



FINAL REPORT

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Process- and Scale-based Determinants of Survival for Translocated Mojave Desert Tortoises in the Ivanpah Valley, California; April 2011 through May 2017

Prepared for:

Solar Partners I, LLC; Solar Partners II, LLC; Solar Partners VIII, LLC; and all ISEGS permitting agencies

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Executive Summary

This report presents the results from a multi-year study (April 2011 through May 2017) of the translocation of federally threatened Mojave desert tortoises (*Gopherus agassizii*) at the Ivanpah Solar Electric Generating System (ISEGS) in the Ivanpah Valley of southern California. Translocation has been implemented in several locations as a method to mitigate potentially harmful effects of anthropogenic activities. However, the factors that have influenced the success of translocation efforts have been poorly understood. This study assessed environmental variables at multiple spatial and temporal scales to evaluate the potential effects and factors that influence desert tortoise survival, including short-distance translocation.

As required and described in the Revised Biological Opinion (2011) and the associated Effectiveness Monitoring Plan (EMP), Mojave desert tortoises that were translocated from within ISEGS boundaries to an adjacent area in the Ivanpah Valley have been monitored over nearly five years to understand the effects of short-distance translocation on tortoise survival and other demographic parameters. Specifically, the two primary objectives of the EMP were to: 1) collect data on tortoise survival and its anticipated drivers and 2) investigate and determine the processes and scales influencing tortoise survival.

To achieve Objective 1, translocated tortoises ($n = 73$), along with resident ($n = 112$) and control ($n = 149$) tortoises (the three groups in this study), have been monitored since 2011, particularly when tortoises are typically most active (i.e., the “active season” between April and October each year). Radio-tracked tortoises were captured every May and September for health assessments and pathogen sampling, downloading of thermal data, and replacement of transmitters, as needed. Data were also collected on environmental variables at local- (e.g., vegetation cover, plant species richness, rainfall, temperature) and landscape-scales (e.g., shrub and wash density, vegetation greenness, terrain characteristics). Analyses were then performed to determine how physical (e.g., soil and vegetation properties, barriers to movement) and biological processes (e.g., tortoise movement patterns, habitat use [i.e., space use], health status, pathogens) influenced tortoise survival among study groups.

Key results related to Objective 1:

- In the first few months of the first active season post-translocation, translocated tortoises increased their movements, showed decreased space use intensity (i.e., exhibited movement behavior that was less concentrated in a particular location), and experienced higher ambient temperatures than did resident and control tortoises. However, space use and thermal conditions of translocated tortoises were indistinguishable from those of control and resident tortoises thereafter.
- Tortoise movements across study groups were influenced by individual tortoise characteristics (e.g., size, sex), landscape features (e.g., vegetation greenness), and weather (e.g., rainfall and temperature). For example, movements increased during periods of greater rainfall and when cooler temperatures coincided with lower rainfall.

To achieve Objective 2, annual and five-year (i.e., cumulative) survival probabilities of translocated, resident, and control tortoises within the Ivanpah Valley study area during the period April 15, 2012, to May 31, 2017, were estimated using known-fate models. Models incorporated several individual-level (e.g., size, sex, body condition) and landscape-scale predictor variables to determine relative influence of those variables on survival among study groups. We analyzed data from two size classes: tortoises with a midline carapace length (MCL) between 120 and 160 mm and tortoises with a MCL of > 160 mm MCL. For each size class, we evaluated the support for survival models that incorporated different variables using contemporary inferential methods, including an information criterion and model-averaging.

Key results related to Objective 2:

- Survival estimates of immature and adult tortoises in the Ivanpah Valley study area (i.e., between 0.89 – 1.0) were among the highest annual survival probabilities for tortoises of any published study to date. In other words, these survival estimates indicate that, on average, between 89% and 100% of tortoises survived each year, with larger (i.e., older) tortoises at the high end of that range.
- Translocation did not negatively affect survival of desert tortoises in this study. Estimates of annual and cumulative survival probability were not statistically different among control, resident, and translocated tortoises for either size class. The lack of support for a difference, in spite of the high precision of the estimates, was likely a consequence of survival estimates for all groups being high (nearly 1.0).
- For tortoises in the larger size class, survival probability increased with body size across all study groups.
- In addition, survival probability decreased as home range size increased across all study groups.
- For tortoises in the smaller size class, topographic roughness had a significantly negative impact on tortoise survival across all study groups.
- Collectively, translocations had short-term impacts on space use and the thermal conditions experienced by desert tortoises at the ISEGS, but those impacts were not apparent one year later, and translocations did not appear to have any negative impacts on the condition, growth, or mortality of tortoises.

Based on the findings described above, we have achieved the two objectives of the EMP within the short-term, five-year duration of the EMP. The results of the study to date allow us to conclude the following:

- Short-distance translocation releases had relatively minimal impacts on desert tortoises in the Ivanpah Valley study area.
- Translocating individuals in the spring may have been important for giving tortoises time to dig burrows and familiarize themselves with their surroundings prior to being exposed to hot summer temperatures.
- Our study indicated that translocation methods that minimize stressful environmental conditions during the period immediately following translocation may have the greatest

success. Examples of methods that likely contributed to high survivorship included that translocated tortoises were released in early spring within 500 meters of their median location prior to being removed from the project site, and they were given access to water the day before release and hydrated immediately prior to release.

- Finally, this study is an important step for science-based, mitigation-driven actions implemented to evaluate and reduce impacts of translocation on the Mojave desert tortoise and other sensitive species.

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1. Background

The Mojave desert tortoise (*Gopherus agassizii*) is listed as threatened under the U.S. Endangered Species Act (ESA) and the California Endangered Species Act due to several threats, including loss and degradation of habitat due to human activities (e.g., urbanization, military training, mining, and energy production), subsidized predation, and disease (USFWS 1990). In recent years, translocation of tortoises has been implemented in several locations in the Mojave Desert to mitigate potentially harmful effects of some of these activities, particularly military training and renewable energy development (Esque et al. 2010, Drake et al. 2012, Farnsworth et al. 2015). However, there remains a need for robust characterization of drivers of tortoise survival following translocation. In this report, we present the results of a multi-year (2011-2017) study designed to evaluate potential effects of translocation on the movement, survival, and health of desert tortoises. The work was conducted at the Ivanpah Solar Electric Generating System (ISEGS) and adjacent areas in the Ivanpah Valley of southern California.

1.1 ISEGS project background

The ISEGS site is located on approximately 1,457 hectares (5.6 square miles) west of the Ivanpah Dry Lake, on Bureau of Land Management (BLM) land west of Interstate 15 (I-15) in San Bernardino County, California (Fig. 1). Construction was initiated in 2010 and completed in May 2014. Solar Partners I, LLC; Solar Partners II, LLC; and Solar Partners VIII, LLC (Solar Partners) are the owners of the Ivanpah Solar Electric Generating System (ISEGS), a nominal 370-megawatt (MW) solar energy project in southern California's Mojave Desert, near the Nevada border. The project was developed by BrightSource Energy, Inc. and is operated for Solar Partners by NRG Energy Services, LLC (NRG). The project site consists of three solar power electrical generating facilities: Ivanpah 1 (the southern unit) covers approximately 370 hectares (1.4 square miles); Ivanpah 2 (the middle unit) covers approximately 436 hectares (1.7 square miles); and Ivanpah 3 (the northern unit) covers approximately 500 hectares (1.9 square miles). The remaining disturbance areas include common access roads, gas lines, generation tie-lines, and construction and operations facilities. All three phases share an administration building, an operations and maintenance building, a substation located between Ivanpah 1 and 2, and paved roads to access each site. The project ties into the existing Kern River Gas Transmission Line about 0.8 km (0.5 mile) north of the Northern Rare Plant Mitigation Area and into the Southern California Edison 230/115 kilovolt (kV) line that crosses between the Ivanpah 1 and 2 sites.

Each unit consists of solar arrays of heliostats (or mirrors) that focus solar energy on central solar power tower receivers near the center of each of the heliostat arrays. Ivanpah 1 (nominal 120 MW) has a heliostat array consisting of approximately 53,500 heliostats. Ivanpah 2 and 3 (nominal 125 MW each) have heliostat arrays consisting of approximately 60,000 heliostats. The heliostat array of each unit is arranged around a single centralized solar power tower (SPT) that is 140 meters (459 feet) in height, including a boiler and superheater panel with an upper

steam drum and protective ceramic insulation panels (20 meters [65.5 feet]) on top. Each solar power plant has a power block in the approximate center of the heliostat array. The power block includes an SPT, a receiver boiler, a steam turbine generator (STG) set, an air-cooled condenser, and other auxiliary systems.

Because the ISEGS project site is located in known desert tortoise habitat, the BLM granted the project a right-of-way grant in accordance with Section 7 of the ESA. To guide the translocation strategy and associated monitoring, the federal agencies (US Fish and Wildlife Service [USFWS] and BLM) with authority for managing the desert tortoise and its habitat issued a final Biological Opinion (USFWS 2010; 2011) that mandated the following:

“During monitoring, BrightSource will investigate the drivers of post-translocation survival. Specifically, it will investigate the interdependent roles of desert tortoise movement patterns, habitat use, health status, environmental toxicants, road noise and vibration, and physical features (e.g., habitat structure, composition, and fragmentation, soil properties) and processes (e.g., precipitation and temperature gradients) across a focal study landscape (i.e., translocated, recipient, and control populations within Ivanpah Valley). BrightSource will compare the information collected on the movements, home ranges, habitat characteristics, disease prevalence, and survival of the resident and control populations with that collected on translocated desert tortoises. BrightSource will perform health assessments on the monitored populations at least twice per year.”

In accordance with the monitoring requirements outlined in the 2011 Biological Opinion (USFWS 2011), a comprehensive Effectiveness Monitoring Program (EMP) was developed to characterize conditions that influence survival of translocated desert tortoises. The EMP and its objectives are briefly described in the following section. For more details, see Dickson and Farnsworth (2012).

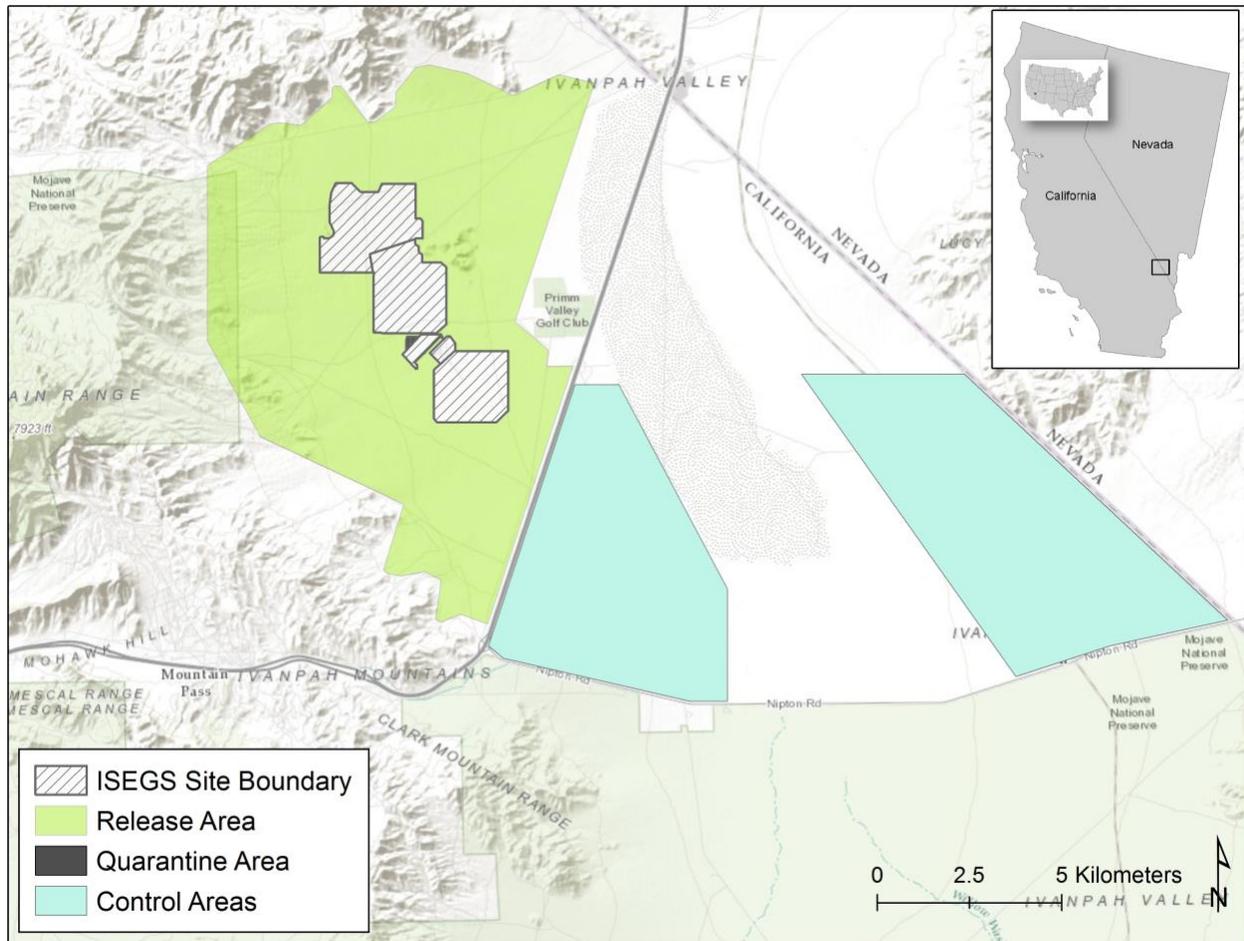


Figure 1. ISEGS project footprint within the Ivanpah Valley study area in southern California described in the Effectiveness Monitoring Plan (EMP).

1.2 EMP overview and objectives

The Revised Biological Opinion (USFWS 2011) outlined five broad biotic and abiotic factors hypothesized to be primary drivers of tortoise survival: weather and climate (i.e., precipitation and temperature), disease, vegetation, physical features (e.g., soil and topography), and the direct and indirect anthropogenic impacts (e.g., noise and vibration, environmental toxicants, barriers to movement). As described in the Revised Biological Opinion (USFWS 2011), the relative manner in which these drivers impact survival—either through direct effects on tortoise populations or as interacting effects working in concert—remains uncertain, but should be accounted for when isolating the effects of translocation from other potential drivers of survival.

To fulfill the requirements of the Biological Opinion (USFWS 2011), the EMP focused on the following specific objectives (see Dickson and Farnsworth 2012 for details):

- **Objective 1:** Collect data on tortoise survival and its anticipated drivers using a

combination of comprehensive fieldwork—including tortoise tracking—and contemporary remote sensing. These data are crucial for understanding how translocation affects survival and individual and population scales over short- and long-term periods.

- **Objective 2: Investigate and determine the processes and scales influencing tortoise survival.** In order to understand individual- and population-level survival processes, along with the relationships among interacting drivers from individual to population scales, data must be synthesized and compared across ecological levels (scales) using an appropriately conceived modeling framework.

In particular, the EMP was developed to comprehensively address the potential impacts of how physical (e.g., habitat characteristics, vegetation cover, soil properties, barriers to movement) and biological processes (e.g., tortoise movement patterns, habitat use, health status, pathogens) influence tortoise survival on multiple spatial and temporal scales. The EMP was principally designed to measure and identify these drivers of survival for translocated tortoises, resident tortoises (i.e., those already living in the area to which tortoises were translocated), and control tortoises (i.e., those living in areas outside of the ISEGS project site) within the Ivanpah Valley study area described in the EMP (hereafter “Ivanpah study area”; Fig. 1). Studying resident and control tortoises allowed us to isolate the effects—if any—of translocation from other potentially confounding variables (e.g., environmental variables). This study has monitored tortoise survival and its potential drivers for the first five years following short-distance translocation.

1.3 Purpose of this report

The purpose of this report is to present results of work at the ISEGS project site between April of 2011 and May of 2017 that supported the two EMP objectives associated with tortoise translocations (Section 1.2). This report provides updates, where necessary, to information provided in previous seasonal or annual reports to NRG Energy, Inc., as well as updates to results to this work previously published in the peer-reviewed scientific literature (namely, Farnsworth et al. 2015, Brand et al. 2016, and Sadoti et al. 2017). In addition, this report presents results of known-fate survival models designed to identify potential individual- and landscape-scale drivers of post-translocation survival over the five-year period between May of 2012 and May of 2017. The Revised Biological Opinion (USFWS 2011) and the EMP (Dickson and Farnsworth 2012) emphasized post-translocation survival estimates as the primary priority for the ISEGS project; thus, this report provides greater detail about the survival modeling framework and results than previous reports or publications.

In the sections that follow, we describe methods, results and interpretation, and conclusions related to work addressing the EMP objectives—particularly the survival analyses—described above. [Section 2](#) presents the methodological steps, including information about the ISEGS study area, fieldwork to collect data outlined in the EMP, as well as data analysis approaches (Section 2.3), and description of the modeling approach for the comprehensive survival analysis (Section 2.4). [Section 3](#) presents results and interpretations of data collection and analyses

(Sections 3.2), including the comprehensive survival analyses (Section 3.3). [Section 4](#) presents brief conclusions based on findings to date. Subsequent sections present acknowledgements ([Section 5](#)), literature cited ([Section 6](#)), and appendices ([Sections 7 and 8](#)).

Further details on the Ivanpah Valley study area, study design, and data analysis approaches can be found in Farnsworth et al. (2015), Brand et al. (2016), and Sadoti et al. (2017). Importantly, these peer-reviewed scientific publications, which were co-authored by authors of the present report, were designed to inform and evaluate the study design and key elements of the EMP, as proposed. Thus, these papers are frequently referenced throughout this report.

2. Field methods and analytical approaches

2.1 Study area

The Ivanpah Valley presently encompasses three active renewable energy facilities including ISEGS, and is recognized as important for maintaining linkages between Mojave desert tortoise conservation areas in California and Nevada (USFWS 2011). The Ivanpah Valley study area encompassed three contiguous tracts of BLM-administered land approximately 75 km southwest of Las Vegas, NV (Fig. 1). In addition to a concentrated solar thermal power plant, the ISEGS facility includes fences surrounding the project footprint that prohibit the passage of tortoises. In addition, the area is bisected by I-15 and includes paved public roads accessing ISEGS, numerous unpaved roads, a golf course, elevated power transmission lines and towers, as well as two other solar power plants.

Elevation across the valley ranges from 790 to 1830 m, with vegetation consisting of Mojave Desert scrub dominated by creosote bush (*Larrea tridentata*) and white bursage (*Ambrosia dumosa*). Average annual precipitation is approximately 20.1 cm, and rainfall usually peaks in July-August and during winter (1981-2010; Global Historical Climatology Network station USC00267369, Searchlight, NV). Soil types vary from silt/clay to sand/loam, with desert tortoises typically occupying the relatively low-lying alluvial fans, plains, and colluvial/bedrock slopes.

2.2 Tortoise handling, translocation, and study groups

All tortoise capture, handling, and marking procedures were done in accordance with official USFWS protocols, including those put forth in the June 10, 2011, Revised Biological Opinion (USFWS 2011) and the 2009 Desert Tortoise Field Manual. In addition, a condition of certification (BIO-9) in the California Energy Commission ISEGS Commission Decision (07-AFC-5C), requires a Desert Tortoise Translocation Plan. Section 1.3 of the approved Desert Tortoise Translocation Plan goals were to: 1) translocate all desert tortoises from fenced areas to nearby suitable habitat; 2) minimize impacts on resident desert tortoises outside fenced areas; 3) minimize stress, disturbance, and injuries to translocated tortoises; and 4) assess the success of the translocation effort through monitoring. The fieldwork conducted according to the EMP

framework met these goals. Tortoise handling and translocation methods were explained in detail in the EMP (Dickson and Farnsworth 2012) and are summarized briefly below.

Beginning in October of 2010, USFWS-authorized biologists located and captured tortoises within the ISEGS project boundary and placed them in quarantine pens established on the project site to ensure that none of the individuals slated for translocation exhibited signs of disease or tested positive for *Mycoplasma* species. All tortoise handling and tracking procedures were explicitly mandated and permitted by the USFWS (USFWS 2010). During spring 2012, short-distance translocated tortoises were hydrated immediately prior to release per USFWS direction. An additional hydration event was added, all short distance translocated tortoises were soaked in water for one hour during the day prior to their release.

As specified by the Revised Biological Opinion (USFWS 2011), translocated tortoises were defined as those individuals moved from quarantine pens to the release area because they had grown to have a midline carapace length (MCL) of at least 120 mm by April of 2012, when the primary translocation event occurred. Most tortoises remaining in the quarantine pens after this date were < 120 mm. Tortoises that were captured inside the project footprint and within 500 meters from the project boundary were originally referred to as “translocated-short” or “short-distance translocated” tortoises. Tortoises that were found inside the project footprint at a distance greater than 500 m from the boundary—referred to as “translocated-long” or “long-distance translocated” tortoises—were moved to an enclosed area along I-15 in late 2012. Tortoises were tracked prior to being removed and taken to the quarantine pens, which allowed identification of at least a portion of the tortoise’s previous home range prior to release. This was necessary because the Biological Opinion mandated that translocated animals be released within 500 m of their median location prior to being removed from the project site and placed into the quarantine pens. For further details on tortoise handling and translocation protocols, see the Revised Biological Opinion (USFWS 2011) and ISEGS EMP (Dickson and Farnsworth 2012).

We established three unique study groups for monitoring and analysis within the Ivanpah Valley study area: translocated tortoises, resident tortoises, and control tortoises. Translocated and resident tortoises occupied the release area (8,798 ha) surrounding the ISEGS project site (Fig. 1). As described above, the translocated group ($n = 90$ total) included short-distance translocated tortoises ($n = 73$) and long-distance translocated tortoises ($n = 17$). In 2011, surveys in the area surrounding the ISEGS project site and in control areas were conducted to locate, measure, and, as appropriate, track tortoises with very high frequency radio transmitters, with the goal of establishing a resident group and a control group (Fig. 1). The resident group ($n = 112$) referred to tortoises already living in areas to which tortoises removed from the ISEGS project site were translocated, and it was established to examine the potential influence translocated tortoises might have on patterns of habitat use (also referred to as “space use” in this report) of tortoises with an established home range. Control tortoises ($n = 149$) occupied two areas on the east side of I-15 (western area: 3,560 ha; eastern area: 4,220 ha), opposite the ISEGS site (Fig. 1). The control group (initially referred to as two groups in prior publications and reports: “control west” [$n = 115$] and “control east” [$n = 34$]) was

established as a baseline for comparison with translocated tortoises and occupied areas representative of the variability in habitat and environmental conditions that existed across the release area. Individuals from the eastern control area were monitored until May 2016.

In this report, presentation of data collection and analysis of environmental variables generally maintains the subgroups of translocated and control tortoises (as well as the resident group), unless otherwise noted. However, to maximize group-level sample size, the survival analysis used a single translocated group (i.e., short-distance translocated), a single control group that pooled tortoises from both control areas, and the resident group.

2.3 Data collection on tortoise survival and anticipated drivers

This section summarizes methods for collecting and analyzing data described in the EMP that were anticipated to potentially inform survival analyses—i.e., in fulfillment of Objective 1. Detailed field protocols are presented in [Appendix A](#), and a full list of individual and environmental variables measured or derived for proposed use in survival analyses are presented in [Appendix B](#). Additional details about how these variables were used in the comprehensive survival analyses are presented in [Section 2.4](#).

Mortality data collection

Basic data on tortoise mortality were collected over the period April 15, 2012, to May 31, 2017. Upon finding a deceased tortoise, information was recorded on date, time, location, and the apparent circumstances of its death. These data included notes of trauma on the tortoise (e.g., tooth or chew marks, missing limbs, etc.), other evidence of predators (e.g., scat, hair, tracks), sign from other tortoises, and other potential indicators that may have provided insight into the cause of death. Finally, photos were taken of the tortoise and its surroundings. In most instances, the circumstances surrounding the death of an animal were not observed; therefore, the available evidence was used to determine a *suspected* cause of death. In some cases, it was not possible to make a determination and the cause of death was categorized as “unknown.”

Movement processes: Radio tracking and space use analyses

Studies on Mojave desert tortoises have identified that differential space use patterns can occur between the sexes, and for immature versus adult tortoises (Harless et al. 2009, Nussear et al. 2012, Farnsworth et al. 2015). We compared space use patterns of translocated tortoises to those of resident and control tortoises to evaluate the success of translocation and to provide insights into drivers of survival across the study area.

Tortoises in each study group were equipped with radio transmitters (Holohil Systems Ltd., Ontario, Canada) using the method described in Boarman et al. (1998). All tortoises were tracked on an approximately weekly basis between 2012 and 2017, typically during mid-February through mid-October, between the hours of 0600 and 1800, regardless of prevailing weather conditions. Outside of the active season, tortoises were tracked every other week, in accordance with the Revised Biological Opinion (USFWS 2011). During each encounter, biologists recorded geographic (Universal Transverse Mercator [UTM]) coordinates and

information about a tortoise's location relative to landscape features (e.g., burrow, shrub, open area), and its activity (e.g., walking, basking, mating). Transmitters were replaced when the factory-calculated battery life remaining on a given transmitter reached a minimum of 10%.

Within each active season and study group, we derived estimates of space use for each tortoise using all encounters obtained in that season (see also Farnsworth et al. 2015). Briefly, we used a kernel density estimation approach (Worton 1989) on data for all individuals with ≥ 25 encounters during an active season, which was meant to balance the selection of an appropriate minimum number of encounters with removal of individuals from the dataset. We used the Geospatial Modeling Environment (Beyer 2012) in ArcGIS (version 10.3, Esri, Redlands, CA, U.S.A.) to calculate 95% fixed-kernel density estimates and resultant utilization distributions at a 30-m pixel resolution. These variables describe a three-dimensional probability density function, such that they exhibit higher probability mass (i.e., reflect higher space use intensity) in portions of the surface having a greater density of encounters. Throughout this report, we also refer to the area under the utilization distribution as the home range of an individual. Because tortoise encounters occurred on a weekly basis, we were not concerned about potential issues of spatial or temporal serial autocorrelation. We used ArcGIS to relate individual encounters to kernel density estimates (i.e., utilization distribution pixels) by intersecting each utilization distribution with the locations used to derive it.

In addition to the utilization distribution analyses, we used the encounter data to create a proxy for movement based on distance and elapsed time between encounters (after Farnsworth et al. 2015). We calculated the straight-line distance between consecutive encounters for each tortoise using UTM coordinates, and then scaled this distance by the number of days between consecutive encounters to obtain a movement rate (meters per day).

We also explored how space use patterns, including burrow use and burrow-switching distance, were related to individual-level predictor variables and environmental predictor variables operating at multiple scales (for details, see Sadoti et al. 2017). For example, we analyzed tortoise utilization distributions in relation to remotely sensed (e.g., aerial photograph and satellite-based information) data that quantified static habitat features relevant to tortoise life history, such as shrub and wash presence and density across the study area. Resultant, derived data layers were used for analyses presented in Farnsworth et al. (2015) and Sadoti et al. (2017).

Local-scale environmental variables

Local-scale environmental variables can be important proximate influences on desert tortoise movements, space use patterns, and fitness. For example, shrub type and density, as well as burrow availability, provide critical shelter from extreme environmental conditions and predators. To assess local scale environmental variables, we performed vegetation surveys to measure and quantify key vegetation attributes, including cover, height, and species composition of shrub vegetation across the study area (see Appendix A, [Sections 7.1](#) and [7.2](#) for protocols).

Overall, 100 x 100-m vegetation plots ($n = 32$) were sampled each year in spring and fall from 2012 through 2016 (Fig. 2). A change in sampling protocol occurred from 2012 to 2013 to increase the sample size from 400 points per plot to 1,000 points per plot to enhance overall efficiency and increase sample sizes for analyses. Therefore, the species counts reported for 2012 are not directly comparable to the 2013–2015 data. In addition, sampling in 2012 was restricted to the spring. Starting in 2013, we also collected data in the fall to capture the fall forage pulse from the region’s monsoon season.

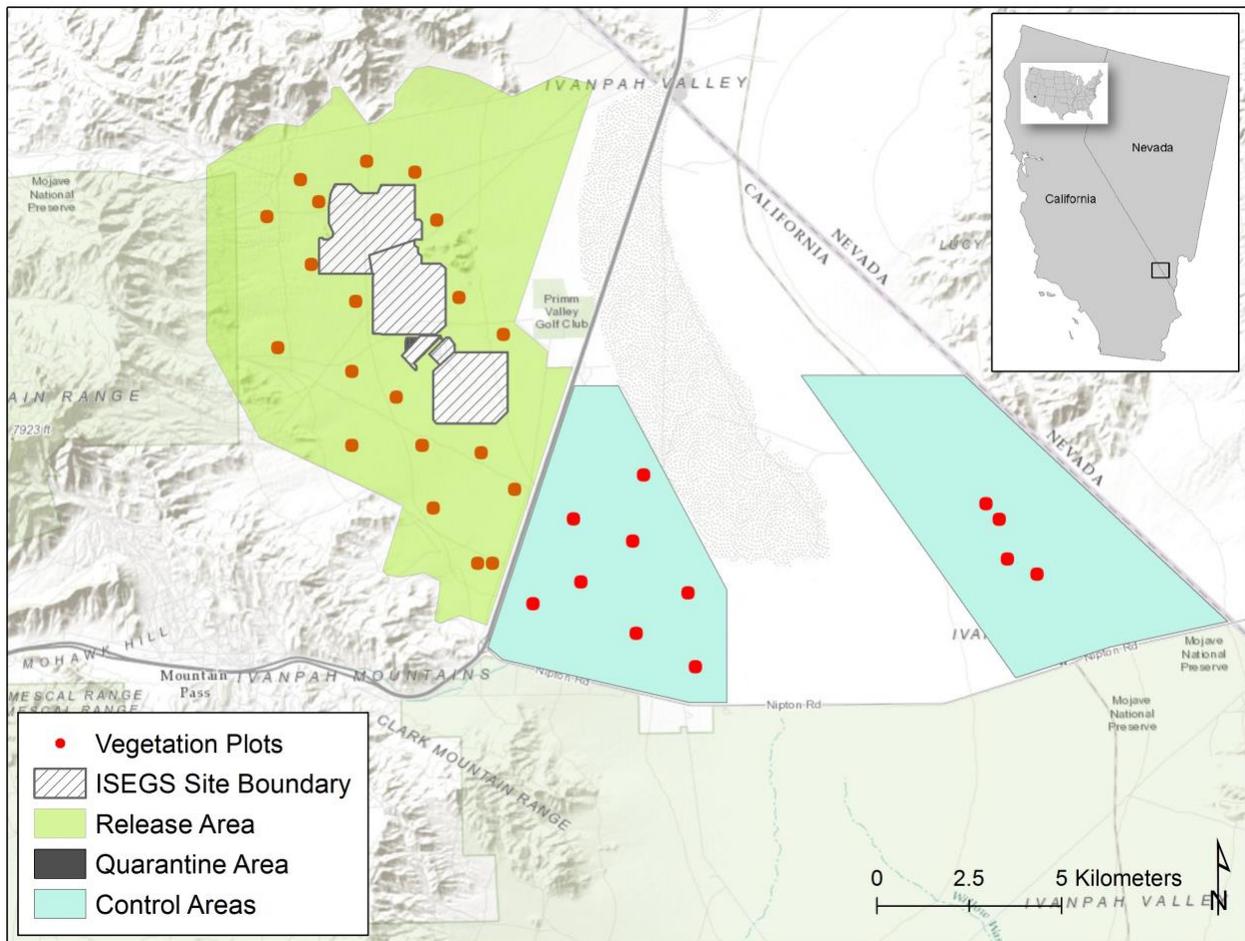


Figure 2. Vegetation monitoring plots within the Ivanpah Valley study area.

To capture annual and seasonal microclimatic variation, 18 rain gauges were installed in August of 2012 and six automated weather stations were installed across the study area in May of 2013 (Fig. 3) (see [Appendix A, Section 7.2](#) for protocol). All weather stations began to download data consistently on May 29, 2013, and recorded weather variables at one-hour increments. The stations collected data on temperature and precipitation at fifteen minute intervals, as well as data on humidity and other weather-based parameters. Weather station data were downloaded 3–4 times per year.

Local-scale environmental variables were not used as standalone predictor variables in survival analyses because these data could not be reasonably linked to the individual tortoise utilization distributions used to estimate survival ([Appendix B](#)). However, these variables were useful for verifying the accuracy of remotely sensed data, which were used to derive dynamic, landscape-scale predictor variables that were ultimately used in our survival models (see [Section 3.2](#) and [Appendix B](#)).

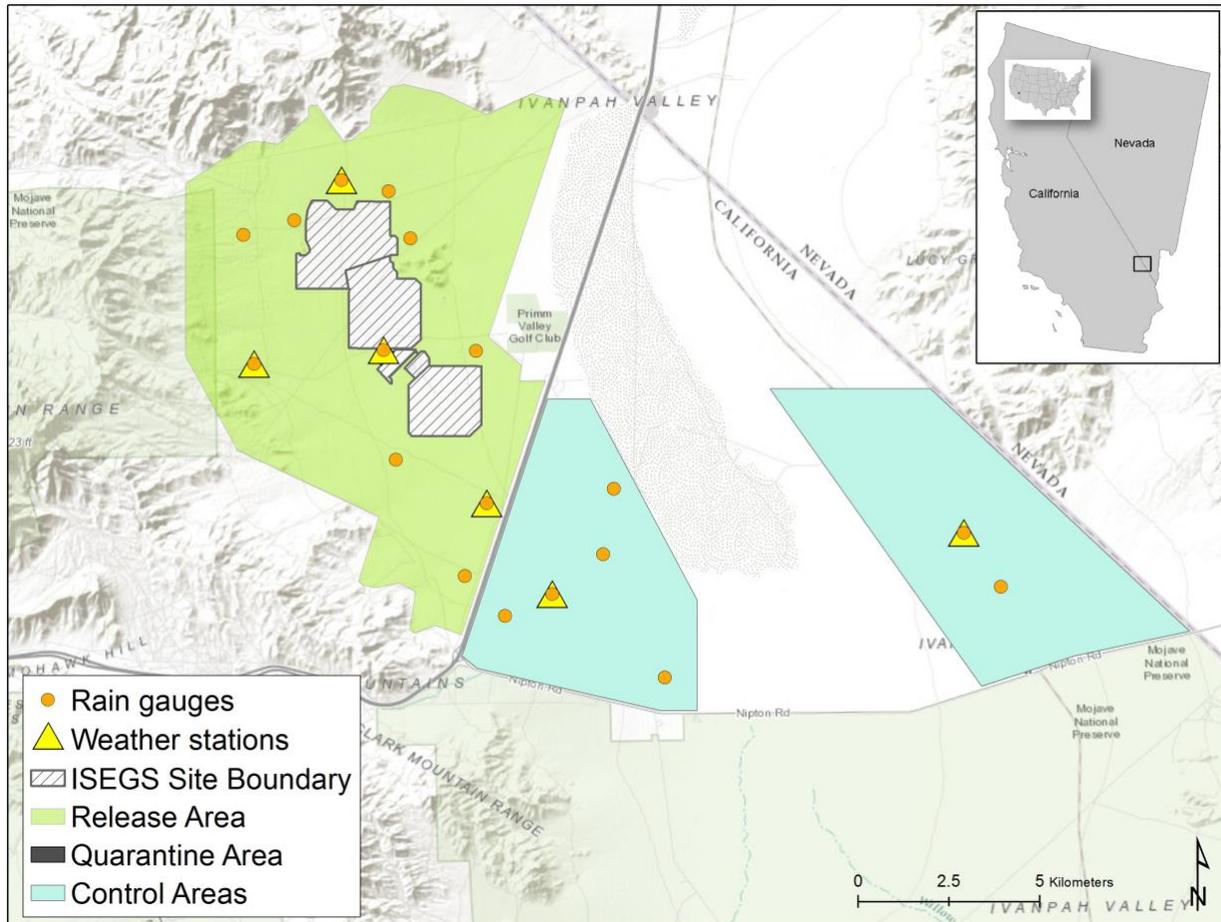


Figure 3. Rain gauges and weather stations within the Ivanpah Valley study area.

Landscape-scale environmental variables

To quantify landscape-scale variables hypothesized to influence tortoise survival and other demographic or behavioral parameters, we derived multiple data layers developed from remotely sensed data (high-resolution aerial photography and satellite-based information), including shrub density, wash density, the normalized difference vegetation index (NDVI; an estimate of vegetation cover or forage availability), and temperature and precipitation (see [Section 2.4](#), [Appendix B](#) for full list of environmental variables measured or derived for this study). We also obtained or derived data layers describing elevation, slope, aspect, topographic roughness, soil type and texture, road and fence density, and burrow density. Detailed descriptions of the data and methods used to derive our landscape-scale variables can be found

in Farnsworth et al. (2015) and Sadoti et al. (2017). The subset of landscape-scale variables used in the survival analyses are further described below (Sections [2.4](#) and [3.3](#), and [Appendix B](#)).

Thermal assessments

To monitor post-translocation thermoregulatory behavior and its relationship to survival, a subset of radio-telemetered tortoises ($n = 236$; 74 translocated, 75 residents, and 87 controls) was also fitted with temperature data loggers (Thermochron iButton® DS1922L, Maxim Integrated, San Jose, CA; width 1.6 cm, height 0.5 cm, weight < 3 grams) to record temperatures experienced by tortoises (see [Appendix A, Section 7.3](#) for attachment protocol). We concurrently recorded ambient temperatures and temperatures in refuges (i.e., burrows, shrubs, and other cover sites) to enable comparison between environmental temperatures and those experienced by tortoises. Thus, we were able to compare thermal conditions experienced by animals in different study groups, with a focus on whether translocation impacted behavioral thermoregulation (work described in Brand et al. 2016).

Brand et al. (2016) focused on two predictor variables: average daily maximum temperatures and the length of time that tortoises spent $\geq 35^{\circ}\text{C}$ per day. This $\geq 35^{\circ}\text{C}$ threshold reflects the putative preferred maximum temperature based on previous studies of tortoise behavioral thermoregulation and thermal constraints on tortoise activity (Zimmerman et al. 1994; Sieg et al. 2015). We integrated these same thermal predictor variables into the survival modeling framework (see below) in an effort to control for thermal conditions when testing for an effect of translocation on tortoise survival ([Section 2.4](#)).

Health assessments and pathogen transmission

We conducted bi-annual (May and September) health assessments beginning in spring 2012 to quantify general patterns in health status among tortoises and study groups (see [Appendix A, Section 7.4](#) for protocol). We conducted visual health assessments that included, but were not limited to, documenting clinical signs of upper respiratory tract disease (i.e., discharge from nares and/or eyes, swelling and/or redness of eyes, lethargic behavior, poor body condition), shell disease (i.e., lesions typical of cutaneous dyskeratosis, peeling laminae or scutes, other lesions of the bone or scute, mold, and fungus), and trauma (i.e., missing or other trauma to the limbs and trauma to the shell). We used protocols developed by the USFWS to evaluate body condition scores (Lamberski 2013) and test whether tortoise condition varied among study groups and over time. Blood and oral samples were also collected and tested via an enzyme-linked immunosorbent assay (ELISA) at the University of Florida, a method that detects exposure to the bacteria *Mycoplasma agassizii* and *M. testudineum*. Since implementation of the EMP began in April, 2012, 4,158 samples have been collected for the purpose of ELISA testing, including samples from individuals in each study group. We report the results of ELISA testing in this report, but—as described in Section 3.2—there were too few ELISA-positive tortoises to include infection status as a predictor variable in survival analyses.

Anthropogenic impacts: metals toxicity, barriers, noise and vibration

Metals toxicity

Because potentially toxic substances have been found in higher concentrations in sick tortoises versus controls (Jacobson et al. 1991), we hypothesized that environmental contaminants would negatively affect tortoise health and survival (Chaffee and Berry 2006). Between 2013 and 2015, we sampled tortoise blood using a novel “dried blood spot” technique (see [Appendix A, Section 7.5](#)). Samples were collected from tortoises across the study area from fall 2013 through spring 2015 to measure concentrations of heavy metals, including iron, arsenic, cadmium, mercury, lead, selenium, thallium, titanium, and uranium. This method had significant advantages because it was efficiently implemented during standard health assessments and was non-invasive relative to typical tissue sampling procedures for metal concentration analyses (Appendix A, Section 7.5). However, metal concentrations in blood are ephemeral and—when present—reflect recent exposure or remobilization from storage in the liver for reproduction (Grillitsch and Schiesari 2010). Therefore, we acknowledge that using blood as the tissue of analysis posed a tradeoff between sampling efficiency and reduced tortoise handling and the ambiguous temporal signal of metal concentrations in blood relative to other tissues (e.g., liver, muscle, bone, scute) (Grillitsch and Schiesari 2010).

Samples collected during necropsies that could be preserved (including bone, scute, liver, lung, kidney, and muscle) were also submitted for analysis (see [Appendix A, Section 7.5](#) for sampling protocols related to metal concentrations). Finally, to quantify metal toxins in the tortoises’ habitats, soil and plant samples were also collected (in 2012 and in 2013 and 2014, respectively) from across the study site for 29 elements, including heavy metals, as well as essential and trace elements. However, tissue, soil, and plant data were not included in survival analyses because they were not expected to be directly related to tortoise survival.

Anthropogenic barriers, noise, and vibrations

High-speed road networks, including highways and freeways, can be detrimental to native species of wildlife at individual and population levels (Forman et al. 2003) by creating barriers to movement and increasing stress through effects such as noise propagation (Wikelski and Cooke 2006, Eigenbrod et al. 2009). To quantify the disturbance potential of I-15 and surrounding roads with heavy vehicle traffic, we measured road noise and vibration at 80 points within vegetation monitoring plots, along with transects from I-15. We also measured noise emitted from the three ISEGS towers during operational and non-operational conditions, as well as background noise levels within the project area (see [Appendix A, Section 7.6](#) for protocols).

We used the SPreAD-GIS software package (Reed et al. 2010) to predict noise propagation across the study area due to vehicle traffic, construction, and testing of the ISEGS towers in 2013. In 2013, Ivanpah (tower) 1 was constructed and being tested, and Ivanpah (towers) 2 and 3 were being constructed. Thus, the noise that was measured was indicative of construction and not operations. In addition, there were multiple sound sources reported around the towers, including heavy equipment. To estimate noise propagated from each tower, we used 90th percentile values of weekly noise measured at each tower from April through October 2013. We used maximal values because measurements were taken ~200-m away from the towers, whereas SPreAD-GIS assumes that measurements are taken 15 m from the sound

source. We used average weather measurements (temperature, relative humidity, wind speed, wind direction, and cloud cover) taken at the same locations in 2013 as input into SPreAD-GIS. To estimate noise propagated from I-15, we averaged noise measurements taken at four sample locations at a distance of 15 m from the interstate. We assumed that this was constant for the I-15 corridor passing through the study area and throughout 2013. We used average April through October 2013 weather variables from the single weather station closest to I-15. Desert tortoise hearing is apparently most sensitive to sounds between 125 and 750 Hz (Bowles et al. 1999). The SPreAD-GIS tool models noise propagation in eight discrete frequency bands within the range 400 – 2000 Hz, so average noise from the towers and I-15 was modeled at three discrete frequencies: 400, 500, and 630 Hz.

Data on tortoise space use intensity in 2013 were compared to our modeled estimates of noise propagation in that year. Noise propagation estimates (i.e., log-transformed kernel density estimate values) were integrated into an analysis that had originally been designed to test for an effect of individual-level (e.g., sex, translocation status) and environmental (e.g., shrub and wash density, burrow use) predictor variables on space use intensity (as detailed in Farnsworth et al. 2015), and to evaluate what additional explanatory power these noise sources contributed to an analysis of tortoise space use in 2013. Within an information-theoretic framework (see [Section 2.4](#) for more details), we used a linear mixed-effects model structure and an information-theoretic approach (Burnham and Anderson 2002) to estimate and compare the determinants of space use intensity, given the log-transformed kernel density estimate values and explanatory variables described above. To compare the relative strength of association between demographic and environmental variables and the noise propagation estimates, we used multi-model inference (i.e., all-subsets modeling, as opposed to a smaller candidate set; see below) to compute model-averaged regression coefficients, unconditional standard errors, and cumulative Akaike's information criterion (AIC) weights of evidence (ranging from 0 to 1.0) as measures of relative variable importance, where higher weights indicated greater importance (Burnham and Anderson 2002).

Several anthropogenic variables were included in the survival analyses described below. Approaches for including data on metal concentrations in the survival analyses also are further described below (Sections [2.4](#) and [3.2](#)). Road and fence densities (described in Sadoti et al. 2017) were included in the survival analysis to examine potential effects on survival of anthropogenic barriers to tortoise space use and direct mortality from vehicle collisions. However, noise and vibration were not included in this analysis because they were expected to be potential influences on proximate tortoise behavior and space use, but not expected to be directly related to tortoise survival.

2.4 Comprehensive survival analysis

Based on the principal objectives of the EMP, we considered survival probability to be the primary metric for evaluating the effects of translocation. At the request of federal agency biologists, we used the tortoise tracking data and a known-fate model (White and Garrott 1990) to estimate annual and cumulative survival probabilities. We also used the known-fate model

to evaluate the effects of several variables on survival probability. Throughout our description of the survival analyses and the associated results, we refer to these variables as predictor variables. A known-fate model is used to estimate survival probability when marked individuals can be located with certainty (e.g., when animals are radio-telemetered). To estimate annual survival probability, the model requires yearly data on the fates (alive or dead) of individuals throughout the duration of the study, and we used the data collected during annual spring health assessments as the focal sampling period (even though alive/dead status was known for other times of year). Therefore, estimates of survival probability are for the period from May in a given year to May the following year. We refer to these periods as survival intervals. We had data from every spring health assessment from 2012 to 2017 and, therefore, were able to estimate survival probability over five intervals. In addition to estimating annual survival probability, we derived estimates of cumulative survival probability (i.e., the probability a tortoise survives from May of 2012 to May of 2017 [five years]).

We performed analyses on two datasets: 1) tortoises with MCL between 120 and 160 mm (hereafter, 120/160 MCL dataset), and 2) tortoises with MCL > 160 mm (hereafter, > 160 MCL dataset). Tortoises were assigned to a particular size class—120/160 or >160—based on their MCL measurement at the beginning of a survival interval. For example, a tortoise with an MCL of 130 mm during the health assessment in the spring of 2013 was included in the 120/160 dataset. However, if this tortoise grew to 170 mm by the health assessment in the spring of 2015, it was included in the > 160 dataset thereafter. As described above ([Section 2.2](#)), we used three study groups in the survival analyses: a resident group; a control group, which included tortoises from both control areas; and a translocated group, which included only short-distance translocated tortoises. Only short-distance translocated tortoises were used in survival analyses because they were placed into the release area, whereas long-distance translocated tortoises remained in the enclosed area near I-15. Tortoises from the eastern control area were not monitored after May 2016; thus, survival probabilities for these tortoises were not estimated for the final interval (May 2016 to May 2017).

We used an information-theoretic approach (Burnham and Anderson 2002) to draw inferences from the data described above. Given the data, this approach includes the following steps: 1) developing a ‘competing’ set of hypotheses regarding the causes of variation in the response variable (e.g., survival probability); 2) converting these hypotheses into mathematical models (the set of models is referred to as the ‘candidate set’); and 3) using an information criterion to identify the model or set of models from which inference should be made. We used AIC adjusted for small sample size (AIC_c) to compare models. When interpreting a set of candidate model results, the model with the lowest AIC_c value has the most support (and highest ‘rank’), although other models may also be supported, such as those within 8 AIC_c units of the highest-ranked model (see Anderson 2008). We used this common guideline in evaluating the models in each of the candidate sets of models described below.

As an additional step to inference, we compared models that included effects of predictor variables to a model with no predictor variables (a ‘null’ or ‘intercept-only’ model; Anderson 2008) and examined 95% confidence intervals around estimates of regression coefficients. If a

model with effects of one or more predictor variables had a lower ranking than the model with no predictor variables, we concluded that the variable did not affect survival. Similarly, if the 95% confidence intervals around estimates of regression coefficients included 0, we concluded that the effect was negligible. Because we used an information-theoretic approach to inference, we did not rely on arbitrary alpha levels or p -values for inferences about predictor variables.

Data for the development of predictor variables were not available for all tortoises in all years. For example, as noted above, a subset of radio-tracked tortoises was fitted with temperature data loggers. Therefore, the dataset for evaluating effects of temperature on the survival probability of tortoises had fewer individuals than the dataset for evaluating effects of group on survival probability. To maximize the number of tortoises in each analysis, we developed different datasets to evaluate the effects of predictor variables on survival. We separately analyzed each dataset using the following predictor variables (see [Appendix B](#) for more details):

- Analysis 1: ‘individual-level’ predictor variables (study group [control, resident and translocated tortoises; see Section 2.1 for descriptions of groups], sex, and size [MCL]),
- Analysis 2: all the predictor variables in Analysis 1 plus body condition score
- Analysis 3: all the predictor variables in Analysis 1 plus the toxicity predictor variables (iron, selenium, and lead concentrations in tortoise blood)
- Analysis 4: all the predictor variables in Analysis 1 plus the thermoregulation predictor variables (average daily maximum temperature during the active season, and the amount of time tortoises are exposed to temperatures $\geq 35^{\circ}\text{C}$ during the active season)
- Analysis 5: all the predictor variables in Analysis 1 plus the landscape-scale predictor variables (e.g., home range area, shrub density).

Analysis 1 had the highest sample size in terms of the number of tortoises enlisted in this study and available covariate data for each time individual tortoises were encountered. Therefore, of the different survival analyses in this report, we consider Analysis 1 to be the most robust evaluation of the effect of short-distance translocation on survival probability of tortoises. For Analyses 2 through 5, we shifted the focus to evaluate effects of other predictor variables and differences in the effects of predictor variables among groups. For example, in the analysis of effects of metals toxicity, we fit models to address the question: are concentrations of iron, selenium, and lead correlated with tortoise survival, and do the correlations differ among control, resident, and translocated tortoises? However, if an effect of group was supported in Analyses 2 through 5, we compared estimates of annual and cumulative survival probability among groups and provided figures of the estimates. Prior to modeling, we centered and standardized values for all continuous predictor variables based on recommendations in Schielzeth (2010). We diagnosed multicollinearity among variables using a variance inflation factor (VIF; Neter et al. 1996), and we also assessed univariate correlations using a correlation matrix. No variables had a VIF > 2.0 or a Pearson’s correlation coefficient > 0.70 . We also performed model-averaging, for annual and cumulative survival probability only, to draw inference from more than one model when multiple models were supported by the data.

For the complete list of individual-level predictor variables and environmental predictor variables, see [Appendix B](#).

Analysis 1 - Treatment group, sex, and size

In the > 160 dataset, there were 125 tortoises in the control group, 95 tortoises in the resident group, and 67 tortoises in the translocated group. We used MCL measurements from the spring health assessments in a year to predict tortoise survival probability over the following survival interval (i.e., we used MCLs from the health assessment in the spring of 2012 to model the probability of survival from May, 2012 to May, 2013). Known-fate models cannot accommodate missing data for predictor variables. Therefore, if MCL was not collected for a tortoise during a spring health assessment, we removed the data for the tortoise for that particular survival interval or used MCL data from another source. For example, in < 1% of cases, we used data from the health assessment in the previous fall as a substitute for missing MCL data, because tortoises are expected to grow very little from a health assessment in the fall to a health assessment in the following spring.

Sex was not determined for the majority (55%) of individuals in the 120/160 dataset, and a preliminary analysis indicated that the data were not adequate for estimating effects of year. Therefore, the models included in the analysis of this dataset only assessed effects of group and MCL on survival probability, as well as their interaction.

For the > 160 dataset, with the exception of five individuals, the sexes were known. We retained the five individuals in the dataset, but we classified them as unknown sex. In a preliminary analysis, we evaluated the hypothesis that survival probability differed between males, females and individuals of unknown sex. Effects of sex were not supported, and we therefore combined the sexes in the final analysis. Due to the larger sample of tortoises in the > 160 dataset, we were able to evaluate more complex models of survival probability. In addition to effects of group and MCL, we also included effects of year in the candidate set, because we hypothesized that translocation could have short-term effects on survival probability, similar to the short-term effects on movement and thermoregulatory behaviors that we previously reported (Farnsworth et al. 2015, Brand et al. 2016, Sadoti et al. 2017).

Analysis 2 - Body condition score

We used the body condition score from the health assessments (see [Section 2.3](#) and [Appendix A, Section 7.4](#)) in spring of each year to model survival probability over the subsequent interval. Because body condition score can change over short periods of time, we did not use scores from previous or subsequent health assessments as replacements for missing scores, as we did for MCL. Rather, tortoises with missing scores over an interval did not contribute to estimates of survival probability over those intervals. Body condition scores were missing for a small percentage (< 1%) of tortoises.

As discussed above, the sexes of most individuals in this dataset were not known. Therefore, the models in the analysis of the 120/160 dataset included effects of group, size (MCL), and body condition. Body condition scores ranged from 3 to 5 in the dataset, but only a single

tortoise had a score of 3 at the beginning of one interval so we combined the scores of 3 and 4. Therefore, models with an effect of body condition evaluated the hypothesis that annual survival probability of tortoises with scores of 4 (lower body condition) differed from tortoises with scores of 5 (higher body condition). The 120/160 dataset included 24 tortoises in the control group and eight tortoises each in the resident and translocated groups.

In the analysis of the > 160 dataset, we included effects of group, size (MCL), and body condition in the candidate set of models. We conducted preliminary analyses of the data and found no evidence of sex effects and excluded effects of sex in the final analysis. The range of body condition scores was 3 to 6, but over 96% of the scores were 4 (59%) or 5 (37%). Therefore, we combined scores of 3 and 4 into one category and scores of 5 and 6 into a second category, and models with an effect of body condition evaluated the hypothesis that annual survival probability of tortoises with scores of 3 or 4 differed from tortoises with scores of 5 or 6. In the > 160 dataset, there were 125 tortoises in the control group, 95 tortoises in the resident group, and 67 tortoises in the translocated group.

Analysis 3 - Toxicity

From the fall of 2013 to the spring of 2015, blood samples were collected during health assessments (see [Section 2.3](#) and [Appendix A, Section 7.5](#)). We used the metal concentration data generated from blood samples collected in the spring of 2014 and 2015 to model annual survival probability from May of 2014 to May of 2015 and May of 2015 to May of 2016. For many toxicants, concentrations were below detection limits. However, for iron and selenium, concentrations were above detection limits for all individuals, and for lead, concentrations were above detection limits for over 96% of sampled tortoises in 2014 and over 91% of tortoises in 2015. The detection limit for lead was 10 parts per billion, and we assigned a value of 0 to all individuals for which lead concentrations were below the detection limit. Iron concentrations were measured in parts per million, and selenium concentrations were measured in parts per billion.

After excluding individuals with no information on survival between 2014 and 2016 or no toxicology data, the sample size for the 120/160 dataset was very small and had no mortalities. Therefore, we did not analyze those data. For the analysis of the > 160 dataset, candidate models included the effects of group, concentrations of each of the three toxicants, and interactions between group and toxicant concentrations. Preliminary analyses indicated no effect of sex. Therefore, we did not include effects of sex in the final set of candidate models. Because an association between MCL and annual survival probability was strongly supported in previous analyses, however, we included the effect of MCL in this analysis. The > 160 dataset included 106 tortoises in the control group, 78 tortoises in the resident group, and 54 tortoises in the translocated group.

Analysis 4 - Predictor variables related to thermoregulation

We used the data from the temperature data loggers (iButtons) on radio-telemetered tortoises (see [Section 2.3](#) and [Appendix A, Section 7.3](#)) to evaluate possible effects of the thermoregulatory behavior of tortoises on survival probability.

For the 120/160 dataset, data were only available for 22 tortoises (11 control tortoises, four resident tortoises, and seven translocated tortoises) after removing individuals for which temperature data from loggers were not collected. In addition, only three years of survival data remained (2012-2013, 2013-2014, and 2014-2015). Therefore, we fit simple models to the data. The models in the candidate set included effects of MCL, the average daily maximum temperature experienced by tortoises during the active season, and the amount of time tortoises were exposed to temperatures $\geq 35^{\circ}\text{C}$ in each active season.

A higher sample size was available for the >160 dataset, so the candidate set of models included effects of the average daily maximum temperature and the amount of time $\geq 35^{\circ}\text{C}$ for each active season, as well as interactions between these predictor variables and group. We also included MCL in the models. The > 160 dataset included 84 tortoises in the control group, 73 tortoises in the resident group, and 53 tortoises in the translocated group.

Analysis 5 - Landscape-scale predictor variables

We identified landscape-scale predictor variables that represented aspects of tortoise home ranges that could affect probabilities of annual survival, including abiotic and biotic habitat characteristics (shrub, burrow and wash density, NDVI, bulk density of soils, topographic roughness), weather (precipitation and maximum temperature during active seasons), and anthropogenic impacts (road and fence density; see [Appendix B](#) for descriptions of the predictor variables used in the survival analyses).

The 120/160 dataset had a small number of tortoises. It only included 39 individuals (23 control tortoises and eight each of the resident and translocated tortoises) and only three mortalities. Therefore, we only fit models with landscape-scale predictor variables, MCL, and group effects.

With the > 160 dataset, we evaluated candidate models that included effects of each of the predictor variables, as well as a model with no predictor variables. We also evaluated models that combined the effects of predictor variables with effects of groups and MCL. Finally, to assess the possibility of differential responses to the predictor variables by tortoises in different groups, we evaluated models with interactions between group and each of the predictor variables. The > 160 dataset included 123 tortoises in the control group, 93 tortoises in the resident group, and 65 tortoises in the translocated group.

3. Results and interpretation

3.1 Summary of data collection and survival modeling results

Between spring 2012 and spring 2017, we conducted five complete rounds of bi-annual health assessments, during which every tortoise was located, its survival status verified, and its health status – including disease – reviewed. During the study, health assessments and radio tracking were performed on 352 individual tortoises (139 females, 163 males, and 50 of unknown sex),

temperature data were obtained on 270 tortoises, and heavy metal concentrations from blood samples were quantified for 284 tortoises. In the next two sections, we present results from collection and analyses of field data (Objective 1; [Section 3.2](#)), and describe and interpret the results of the survival modeling (Objective 2; [Section 3.3](#)). Here, we provide brief summaries of results of work toward each objective.

Key results related to Objective 1 (data collection and analyses of anticipated drivers of survival) included:

- In the first two months of the first active season post-translocation, translocated tortoises increased their movements, showed decreased space use intensity (i.e., exhibited movement behavior that was less concentrated in a particular location), and experienced higher ambient temperatures than did resident and control tortoises. However, space use and thermal conditions of translocated tortoises were indistinguishable from those of control and resident tortoises thereafter (Farnsworth et al. 2015, Brand et al. 2016).
- Tortoise movements across study groups were influenced by individual tortoise characteristics (e.g., size, sex), landscape features (e.g., vegetation greenness), and weather (e.g., rainfall and temperature). For example, movements increased during periods of greater rainfall and when cooler temperatures coincided with lower rainfall (Sadoti et al. 2017).

Key results related to Objective 2 (investigation of processes and scales that influence tortoise survival) included:

- Survival estimates of tortoises in the Ivanpah Valley study area (i.e., between 0.89 – 1.0) were among the highest annual survival probabilities for tortoises of any published study to date.
- Translocation did not negatively affect survival of desert tortoises in this study. Estimates of annual and cumulative survival probability were not statistically different among control, resident, and translocated tortoises for either size class. The lack of support for a difference, in spite of the high precision of the estimates, was likely a consequence of survival estimates for all groups being high (nearly 1.0). Because no statistical difference of survival of the three groups was apparent, the inference of the effects of translocation versus environmental variables during this period of study was limited.
- For tortoises in the larger size class, survival probability increased with body size across all study groups.
- In addition, survival probability decreased as home range size increased across all study groups.
- For tortoises in the smaller size class, topographic roughness had a significantly negative impact on tortoise survival across all study groups.
- Collectively, translocations had short-term impacts on space use and the thermal conditions experienced by desert tortoises at the ISEGS, but those impacts were not apparent one year later, and translocations did not appear to have any negative

impacts on the condition, growth, or mortality of tortoises.

3.2 Data collection on tortoise survival and anticipated drivers

Mortality data collection

Through the end of May of 2017, mortalities of 64 radio-tracked tortoises were documented within the Ivanpah Valley study area, with the most prevalent apparent cause of death being predation by canids (Tables 1 and 2).

Table 1. Suspected cause of death for tortoises in the smallest size class (120-160 mm MCL). The number of tortoises in each category is presented for the Ivanpah Valley study area in general and for each of the study groups monitored during the period April 15, 2012, to May 31, 2017.

Suspected cause	Control		Resident	Short-distance Translocated	Long-distance Translocated	Total
	East	West				
Ants	0	1	0	0	0	1
Canid	1	3	4	1	0	9
Crushed	0	0	0	1	0	1
Eagle	0	0	0	0	0	0
Entombed	0	0	0	0	0	0
Euthanized	0	0	0	0	0	0
Hyperthermia or flipped on back	1	1	1	1	0	4
Unknown	0	0	0	0	1	1
Total	2	5	5	3	1	16

Table 2. Suspected cause of death for tortoises in the largest size class (MCL > 160 mm). The number of tortoises in each category is presented for the Ivanpah Valley study area in general and for each of the study groups monitored during the period April 15, 2012, to May 31, 2017.

Suspected cause	Control		Resident	Short-distance Translocated	Long-distance translocated	Total
	East	West				
Ants	0	0	0	0	0	0
Canid	1	3	9	6	2	21
Crushed	1	1	1	0	0	3
Eagle	0	0	0	1	0	1
Entombed	0	0	1	1	0	2
Euthanized	1	0	0	0	1	2
Hyperthermia or flipped on back	1	4	1	5	0	11
Unknown	0	2	3	3	0	8
Total	4	10	15	16	3	48

Movement processes: Radio tracking and space use analysis

Translocated tortoises had larger home ranges and lower indices of space use intensity (i.e., had less concentrated movements) compared to resident and control groups during the first two months of the first active season post-translocation, but these patterns were not present in the second season (Farnsworth et al. 2015). Similarly, average daily displacement was greater for translocated tortoises than for resident and control tortoises during the 2012 active season only; in subsequent active seasons, displacement of all study groups was similar (Fig. 4). Thus, translocation apparently resulted in one active season of increased movement, followed by space use patterns in subsequent seasons that were indistinguishable from control tortoises (see also Farnsworth et al. 2015) (Table 3).

Space use patterns among study groups varied with sex and age (Farnsworth et al. 2015). Male tortoises had significantly larger home ranges than females, while immatures had significantly smaller home ranges than either adult male or adult female tortoises. Males typically had greater home range overlap with each other than did females with other female tortoises.

Overall space use intensity increased (e.g., reflecting a smaller home range) as the number of times a tortoise was classified as being in a burrow increased (Farnsworth et al. 2015; Sadoti et al. 2017). In addition, decreasing space use intensity was correlated with increasing wash density (Fig. 5). Furthermore, within a tortoise active season, movement rate between burrows occurred at two scales in the Ivanpah study area: a local scale that represented concentrated activity around a single burrow or 'home base,' and larger scale movements that represented migrations to new home bases based on factors associated with population characteristics, weather, and human infrastructure using generalized mixed effects models (Sadoti et al. 2017) (Fig. 6). Tortoises were more likely to move among activity centers when they were further from minor roads and in the vicinity of barrier fencing, and movement between activity centers was more common during periods of greater rainfall and during periods where cooler temperatures coincided with lower rainfall. However, topographic effects (e.g., slope, roughness), local burrow density, and wash density were not significant influences on probability of movement between activity centers, even when included in models with NDVI as a predictor variable.

Table 3. Average tortoise home range (i.e., utilization distribution) area in hectares (ha) presented by study group and year. Note that in the survival analyses presented below, these study groups were pooled into three groups: controls, residents, and translocated (Sections 2.4 and 3.3). Home range area was only calculated for individuals with ≥ 25 encounters during an active season. Note also that the short-distance translocated (short-translocated below) 2012 study group had a substantially larger average home range than the other study groups, a result that was not apparent in 2013-2016. There were too few long-distance translocated (long-translocated below) 2012 encounter records to develop a home range estimate for that study group in 2012. We did not estimate home range areas for control east individuals in 2016 because they were not available for study after May 2016.

Study Group	<i>n</i>	Avg UD Area (ha)	SE
<i>2012</i>			
Control East	33	32.44	12.20
Control West	107	25.12	3.56
Resident	99	45.69	7.92
Short-Translocated (2011)	15	32.70	9.91
Short-Translocated (2012)	54	113.30	23.28
<i>2013</i>			
Control East	31	29.08	4.18
Control West	104	34.08	5.63
Resident	99	47.14	7.52
Short-Translocated (2011)	16	70.07	22.06
Short-Translocated (2012)	47	105.23	61.10
Long-Translocated (2012)	17	54.10	17.49
<i>2014</i>			
Control East	28	31.28	7.15
Control West	100	46.01	6.62
Resident	91	51.40	8.37
Short-Translocated (2011)	15	44.06	10.30
Short-Translocated (2012)	43	45.78	11.34
Long-Translocated (2012))	14	44.49	18.04
<i>2015</i>			
Control East	26	30.14	5.80
Control West	93	27.44	3.64
Resident	88	52.80	13.62
Short-Translocated (2011)	14	48.17	11.03
Short-Translocated (2012)	41	35.43	5.09
Long-Translocated (2012))	14	29.37	7.92
<i>2016</i>			
Control West	91	24.55	2.85
Resident	85	43.58	8.39
Short-Translocated (2011)	14	52.48	9.48
Short-Translocated (2012)	38	57.44	17.04
Long-Translocated (2012)	33	32.44	12.20

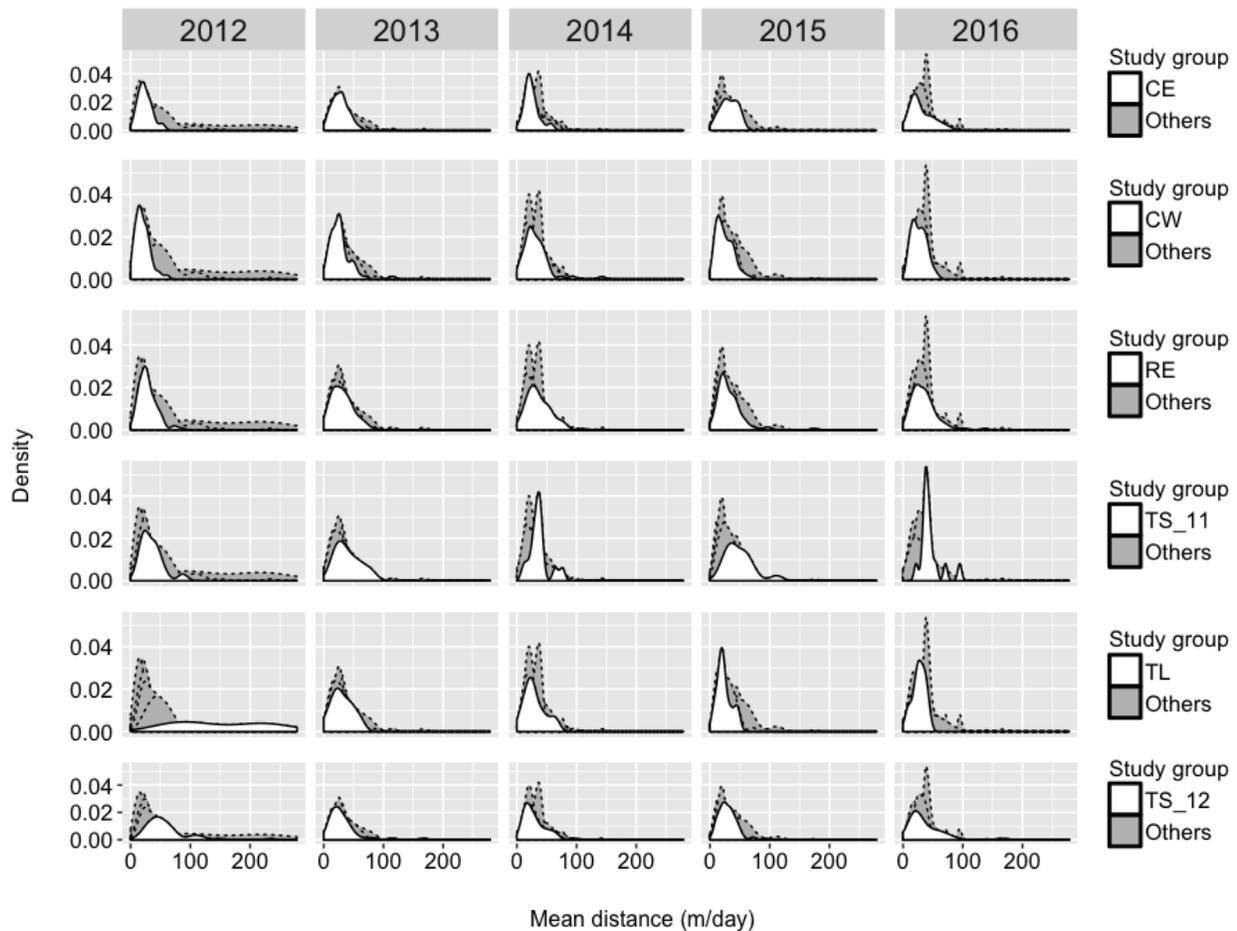


Figure 4. Density plots of the distribution of time-scaled distances (in meters, adjusted for days between subsequent encounters) for tortoises monitored during the 2012-2016 active seasons (approximately April through October). Study group abbreviations are: CE = control east, CW = control west, RE = residents, TS_11=translocated short 2011, TL = translocated long (i.e., I-15 pen), and TS_12 = translocated short 2012. Note that CE individuals were not monitored after May 2016. The distributions shown in white in each row represent one of the five study groups (indicated by the legend for each row), while shaded distributions represent all other groups. Note the difference in distributions between the 2012 translocated tortoises and all other study groups in 2012 (lower left panel), a result that was not observed for 2013 through 2016.

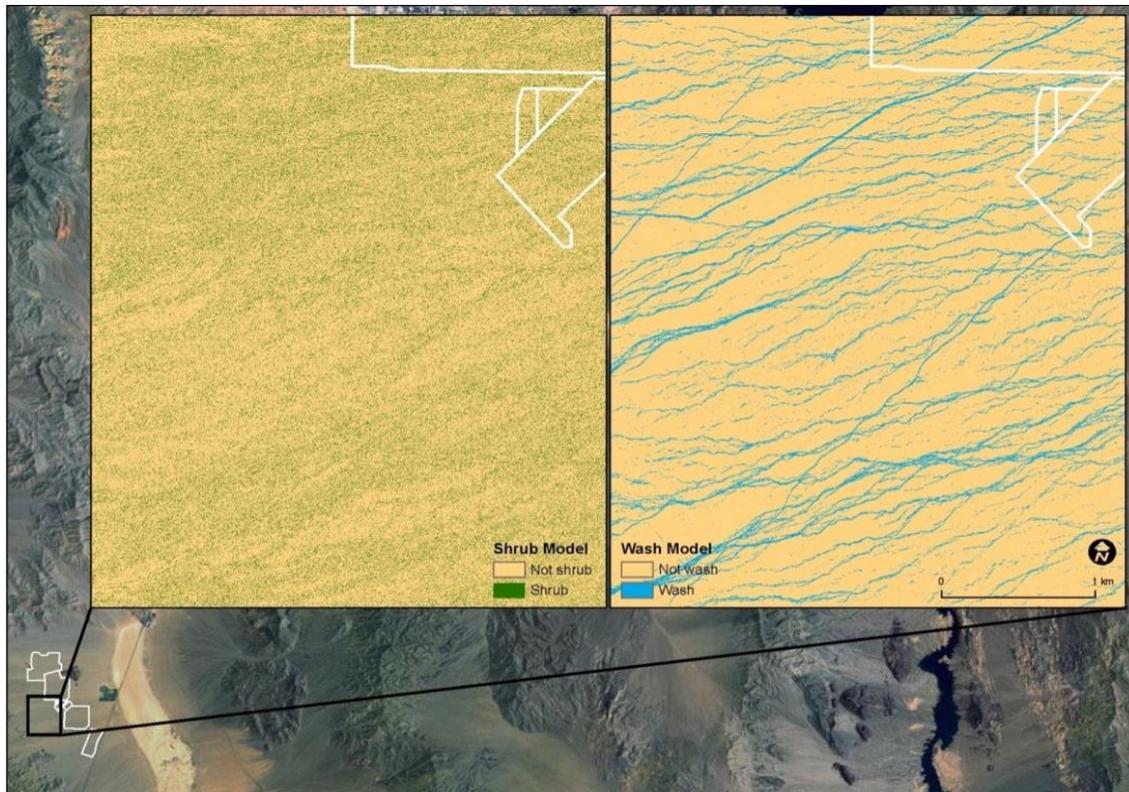


Figure 5. Examples of shrub (left) and wash (right) density layers, derived with 1-m resolution digital orthophotos and machine learning algorithms (detailed in Farnsworth et al. 2015).

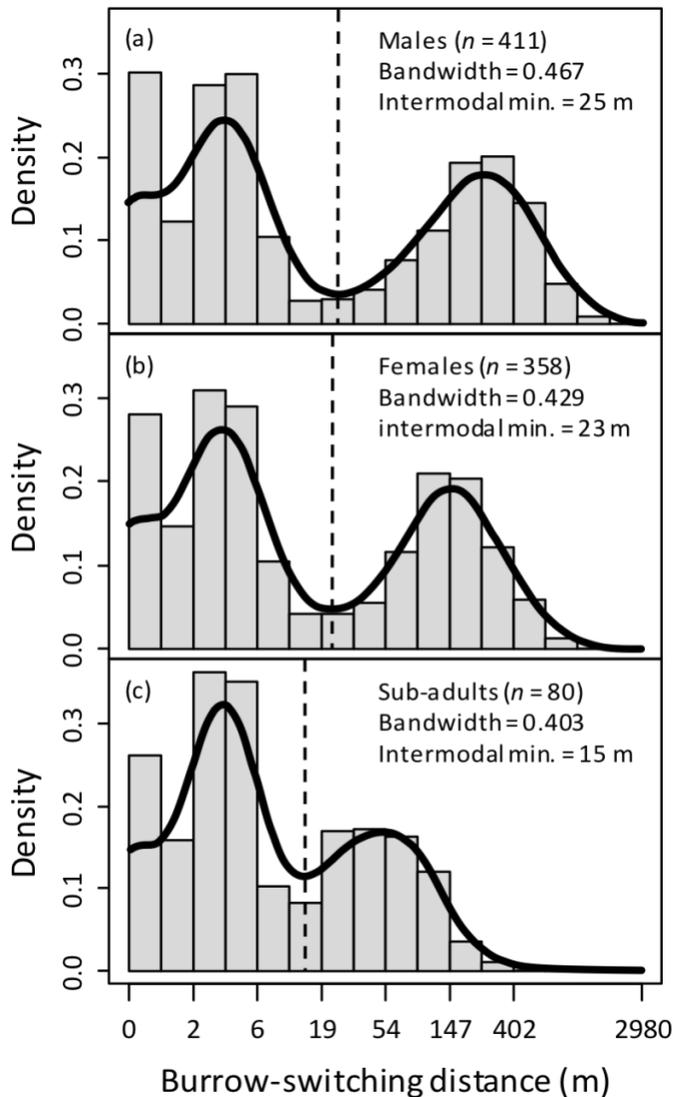


Figure 6. Bimodal distributions of burrow-to-burrow movement distances by desert tortoises within (< intermodal minima indicated by dashed lines) and between (> intermodal minima) activity centers, based on weekly (5–8 day) radio-tracking encounters in the Ivanpah Valley (from Sadoti et al. 2017). These patterns were predicted for males (a), females (b), and subadults (i.e., immatures) (c) based on factors associated with population characteristics, weather, and human infrastructure using generalized mixed effects models.

Local- and landscape-scale environmental variables

Environmental conditions with the Ivanpah Valley varied temporally and spatially. Plant species richness was generally higher in spring than fall throughout the study period (Table 4). Annual and seasonal summaries of temperature and rainfall show that temperatures were lower and rainfall more abundant in the warm seasons of 2013 and 2014 than during the subsequent two warm seasons (Tables 5 and 6). The warm season was defined as July 4 to October 14 and the

cool season was defined as October 15 to April 14 (Hereford et al. 2004). These data also show that average total rain was higher in the 2013 and 2014 warm seasons than in the 2013 and 2014 cool seasons.

Table 4. Plant species richness across 32 plots sampled in the spring of 2012 and the spring and fall of 2013 through 2016 within the Ivanpah Valley study area. Note that the sampling protocol changed between the 2012 and 2013 seasons, as described in [Section 2.3](#) of this report.

Season	Year	Mean Species Richness	Standard Deviation
Spring	2012	11.28	6.50
Spring	2013	24.28	11.40
Spring	2014	33.23	19.38
Spring	2015	32.29	17.95
Spring	2016	21.81	13.65
Fall	2013	23.03	7.17
Fall	2014	21.71	7.67
Fall	2015	11.55	6.69
Fall	2016	13.78	6.42

Table 5. Summary of temperature based on six on-site weather stations established in the Ivanpah Valley study area. The warm season was defined as July 4 to October 14 and the cool season was defined as October 15 to April 14.

Season	Year(s)	Avg Max Temp (°C)	Avg Min Temp (°C)
Warm	2013	33.05	18.95
Warm	2014	34.74	19.97
Warm	2015	35.80	20.78
Warm	2016	35.36	20.13
Cool	2013-2014	18.07	4.45
Cool	2014-2015	19.75	6.29
Cool	2015-2016	17.93	4.91
Cool	2016-2017	18.14	5.86

Table 6. Summary of rainfall based on six on-site weather stations within the Ivanpah Valley study area. The warm season was defined as July 4 to October 14 and the cool season was defined as October 15 to April 14.

Season	Year(s)	Avg Total Rainfall (mm)
Warm	2013	128.02
Warm	2014	132.08
Warm	2015	65.53
Warm	2016	30.48
Cool	2012-2013	51.56
Cool	2013-2014	78.23
Cool	2014-2015	85.85
Cool	2015-2016	95.50
Cool	2016-2017	128.02

As mentioned above, local-scale environmental variables were not used as standalone predictor variables in survival analyses. However, robust relationships between local-scale environmental variables and remotely sensed data confirmed that the latter data types could be used as dynamic predictor variables in our survival analyses. The positive correlation (Pearson correlation coefficient = 0.75) between vegetation trends observed in plot-level data (Table 4) and remotely sensed NDVI data confirmed that changes in plant cover across the study area are reflected in changes in the NDVI signal (Fig. 7), illustrating how trends in green-up translate to specific forage availability, and, by extension, individual and group-level movement and survival over time. Likewise, temperature (Pearson correlation coefficient = 0.96; Fig. 8) measured at weather stations was correlated with remotely derived measures of temperature. Monthly precipitation derived from rain gauges was similar to remotely derived measures, with differences between the two metrics varying across months (Fig. 9).

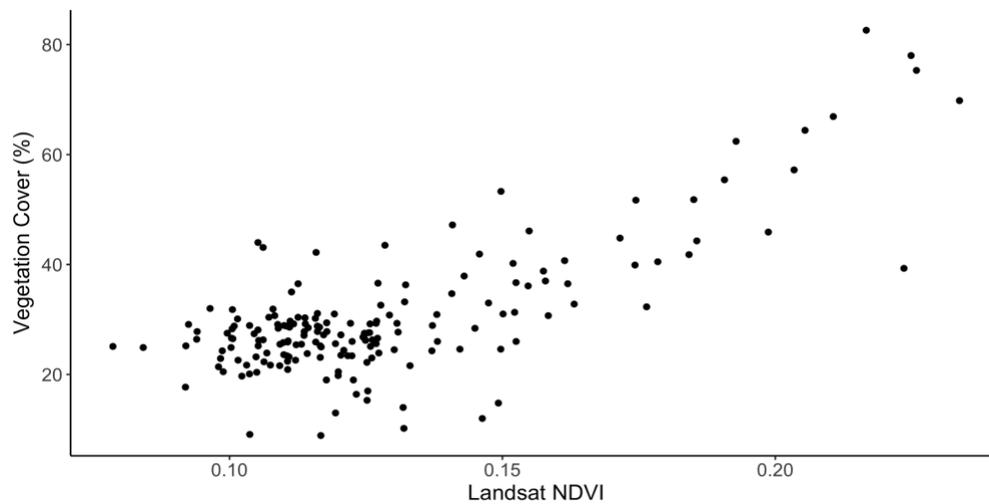


Figure 7. Scatter plot of Landsat NDVI and plot-level vegetation cover ($n = 177$) in the fall and spring of 2013-2015. The Pearson correlation coefficient between these plot-level data and remotely sensed data is 0.75, indicating that higher NDVI values correspond to greater plant cover across the study area.

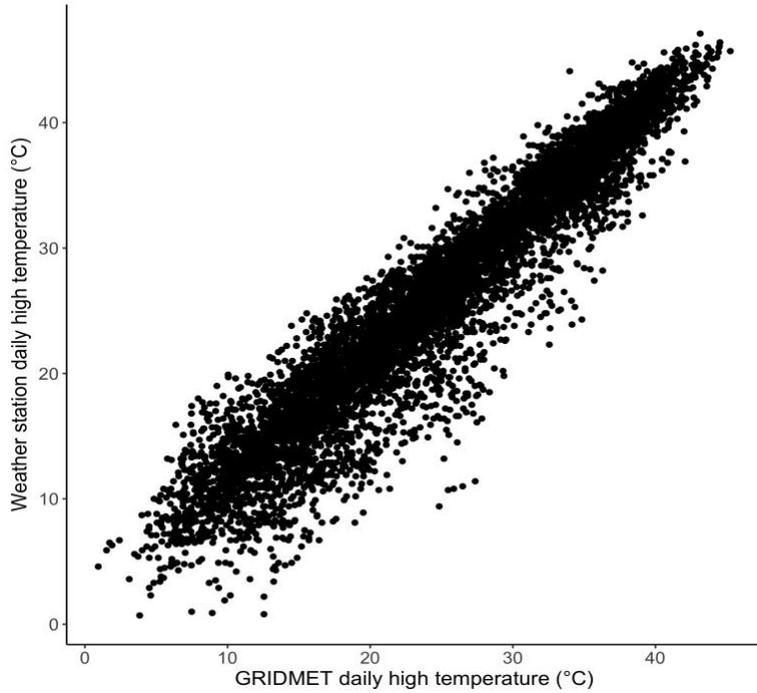


Figure 8. Scatter plot of daily gridded 4-km temperature data (GRIDMET; Abatzoglou 2011) and daily weather station data from 2013-2015 (Pearson correlation coefficient = 0.96).

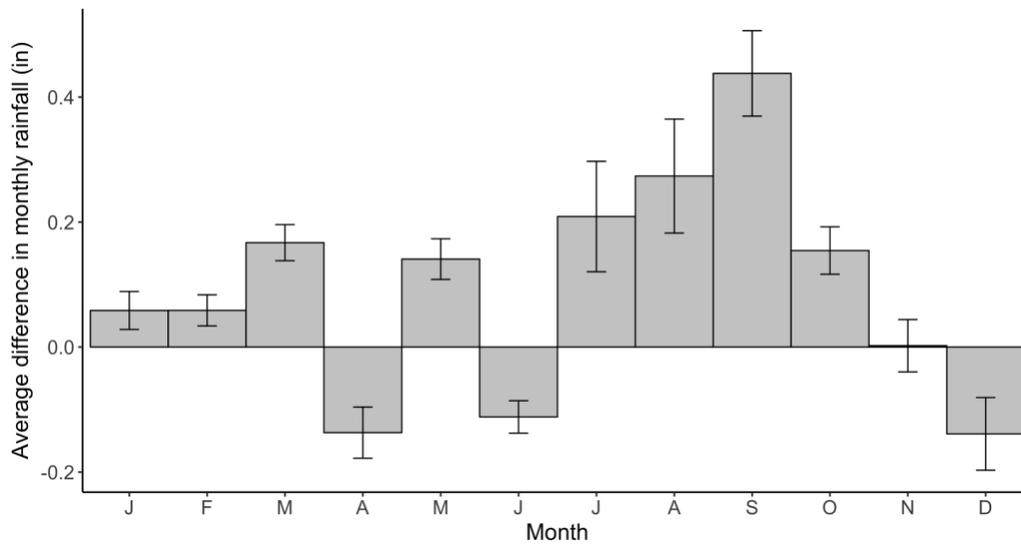


Figure 9. The average difference (error bars = standard errors) in monthly rainfall between (1) local measures derived from 18 rain gauges within the Ivanpah Valley study area, and (2) remotely-derived measures based on daily gridded 4-km rainfall data (GRIDMET; Abatzoglou 2011). Data are from 2012-2016.

Thermal assessments

Generalized estimating equations (i.e., mixed models) were used to evaluate the thermal conditions experienced by tortoises. For the period 2012-2014, maximum daily tortoise temperature increased with maximum daily ambient temperature, then leveled off at highest ambient temperatures, indicating that tortoises in all three study groups—translocated, resident, and control—were able to behaviorally thermoregulate at these high temperatures (Brand et al. 2016).

We also found that the thermal conditions experienced by translocated tortoises were more extreme initially, but that the differences between the translocation group and the other study groups diminished over time (Fig. 10). During the first month post-translocation, translocated tortoises were exposed to significantly higher average maximum daily temperature (37.1°C, 95% CI: 36.7-37.5°C) than resident (34.8°C, 34.2-35.4°C) and control (35.9°C, 35.9-36.2°C) tortoises; those differences were smaller in the second month, with no differences thereafter during the first active season (Brand et al. 2016) (Fig. 10). Similarly, during the first month, translocated tortoises also spent more time per day above 35°C (138 minutes, 95% CI: 120-155 mins) than resident (51 mins; 35-67 mins) and control (57 mins; 46-69 mins) tortoises, with smaller effects in the second and fourth months, and no differences in subsequent years (Fig. 10). Despite these initial differences, the maximum temperature experienced by translocated tortoises in the first month was within the range of temperatures experienced by tortoises in the other study groups.

Thermal conditions varied by sex and age, in addition to translocation treatment. During the first year, adult translocated males had higher temperatures than females, which Brand et al. (2016) suggested was perhaps due to the establishment of larger home ranges or a greater number of burrows used by males during summer (Rautenstrauch et al. 2002, Harless et al. 2009). Resident immature tortoises had higher temperatures than translocated or control tortoises, which could suggest displacement or increased movements of resident immature tortoises following introduction of translocated tortoises to their home ranges; however, mechanisms are unknown and the sample size of resident immature tortoises was low ($n = 5$; Brand et al. 2016). As described by Brand et al. (2016), initial differences in thermal conditions among groups may have converged over time because tortoises were released with time to find or construct burrows during cooler environmental temperatures in spring (Henen 1997, Nussear et al. 2012).

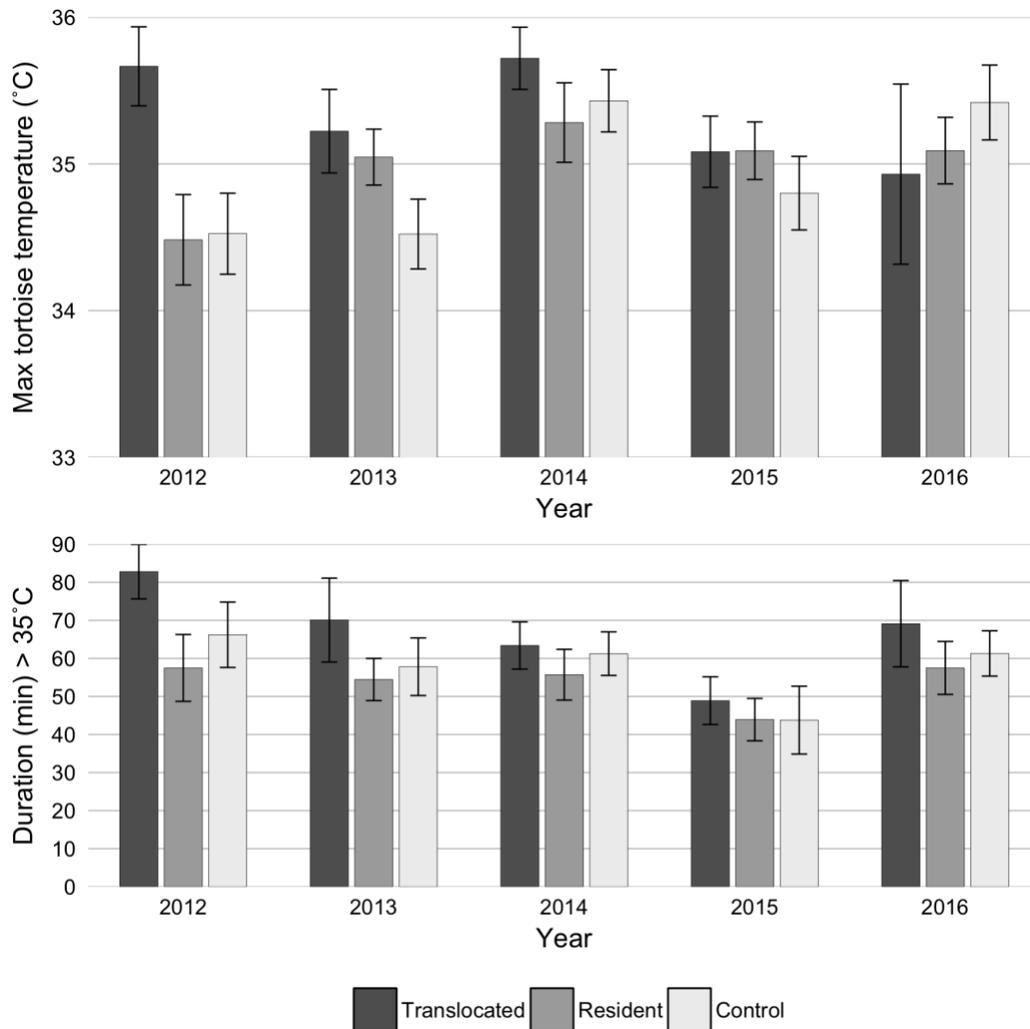


Figure 10. Mean maximum daily temperatures (top) and mean daily duration spent $\geq 35^{\circ}\text{C}$ (bottom) for translocated (short- and long-distance; $n = 74$ total), resident ($n = 75$), and control (east and west; $n = 85$ total) tortoises during active seasons between 2012-2016. (Note: Brand et al. (2016) showed similar data and trends, but only for 2012-2014 and the translocated group only included short-distance translocated tortoises.)

Health assessments and pathogen transmission

Tortoise body condition was similar among study groups. For example, the average body condition score calculated for each study group in each year (April 2012 through September 2016) varied between 4.25 and 4.94, suggesting little variability across study groups or over time. Based on the USFWS index (Lamberski 2013), these estimates suggest that tortoises in all study groups, on average, were in good condition. Over the long-term, tortoises in all groups exhibited increases in the average percent change in body condition and carapace length, further indicating that translocated individuals did not experience a decline in body condition over time (Brand et al. 2016).

Our health assessments detected evidence of tortoise exposure to the bacteria *M. agassizii* and *M. testudineum*. Only two tortoises (#646 and #05) tested positive for both *Mycoplasma* spp. bacteria (Tables 7 and 8).

Through May 2017, 18 individual tortoises tested positive for *M. agassizii* over the 11 health assessment survey occasions, with a total of 32 ELISA-positive samples (Table 7). Some individuals tested positive on more than one occasion. There were 14 positive tests (nine individuals) among translocated tortoises, 15 positive tests (seven individuals) among control tortoises, and three positive tests (two individuals) among resident tortoises. In 2012, there appeared to be a cluster of test-positive control tortoises; however, that pattern did not persist (Fig. 11). For individuals testing positive on consecutive health occasions, it could not be determined if they remained antibody positive from one exposure event or if repeated exposures occurred between seasons. However, there were notable exceptions. For example, tortoise #552 tested positive in the spring and fall of 2013, but then was test-negative until the spring and fall of 2015, when it seroconverted (i.e., tested positive again), possibly indicating a new exposure event. Tortoise #554 (a control female) exhibited a similar pattern (Table 7).

For *M. testudineum*, 15 individual tortoises tested positive for *M. agassizii* over the 11 health assessment survey occasions, with a total of 22 ELISA-positive samples (Table 8). There were nine positive tests (three individuals) among translocated tortoises, eight positive tests (seven individuals) among control tortoises, and five positive tests (five individuals) among resident tortoises. Two tortoises (#613 and #05) had repeated test-positive samples.

The prevalence of infected tortoises in the Ivanpah study area (maximum 3.2% of tortoises sampled during each health assessment, typically between 0% and 2%) was low compared to prevalence documented at other sites during previous studies (Jacobson et al. 2014). This low prevalence might be due to isolation from other tortoise populations due to surrounding anthropogenic and geographic features such as I-15, the Clark Mountains, and Las Vegas. As mentioned in [Section 2.3](#), ELISA test status was not included as a predictor variable in survival estimates due to the relative infrequency of ELISA-positive tortoises.

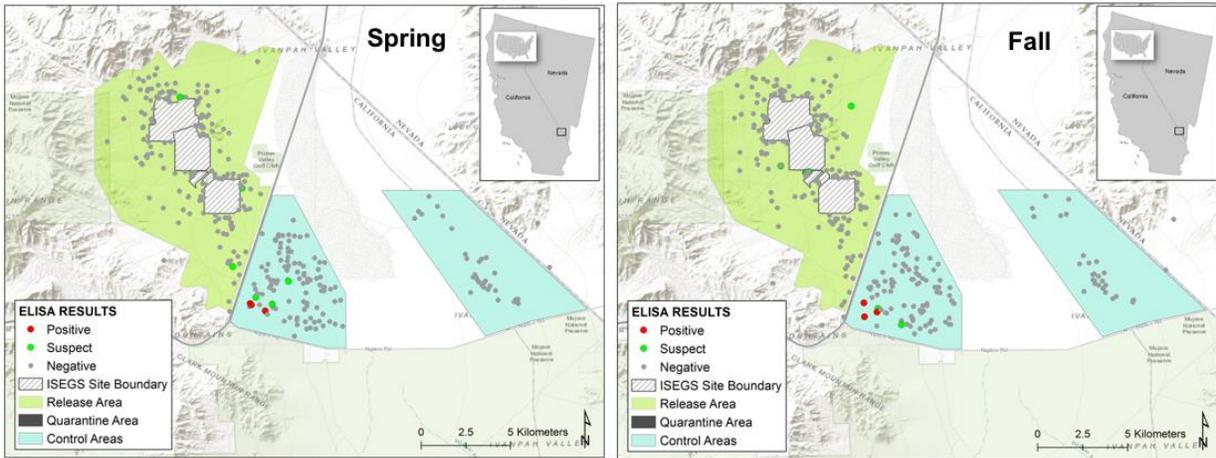
Table 7. Prevalence of *M. agassizii* (i.e., percentage of tortoises that tested positive, shown with number positive and total number sampled) among tortoises enrolled in the EMP across seasons and years and identification of ELISA test-positive individuals. Sex and group are indicated as follows: F = female, M = male, J = juvenile, CW = control west, TS₁₁ = translocated-short 2011, R = resident, TS₁₂ = translocated-short 2012.

Season	Prevalence	Tortoise ID (sex, study group)
Spring 2012	0.9% (3/343)	554(F,CW), 549(M,CW), 646(F,CW)
Fall 2012	0.8% (3/368)	546(M,CW), 549(M,CW), 646(F,CW)
Spring 2013	1.7% (6/363)	06(M,TS ₁₁), 172(M,R), 546(M,CW), 552(M,CW), 564(F,TS ₁₂), 646(F,CW)
Fall 2013	0.8% (3/375)	94(M,TS ₁₂), 552(M,CW), 647(J,CW)
Spring 2014	0.0% (0/389)	
Fall 2014	0.5% (2/390)	08(F,TS ₁₁), 223(TS ₁₂)
Spring 2015	1.7% (5/288)	05(M,TS ₁₂), 08(F,TS ₁₁), 113(M,R), 114(M,TS ₁₁), 552(M,CW)
Fall 2015	1.6% (6/372)	05(M,TS ₁₂), 62(M,TS ₁₁), 100(M,TS ₁₁), 113(M,R), 552(M,CW), 623(F,CW)
Spring 2016	0.4% (1/276)	05(M,TS ₁₂)
Fall 2016	0.4% (1/243)	05(M,TS ₁₂)
Spring 2017	0.8% (2/239)	05(M,TS ₁₂), 554(F,CW)

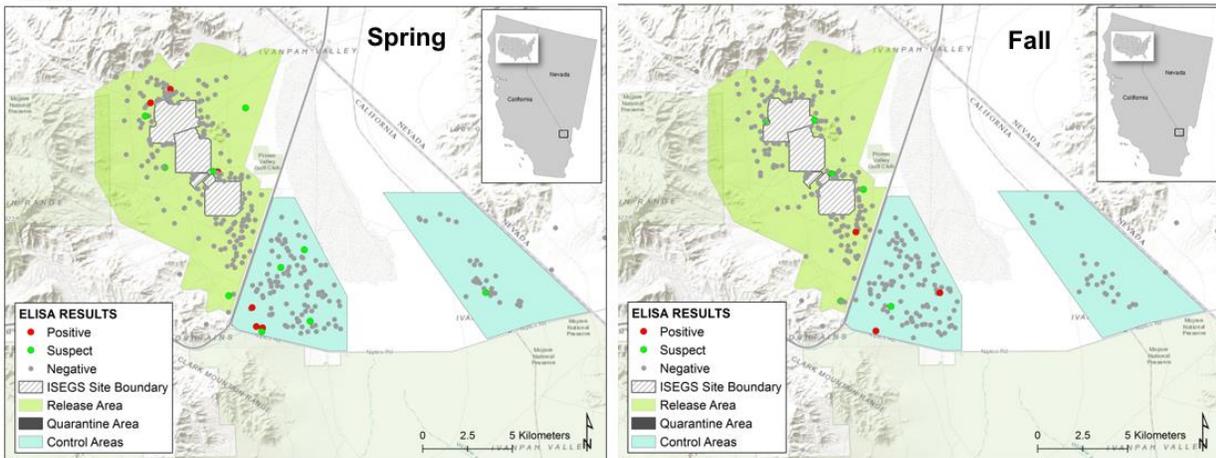
Table 8. Prevalence of *M. testudineum* (i.e., percentage of tortoises that tested positive, shown with number positive and total number sampled) among tortoises enrolled in the EMP across seasons and years and identification of ELISA test-positive individuals. Sex and group are indicated as follows: F = female, M = male, J = juvenile, CW = control west, TS₁₁ = translocated-short 2011, R = resident, TS₁₂ = translocated-short 2012.

Season	Prevalence	Tortoise ID (sex, study group)
Spring 2012	3.2% (10/312)	09(M,TS ₁₂), 515(F,CE), 23(F,R), 524(M,CE), 70(F,R), 89(M,R), 230(M,R), 565(M,CW), 613(F,CW), 597(M,CW)
Fall 2012	0.9% (3/326)	316(M,R), 613(F,CW), 586(M,CW)
Spring 2013	0.3% (1/309)	05(M,TS ₁₂)
Fall 2013	0.7% (2/294)	05(M,TS ₁₂), 646(F,CW)
Spring 2014	0.0% (0/293)	
Fall 2014	0.0% (0/291)	
Spring 2015	0.4% (1/277)	05(M,TS ₁₂)
Fall 2015	0.4% (1/278)	05(M,TS ₁₂)
Spring 2016	0.4% (1/276)	05(M,TS ₁₂)
Fall 2016	0.8% (2/243)	05(M,TS ₁₂), 265(F,TL ₁₂)
Spring 2017	0.4% (1/239)	05(M,TS ₁₂)

2012



2013



2014

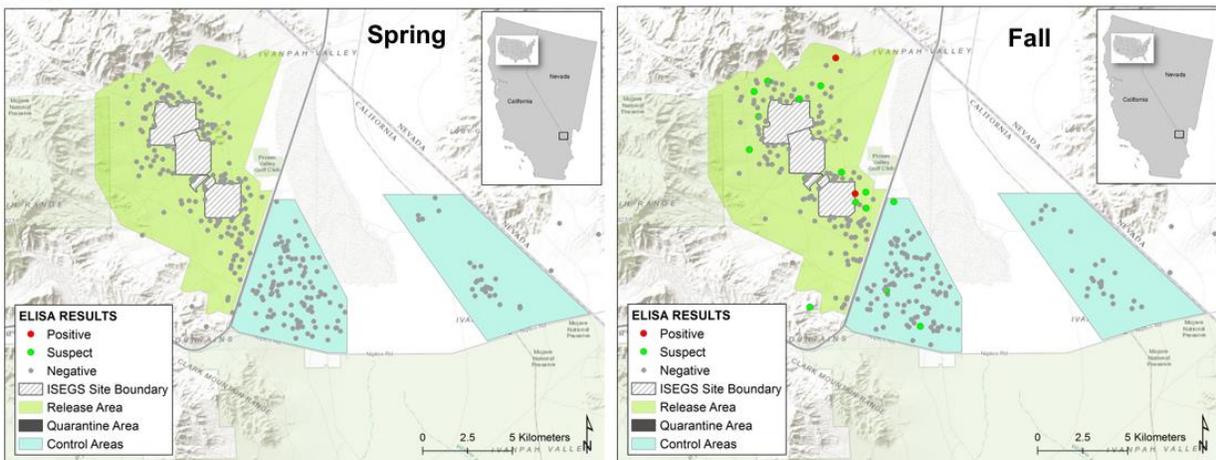
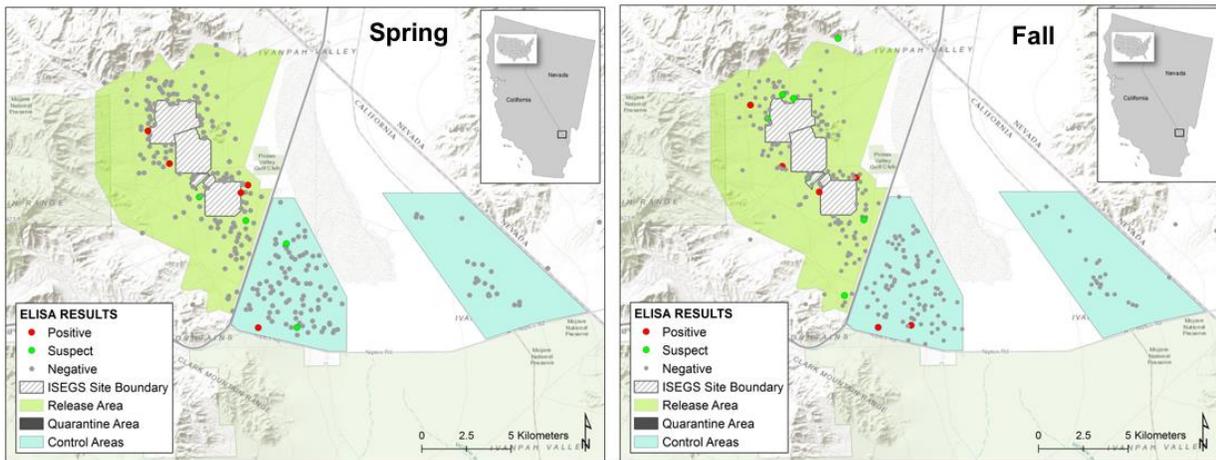
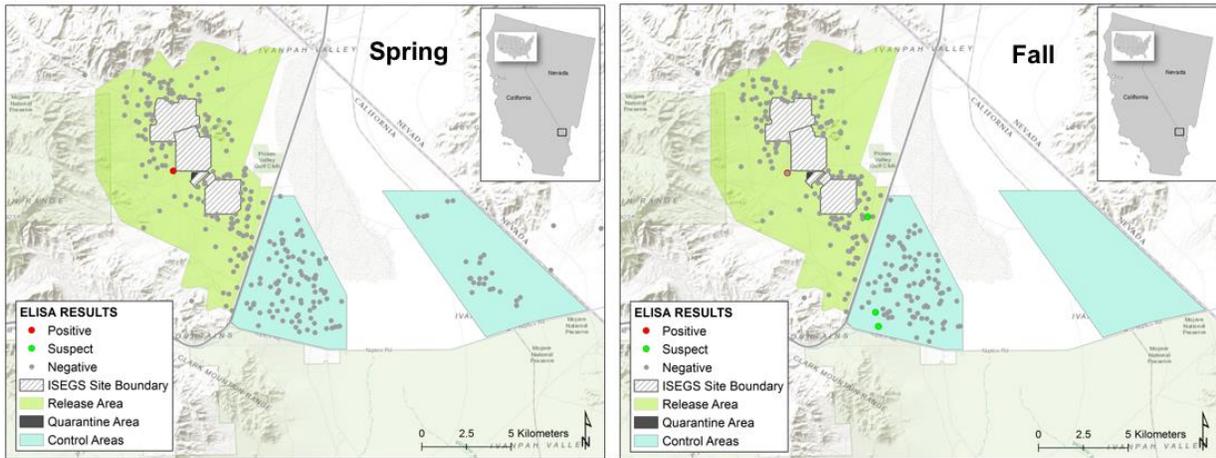


Figure 11. Spatial distribution of ELISA test results for the bacterium *M. agassizii* in tortoises during the spring (left column) and fall (right column) of 2012 through 2016 within the Ivanpah Valley study area (continues on following page). Red dots indicate positive tests, green dots indicate suspect results, and gray dots indicate negative tests.

2015



2016



2017

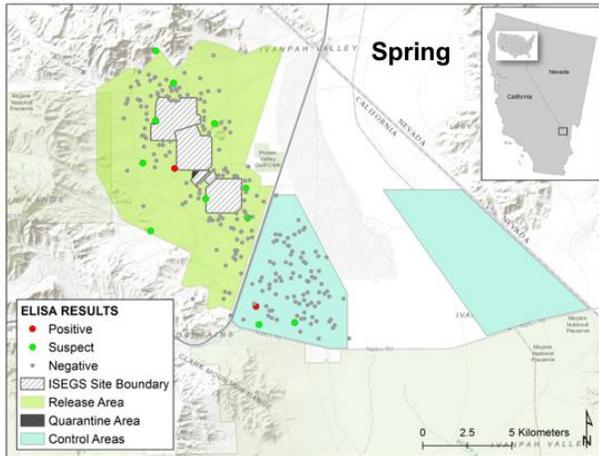


Figure 11 (continued). Spatial distribution of ELISA test results for the bacterium *M. agassizii* in tortoises during the spring (left column) and fall (right column) of 2012 through 2016 within the Ivanpah Valley study area. Red dots indicate positive tests, green dots indicate suspect results, and gray dots indicate negative tests.

Anthropogenic impacts

Metal toxicity

Concentrations of several metals in tortoise blood samples never (e.g., mercury, titanium, thorium, and uranium) or rarely (i.e., typically 0-7% of samples in a given season for cadmium and arsenic) exceeded minimum levels of detection. Lead, selenium, and iron concentrations were generally detectable (i.e., 67%-100% of samples in a given year), but were typically lower than or within published ranges for turtles, reptiles, and other vertebrates (Nagle et al. 2001; Hamilton et al. 2004; Burger et al. 2007; Buekers et al. 2009; Martinez-Lopez et al. 2009; Grillitsch and Schiesari 2010; Yu et al. 2011) (Fig. 12).

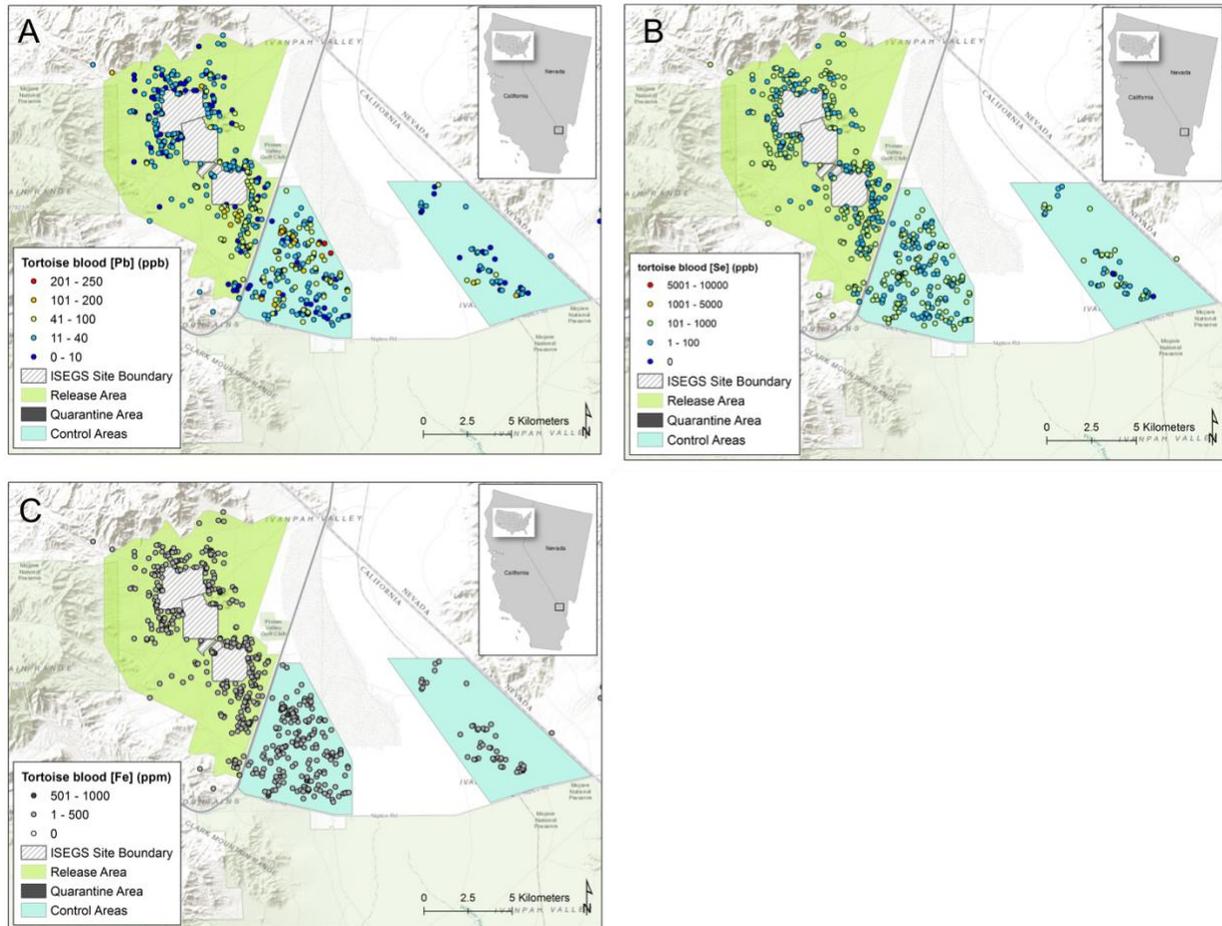


Figure 12. Spatial distributions of lead (Pb) (A), selenium (Se) (B), and iron (Fe) (C) concentrations in blood samples collected from desert tortoises within the Ivanpah Valley study area. For Pb and Se, dark blue circles were below detection limits, light blue were above detection but below minimum values reported in peer-reviewed literature (see text for details), and all other values were within the range of literature values. Fe values are shown in generalized bins because no published values were available.

Anthropogenic noise

Sound levels ranged from 23 to 55 decibels (dB) and averaged 38 dB (SD = 5) across the study area. Vibration levels ranged from 0.0001 to 0.03 mm/sec and averaged 0.004 mm/sec (SD = 0.004). Across the four transects extending from the I-15 corridor, the maximum sound level

ranged from 71 to 77 dB at locations proximate to the interstate (15 to 25 m), whereas the minimum sound level ranged from 31 to 43 dB at locations further from the interstate (655 to 1000 m). For reference, the common noise level of light auto traffic is 50 dB, and continuous vibration from traffic at 0.51 mm/sec is at the threshold of human perception.

Given the data, anthropogenic noise had little or no effect on translocated or resident tortoises (Table 9). Although our results suggested that construction noise levels in 2013—may have influenced tortoise space use in that year, it should be noted that the data we analyzed did not emerge from an experiment conducted over multiple seasons. In 2013, the only year when sound data were collected, the construction noise by unknown sex interaction term had high relative importance ($w_+(j) = 0.99$) and was positive, providing evidence for a relationship between construction noise and an increase in the concentration of space use for tortoises of unknown sex (i.e., immature tortoises) after controlling for a number of other variables (Table 9; Fig. 13). The remaining noise variables all had much less support in the data. In this analysis, 13% of the unknown sexes were translocated tortoises and 29% were resident.

Table 9. Model-averaged parameter estimates ($\tilde{\beta}$) and cumulative Akaike's Information Criterion weights (w_+) for all variables used to model space use intensity in the 2013 active season. Model variables included noise propagation from the around the ISEGS towers and the I-15 corridor, as well as density of all road types in the Ivanpah study area.

Variable	$\tilde{\beta}$	SE	w_+
<i>Intercept</i>	2.53	0.09	--
Sex Male	-1.15	0.11	1.00
Sex Unknown	1.04	0.21	1.00
Construction Noise*Sex Unknown	0.44	0.22	0.99
I-15 Noise*Sex Male	-0.03	0.04	0.55
Construction Noise	-0.04	0.07	0.50
I-15 Noise	-0.01	0.03	0.45
Construction Noise*Sex Male	0.04	0.08	0.44
Road Density	0.01	0.02	0.40
Translocated	-0.06	0.14	0.39
Control East	-0.04	0.14	0.32
I-15 Noise*Sex Unknown	-0.01	0.06	0.29
Resident	0.00	0.07	0.28

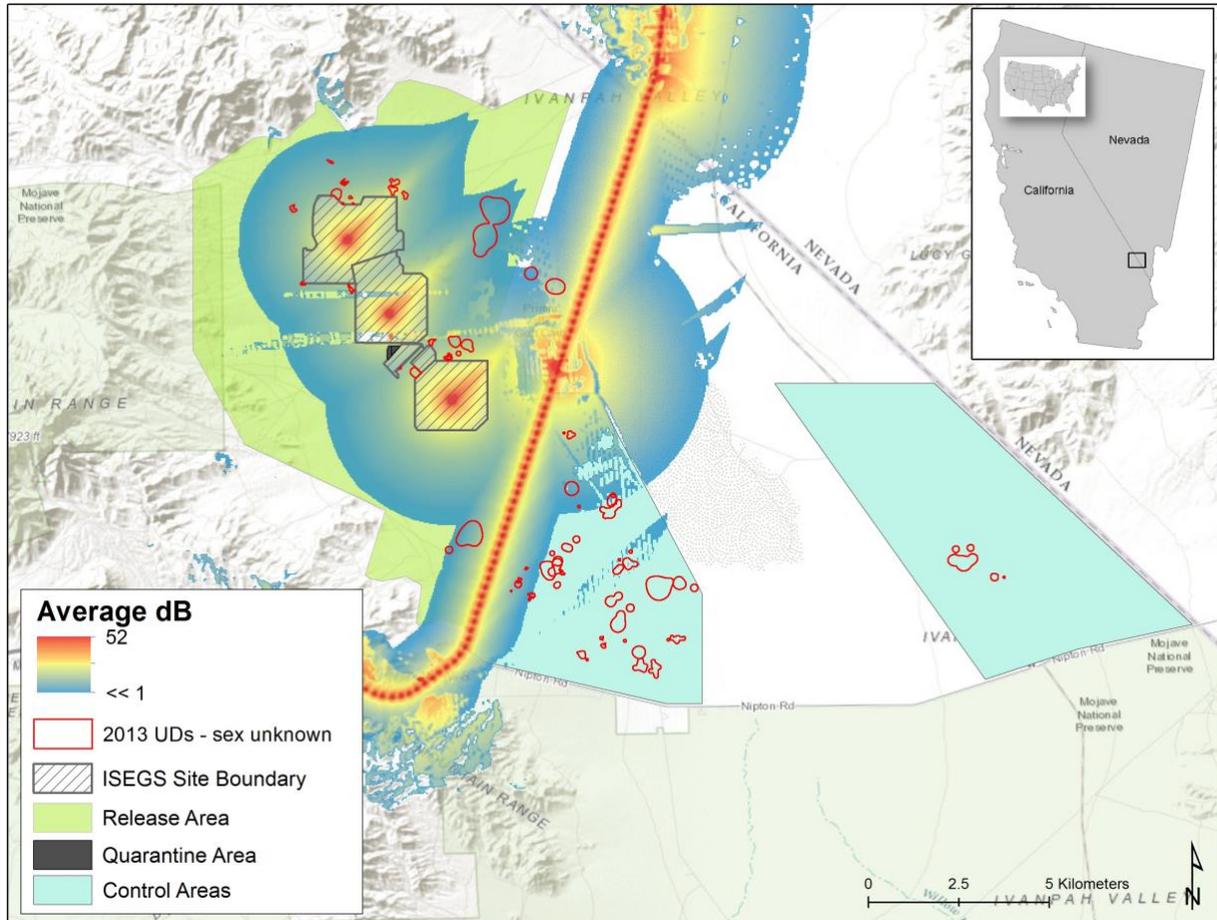


Figure 13. Noise propagation (sounds levels in dB) from the I-15 corridor and construction at the ISEGS facility, averaged across the frequencies 400, 500, and 630 Hz within the Ivanpah Valley study area in 2013. Noise levels and weather were sampled in the field, and SPreAD-GIS software (Reed et al. 2010) was used to model propagation across the study area in 2013. Home ranges (utilization distributions; UDs) of tortoises of unknown sex ($n = 28$) in 2013 are displayed in red outlines because our model of space use intensity indicated that construction noise had a positive effect on space use intensity for tortoises of unknown sex (predominantly immatures) in 2013.

3.3 Comprehensive survival analysis

In this section, we describe the results of the five survival analyses described in Section 2.4. We briefly summarize those analyses (i.e., which variables were included) and the key inferences drawn from the two datasets (i.e., 120/160 and > 160 mm MCL) (Table 10). As mentioned in Section 2.4, we consider Analysis 1 to be the most robust evaluation of the effect of short-distance translocation on survival probability of tortoises in this study because Analysis 1 had the largest sample sizes among groups.

Table 10. Summary of the key inferences regarding effects of individual- and landscape-scale predictor variables on survival probability in tortoises at the Ivanpah Valley study area, and for each of the five analyses. 'N/A' indicates that data were not available (i.e., too few records existed) for tortoises from 120-160 mm MCL to perform Analysis 3. Descriptions of predictor variables are in [Appendix B, Table 8.2](#).

Analysis No.	Predictor Variables	Key Inferences by Dataset	
		120/160 MCL	> 160 MCL
Analysis 1	Treatment group, Size (Midline Carapace Length [MCL]), and Sex	i) No effects of predictor variables	i) Annual survival probability increases with size ii) Annual and cumulative survival probabilities are not statistically different among tortoises in different groups or among sexes
Analysis 2	Body condition	i) No effects of predictor variables	i) Annual survival probability increases with size ii) Annual and cumulative survival probabilities are not statistically different among tortoises in different groups, among sexes or among body condition scores
Analysis 3	Iron, Selenium and Lead concentrations in blood	N/A	i) Annual survival probability increases with higher concentrations of selenium in the blood of tortoises for all groups and increases with higher concentrations of iron in the blood of translocated tortoises ii) Annual survival probability is not affected by concentration of lead in the blood of tortoises or the size of tortoises and is not statistically different among tortoises in different groups or among sexes
Analysis 4	Maximum temperature and Duration $\geq 35^{\circ}\text{C}$	i) No effects of predictor variables	i) Annual survival probability increases with size ii) The evidence for effects of both temperature-related predictor variables was equivocal, and annual survival probability is not statistically different among tortoises in different groups or among sexes
Analysis 5	Home range size, Burrow density, Shrub density, Wash density, Topographic roughness, Soil bulk density, Mean NDVI, Coefficient of variation of NDVI, Road density, Fence density, Precipitation, and Maximum temperature	i) Annual survival probability decreased with increasing topographic roughness	i) Annual survival probability increases with size and decreases with size of tortoise home range ii) There was no support for any other landscape-scale predictor variables and no evidence that annual survival probability was different among groups or sexes

Analysis 1 - Treatment group, sex, and size

Survival of tortoises in the smallest size class (120/160 MCL dataset) did not vary by study group or size (MCL). The highest-ranked model was a model with no predictor variables (Table 11). In addition, model-averaged estimates of annual and cumulative survival probability were nearly identical for control, resident, and translocated tortoises, and the 95% confidence intervals for the three groups broadly overlapped (Figs. 14 and 15).

Table 11. Candidate model-selection results for the evaluation of effects of group and midline carapace length (MCL) on tortoises in the 120/160 MCL dataset. Columns show: $-2LL$ = -2 times the log of the likelihood function at its maximum, k = number of parameters in model, AIC_c = Akaike's Information Criterion value adjusted for small sample size, ΔAIC_c = difference between AIC_c of a given model and the AIC_c of the highest ranked model, and w_i = Akaike weight. We did not include fixed effects of sex and year due to insufficient data.

Model	-2LL	k	AIC_c	ΔAIC_c	w_i
No Predictor Variables	45.1	1	47.1	0.0	0.49
MCL	43.5	2	47.7	0.6	0.37
Group	44.2	3	50.6	3.5	0.09
Group+MCL	43.0	4	51.6	4.5	0.05
Group*MCL	42.5	6	55.9	8.8	0.00

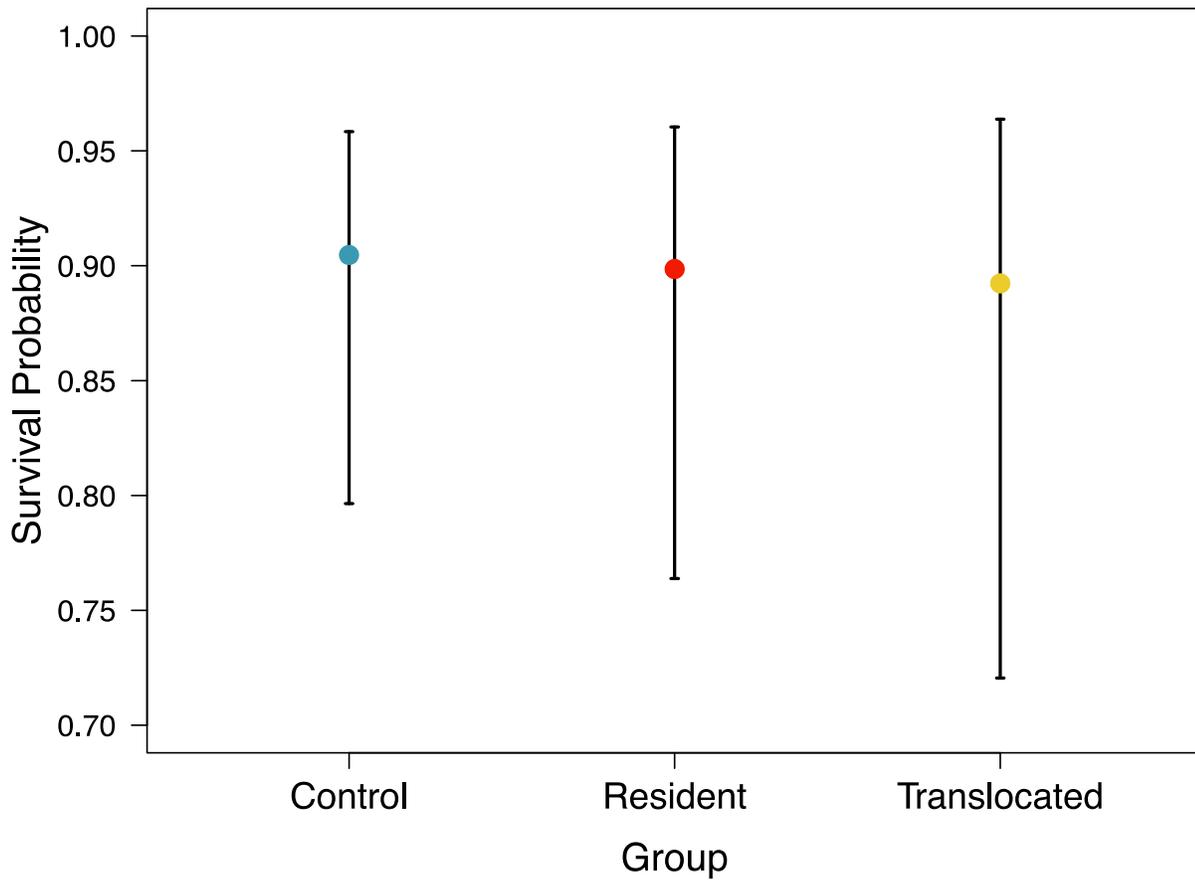


Figure 14. Model-averaged estimates of annual survival probabilities from May 2012 to May 2017 for control, resident, and translocated tortoises in the Ivanpah Valley study area from the analysis of data on the smaller size class of tortoises (120 to 160 mm MCL). Error bars around estimates represent 95% confidence intervals. We do not show estimates for each survival interval, because the estimates for each group are the same across intervals (i.e., year effects were not included).

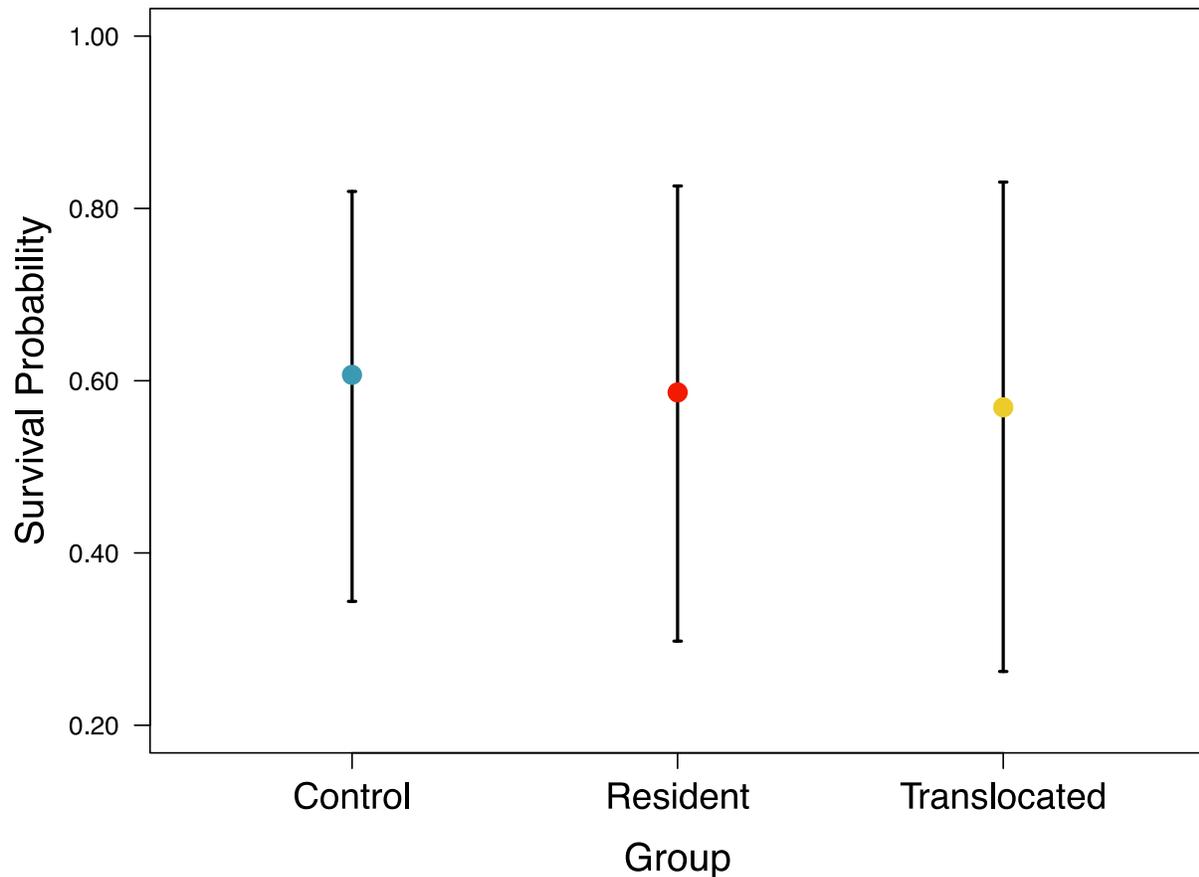


Figure 15. Model-averaged estimates of cumulative survival probabilities from May 2012 to May 2017 for control, resident, and translocated tortoises in the Ivanpah Valley study area from the analysis of data on the smallest size class of tortoises (120-160 mm MCL). Estimates are for tortoises of average size (MCL). Error bars around estimates represent 95% confidence intervals.

Survival of tortoises in the largest size class (> 160 MCL dataset), in contrast, varied by size. MCL was included in each of the five highest-ranked models (Table 12) and the 95% confidence interval (CI) around the estimated regression coefficient for MCL in the highest-ranked model (0.58 [0.27 - 0.88]) did not overlap 0. The estimates of survival probability from the highest-ranked model for the smallest and largest tortoises in the > 160 dataset were 0.89 (0.77 – 0.95) and 1.00 (0.98 - 1.00), respectively. The highest-ranked model also included an effect of group (Table 12). Although estimates of regression coefficients from this model indicated higher annual survival probabilities for control tortoises relative to translocated tortoises (with an estimated regression coefficient for control tortoises of 0.76 [0.01 – 1.51]), several lines of evidence cast doubt on whether the apparent effect is biologically meaningful. First, the second-ranked model did not include a group effect, and it had nearly identical support in the data ($\Delta AIC_C = 0.1$). Second, the model that included only a group effect was not supported in the data. Finally, the estimate of annual survival probability for translocated tortoises from the

highest-ranked model (conditioned on group and MCL) was 0.96, indicating that estimates for control tortoises cannot be considerably higher. Indeed, estimates for control tortoises only increased to 0.98. The lack of support for a difference among groups, in spite of the high precision of the estimates, was likely a consequence of survival estimates for all groups being high (nearly 1.0). In other words, these survival estimates indicate that nearly 100% of tortoises in any study group survived a given year and are similar to or higher than other published estimates of annual survival probabilities for immature and adult tortoises (Doak et al. 1994, Zylstra et al. 2013, Nafus et al. 2017). Finally, there were no statistical differences in model-averaged annual (Fig. 16) or cumulative (Fig. 17) survival estimates among groups.

Table 12. Candidate model-selection results for the evaluation of effects of group, midline carapace length (MCL), and year on tortoises in the > 160 dataset. Columns show: $-2LL$ = -2 times the log of the likelihood function at its maximum, k = number of parameters in model, AIC_c = Akaike's Information Criterion value adjusted for small sample size, ΔAIC_c = difference between AIC_c of a given model and the AIC_c of the highest ranked model, and w_i = Akaike weight.

Model	-2LL	k	AIC_c	ΔAIC_c	w_i
Group+MCL	357.8	4	365.8	0.0	0.43
MCL	361.9	2	365.9	0.1	0.41
Year+MCL	357.1	6	369.2	3.4	0.08
Group*MCL	357.5	6	369.6	3.7	0.07
Year*MCL	354.0	10	374.1	8.3	0.01
No Predictor Variables	375.2	1	377.2	11.4	0.00
Group	371.6	3	377.6	11.8	0.00
Group+Year	367.4	7	381.5	15.7	0.00
Group*Year	360.3	15	390.7	24.9	0.00

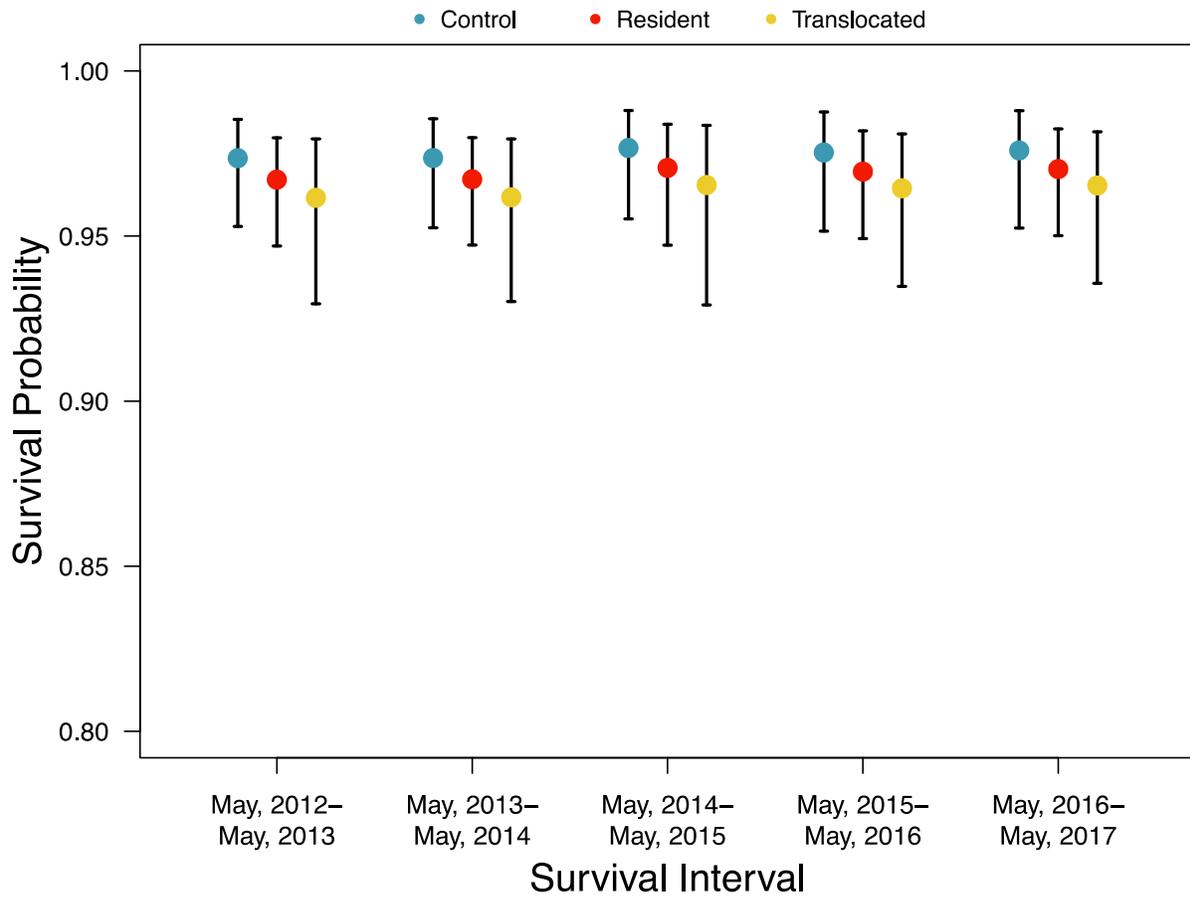


Figure 16. Model-averaged estimates of annual survival probabilities from May 2012 to May 2017 for control, resident, and translocated tortoises in the Ivanpah Valley study area from the analysis of data on the largest size class of tortoises (> 160 mm MCL). Estimates are for tortoises of average size (MCL). Error bars around estimates represent 95% confidence intervals.

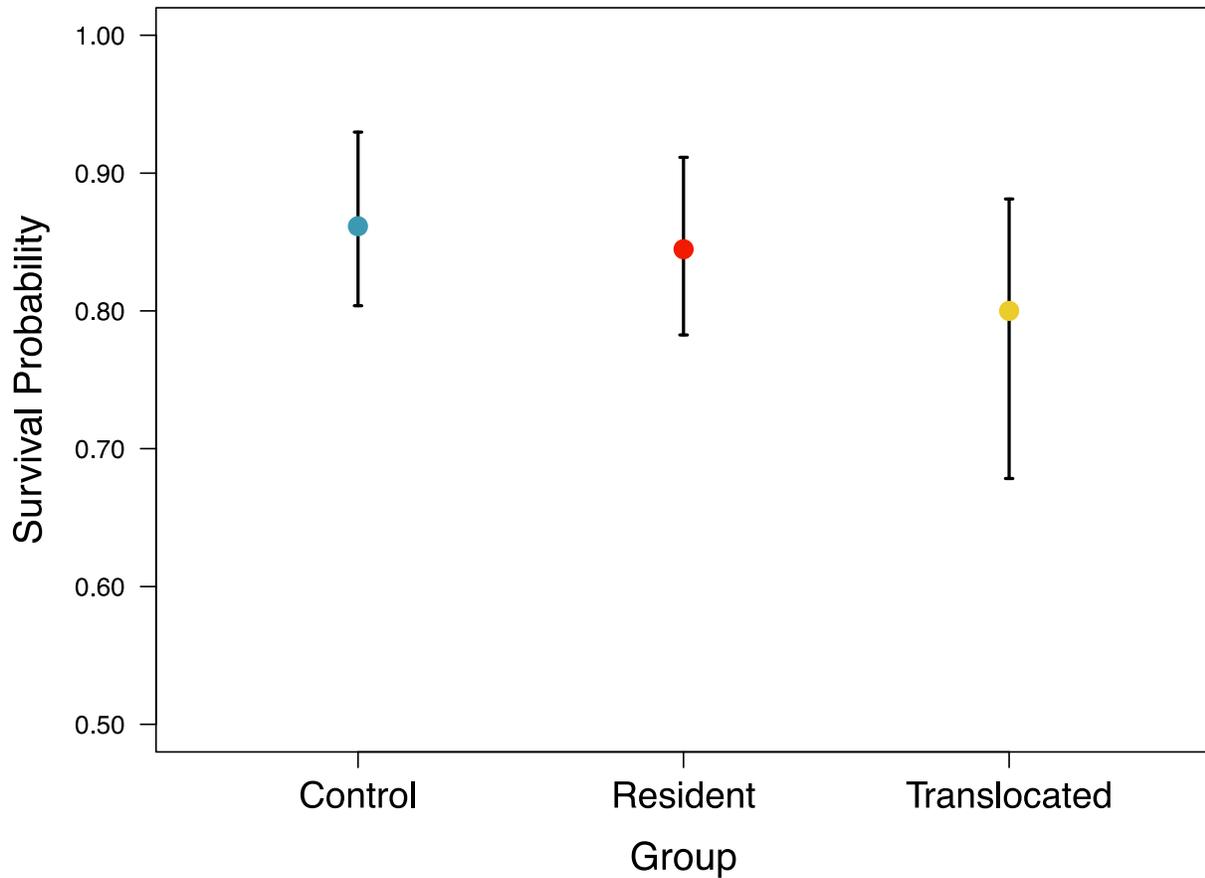


Figure 17. Model-averaged estimates of cumulative survival probabilities from May 2012 to May 2017 for control, resident, and translocated tortoises in the Ivanpah Valley study area from the analysis of data on the largest size class of tortoises (> 160 mm MCL). Estimates are for tortoises of average size (MCL). Error bars around estimates represent 95% confidence intervals.

Analysis 2 - Body condition score

When assessing the effect of body condition, we found that the highest-ranked model in our analysis of the 120/160 dataset was a model with no predictor variables (Table 13). The 95% confidence intervals around estimates of regression coefficients for all predictor variables overlapped 0, indicating that body condition did not affect survival in desert tortoises in the Ivanpah Valley.

Table 13. Candidate model-selection results for the evaluation of effects of group, midline carapace length (MCL), and body condition score (BCS) on tortoises in the 120/160 dataset. Columns show: $-2LL$ = -2 times the log of the likelihood function at its maximum, k = number of parameters in model, AIC_c = Akaike's Information Criterion value adjusted for small sample size, ΔAIC_c = difference between AIC_c of a given model and the AIC_c of the highest ranked model, and w_i = Akaike weight.

Model	-2LL	k	AIC_c	ΔAIC_c	w_i
No Predictor Variables	45.1	1	47.1	0.0	0.36
MCL	43.5	2	47.7	0.6	0.27
BCS	44.9	2	49.1	2.0	0.13
MCL+BCS	43.3	3	49.7	2.6	0.10
Group	44.2	3	50.6	3.5	0.07
Group+MCL	43.0	4	51.6	4.5	0.04
Group+BCS	43.9	4	52.5	5.4	0.02
Group*MCL	42.5	6	55.9	8.8	0.00
Group*BCS	43.9	6	57.3	10.2	0.00

In a comparable analysis using the > 160 dataset, we found additional evidence that size influenced survival. The four highest-ranked models each included the effect of MCL (Table 14), and the estimate of the regression coefficient from the highest-ranked model indicated a positive association between MCL and survival probability (the estimate (0.54 [0.23 – 0.86])). The estimate was similar to the estimate from Analysis 1. The two highest-ranked models also included an effect of group, and the estimate of the regression coefficient for the control tortoises was 0.99 (0.20 – 1.79), suggesting a higher survival probability for control tortoises. However, as we noted above in Analysis 1, this effect does not appear to be biologically meaningful; models that did not contain the group effect were also supported, and model-averaged estimates of survival probability (conditioned on MCL) for translocated and control tortoises were only slightly different (0.96 [translocated] vs. 0.98 [control]; Fig. 18). Models that included an effect of body condition score had little support in the data. Estimates of the regression coefficients for body condition from the models were near 0, and their 95% confidence intervals overlapped 0.

Table 14. Candidate model-selection results for the evaluation of effects of group, midline carapace length (MCL), and body condition score (BCS) on tortoises in the > 160 dataset. Columns show: $-2LL$ = -2 times the log of the likelihood function at its maximum, k = number of parameters in model, AIC_c = Akaike's Information Criterion value adjusted for small sample size, ΔAIC_c = difference between AIC_c of a given model and the AIC_c of the highest ranked model, and w_i = Akaike weight.

Model	-2LL	<i>k</i>	AIC_c	ΔAIC_c	w_i
Group+MCL	336.8	4	344.9	0.0	0.59
MCL	343.4	2	347.4	2.5	0.17
Group*MCL	342.0	6	348.1	3.2	0.12
BCS+MCL	336.4	3	348.5	3.6	0.10
Group*BCS	340.4	6	352.5	7.6	0.01
Group	348.0	3	354.0	9.2	0.01
Group+BCS	347.2	4	355.2	10.3	0.00
No Predictor Variables	353.7	1	355.7	10.8	0.00
BCS	352.4	2	356.4	11.6	0.00

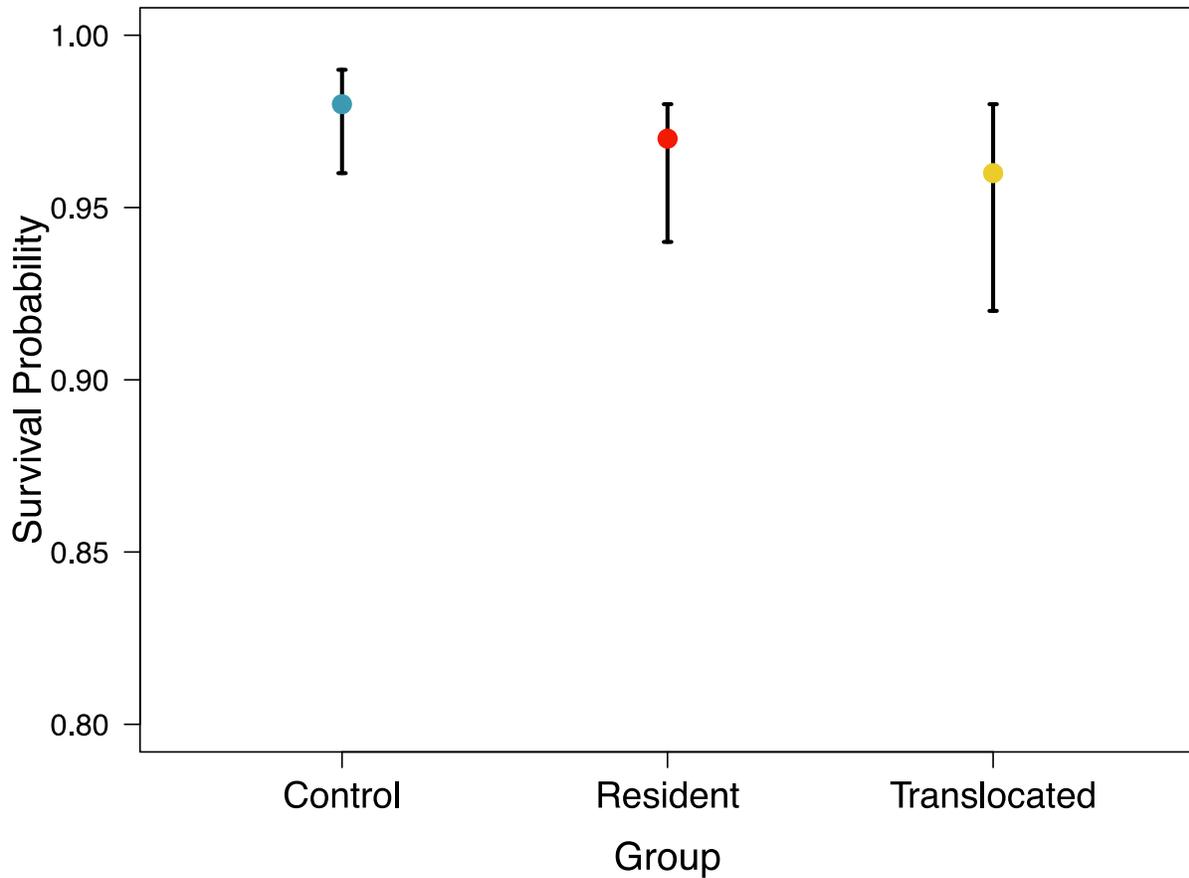


Figure 18. Model-averaged estimates of annual survival probabilities from May 2012 to May 2017 for control, resident, and translocated tortoises in the Ivanpah Valley study area from the analysis of data on the largest tortoises (> 160 mm MCL). Estimates are for tortoises of average size (MCL) and for tortoises with body condition scores of three or four. Error bars around estimates represent 95% confidence intervals. Note that there was no effect of year, thus annual estimates of survival are the same for every year.

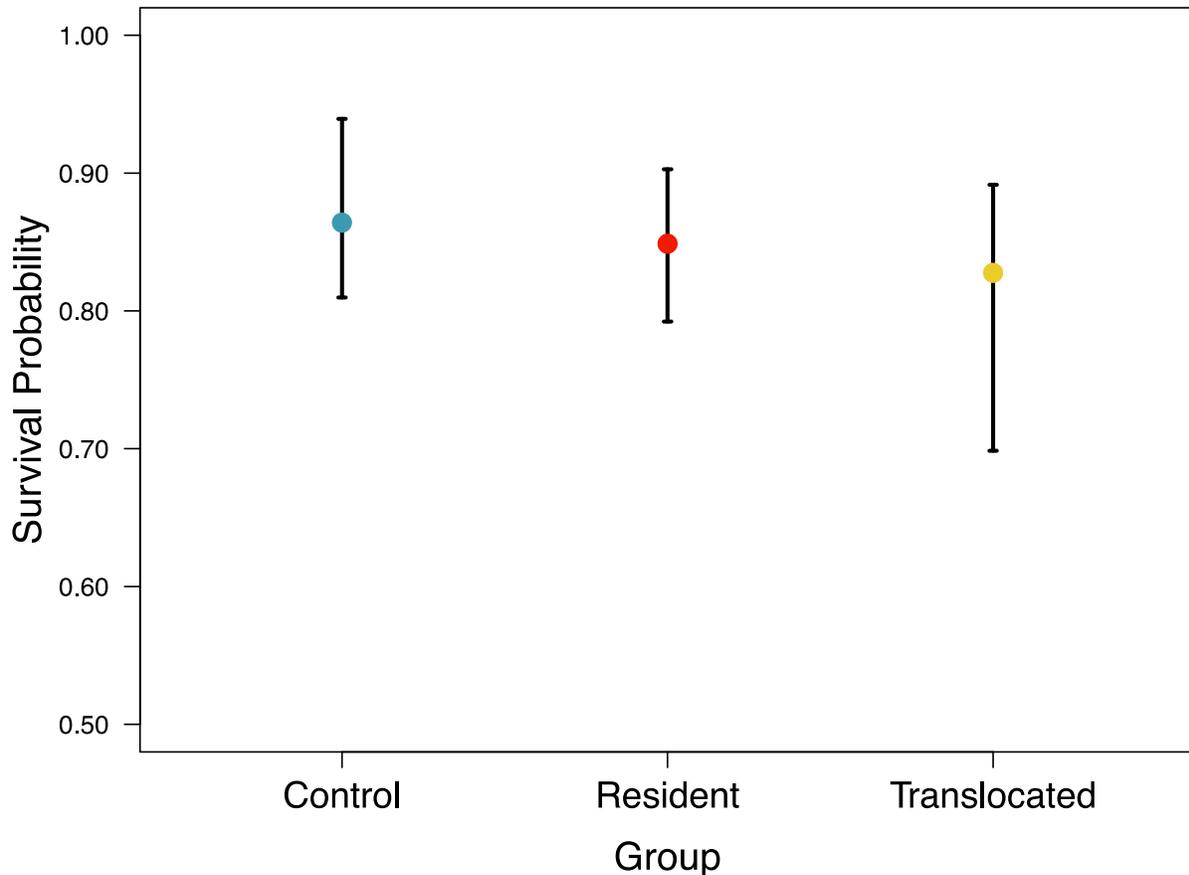


Figure 19. Model-averaged estimates of cumulative survival probabilities from May 2012 to May 2017 for control, resident, and translocated tortoises in the Ivanpah Valley study area from the analysis of data on the largest tortoises (> 160 mm MCL). Estimates are for tortoises of average size (MCL) and for tortoises with body condition scores of three or four. Error bars around estimates represent 95% confidence intervals.

Analysis 3 - Toxicology

Metal concentration—selenium and iron, in particular—was associated with survival in desert tortoises, possibly indicating a positive effect of increasing concentrations of essential elements (Hamilton et al. 2004). As mentioned above, the sample size for the 120/160 dataset was very small and had no mortalities; therefore, we did not estimate survival probabilities for tortoises in this dataset. However, for the >160 dataset, the highest-ranked candidate models included effects of selenium and iron concentrations and an interaction between iron concentration and group (Table 15). No other models were higher ranked than the model with no predictor variables. The estimate of the regression coefficient for selenium from the highest-ranked model was 0.99 (0.04 – 1.94), indicating that tortoises with higher selenium concentrations in their blood had higher annual survival. The estimated regression coefficient for iron from the second-ranked model was 0.58 (-0.02 – 1.86), suggesting no relationship between iron concentrations and annual survival probability when individuals were pooled across groups. We

found no evidence that survival probability was affected by lead concentrations and size or that it differed among groups or sexes.

Table 15. Candidate model-selection results for the evaluation of effects of group, iron, selenium and lead concentrations, and MCL on tortoises in the > 160 dataset. Columns show: -2LL = -2 times the log of the likelihood function at its maximum, k = number of parameters in model, AIC_c = Akaike's Information Criterion value adjusted for small sample size, ΔAIC_c = difference between AIC_c of a given model and the AIC_c of the highest ranked model, and w_i = Akaike weight.

Model	-2LL	k	AIC_c	ΔAIC_c	w_i
Selenium	110.3	2	114.3	0.0	0.34
Iron	111.3	2	115.3	1.0	0.20
Group*Iron	104.4	6	116.7	2.4	0.10
No Predictor Variables	115.2	1	117.2	2.9	0.08
Group+Selenium	109.2	4	117.4	3.1	0.07
MCL	113.8	2	117.9	3.6	0.06
Group+Iron	110.3	4	118.4	4.1	0.04
Lead	114.6	2	118.6	4.3	0.04
Group*Selenium	107.5	6	119.8	5.5	0.02
Group	114.2	3	120.3	6.0	0.02
Group+MCL	113.2	4	121.4	7.0	0.01
Group+Lead	113.5	4	121.6	7.3	0.01
Group*Lead	110.6	6	122.9	8.6	0.00
Group*MCL	112.7	6	124.9	10.6	0.00

Analysis 4 – Thermoregulation

Thermal conditions did not appear to influence the survival of tortoises in the smallest size class. When analyzing the 120/160 dataset, none of the candidate models were ranked higher than the model with no predictor variables (Table 16). As we noted above (Section 2.4), group and sex effects were not evaluated in this analysis due to small sample sizes.

Table 16. Candidate model-selection results for the evaluation of effects of thermoregulation predictor variables and midline carapace length (MCL) on tortoises in the 120/160 dataset. “Maximum” refers to the average daily maximum temperature experienced by a tortoise during an active season, and “duration” refers to the average daily duration of time tortoises experienced temperatures $\geq 35^{\circ}\text{C}$ during an active season. Columns show: $-2LL$ = -2 times the log of the likelihood function at its maximum, k = number of parameters in model, AIC_c = Akaike's Information Criterion value adjusted for small sample size, ΔAIC_c = AIC_c of the highest ranked model subtracted from the AIC_c of a model, and w_i = Akaike weight.

Model	-2LL	k	AIC_c	ΔAIC_c	w_i
No Predictor Variables	23.8	1	26.0	0.0	0.49
MCL	23.6	2	28.1	2.1	0.18
Maximum	23.7	2	28.1	2.1	0.17
Duration	23.8	2	28.2	2.2	0.16

For the > 160 dataset, each candidate model was ranked higher than the model with no predictor variables (Table 17). The effects of MCL and group had particularly strong support, as they were in five and three, respectively, of the five highest-ranked models (Table 17). Although models with predictor variables describing tortoise temperatures were included in strongly supported models, 95% CIs around estimates of regression coefficients from some models included 0 and did not include 0 in other models. Therefore, the evidence from our analyses for effects of temperature on annual survival probability in tortoises is equivocal.

As in previous analyses, there was strong support for a positive effect of MCL on annual survival probability. The estimate of the regression coefficient for MCL from the highest-ranked model was 0.41 (0.04 – 0.78). The estimate of the regression coefficient from the highest-ranked model for the effect of being a control tortoise was 1.03 (0.12 – 1.93). However, as previously discussed, the effect does not appear to be biologically meaningful; model-averaged estimates of annual survival probability (conditioned on either thermal variable) were similar among control and translocated tortoises (0.95 [translocated] and 0.98 [control]; Fig. 20). The 95% CIs around the estimate of the regression coefficient for the effect of being a resident tortoise included 0, indicating that survival probability did not differ between resident and translocated tortoises (Fig. 20). Estimates of cumulative survival probability were also similar among groups, and their 95% CIs broadly overlapped (Fig. 21).

Table 17. Candidate model-selection results for the evaluation of effects of group, thermoregulation predictor variables, and midline carapace length (MCL) on tortoises in the > 160 dataset. “Maximum” refers to the average daily maximum temperature experienced by a tortoise during an active season, and “duration” refers to the average daily duration of time tortoises experienced temperatures $\geq 35^{\circ}\text{C}$ during an active season. Columns show: $-2LL$ = -2 times the log of the likelihood function at its maximum, k = number of parameters in model, AIC_c = Akaike's Information Criterion value adjusted for small sample size, ΔAIC_c = difference between AIC_c of a given model and the AIC_c of the highest ranked model, and w_i = Akaike weight.

Model	-2LL	<i>k</i>	AIC_c	ΔAIC_c	w_i
Group+MCL+Duration	263.1	5	273.1	0.0	0.18
Group+MCL	265.3	4	273.4	0.2	0.16
Group+MCL+Maximum	263.5	5	273.6	0.4	0.15
MCL+Maximum	267.9	3	273.9	0.7	0.13
MCL+Duration	268.4	3	274.4	1.3	0.10
MCL	270.7	2	274.7	1.6	0.08
Group+Duration	267.9	4	275.9	2.8	0.05
Duration	272.4	2	276.5	3.3	0.03
Maximum	272.7	2	276.7	3.5	0.03
Group*MCL	265.3	6	277.3	4.2	0.02
Group*Maximum	265.3	6	277.4	4.2	0.02
Group+Maximum	269.3	4	277.4	4.2	0.02
Group	273.1	3	279.2	6.0	0.01
Group*Duration	267.4	6	279.5	6.4	0.01
No Predictor Variables	278.2	1	280.2	7.0	0.01

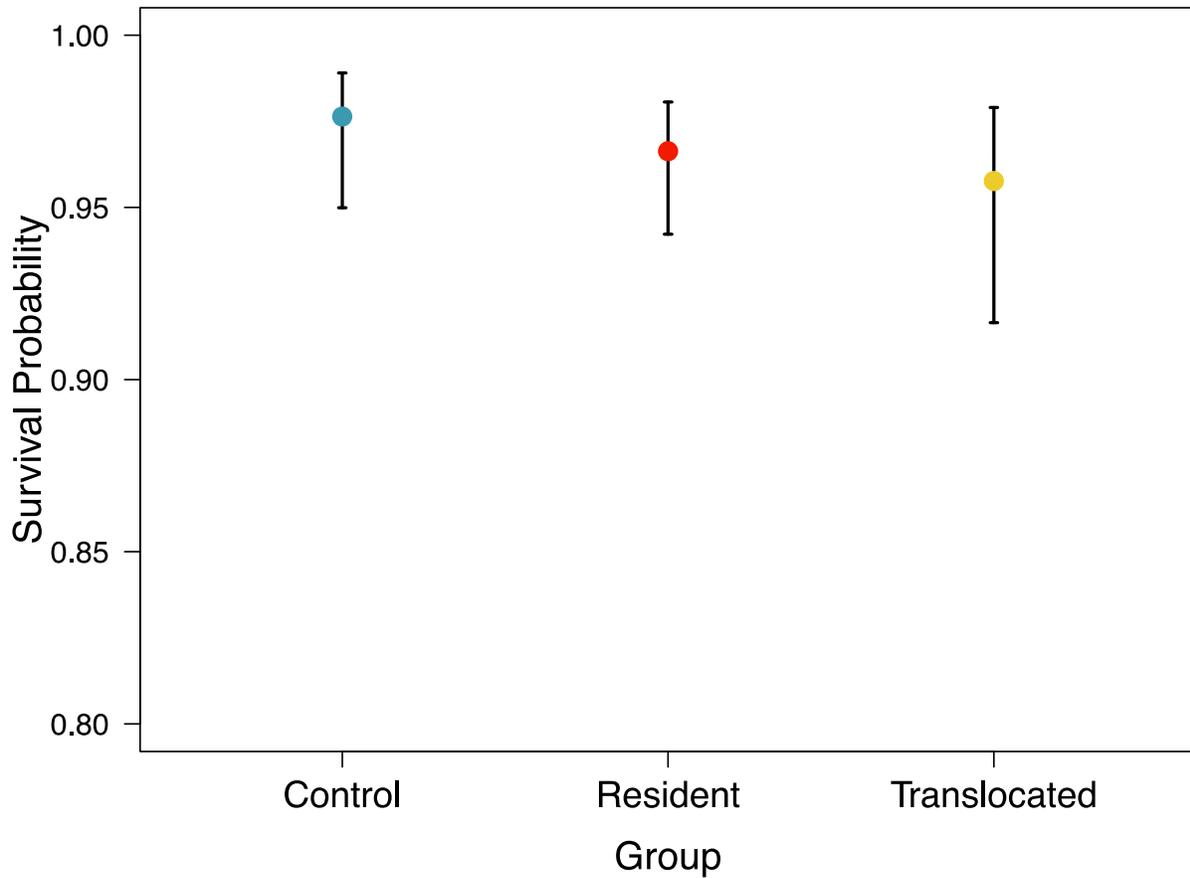


Figure 20. Model-averaged estimates of annual survival probabilities from May 2012 to May 2017 for control, resident and translocated tortoises in the Ivanpah Valley study area from the analysis of data on tortoises in the largest size class (> 160 mm MCL). Estimates are for tortoises of average size (MCL) and for tortoises that experienced the average duration of time exposed to $\geq 35^{\circ}\text{C}$ and the average daily maximum temperature. Error bars around estimates represent 95% confidence intervals. Note that there was no effect of year, thus annual estimates of survival are the same for every year.

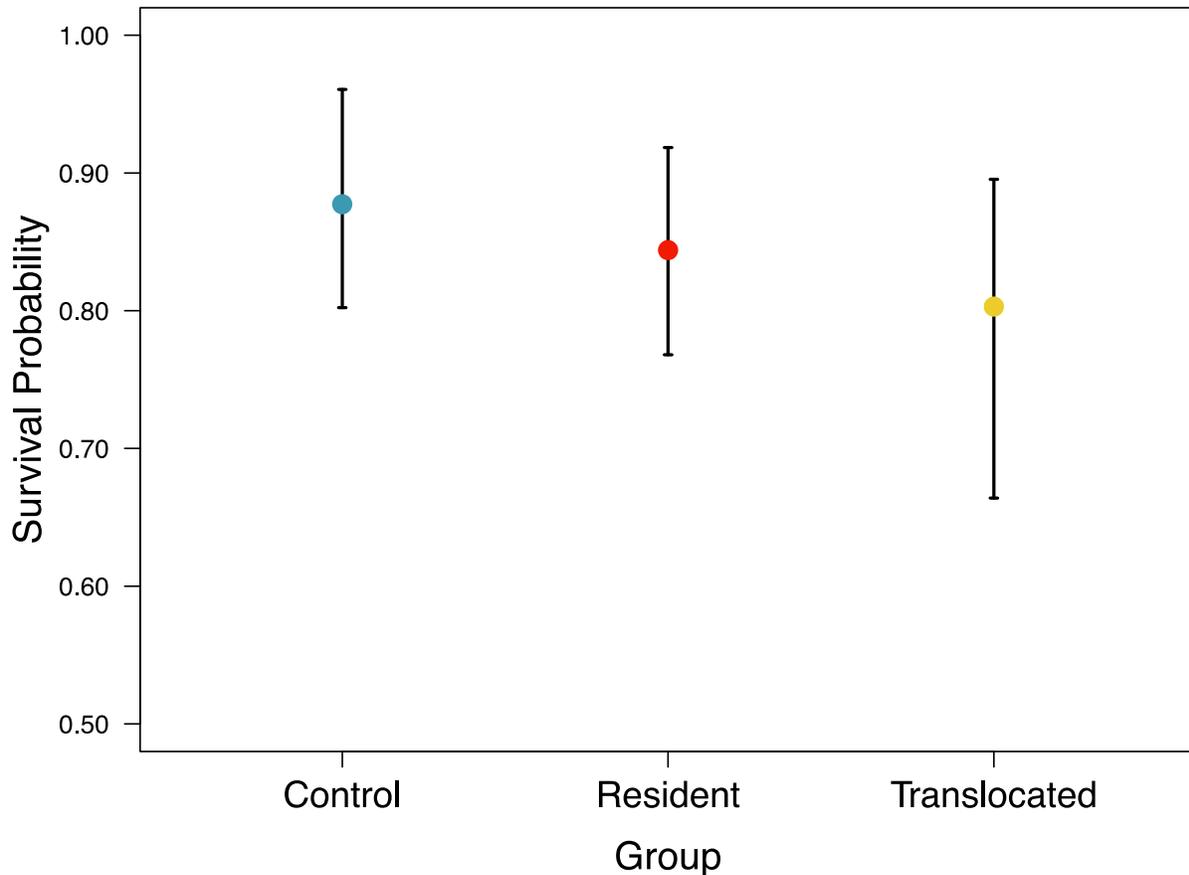


Figure 21. Model-averaged estimates of cumulative survival probabilities from May 2012 to May 2017 for control, resident and translocated tortoises in the Ivanpah Valley study area from the analysis of data on tortoises in the largest size class (> 160 mm MCL). Estimates are for tortoises of average size (MCL) and for tortoises that experienced the average duration of time exposed to $\geq 35^{\circ}\text{C}$ and the average daily maximum temperature. Error bars around estimates represent 95% confidence intervals.

Analysis 5 - Landscape-scale predictor variables

Topography (i.e., roughness of home ranges) was found to influence the survival of tortoises in the smallest size class. The two highest-ranked models for the 120/160 dataset included the effect of topographic roughness (Table 18) and the estimated regression coefficient for that predictor variable was -1.19 ($-2.31 - -0.07$), suggesting some evidence for tortoises having lower survival in areas with higher topographic roughness. Effects of group were also included in the highest-ranked models (Table 18); however, 95% confidence intervals around the effects of being a control or resident tortoise included zero. There was no evidence that any of the other predictor variables were strongly associated with survival probability.

Table 18. Candidate model-selection results for the evaluation of effects of group, landscape-scale predictor variables, and midline carapace length (MCL) on tortoises in the 120/160 dataset. The entire candidate set of models is not included due to the low level of support of most of the predictor variables. The model with the group effect was lower-ranked than other models but is included for comparison. Columns show: $-2LL$ = -2 times the log of the likelihood function at its maximum, k = number of parameters in model, AIC_c = Akaike's Information Criterion value adjusted for small sample size, ΔAIC_c = difference between AIC_c of a given model and the AIC_c of the highest ranked model, and w_i = Akaike weight. Landscape-scale environmental variables in models are: Roughness = topographic roughness of a home range, Precipitation = total precipitation at a home range for each active season (see Appendix B for additional details).

Model	-2LL	<i>k</i>	AIC_c	ΔAIC_c	w_i
Roughness	30.6	2	34.8	0.0	0.76
Group+Roughness	30.6	4	39.2	4.4	0.08
No Predictor Variables	40.4	1	42.5	7.7	0.02
Precipitation	38.4	2	42.6	7.8	0.02
Group	38.6	3	45.0	10.2	0.00

In contrast, home range size was found to influence survival of individuals in the > 160 dataset. Sixteen models were within 8 AIC_c units of the highest-ranked model and were more supported than the model with no predictor variables (Table 19). However, when examining estimates of regression coefficients and their 95% confidence intervals, we found that there was strong support for an effect of size (MCL) and tortoise home range size. The estimated regression coefficient for home range size was -0.20 (-0.39 – -0.02), indicating that tortoises with larger home ranges have lower survival, and the estimated regression coefficient (from the highest-ranked model) for MCL was 0.67 (0.21 – 1.11). For all other landscape-scale predictor variables, 95% confidence intervals around estimates of regression coefficients included 0, indicating no support. In addition, there was no evidence for an effect of group in this analysis (Fig. 22). Estimates of cumulative survival probability were also similar among groups, and their 95% CIs broadly overlapped (Fig. 23).

Table 19. Candidate model-selection results for the evaluation of effects of group, landscape-scale predictor variables, and midline carapace length (MCL) on tortoises in the > 160 dataset. The entire candidate set of models is not presented due to the low level of support of most of the models. The model with the group effect and the model with no predictor variables were lower-ranked than other models but are included for comparison. Columns show: $-2LL$ = -2 times the log of the likelihood function at its maximum, k = number of parameters in model, AIC_c = Akaike's Information Criterion value adjusted for small sample size, ΔAIC_c = difference between AIC_c of a given model and the AIC_c of the highest ranked model, and w_i = Akaike weight. Names in models are: area = home range size of tortoises, road = road density, soilBD = soil bulk density, fence = fence density, burrow = burrow density, Tmax = average daily maximum temperature, NDVI.CV = the coefficient of variation of NDVI values, wash = wash density, shrub = shrub density, NDVI.MEAN = the mean of NDVI values, precipitation = total precipitation at a home range for each active season, roughness = topographic roughness of a home range (see Appendix B for additional details).

Model	-2LL	k	AIC_c	ΔAIC_c	w_i
MCL+Area	221.7	3	227.7	0.0	0.42
MCL+Road	225.0	3	231.1	3.3	0.08
MCL+SoilBD	225.1	3	231.1	3.4	0.08
MCL	227.7	2	231.7	3.9	0.06
MCL+Wash	226.3	3	232.3	4.6	0.04
MCL+Burrow	226.6	3	232.6	4.9	0.04
MCL+Road+Fence	224.6	4	232.7	4.9	0.04
MCL+NDVI.CV	226.9	3	232.9	5.2	0.03
MCL+Tmax	227.0	3	233.1	5.3	0.03
MCL+Fence	227.3	3	233.3	5.6	0.03
MCL+Shrub	227.5	3	233.5	5.7	0.02
MCL+NDVI.Mean	227.5	3	233.5	5.8	0.02
MCL+Precipitation	227.5	3	233.6	5.8	0.02
MCL+Roughness	227.6	3	233.6	5.9	0.02
Area	230.1	2	234.1	6.3	0.02
Group+ MCL	226.9	4	234.9	7.2	0.01
Road	232.3	2	236.3	8.6	0.01
No Predictor Variables	236.6	1	238.6	10.8	0.00

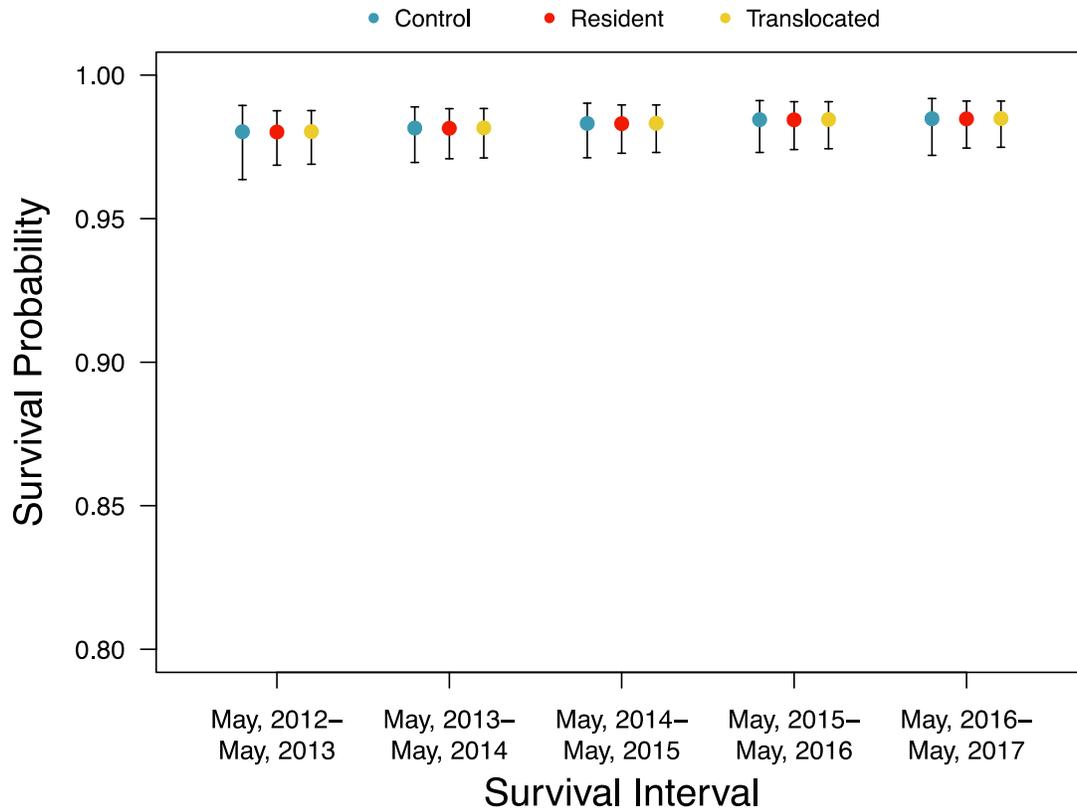


Figure 22. Model-averaged estimates of annual survival probabilities from May 2012 to May 2017 for control, resident, and translocated tortoises in the Ivanpah Valley study area from the analysis of data on tortoises in the largest size class (> 160 mm MCL). Estimates are for tortoises of average size (MCL) with landscape-level covariate data. Error bars around estimates represent 95% confidence intervals. Note that there was no effect of year, thus annual estimates of survival are the same for every year.

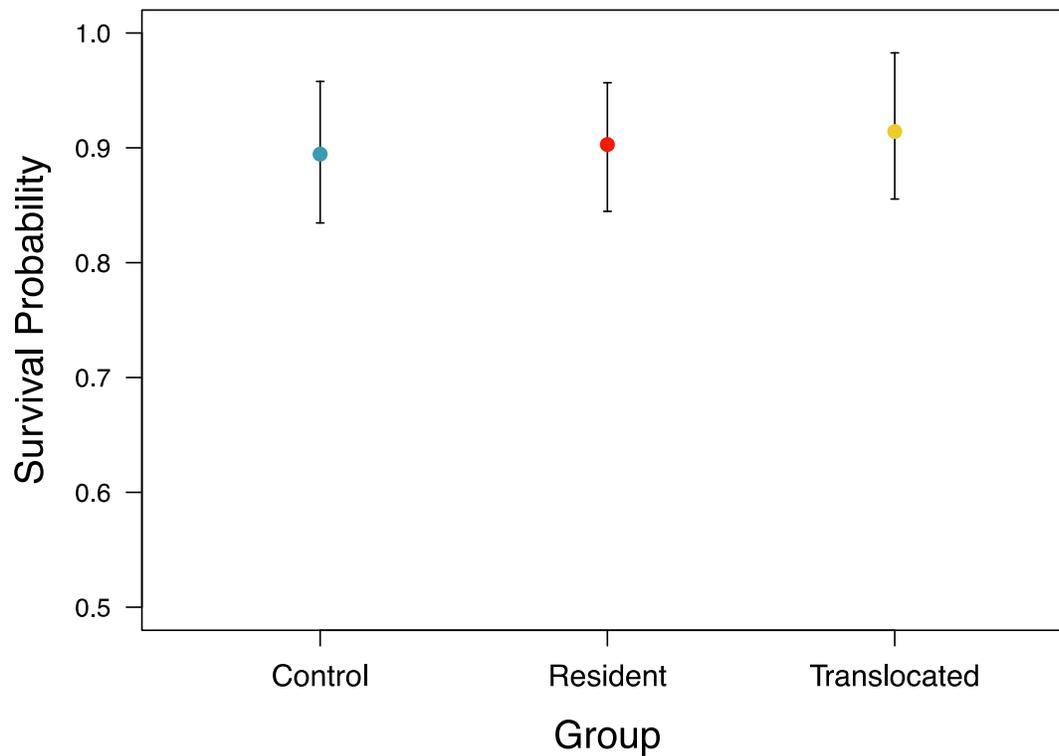


Figure 23. Model-averaged estimates of cumulative survival probabilities from May 2012 to May 2017 for control, resident and translocated tortoises in the Ivanpah Valley study area from the analysis of data on tortoises in the largest size class (> 160 mm MCL). Estimates are for tortoises of average size (MCL) with landscape-level covariate data. Error bars around estimates represent 95% confidence intervals.

4. Conclusions

Translocation has become a common mitigation technique to reduce negative effects of human activities on protected species. For example, several studies that have evaluated desert tortoises translocated following exurban or military development have found no effect of translocation on stress (Drake et al. 2012), reproductive output (Nussear et al. 2012), or survival (Field et al. 2007, Esque et al. 2010, Nussear et al. 2012), but possible effects on paternal genetic integration (Mulder et al. 2017). For both long-distance (Field et al., 2007, Nussear et al., 2012) and short-distance (Farnsworth et al. 2015, Hinderle et al. 2015) translocations, increased movement has been most consistently observed effect.

This report presented results associated with the two main objectives of the ISEGS EMP for desert tortoise translocation to: 1) collect and analyze data on potential drivers of tortoise survival, and 2) investigate the processes and scales influencing tortoise survival. Within the nearly six years since translocations began, these objectives have been achieved: we collected and analyzed data on individual-level factors (e.g., size, sex) and environmental variables (e.g.,

thermal conditions, local- and landscape-level variables, anthropogenic factors) and analyzed their potential effects on tortoise survival within the Ivanpah Valley study area. The key findings of this study were as follows:

- In the first two months of the first active season post-translocation, translocated tortoises increased their movements, showed decreased space use intensity, and experienced higher ambient temperatures than did resident and control tortoises. However, space use and thermal conditions of translocated tortoises were indistinguishable from those of control and resident tortoises thereafter.
- Annual and cumulative survival probabilities of translocated tortoises were not different from those of resident or control tortoises. Furthermore, survival estimates of immature and adult tortoises in the Ivanpah Valley study area were among the highest annual survival probabilities published in the scientific literature (Doak et al. 1994, Zylstra et al. 2013, Nafus et al. 2017). Given the importance of survival probabilities in older age classes to dynamics of turtle populations, generally (Heppell 2008), and desert tortoise populations, in particular (Doak et al. 1994, Reed et al. 2009), it is worth highlighting that survival probability estimates of our study groups all approached 1.0 (i.e., the maximum value possible). In other words, survival estimates indicated that, on average, between 89% and 100% of tortoises survived each year, with larger (i.e., older) tortoises at the high end of that range.

Based on relatively short-term differences in space use and thermal effects related to short-distance translocations, coupled with the lack of negative effects on condition, growth, or mortality that we observed in this study, we conclude the following:

- Short-distance translocation releases in spring had relatively minimal impacts on desert tortoise space use and other behaviors in the Ivanpah study area (Farnsworth et al. 2015, Brand et al. 2016, Sadoti et al. 2017).
- Spring translocations might have given tortoises time to dig burrows and familiarize themselves with their surroundings prior to being exposed to hot summer temperatures.
- Translocation methods that minimize stressful environmental conditions during the period immediately following translocation may have the greatest success.
- This study serves as an important example of how translocations can be combined with intensive monitoring to understand the potential effects of energy and other development on sensitive species.

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7. Appendix A: Protocols for field implementation of the translocation Effectiveness Monitoring Program (EMP)

- 7.1. Local-scale Measurements of Vegetation and Habitat Features
- 7.2. Climatic Processes Associated with Desert Tortoise Habitat
- 7.3. Thermal Assessments of Tortoises and Associated Burrows
- 7.4. Health and Pathogen Transmission Monitoring
- 7.5. Environmental Toxicant and Contaminant Monitoring
- 7.6. Road Noise and Vibration

7.1 Local-scale Measurements of Vegetation and Habitat Features

Drafted by Laura Pavliscak, Myles Traphagen, Nate Jones and Kelly Herbinson, Sundance Biology and Kiva Biological Consulting

To measure and monitor the influence of environmental variables at a local scale, we supplemented a previous inventory for the study site (conducted in 2010) with long-term, repeat-measure vegetation sampling, assessing key attributes of perennial and annual vegetation. Variables such as cover, height, density, frequency, and species diversity were considered, as well as soil characteristics, in order to assess tortoise forage and shelter site potential, and to monitor habitat quality changes over the study period.

On-the-Ground Protocol

Field personnel sampled vegetation once per year in the spring, and again in the fall in order to examine changes over time. The number and spatial distribution of sampling transects and plots were determined in an adaptive framework to accommodate the distribution of study animals and environmental variables of interest. Our vegetation sampling protocol evaluated local-scale habitat characteristics along transects based on topographic and vegetative community features across the study area to capture the naturally occurring heterogeneity in tortoise habitat.

7.2 Climatic Processes Associated with Desert Tortoise Habitat

Drafted by Myles Traphagen and Kelly Herbinson; Sundance Biology and Kiva Biological Consulting

We implemented a systematic, long-term weather monitoring program to provide valuable information on the role of weather in influencing desert tortoise habitat use. We gathered weather data from a network of weather stations throughout the Ivanpah Valley. Detailed weather data provided insight into the relationship between local-scale weather patterns and landscape-scale environmental variables, which we were able to incorporate in survival analyses.

For desert tortoises, one specific impact of drought involves forage plants that have been identified as crucial for the species to survive the hyper-arid conditions of the Mojave Desert, notably, annual plants containing compounds that promote potassium excretion potential (PEP). Such plants appear to be restricted in time and space to very moist conditions, and thus achieve abundance in numbers and biomass only in years of high winter rainfall and relatively cool springs, such as the 1991/92 and 1997/98 El Niño-Southern Oscillation events (Oftedal 2001). Thus, the need for monitoring these specific plant species, in association with prevailing weather conditions, is of utmost importance.

On-the-Ground Protocol

To collect weather data, six automated data-logging weather stations were established within the project boundaries and on the control and recipient sites. The weather stations collected information on precipitation, temperature, relative humidity, evapotranspiration, and solar radiation, all on an hourly basis.

To augment the weather station data and quantify spatial variability in rainfall, a network of 18 low-cost manual rain gauges were deployed within the project boundaries and on the control and recipient sites. To reduce costs and increase efficiency, rainfall data were collected by radio telemetry personnel on their regular routes following rainfall events. By collecting data on localized precipitation, we were able to examine the association between rainfall and habitat predictor variables in the survival analysis.

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7.3 Thermal Assessments of Tortoises and Associated Burrows

Drafted by Jay Meyers and Kelly Herbinson; Sundance Biology and Kiva Biological Consulting

Temperature data loggers were covered and affixed with epoxy to either the costal or marginal scutes of each tortoise. Placement of the iButton was dictated by the size and shell morphology of the tortoise. To determine the best placement of the iButton, a subset of tortoises in the holding pens were affixed with up to three iButtons and then monitored to ensure the feasibility of these locations for placement on wild tortoises. iButtons weigh less than three grams (5 g total with the included epoxy), and the total weight of the transmitter (approximately 20 g with epoxy) and iButton combined was under 5% of an animal's body weight in tortoises over approximately 130 mm MCL. For tortoises smaller than 130 mm, iButtons were modified by removing the outer canister, bringing the total weight down to approximately 1 g (Lovegrove 2009). On small tortoises, we typically placed modified iButtons on one of the costal scutes, but loggers were placed on pen animals first to confirm the appropriateness of the attachment site.

Cover Sites: To monitor tortoise thermoregulatory behavior, it is necessary to adequately describe the thermal profiles of cover sites used by the tortoises. Data loggers were placed in multiple cover sites, including soil and caliche burrows. Burrow temperatures were monitored by attaching an iButton to flexible wire that was threaded down to the burrow terminus. The exposed end of the wire was staked at the burrow entrance to reduce the chance of it being pulled into the burrow. Data loggers also monitored above-ground cover sites and ambient temperatures. These loggers were attached to a holder that sunk into the ground so that the final position of the button was just above the surface of the ground. To reduce the effect of direct sunlight on the iButton, a 3-in semi-translucent cover was placed on top of the stake to reduce direct radiance on the iButton. Data loggers monitoring cover sites were set to record at 30-60 minute intervals, requiring them to be downloaded less frequently than for tortoises. Data were downloaded and managed in the Microsoft Access database developed for the EMP. Data loggers were replaced as needed due to damage or loss.

Literature Cited

Lovegrove, B.G. (2009). Modification and miniaturization of thermochron iButtons for surgical implantation into small animals. *J. Comp. Physiol. B* 179: 451-458.

7.4 Health and Pathogen Transmission Monitoring

Drafted by Liz Smith, Peter Woodman and Kelly Herbinson; Sundance Biology and Kiva Biological Consulting

Prior to the current study, the effects of translocation on the health of desert tortoises were unknown. Desert tortoises translocated from the Fort Irwin National Training Center were monitored for health over the last three years; however, no conclusive results have been documented (Berry pers comm). Two health issues have been implicated in high mortality events for the desert tortoise at one or more sites: upper respiratory tract disease (caused by the pathogens *Mycoplasma agassizii* and *M. testudineum*) and shell lesions indicative of cutaneous dyskeratosis (a shell disease of unknown origin with unknown physiological processes leading to compromised health or death.) The latter disease is typified by lesions on the growth annuli, primarily on the scutes and large scales of the forelimbs. Areas affected with cutaneous dyskeratosis appear discolored, dry, rough, and flakey, with peeling and chipping through multiple cornified layers (Homer et al. 2001).

Large die-offs of tortoises have been attributed to epizootics of *M. agassizii* (Sandmeier et al. 2009), but those die-offs also coincided strongly with periods of stress associated with drought and lack of forage. In this study, our goal was to disentangle this relationship by conducting frequent, comprehensive health assessments that allow us to quantify the role played by pathogens in influencing tortoise survival.

In conjunction with a comprehensive monitoring effort, data were collected on the health status of all tortoises in the three study groups: translocated, resident, and control, for both long- and short-distance translocations. Health assessments were conducted during spring and fall of each active season, as stipulated by USFWS (USFWS 2011a), with the additional condition

that we used a modified version of the Berry and Christopher (2001) data form (i.e., a much more detailed data form that allows for greater detail regarding potential health abnormalities from upper respiratory tract disease and cutaneous dyskeratosis). All tortoises were handled as stipulated by all regulatory agencies and great care was taken to minimize stress and disturbance to each animal (Berry et al 2002).

On-the-Ground Protocol

A detailed and specific protocol is already currently in place for monitoring tortoise health (see the June 2011 ISEGS Biological Opinion (USFWS 2011b), the USFWS Health Assessment Handbook (USFWS 2011a) and Berry and Christopher (2001) for more information). USFWS-approved field personnel conducted health assessments on all radio-tagged tortoises twice per year: mid-May and early to mid-September. Blood and oral swabs were collected twice per year in conjunction with the health assessments to assess within-year transmission dynamics.

The visual health assessment included but was not limited to: clinical signs of upper respiratory tract disease (discharge from nares and/or eyes, redness and/or swelling of eyes, lethargic behavior, and poor body condition score), shell disease (lesions typical of cutaneous dyskeratosis, peeling laminae or scutes, other lesions of the bone or scute, mold, and fungus), and trauma (missing or other trauma to the limbs and trauma to the shell). Clinical assessments included ELISA testing for *Mycoplasma agassizii* and *M. testudineum*.

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7.5 Environmental Toxicant and Contaminant Monitoring

Drafted by Brian Cohn and Kelly Herbinson; Sundance Biology and Kiva Biological Consulting

Elemental toxicity related to heavy metals and anthropogenic pollutants is one of many suspected causes of elevated morbidity and mortality of desert tortoises. The need for a

toxicology investigation is increasing, particularly as tortoise habitat becomes increasingly fragmented and tortoises are forced closer to potentially toxic regions like highway buffers (e.g. I-15 corridor), factories, and mines.

We implemented a monitoring effort that evaluated potential toxicants in air, soil, vegetation, and tortoises, with the aim of evaluating the impact of potential environmental toxins on tortoise health and survival in all three study groups: translocation, resident, and control. We evaluated the distribution of metal concentration values across the study area in relation to potential anthropogenic sources. The sites collectively contain highly developed or disturbed areas (proximate to I-15) as well as less impacted ecosystems (e.g. upper bajada of recipient site, eastern portions of control site). By measuring metal concentrations at a variety of sites, we were able to quantify natural and anthropogenic toxicant levels, to be used in analyses to determine whether they influence health and disease. To accomplish this, we sampled potential toxins from the environment and habitat components to determine current levels and we also plan to continue to monitor these levels for changes over the course of the project. Finally, we collected and analyzed blood samples from live tortoises during health assessments to quantify heavy metal concentrations across groups and across the study area. Tissue samples were also collected from recently deceased project tortoises (where scutes and/or body tissue and organs are present).

On-the-Ground Protocol

Field personnel collected dust samples at 12 sampling locations across the study area, including the quarantine pen, recipient sites and control sites. All samples were collected and prepared for laboratory analyses using inductively coupled plasma mass spectrometry (ICP-MS), which was used to quantify 29 trace and non-trace elements. All soil and vegetation samples were packed and shipped to the University of Alaska Anchorage for analysis. Soil and vegetation toxicology monitoring followed the protocols presented in Chaffee and Berry (2006), with samples collected in conjunction with vegetation (see above) to maximize efficiency.

Soil samples were collected at depths of ~2-8 cm using soil cores, a distance meant to target the depth to which the roots of annual and perennial plant species important to desert tortoises generally grow. A subset of soil samples was used to assess soil texture. Harmful metals were tested at the Applied Science, Engineering, and Technology Laboratory (ASET) at the University of Alaska, Anchorage, on homogenized samples collected from within burrows of translocated, resident, and control tortoises. Experienced botanists collected plant samples and soil cores across the translocation, resident, and control burrow sites at the same time.

As in the case of soil sampling, plant samples were collected both parallel and perpendicular to high traffic roadways and other road types to observe the potential influence of roads as point sources for concentrating potential toxins in plant tissue. The goal was to generate a portrait of how potential toxins changed over space and time. We collected plants in spring (April-May), with a focus on annuals and perennials known to be consumed by tortoises as well as forage locations defined by the home ranges of radio-tracked tortoises. We measured the potential

toxin content of PEP plants, tortoise cover, alternative foods, and exotic and invasive plants. Plant samples were sent to ASET lab at the University of Alaska, Anchorage, for analyses.

Sampling locations were chosen to represent the ecological characteristics and processes across the landscape in the Ivanpah Valley. Sampling will take place over the life of the monitoring program to evaluate temporal linkages between potential toxin exposure to tortoises and their survival.

Dried Blood Spot Procedure

We used a relatively novel dried blood spot (DBS) analytical procedure (validated by Lehner et al., 2013) that analyzes toxin concentrations in whole blood using ICP-MS. Whole blood samples were collected on filter paper. This offered the advantage that it enabled both ELISA testing and DBS testing. During health evaluations, we drew up to 0.25-3 ml of blood from each individual, with the amount depending on the weight of the animal at the time blood was drawn (USFWS 2013). No additional sampling was required, as the heavy metal analysis required only 50 μ L of blood per DBS test. Another advantage of the DBS method is that sample storage (Whatman 903[®] Filter Card) requirements are minimal, as samples only need to be frozen for long-term storage and the cards are compact.

Element concentrations were determined for each blood sample at the Michigan State University Diagnostic Center for Population and Animal Health. The spot was removed from the card using acetone-rinsed stainless steel scissors. Blood and blank paper spots were placed in separate 5 mL Teflon digestion vessels (Savillex, Minneapolis, MN), to which 250 mL of concentrated nitric acid (Suprapur, Merck) was added; the vessels were then heated in an oven at 95°C overnight. After cooling the vessels, increments of water were added until a 500 mg (\pm 5 mg) mass was obtained, and the solution was centrifuged for 10 min at 3000 rpm. For quality control, Lyphochek-2 and -3 standards (Bio-Rad, Hercules, CA) were also run simultaneously. As, Cd, Pb, Hg, and Se were determined by using ICP-MS (7500ce ICP-mass spectrometer; Agilent, Santa Clara, CA). The limits of quantification (LOQs) were 10 ppb for As, Cd, and Se and 20 ppb for Hg and Pb.

The laboratory measured standard curves based on five points plus a blank, which gave good refit values down to 10 ppb (Fe, As, Cd, Pb, Hg, Se, Tl, Th) or 20 ppb Hg. The limits of detection and limits of quantitation were calculated analyzing repeated blanks for any background signal present in the untreated paper, determining the standard deviation of the values ($n = 10$), and multiplying by 3.3 times or 10 times, respectively, according to established methods (Lehner et. al 2013). Concentrations estimated based on blank spots on the papers were lower than the limits of quantification.

Although acute poisoning concentrations remain unknown for desert tortoises, this test panel method was shown to be suitable for the diagnosis of heavy metals in domesticated and other wildlife species. Blood concentrations of As, Cd, Hg, Pb and Tl are generally <50 mg/L (Lehner et. al 2013).

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7.6 Road Noise and Vibration and Tower Noise

Drafted by Bill Boarman, Kelly Herbinson, and Laura Pavliscak; Sundance Biology and Kiva Biological Consulting

The proliferation of roads and highways throughout the range of the desert tortoise has significantly impacted tortoise mortality rates (FWS 1995, Boarman 2002). One cause of tortoise mortality due to roads is moving vehicles. Tortoises that move more than average are at an even greater risk of being run over, which means adult and sub-adult males are the most at risk (Sazaki et al. 1995 and Boarman and Sazaki 2006). Additionally, translocated animals are also known to move more than average (Nussear 2004), which puts them at an increased risk of road mortality as well. Previous research has found that most roads have a tortoise depletion zone within a distance of approximately 400 meters, and perhaps farther for older and more heavily traveled roads (Boarman and Sazaki 2006). This depletion zone may be attributed to road kills, but it may also be caused by indirect effects such as airborne contaminants (Homer et al. 1998), noise, vibration, or vegetation changes associated with habitat degradation (Frenkel 1970, Johnson et al. 1995).

To determine the effect of roads on tortoise survival, we monitored noise, vibration, and environmental toxicants as well as the movement of associated tortoises (see above) along the

edge of Interstate I-15. We tracked tortoises that moved to the edge of I-15 weekly (an established requirement in the Biological Opinion) to determine movement patterns associated with the highway.

Noise monitoring was also conducted at each of six locations proximate to the ISEGS towers. Our goal was to quantify noise emitted from the towers during operational and non-operational conditions, as well as background noise levels within the project area. Monitoring locations were representative of noise-sensitive locations in the project area.

On-the-Ground Protocol

We set up acoustic noise and vibration measuring instruments in the release and control sites. The Caltrans traffic noise measurement protocol was implemented to ensure consistency with other studies completed in California. Noise monitoring was conducted using the Larson Davis Model 820 sound level meter with a Model PRM828 5.5 inch precision preamplifier and a 0.5 inch precision air condenser microphone with a 3.5 inch windscreen. This meter meets the requirements of the American National Standards Institute (ANSI) S1.4, International Electro-technical Commission (IEC) 651, and 804-1985 standards for type 1 accuracy. The microphone was placed ~8-10 cm from the ground to mimic the height at which sounds would be heard by a tortoise. A single microphone was used at each sample point. Sampling periods were adjusted depending on the extent of temporal variability in sound levels as per ANSI S1.13-1971 and ANSI S12.9-1988. The noise fluctuation at each sample point was within 10 dB and relatively steady depending on traffic pattern. Thus, a measurement of no less than two minutes was taken at each sample point with a minimum of three repetitions.

Sample locations were chosen to represent vibration and noise distribution across the Ivanpah Valley study area. The primary focus of this monitoring effort was the noise produced by traffic traveling along the I-15 corridor. Therefore, several transects were selected to measure vibration and noise starting at the edge of I-15, moving perpendicular at 50-100 m intervals until ambient noise and vibration levels were attained. BLM dirt roads and other secondary and tertiary roadways were characterized by similar transects. We measured pass-by scenarios (e.g., a single pick-up truck driving down the road) to characterize the extent and magnitude of vibration and noise on these smaller, less traveled road systems. Additionally, 32 locations coinciding with the vegetation monitoring plots were also sampled to ensure characterization of valley-wide noise and vibration distribution, specifically that of the release and control sites of the ISEGS EMP. Each point was sampled at least once during average traffic conditions and if possible during high and low traffic conditions.

Vibration monitoring at ISEGS was conducted using an Instantel Blastmate III Vibration Seismograph, equipped with a triaxial velocity geophone. The instrument measures a time history of vibration in each of three mutually perpendicular directions (vertical, longitudinal, and transverse). From these three directions a peak acceleration, velocity, and displacement is measured for each vibration event. Adjacent to I-15, air vibration was measured using a fourth channel on the Blastmate III, which allows a microphone whose output units are pressure (Pascals).

Noise monitoring proximate to the ISEGS towers was conducted using the Extech Instruments Model 407732 Digital Sound Level Meter with a windscreen. This instrumentation complies with ANSI and IEC for Type 2 SLM standards. An Extech Instruments Model 407722 Sound Level Calibrator was used to calibrate the sound level meter before and during the monitoring effort.

Three short-term noise level measurements (six minutes in duration) were conducted at each of six sites proximate to the towers, twice a day (morning and afternoon) and approximately weekly from February 21, 2013, through October 22, 2013. The microphone was placed at 1.5 m from the ground surface, the preferred position in terms of microphone height for most construction and traffic related monitoring. A single microphone was used at each sample point. For receiver distances greater than 100 m from the source, meteorological conditions can have a large influence on sound travel (e.g., distance, level, frequency). Therefore, meteorological conditions (wind speed and direction, temperature, humidity, and cloud cover) were documented prior to data collection and whenever substantial changes in conditions were noted.

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8. Appendix B. Individual-level and landscape-scale variables measured or derived for use in analyses

Table 8.1. Landscape-scale variables measured or derived in this study.

<i>Variables</i>	<i>Description</i>
Movement(s) and space use	Distance moved per day and within activity centers, area under the utilization distribution and burrow density
Thermal condition	Average daily maximum temperature for tortoises and average daily duration a tortoise experiences temperatures > 35C
Wash density	Estimate of wash density within each individual's utilization distribution, based on CIR DOQQ data and estimates of NDVI
Shrub cover	Estimate of shrub cover within each individual's utilization distribution, based on CIR DOQQ data and estimates of NDVI
Greenness	Landsat-derived NDVI or EVI as proxy for, e.g., forage availability and precipitation
Terrain	Aspect and estimate of topographic roughness integrating over elevation and slope
Soil properties	Bulk density, coarse fragments % by volume, % silt, % sand, % clay, and pH*10 in water
Weather	Total precipitation and mean daily maximum temperature over each active season
Anthropogenic: roads and fences	Estimates of road and fence density within utilization distribution and presence of/proximity to infrastructure
Anthropogenic: noise and vibration	Loudness and frequency of sound and magnitude of vibrations related to traffic on I-15
Anthropogenic: toxicity	Heavy metal concentrations in tortoise blood

Table 8.2. Individual- and landscape-scale predictor variables used in the survival analysis.

Analysis	Predictor variable	Description
Analysis 1	Treatment group	Translocated, resident, and control
	Size (Midline Carapace Length [MCL] in mm)	MCL during spring health assessment preceding survival interval
	Sex	Adult male, adult female, and immature (i.e., unknown sex)
Analysis 2*	Body condition	Body condition scores, numeric score (scale of 1-7) of relative degree of emaciation (lowest = 1)
Analysis 3*	Iron concentration	Concentration of iron in blood of tortoises based on dried blood spot samples
	Selenium concentration	Concentration of selenium in blood of tortoises based on dried blood spot samples
	Lead concentration	Concentration of lead in blood of tortoises based on dried blood spot samples
Analysis 4*	Maximum temperature	Average daily maximum temperature a tortoise experiences during an active season
	Duration $\geq 35^{\circ}\text{C}$	Average daily duration a tortoise experiences temperatures $> 35^{\circ}\text{C}$ during an active season
Analysis 5*	Home range size	Area (ha) under the utilization distribution
	Burrow density	Estimate of burrow density within each individual's utilization distribution based on a map of burrows derived from tortoise encounters within burrows
	Shrub density	Estimate of shrub cover within each individual's utilization distribution based on CIR DOQQ data and estimates of NDVI
	Wash density	Estimate of wash density within each individual's utilization distribution based on CIR DOQQ data and estimates of NDVI
	Topographic roughness	The standard deviation of elevation within a home range
	Soil bulk density	The weight of soil in a given volume
	Mean NDVI	Landsat-derived estimate of forage availability and precipitation for a home range
	Coefficient of variation of NDVI	Landsat-derived estimate of the variability in forage availability and precipitation across a home range
	Road density	Estimate of the density of roads within a home range
	Fence density	Estimate of the density of fences within a home range
	Precipitation	Total precipitation at a home range over each active season
	Maximum temperature	Mean daily maximum temperature at a home range over each active season

*Effects of midline carapace length (MCL) and group were included in all analyses and are defined under Analysis 1.