas, Inc.

Riverside Energy Resource Center; Riverside County, California (2004-2008; with SWCA as Biologist). Served as project manager for this project, which included conducting assessments of biological, cultural, paleontological, and socioeconomic resources that could be impacted by the project in conformance with the California Energy Commission's (CEC) Small Power Plant Exemption Application process. Led biological, cultural, and paleontological tasks, which included coordinating with CEC biologists, developing mitigation measures for burrowing owl, a species that was determined to occupy the site prior to its development, and authoring documents. Designed and implemented a burrowing owl mitigation plan that included installation of artificial burrows and revegetation of mitigation area with California native vegetation communities. Client: Power Engineers

Additional Consulting Project Experience

- Biological studies and documentation in support of the Project Viento Warehouse development project, Desert Hot Springs, California (2021-present; with FirstCarbon Solutions as Principal Biologist). Client: Seefried Industrial Properties, Inc.
- Biological studies and documentation in support of the Cornucopia solar project, Fresno County, California (2022-present; with FirstCarbon Solutions as Senior Biologist). Client: BayWa r.e. Solar Projects, LLC
- Biological studies and documentation in support of Reserve at Sloan Canyon residential housing development project, Castaic, California (2021-present; with FirstCarbon Solutions as Senior Biologist). Client: Meritage Homes, Inc.

Additional Consulting Project Experience (continued)

- Biological compliance monitoring in support of the Waalew, Irwin Road, and Linda Vista Tank projects, Barstow and Apple Valley, California (2021-present; with ECORP Consulting as Senior Biologist). Client: Golden State Water Company
- Biological and archaeological studies in support of memorial conservation forests near Lake Arrowhead, California (2019-2020; with Bargas as Principal Biologist). Client: Better Place Forests
- Biological and cultural resources services in support of the Upper Westside Development project, Sacramento, California (2019-2020; with Bargas as Principal Biologist/Archaeologist). Client: Upper Westside, LLC
- Low-effect HCP for Delhi Sands flower-loving fly in support of land sale in Colton, California (2019-2020; with Bargas as Principal Biologist). Client: Confidential
- Biological construction monitoring for the Los Mirasoles Wind Energy Facility, Hidalgo and Starr Counties, Texas (2015-2016; with WEST as Senior Ecologist). Client: EDP Renewables North America LLC
- Desert tortoise survey, biological and cultural resources studies for the Kingman Solar II Facility, Mohave County, Arizona (2015-2016; with WEST as Senior Ecologist). Client: Brookfield Renewable Energy Group
- On-call Biological Services Contract, San Bernardino County, California (2014; with ECORP as Senior Biologist). Client: San Bernardino County Department of Public Works and Flood Control District
- Archaeological and biological services in support of the San Gabriel Trench Grade Separation Project, Los Angeles County, California (2012-2013; with SWCA as Senior Archaeologist/Biologist). Client: Alameda Corridor-East, San Gabriel Valley Council of Governments
- Desert tortoise translocations in support of the Pahrump Community Pit, Nye County, Nevada (2011; with SWCA as Senior Biologist). Client: Bureau of Land Management, Southern Nevada District Office
- Desert tortoise translocations in support of the Fort Irwin Land Expansion Project, San Bernardino County, California (2007-2008; with SWCA as Senior Biologist). Client: Fort Irwin and the National Training Center (sub to U.S. Geological Survey)
- Biological monitoring in support of the Helendale Transition Zone Monitoring Well, San Bernardino County, California (2004-2006; with SWCA as Biologist). Client: Mojave Water Agency
- Desert tortoise survey and ESA Section 7 consultation in support of the Kessler Springs Ranch Employee Housing Project, San Bernardino County (2005; with SWCA as Biologist). Client: National Park Service

Selected Research Experience

Aerial Drone Surveys for Bolson Tortoises at Ranchos San Ignacio and Guimbalete, Coahuila, Mexico – RESI, Inc., Albuquerque, New Mexico (2022-present). Serving as tortoise expert on a team of scientists that is surveying for bolson tortoises at Ranchos San Ignacio and Guimbalete, Coahuila, Mexico within the Bolson de Mapimi Biosphere Reserve. The technique involves using aerial drones to photograph survey areas and artificial intelligence applications to search for tortoises and burrows on aerial drone photographs.

Movements, Growth, and Survival of Head-started Juvenile Mojave Desert Tortoises at Edwards Air Force Base – U.S. Geological Survey, Riverside, California (2017-2019). Served as lead biologist investigating the movements, growth, and survival of juvenile Mojave desert tortoises that were head-started in predator-proof pens at Edwards Air Force Base and released into the wild at two sites. Conducted radio telemetry tracking and seasonal recaptures to perform health assessments, database management, statistical analyses, and technical report preparation. Directed a team of biologists who assisted in the field data collection efforts and coordinated with base project manager to ensure high quality product delivery.

Health of Adult Desert Tortoises in the Mojave National Preserve – U.S. Geological Survey, Riverside, California (2018-2019). Led crews of contracted biologists and volunteers in sampling of adult Mojave desert tortoises at two locations (Ivanpah and Fenner Valleys) in the Mojave National Preserve. Sampling included performing assessments of external health of captured tortoises, and collection of blood samples for microbial antibody testing, nasal lavages for presence of disease-causing bacteria, and oral swabs for presence of herpesvirus.

Evolution of Body Size and Sexually Dimorphic Traits in North American *Gopherus* Tortoises – Dissertation research, University of Southern California (2010-2016). Tested hypotheses pertaining to the evolution of body size, sexual size dimorphism, and sexually dimorphic traits in the North American *Gopherus* tortoises and other tortoise species. Compiled and analyzed existing datasets, developed models, and collected measurements of body size and other morphological traits to test hypotheses. Examined body size and sexual size dimorphism variability in adult Mojave desert tortoises across the range of the species, and test hypotheses to determine the degree to which ecological and phylogenetic constraints have contributed to the evolution of the observed variation; examined the relative influence of selection pressures (natural and sexual) that drove the evolution of sexual size dimorphism and gular horn weaponry in tortoises; and examined

Selected Research Experience (continued)

the divergent pathways between the two sister clades in the genus *Gopherus* in which gular horn weaponry and both male-biased and female-biased SSD is expressed, with testing of hypotheses pertaining to the progression of trait evolution in the genus using fossil evidence, with comparisons to mating strategies, morphological traits, and burrow use behaviors that differ between the clades that provide context for the evolution of the traits. Presented the research at annual meetings of the Desert Tortoise Council and Turtle Survival Alliance, and currently developing manuscripts for publication in peer-reviewed journals.

<u>Ecology, Biogeography, Phylogenetics, and Conservation of the East African Pancake Tortoise</u> – Kenya and Tanzania (2011-present). As Principal Investigator, leading an international group of scientists in updating the conservation status of known wild pancake tortoise (*Malacochersus tornieri*) populations in Kenya and Tanzania, collecting DNA samples to assess range-wide genetic population structure in the species, and implementing local education programs in villages and towns in the vicinity of tortoise populations. The research will build upon previous work by Klemens and Moll (1995) and Malonza (2003) by providing valuable comparative data by which to assess changes in populations over the past two decades – a period when their exploitation has likely intensified, particularly in Tanzania. Assessment of the species' range-wide genetic structure will identify whether range disjunctions and scattered populations have contributed to genetic variation that is currently unrecognized. Implementation of community outreach and education programs in the villages near pancake tortoise populations will provide much-needed information to locals who live and work in proximity to this species. Collected blood samples from two populations in Tanzania and recently obtained authorization from Kenya Wildlife Service to sample tortoise populations in Kenya.

<u>Mojave Desert Tortoise Population Modeling for the Superior-Cronese and Gold Butte-Pakoon DWMAs</u>, San Bernardino County, California, Clark County, Nevada, and Mohave County, Arizona - Bureau of Land Management, National Office (2008-2013). Served as the project manager, client manager, and principal investigator of this project, which entailed conducting research into the population biology of Mojave desert tortoises on two study areas comprised of federal lands administered by the Bureau of Land Management (BLM). Directed a team of more than 40 biologists, statisticians, and GIS specialists who contributed to the project; successfully developed spatially explicit, individual-based population models used to rank the importance of site-specific threats at each of the study areas; and served as primary author of the technical report deliverables. This project consisted of collecting field data, compiling GIS data, conducting

Selected Research Experience (continued)

intensive literature reviews and expert interviews, and developing tortoise occurrence models, population models, and threats models for study areas that included the Superior-Cronese Critical Habitat Unit in San Bernardino County, California and the Gold Butte-Pakoon Critical Habitat Unit in Clark County, Nevada and Mohave County, Arizona.

The modeling effort allowed Dr. Tuma to simulate the effects of site-specific threats on tortoise populations at each study area and develop land management and species conservation strategies that could be implemented by BLM Field and State Offices on tortoise populations within each Critical Habitat Unit. Presented the research at annual meetings of the Desert Tortoise Council, The Wildlife Society, and the World Congress of Herpetology, and published a manuscript (Journal of Wildlife Management).

Juvenile Mojave Desert Tortoise Survivorship Study, San Bernardino County - U.S. Fish and Wildlife Service (2008-2013). Served as project manager, client manager, and principal investigator of this project, which entailed conducting research into the survivorship of head-started juvenile Mojave desert tortoises. Worked with U.S. Fish and Wildlife Service (USFWS) Desert Tortoise Recovery Office and Department of Defense personnel to fund and permit the project and authored technical report deliverables associated with the project. The research entailed radiotelemetric observations of juvenile tortoises that were head-started at the Ft. Irwin Study Site (FISS) and released onto Fort Irwin and BLM lands situated within the Superior-Cronese Critical Habitat Unit in San Bernardino County, California. Presented the research at annual meetings of the Desert Tortoise Council.

Edwards Air Force Base Mojave Desert Tortoise Head-starting, Los Angeles, Kern, and San Bernardino Counties, California – MWH Americas, Inc. for Edwards Air Force Base (2010). Assisted project managers from MWH Americas, Inc. in conducting tortoise head-starting research at Edwards Air Force Base. Directed field crews and performed advanced, specialized field techniques related to the research, including attaching radio transmitters to adult and juvenile tortoises; completing health assessments of sampled female tortoises, including collecting blood samples for antibody testing and nasal lavages for microorganism (*Mycoplasma*) testing; and radiographing female tortoises to determine whether they were gravid with eggs. Also contributed to the year-end report.

Daggett Study Site Mpjave Desert Tortoise Epidemiology Research, San Bernardino County, California – U.S. Geological Survey for Fort Irwin and the National Training Center (2007-2008). Assisted Dr. Kristin Berry of the USGS with conducting health assessments and collecting blood and nasal samples from a population of Mojave desert tortoises near Daggett, California. The project was a mitigation measure for the Ft. Irwin Land Expansion Project. Assisted with surveying for tortoises throughout the study area, conducting full health assessments of each captured tortoise, drawing blood and collecting nasal lavages

Selected Research Experience (continued)

from tortoises, and fitting transmitters to a subset of the sampled tortoises to track the long-term health of these individuals.

Archaic Period Subsistence in Southern California, San Diego County, California – Brian F. Smith and Associates (2000-2002). Conducted an analysis of zooarchaeological collections recovered from several coastal Archaic Period Millingstone Horizon archaeological sites, including the Allan O. Kelly Site (CA-SDI-9649), the Scripps-Poway Parkway Site (CA-SDI-4608), and the Salt Creek Ranch Site (CA-SDI-4530) in San Diego County, California, that were occupied between 6,000 and 2,500 years before present. Identified and analyzed the materials from these sites and augmented the sample with comparisons to several other Archaic Period sites from which substantial faunal remains were recovered and analyzed. Developed the research into a presentation (2002 Society for California Archaeology Annual Meeting) and a publication (Journal of California and Great Basin Anthropology).

Ethnoarchaeology of African American Subsistence in Rural Mississippi, Adams County, Mississippi – University of Southern Mississippi (1997-2000). Conducted an ethnoarchaeological study of subsistence behaviors in an impoverished African American community in rural southern Mississippi. Visited the community for extended weekends over a period of two years, participating in and observing subsistence activities, including hunting and fishing, butchery and fish cleaning, processing of carcasses, cooking, and eating. During these activities, recorded the cultural modifications to vertebrate animal bones and mapped locations of discarded bones. Compared these observations to faunal remains recovered from slave quarters areas of Antebellum Period plantations to determine butchery, processing, cooking, and food discarding behaviors of enslaved African Americans. Awarded two research grants to conduct the work, presented the research (Southeastern Archaeological Conference) and published one manuscript (Historical Archaeology).

Gopher Tortoise Population Research, Forrest and Perry Counties, Mississippi – Mississippi Museum of Natural Science (1994-1996). Served as principal investigator of a study examining the demography of gopher tortoise populations within DeSoto National Forest on lands leased by the Department of Defense for military training activities. Designed and conducted biological field research to determine the effects of environmental disturbances on the life history and population biology of the federally threatened gopher tortoise. The research included conducting radiotelemetric observations of home range size, activity patterns, and habitat use; radiographic observations of clutch sizes in female tortoises; and collection of body measurements to determine growth and maturity rates. Presented the research at annual meetings of the Society for the Study of Amphibians

Selected Research Experience (continued)

and Reptiles and the Gopher Tortoise Council. Used data collected during this study for dissertation research at the University of Southern California.

Yellow Mud Turtle Population Study, Henry County, Illinois – Eastern Illinois University and Illinois Department of Natural Resources, Endangered Species Protection Board (1992-1993). Conducted demographic research on a population of endangered yellow mud turtles (*Kinosternon flavescens*) in support of Master's Thesis research. Independent collection of field data, including aquatic hoop net trapping, drift fence trapping, and radio telemetry to determine home range size, seasonal activity patterns, nesting behaviors, and habitat use. Presented research at annual meetings of the Society for the Study of Amphibians and Reptiles and authored two publications (Herpetological Review and Chelonian Conservation and Biology).

Publications

Berry, Kristin H., Jeremy S. Mack, Kemp M. Anderson, and Michael W. Tuma. 2024. Young, wild desert tortoises lead solitary lives. Chelonian Conservation and Biology. https://doi.org/10.2744/CCB-1608.1

Mwaya, Reginald T., Michael W. Tuma, and Abraham Eustace. 2023. Activity and predation of the threatened pancake tortoise, *Malacochersus tornieri*. African Journal of Ecology 61(3):726-729.

Sandmeier, Franziska C. Chava L. Weitzman, K. Nichole Maloney, C. Richard Tracy, Nathan Nieto, Mike B. Teglas, Kenneth W. Hunter, Sally DuPré, C. M. Gienger, and Michael W. Tuma. 2016. Comparison of current methods for the detection of chronic mycoplasmal URTD in wild populations of the Mojave desert tortoise (*Gopherus agassizii*). Journal of Wildlife Diseases 53(1):91–101.

Tuma, Michael W., Chris Millington, Nathan Schumaker, and Paul Burnett. 2016. Modeling Agassiz's desert tortoise population response to anthropogenic stressors. Journal of Wildlife Management 80:414–429.

Nagy, K. A., L. Scott Hillard, Michael W. Tuma, and David J. Morafka. 2015. Head-started desert tortoises (*Gopherus agassizii*): Movements, survivorship and mortality causes following their release. Herpetological Conservation and Biology 10:203–215.

Tuma, Michael. W. and Craig B. Stanford. 2014. Chapter 17: History of Human Interaction. In: D.C. Rostal, E. D. McCoy, and H. R. Mushinsky (Eds), Biology and Conservation of North American Tortoises. John Hopkins University Press, Baltimore, MD.

Nagy, K. A., Michael W. Tuma, and L. Scott Hillard. 2011. Shell hardness measurement in juvenile desert tortoises, *Gopherus agassizii*. Herpetological Review 42:191-195.

Publications (continued)

Tuma, Michael W. 2006. Range, habitat use, and seasonal activity of the yellow mud turtle (*Kinosternon flavescens*) in Northwestern Illinois: Implications for site-specific conservation and management. Chelonian Conservation and Biology 5:108-120.

Tuma, Michael W. 2006. Ethnoarchaeology of Subsistence behaviors within a rural African American community: implications for interpreting vertebrate faunal data from slave quarters areas of Antebellum plantation sites. Historical Archaeology 40:1-26.

Tuma, Michael W. 2004. Middle to Late Archaic Period changes in terrestrial resource exploitation along the Los Peñasquitos Creek Watershed in western San Diego County: vertebrate faunal evidence from the Scripps Poway Parkway Site (CA-SDI-4608). Journal of California and Great Basin Anthropology 24:53-68.

Amy L. Young, Michael W. Tuma, and Cliff Jenkins. 2001. The role of hunting to cope with risk at Saragossa Plantation, Natchez, Mississippi. American Anthropologist 103:692-704.

Tuma, Michael W. 1998. Slave subsistence at Saragossa: preliminary report on faunal data. Mississippi Archaeology 33:125-138.

Tuma, Michael W. 1993. Life History Notes - *Kinosternon flavescens*, multiple nesting. Herpetological Review 24:31.

Presentations

February 2024. Desert Tortoise Council 49th Annual Symposium. Use of aerial drones to locate Bolsón tortoise populations in the Bolsón de Mapimi, Mexico (with M. Bandy, R. Palomo-Ramos, and R. Kiester).

February 2019. Desert Tortoise Council 44th Annual Symposium. Variables affecting survival of juvenile desert tortoises after release from headstart pens at Edwards AFB, a preliminary report. Part 1. Size and growth (with Kristin H. Berry and Jeremy S. Mack).

February 2019. Desert Tortoise Council 44th Annual Symposium. Variables affecting survival of juvenile desert tortoises after release from headstart pens at Edwards AFB, a preliminary report. Part 2. Behaviors and home range (with Kristin H. Berry and Jeremy S. Mack).

November 2018. California Science Education Conference. The desert tortoise as phenomenon in studying ecological issues (with Julie Bookman and Peter Coddington).

February 2018. Desert Tortoise Council 43rd Annual Symposium. Movements, Growth, and Survival of Head-started, Juvenile Tortoises at Edwards Air Force Base. (with Jeremy S. Mack, Kristin H. Berry, and Kemp Anderson)

Presentations (continued)

February 2017. Desert Tortoise Council 42nd Annual Symposium. Ecological Constraints Imposed by Burrowing Behaviors Drove the Evolution of Divergent Sexual Size Dimorphism in the North American *Gopherus* Tortoises.

August 2016. 14th Annual Symposium on the Conservation & Biology of Tortoises & Freshwater Turtles. Sexual Size Dimorphism in Turtles: Implications for Management of Wild and Captive Populations.

February 2016. The Wildlife Society Western Section Annual Meeting. Modeling Agassiz's Desert Tortoise Population Response to Anthropogenic Stressors.

February 2016. Desert Tortoise Council 41st Annual Symposium. Evolution of Sexually Dimorphic Traits in North American *Gopherus* Tortoises.

February 2015. Desert Tortoise Council 40th Annual Symposium. Mortality and Survival of Juvenile Agassiz's Desert Tortoises at the Fort Irwin Study Site. (with L. Scott Hillard and Kenneth A. Nagy)

February 2015. Desert Tortoise Council 40th Annual Symposium. Divergent Evolution of Sexual Size Dimorphism in North American *Gopherus* Tortoises.

February 2013. Desert Tortoise Council 38th Annual Symposium. Simulating desert tortoise population response to anthropogenic stressors using individual-based, spatially explicit modeling techniques. (with Chris Millington, Nathan Schumaker, and Paul Burnett)

August 2012. 7th World Congress of Herpetology. Individual-based, spatially explicit modeling of desert tortoise population response to anthropogenic threats. (with Chris Millington, Nathan Schumaker, and Paul Burnett)

August 2012. Ecological Society of America 97th Annual Meeting. Modeling population response to anthropogenic threats for a long-lived reptile, the desert tortoise. (with Chris Millington, Nathan Schumaker, and Paul Burnett)

July 2011. Joint Meeting of Ichthyologists and Herpetologists. Modeling habitat for desert tortoises in the northeastern Mojave Desert. (with Emily Kochert and Paul Burnett)

February 2009. Desert Tortoise Council 35th Annual Symposium. Shell hardness index and rate of shell hardening in desert tortoises. (with Kenneth A. Nagy and L. Scott Hillard)

February 2007. Desert Tortoise Council 32nd Annual Symposium. Head-starting desert tortoises: Fort Irwin Release Project 2007. (with Kenneth A. Nagy and L. Scott Hillard)

February 2006. Desert Tortoise Council 31st Annual Symposium. Head-starting desert tortoises: Fort Irwin Release Project. (with Kenneth A. Nagy and L. Scott Hillard)

Presentations (continued)

April 2002. Society for California Archaeology Annual Meeting. Vertebrate Faunal Evidence of Archaic Period Subsistence Changes at an Inland San Diego County Site.

January 2002. Society for Historical Archaeology Annual Meeting. Cultural Aspects of the Upland South Tradition as Represented in the Faunal Assemblage of McConnell's Homestead (Site 15Bb75). (with Grant L. Day, coauthor)

November 1999. Southeastern Archaeological Conference Annual Meeting. Ethnoarchaeological observation of the subsistence behaviors among a rural community of African Americans in southwest Mississippi.

November 1998. Southeastern Archaeological Conference Annual Meeting. Analysis of Vertebrate Faunal Remains from the ImmokaKina'Fa' Site (22Le907). (Susan L. Scott, senior author)

February 1998. Mississippi Academy of Sciences 1998 Annual Meeting. Slave subsistence patterns at a Natchez, Mississippi Antebellum cotton plantation: Evidence from zooarchaeological remains.

January 1998. Society for Historical Archaeology Annual Meeting. Deerskin trade and subsistence specialization in the Black Prairie: Evidence from a late Protohistoric Chickasaw site. (with Susan L. Scott, co-author)

July 1996. Society for the Study of Amphibians and Reptiles Annual Meeting. Sexual maturity and reproduction of *Gopherus polyphemus* in southern Mississippi.

November 1995. Gopher Tortoise Council Annual Meeting. Estimation of home range for *Gopherus polyphemus* in southern Mississippi.

August 1995. Society for the Study of Amphibians and Reptiles Annual Meeting. Calculation of home range for *Gopherus polyphemus* in southern Mississippi.

August 1993. Society for the Study of Amphibians and Reptiles Annual Meeting. Ecology of the yellow mud turtle (*Kinosternon flavescens*) in Illinois.

Volunteer Professional Service

Board of Directors Member, Desert Tortoise Council (2013-present)

Associate Editor, Herpetological Conservation & Biology (2007-present)

Peer reviewer, various biological sciences journals (2006-present)

Awards and Grants

2024 Mohamed bin Zayed Grant for Bolson Tortoise Research

2022 U.S. Fish and Wildlife Service Grant for Bolson Tortoise Research

2019 Turtle Conservation Fund Grant for Pancake Tortoise Research

2019 Mohamed bin Zayed Grant for Pancake Tortoise Research

2015 Royal Ontario Museum's M.A. Fritz Grant Student Travel Award

2015 Turtle Conservation Fund Grant for Pancake Tortoise Research

2015 Mohamed bin Zayed Grant for Pancake Tortoise Research

2013 Desert Tortoise Council's David J. Morafka Memorial Research Award for desert tortoise research

1997 Sigma Xi's Grants in Aid of Research for anthropological research