DESERT TORTOISE OCCUPANCY COVARIATE MONITORING PROTOCOL

ASSESSING THE ENVIRONMENTAL VARIABLES THAT INFLUENCE THE STATUS AND TRENDS OF MOJAVE DESERT TORTOISE (*GOPHERUS AGASSIZII*) IN THE BOULDER CITY CONSERVATION EASEMENT

CLARK COUNTY

MULTIPLE SPECIES HABITAT CONSERVATION PLAN

September 2012

Version 1.0

desert conservation PROGRAM

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ACRONYMS AND ABBREVIATIONS

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BCCE	Boulder City Conservation Easement
BLM	Bureau of Land Management
CART	Classification and Regression Tree
cm	centimeter(s)
covariates	environmental variables
DCP	Desert Conservation Program
GIS	geographic information system
GPS	global positioning system
GRTS	Generalized Random Tessellation Stratified
ha	hectare(s)
KEA	key ecological attribute

km	kilometer(s)
m	meter(s)
MacOS	MacIntosh Operating System
MODIS	Moderate Resolution Imaging Spectroradiometer
mph	miles per hour
MSHCP	Multiple Species Habitat Conservation Plan
NAC	Nevada Administrative Code
NAD	North American datum
NDVI	Normalized Difference Vegetation Index
NIR	near infrared light
NRCS	Natural Resources Conservation Service
oob	out-of-bag data
%	percent
PDOP	position dilution of precision
QA/QC	quality assurance/quality control
R	an open source statistical software
RF	Random Forests software
UNIX	uniplexed information and computing system, a computer operating system
UNLV	University of Nevada, Las Vegas
U.S.	United States
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
UTM	Universal Transverse Mercator
VIS	visible light

ABSTRACT

The Mojave desert tortoise (*Gopherus agassizii*) is a priority species for conservation in Clark County, Nevada (U.S.). It is listed as threatened under the Federal Endangered Species Act and is a covered species under the Clark County Multiple Species Habitat Conservation Plan. Studies have shown that the species has declined and continues to decline throughout its range in the Mojave Desert. Assessing the population status and trends of the species is essential to determine if the species is continuing to decline or beginning to recover in response to protection and management actions. This monitoring protocol accompanies a previously developed occupancy sampling monitoring protocol designed to assess the status and long-term spatial trends of the desert tortoise in the Boulder City Conservation Easement. It describes the measurement of a range of environmental variables (covariates) that are hypothesized to be related to the annual presence of the desert tortoise, including vegetation, substrate (soils), precipitation, disturbances and habitat alterations, and management actions. These covariates will be used to interpret the occupancy sampling data and test for correlations with hypothesized causal factors that influence the presence of desert tortoises. The correlated causal factors will provide information to managers to develop and evaluate management actions intended to increase tortoise presence. Ultimately, these data could be used to develop a statistical model to understand and predict the occurrence of the desert tortoise in this and similar landscapes.

The protocol describes the goals, objectives, and assumptions of the monitoring protocol; list of covariates; sampling design and sampling methods; data management; data analysis, decision-making, management response, and communication of results; and implementation of the protocol. A conceptual ecological model was prepared for the desert tortoise in the Boulder City Conservation Easement to illustrate current understanding of the tortoise as it relates to the abiotic and biotic variables of its habitat, and the causal factors that change those variables. The model was used to select potential covariates, and is presented as an appendix to this protocol. Each covariate is presented with a hypothesis, sampling method, and sampling frequency. A data management plan describing the data collection process, data verification and validation methods, and data management is integrated into this protocol.

1.0 INTRODUCTION

The Clark County Desert Conservation Program (DCP) has initiated a multi-year pilot study using occupancy sampling to assess the status and detect long-term spatial trends for the Mojave desert tortoise (*Gopherus agassizii)* in the Boulder City Conservation Easement (BCCE). The desert tortoise is federally listed as threatened (USFWS, 1990), protected in the State of Nevada (NAC 503.080), and covered under the Clark County Multiple Species Habitat Conservation Plan (MSHCP) Section 10(a)(1)(B) Incidental Take Permit), and therefore, is a priority species for conservation (Clark County, 2000). The MSHCP requires tracking the status and trends of covered species and the United States Fish and Wildlife Service (USFWS) addendum to the Habitat Conservation Plan Handbook ("5-point policy") recommends monitoring the effectiveness of uncertain mitigation practices (Clark County, 2000; USFWS & NOAA, 2000).

This monitoring protocol accompanies the occupancy sampling monitoring protocol (Clark County, 2011) and describes measurements of a range of environmental variables (covariates) that are hypothesized to be related to the annual presence of the desert tortoise. These covariates will be tested for correlations with the tortoise presence and the correlated covariates used to interpret the occupancy sampling data. The correlated causal factors will also be used to develop and evaluate management actions that are intended to increase presence of tortoises. Ultimately, these data can be used to develop a statistical model to understand and predict the occurrence of desert tortoises in similar landscapes.

The occupancy sampling monitoring protocol explores the use of occupancy sampling for monitoring Mojave desert tortoises to meet the needs of land managers for smaller conservation areas. Occupancy sampling assesses the proportion of habitat occupied by a species and does not estimate abundance or density. Zylstra et al. (2010) assessed the efficiency and statistical power of occupancy sampling for the Sonoran desert tortoise in the Sonoran Desert. Their work suggests that occupancy sampling may be more efficient and have greater statistical power to detect annual declines in the proportion of area occupied as compared with annual declines in density detected by line distance sampling. Occupancy sampling has also been suggested as a monitoring approach in the Revised Recovery Plan (USFWS, 2011). The DCP is conducting a multi-year (3 to 5 years) pilot study to test Mojave desert tortoise occupancy sampling and this covariate protocol in the BCCE located in Clark County, Nevada.

1.1 Species Information

Desert tortoises are found in southern Nevada, southeastern California, western and southern Arizona, southwestern Utah, and portions of Sonora and Sinaloa, Mexico (Murphy et al., 2011). Until recently only one species was thought to occur in this range. It is now recognized that tortoise populations west of the Colorado River in Utah, Arizona, Nevada, and California are distinct from the remainder of the taxon (Murphy et al., 2011), and retain the name Mojave desert tortoise (*Gopherus agassizii*).

Desert tortoises are herbivorous terrestrial reptiles that may occur at elevations between sea level and 2,225 meters (m) (7,300 feet) (Luckenbach, 1982). Suitable habitat for tortoises includes areas with sufficient available forage consisting of annual and perennial vegetation, and soils suitable for construction of subterranean burrows for nesting, resting, escaping the heat, and for longer periods of brumation. Tortoises in southern Nevada are active above ground between approximately March 15 and October 15. Tortoise monitoring generally takes place during the most active portion of the above ground period, which is in spring and early summer when preferred annual forage species are most available. During years with low annual plant productivity, tortoises may spend considerably more time below ground.

Tortoise home ranges vary from 10 to 81 hectares (ha) (25 to 200 acres), with individuals able to range up to 11.3 kilometers (km) (7 miles) on a single foray (Berry & Turner, 1986). Males typically have home ranges twice as large as females (Berry & Turner, 1986). Tortoises reach sexual maturity at 15 to 20 years of age and reproductive rates have been shown to be low (Tracy et al., 2004). Key threats to tortoise survival and recovery include, but are not limited to, mortality by vehicles, disease (specifically upper respiratory tract disease), predation, and habitat loss and degradation due to urbanization, grazing, energy development, invasive species, fire, and other disturbances (Tracy et al., 2004; USFWS, 2011). Additional information about tortoise biology and habitat requirements may be found in the Revised Recovery Plan for the Mojave desert tortoise (USFWS, 2011).

1.2 Study Area

Both the occupancy sampling monitoring protocol and this protocol for measuring covariates were developed for the desert tortoise population present on the BCCE. The BCCE is located at the upper reaches of the Eldorado Valley and southwest of the populated area of Boulder City. Shown in Figure 1, the BCCE is split by U.S. Highway 95 into a north section (15,802 ha or 39,048 acres) and a south section (19,172 ha or 47,375 acres). There are 1,040 ha (3,064 acres) designated by Boulder City for energy development (Energy Zone) that are excluded from the south section of the BCCE. Small acreages to the east of U.S. Highway 95 and south of State Route 165 are not included in the study area. The protocol will be tested separately in the two sections of the BCCE.

The BCCE is within a closed drainage basin at an elevation between 549 and 914 meters (1,800 and 3,000 feet) (O'Farrell, 2009). There is no permanent surface water within the BCCE. Runoff following large precipitation events drains onto a playa known as Eldorado Dry Lake, located at the lowest elevation just north of the south section of the BCCE. The soils within the BCCE are primarily young alluvial deposits derived from sedimentary and igneous sources (Heaton et al., 2011). These soils are characterized as gravelly and sandy with coarse texture, low organic matter content, and low carbon/nitrogen ratios (O'Farrell, 2009). Rock outcrops occur within the BCCE at the foothills of the McCullough Range and Eldorado Mountains, and where there are basalt flows and intrusions.

The BCCE is mostly Mojave Desert scrub vegetation with approximately two percent (%) covered by salt desert scrub (Heaton et al, 2011). Approximately 80% of the BCCE is in the valley bottom with deep sands and a near surface hardpan, dominated by vegetation of creosote bush (*Larrea tridentata*) and bursage (*Ambrosia dumosa*) (O'Farrell, 2009). Areas with rocky soils (approximately 15%) are dominated by creosote bush, desert thorn (*Lycium andersonii*), and spiney hop-sage (*Grayia spinosa*) (O'Farrell, 2009).

Land to the east, west, and south is primarily under federal ownership and land to the north is in Boulder City jurisdiction. The northern boundary is approximately 3 km (2 miles) south of residential developments of Boulder City. The Energy Zone and three electrical substations are located in the south section. The eastern edge of the north section is adjacent to the National Park Service Lake Mead National Recreation Area. Managed by the Bureau of Land Management (BLM), Sloan Canyon National Conservation Area is to the west of the easement and Piute-Eldorado Area of Critical Environmental Concern is to the south. Paved roads and desert tortoise exclusion fencing divide the

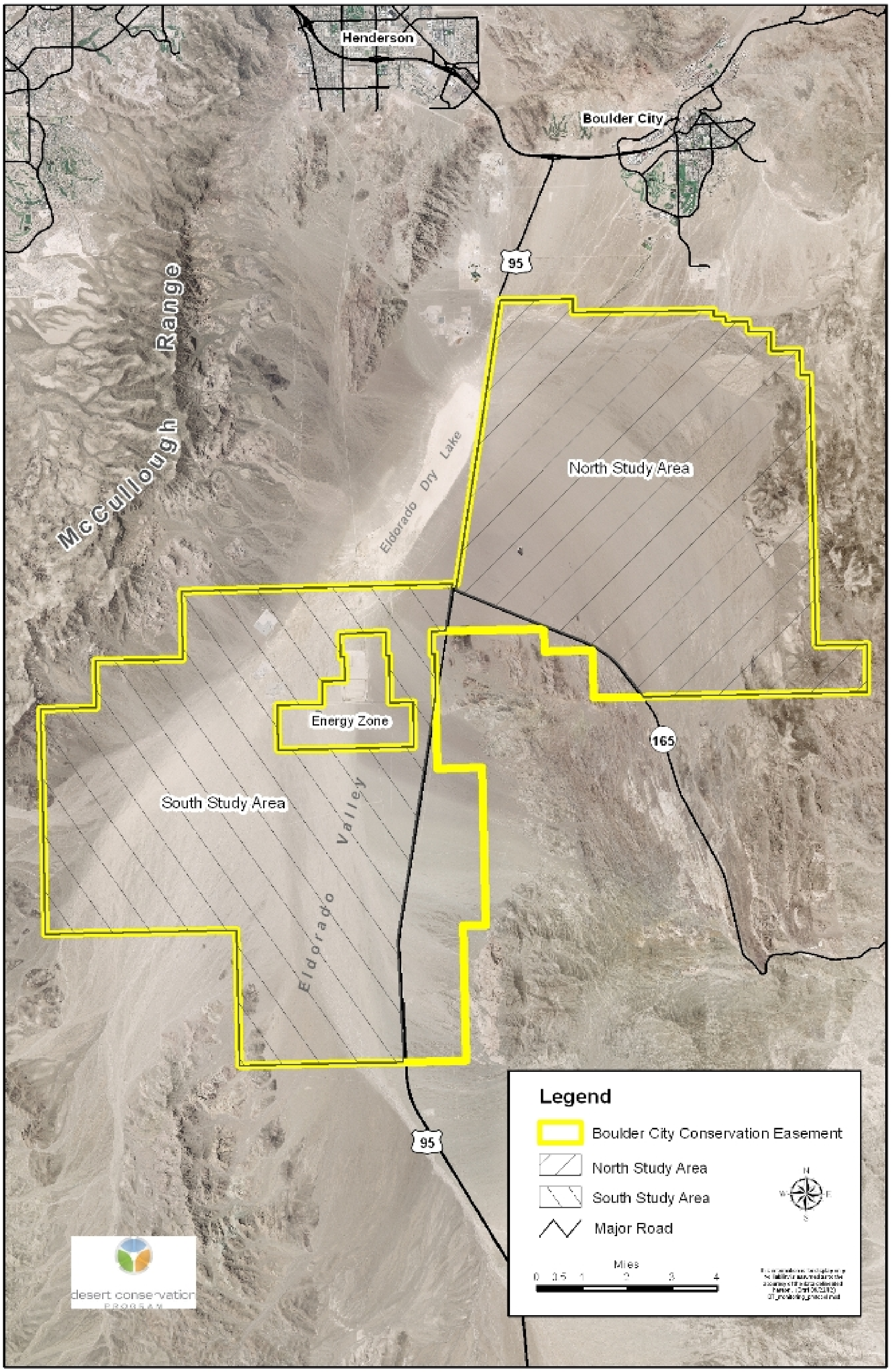

Figure 1. Location of Study Areas within Boulder City Conservation Easement

two sections of the BCCE and also separate most of the north section from adjacent BLM lands. The Eldorado and McCullough mountains surround the BCCE to the east and west, respectively.

Prior to establishment of the easement in 1995, the BLM managed the area for multiple uses including mining, energy transmission, telecommunications, off-highway vehicle racing, hunting, grazing, and open recreation. The conservation easement agreement specifies that of these historical uses, only limited transmission of energy and telecommunications, hunting, non-speed vehicular events, and non-ground disturbing recreation may occur on the BCCE. Clark County is required by the easement agreement to provide law enforcement for the BCCE.

1.3 Occupancy Sampling

The lack of precision at fine scales provided by current methods of estimating abundance and density of Mojave desert tortoises as well as the inability to use existing data to make management and conservation decisions within short timeframes have led to suggestions for different monitoring approaches (Zylstra et al., 2010; Nussear & Tracy, 2007; Tracy et al., 2004). One suggested method is occupancy sampling (USFWS, 2011; Zylstra et al., 2010). Occupancy sampling is defined as determining the proportion of habitat within an area that contains evidence of a targeted species. This approach uses a probabilistic sampling design to select sample units, with each unit visited two or more times per sampling period to incorporate a measure of detectability (MacKenzie et al., 2004; 2005). For tortoises, occupancy sampling will provide spatial distribution of tortoise occupancy in sample units as assessed by two indicators, presence of live tortoises and presence of active burrows.

The use of occupancy sampling for any species is based on the assumption that the status and change over time of a population can be assessed by changes in the proportion of the sample units that are occupied or used by the species. This is a different assumption than sampling for abundance or density and as such is insensitive to changes in density except at low density levels. Thus, the approach assumes that the species will respond to changes in habitat, habitat alteration, or management practices by their occupancy or use of an area. For increases in the population or management success to be detected, tortoises would have to increase in their occupancy of the sample units, and alternately, a decrease would only be measured by a reduction of sample units occupied by the species.

2.0 MONITORING GOALS, OBJECTIVES, AND ASSUMPTIONS

Patterns of tortoise occurrence and use across multiple sampling units can be assessed related to particular areas or environmental variables (covariates). This information can provide valuable information to land managers to assess the species' responses to habitat quality, threats, and management activities. The assessment of covariates will strengthen with multiple years of data from each sample unit.

The goal of this monitoring protocol is to understand the environmental factors that determine the distribution of desert tortoises to improve management decisions to protect and enhance the species.

While habitat has been modeled across the range of the Mojave desert tortoise and in large regions (Nussear et al., 2009; 2010), it has not been assessed at finer scales with the combination of spatial (geographic information system (GIS)) and field data.

The objectives of this monitoring protocol are to:

1. Characterize and monitor a range of environmental variables (covariates) in the BCCE associated with the presence of Mojave desert tortoise.
2. Correlate the pattern and change in desert tortoise occupancy/use with vegetation (cover of shrub and succulent and ephemeral vegetation), substrate (soils), precipitation, disturbances and habitat alteration (roads, off-road vehicle disturbance), and management practices (closing roads, vegetation restoration).
3. Refine the accuracy and efficiency of both the occupancy and covariate monitoring protocols.

These objectives are based on the following assumptions:

1. Tortoises will respond to changes in habitat, habitat alteration, or management practices by altering their occupancy or use of an area.
2. Tortoises will not occupy less-preferred habitat unless more-preferred habitat is beyond capacity to support additional tortoises. Thus, a land management unit that is at or below carrying capacity will have areas that are not occupied by tortoises, and 100% occupancy is not an appropriate goal for many land management units.
3. When an area experiences a decline in tortoises due to emigration and/or mortality, the tortoises will vacate less-preferred habitat areas before vacating more-preferred habitat areas.

3.0 COVARIATES AND COVARIATE SELECTION

The covariates are a range of environmental variables that are hypothesized to be correlated with the annual presence of desert tortoises. Correlated covariates will be used to assist the interpretation of the occupancy sampling data and will be used to develop and evaluate management actions that are intended to increase tortoise presence (i.e., occupancy). Ultimately, these data can be used to develop a statistical model to understand and predict the occurrence of desert tortoises in local landscapes.

The covariates for the desert tortoise data were identified through use of a conceptual ecological model developed for the Mojave desert tortoise within the BCCE (see Appendix C). Conceptual models visually depict the complex causal relationships between a species' life history and its habitat or an ecological system, and how they relate to threats and management actions (DeAngelis et al., 2003; Slauson & Zielinski, 2008; Missouri River Independent Science Advisory Panel, 2011). The model identifies the pathways between management actions, key ecological attributes, and the response of a species or ecological system.

The conceptual ecological model developed for the desert tortoise consists of four components (see Figure 2). The components, from right to left, include life history and demographics, key ecological attributes, ecological changes, and causal factors of change. Arrows are used to represent the relationship of the subcomponents. The direction of the arrows is from left to right – from causal factors of change to their influence on the life history and demographics of the species. The model does not include every possible factor that could be addressed and does not include the linkages within each component of the model. The model focuses on factors determined key to the dynamics of the species and the implementation of management actions.

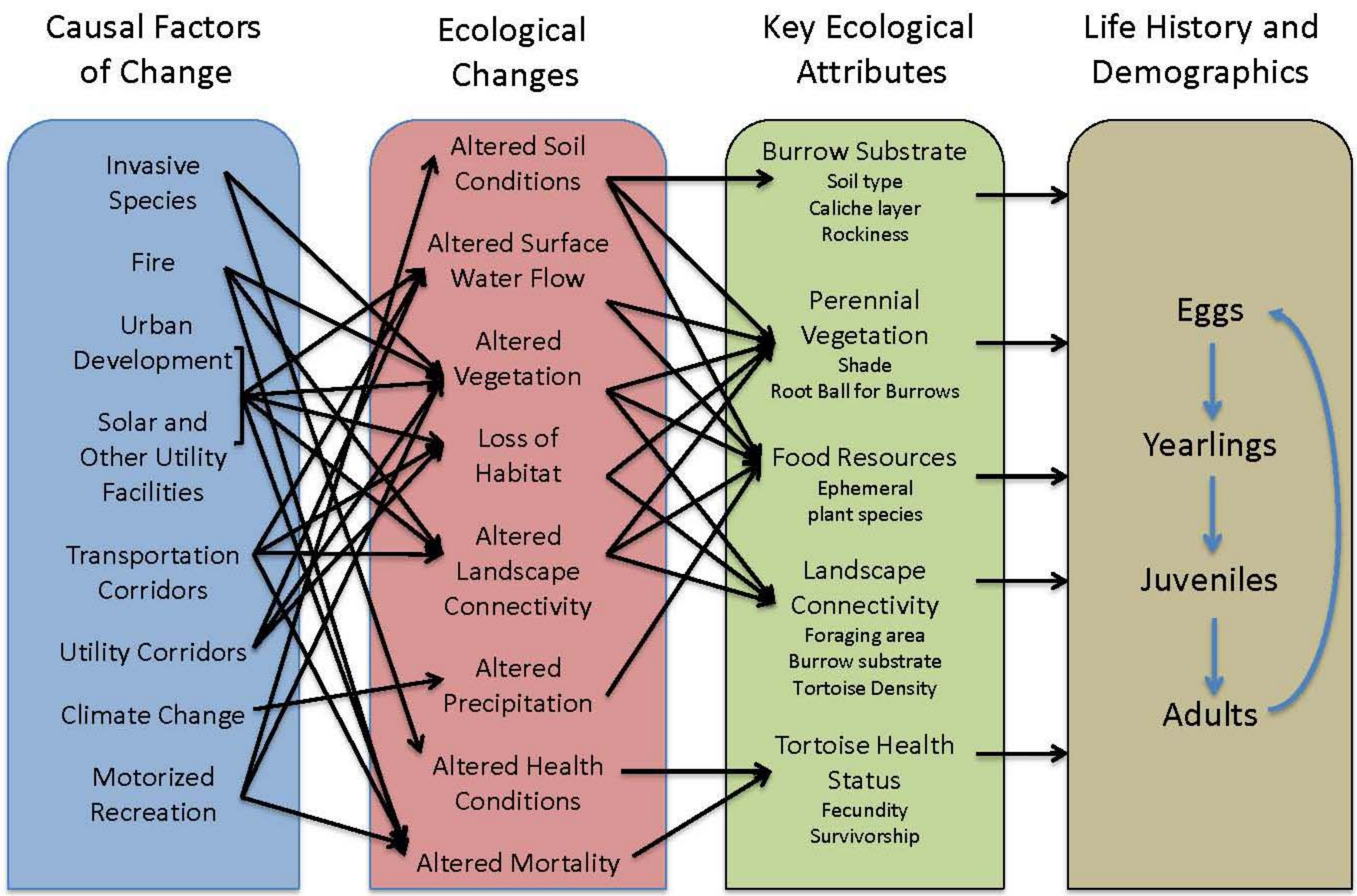

Figure 2. Conceptual Ecological Model for Mojave Desert Tortoise within the BCCE

The important components of the ecological model in relation to the development of the covariates are the key ecological attributes (KEAs) and the causal factors of change. A KEA is a characteristic of the species' biology, ecology, or physical environment that is critical to the species persistence. The KEAs can be physical factors such as the hydrologic regime or fire, or biological factors such as population size or survivorship for a species, or structure and composition of vegetation for an ecological system. While there are many ecological attributes that influence the condition of a species or ecological system, a KEA must strongly influence the species or the ecological system long-term persistence, define or influence its spatial distribution, and contribute highly to resistance and resilience of the species or ecological system. The causal factors of change are the disturbances and habitat alterations that may influence the KEAs, and thus, the presence of desert tortoises.

The covariates identified for the desert tortoise can be placed in five categories – vegetation, substrate (soil), precipitation, disturbances and habitat alterations, and management actions. A summary of these covariates is presented below, with each covariate presented with a hypothesis, sampling method, and sampling frequency.

3.1 Vegetation Covariates

Both perennial shrub vegetation and ephemeral plant species (predominantly spring annuals and short lived perennials) are KEAs for the desert tortoise (USFWS, 2011). The presence of perennial and ephemeral plant species within a natural range of variation reflects the undisturbed nature of tortoise habitat. They also provide specific ecological resources for desert tortoises. Shrubs provide shade and a food resource and some shrub species and size classes of shrub species have elevated root balls that facilitate their use as temporary burrows. Ephemeral plant species provide a primary food source for tortoises (USFWS, 2011; Esque, 1994). Most vegetation covariates will be measured in four subplots systematically placed in each 4 ha sample unit (plot). The covariates include:

1. Vegetative Cover of Perennial Shrub and Succulent Vegetation: Perennial shrubs and succulents provide shade, a food resource, and burrow locations if the root ball of the shrub species is exposed. The most likely shrub and succulent species to be encountered in the BCCE are listed in Table 1. Nussear et al. (2009) found that on a range-wide scale, perennial plant cover was one of the primary factors that best explained the distribution of tortoises.

   - Hypothesis: The presence of desert tortoise over time is related to higher percent cover of perennial shrub and succulent vegetation.
   - Sampling Method: Line intercept has been shown to be the most efficient method for measuring cover of shrub vegetation less than 1.5 m in height (Elzinga et al., 2001), and therefore, the selected sampling method. Line intercept is used to measure the vegetative cover of perennial shrub and succulent species on four 25 m transects, starting 5 m from the center point of the subplot and radiating toward the corners of the subplot at 45, 135, 225, and 315 degrees (see Figure 3). Vegetative cover is measured if any part of a plant crosses the vertical plane of the transect (Elzinga et al., 2001). For this study, gaps in vegetation have to be greater than 20 centimeters (cm) before recording as no vegetative cover. Each species is measured separately, even when overlapping. Bare ground is also measured, with the inverse of bare ground being total vegetative cover.

TABLE 1. PERENNIAL SHRUB AND SUCCULENT SPECIES MOST LIKELY TO BE ENCOUNTERED ON THE BOULDER CITY CONSERVATION EASEMENT	
Species	Family
Ambrosia dumosa	Asteraceae
Encelia farinosa	Asteraceae
Encelia virginensis	Asteraceae
Ephedra nevadensis	Ephedraceae
Eriogonum fasciculatum	Polygonaceae
Grayia spinosa	Chenopodiaceae
Hymenoclea salsola	Asteraceae
Krameria grayi	Krameriaceae
Larrea tridentata	Zygophyllaceae
Lycium andersonii	Solanaceae
Opuntia species (acanthocarpa, basilaris, ramosissima)	Cactaceae
Psorothamnus fremontii	Fabaceae
Sphaeralcea ambigua	Malvaceae
Yucca species (brevifolia, schidigera)	Liliaceae
Source: Nussear et al., 2007	

- Sampling Frequency: The percent cover of perennial shrub and succulent vegetation changes slowly over time because of slow growth and from potential disturbances that reduce cover (Webb et al., 2009), so this covariate is measured the first year of data collection and then at 5-year intervals, based on the duration of the study.

2. Percent Shade Cover of Perennial Shrub and Succulent Vegetation: Desert tortoises require sites to escape the intense heat of the desert, either in burrows or in the shade of perennial shrub and succulent species. This covariate is calculated by subtracting basal cover (the cover of the vegetation at ground level; stem or stems arising out of the ground) from vegetative cover (the projection of all the vegetation on the ground) for all species.

   - Hypothesis: The presence of desert tortoises is related to higher amounts of available shade provided by perennial shrub and succulent vegetation.
   - Sampling Method: Line intercept is used to measure the vegetative and basal cover of all perennial shrub and succulent species on four 25 m transects, starting 5 m from the center point of the subplot and radiating toward the corners of the subplot at 45, 135, 225, and 315 degrees (see Figure 3). Vegetative and basal cover is measured if any part of a plant crosses the vertical plane of the transect (Elzinga et al. 2001). For this study, gaps in vegetation have to be greater than 20 cm before recording as no vegetative cover. Each species is measured separately, even when overlapping. Percent basal cover is subtracted from the percent vegetative cover to calculate percent shade cover for each transect.

- Sampling Frequency: The percent shade cover of perennial shrub and succulent vegetation changes slowly over time because of slow growth and from disturbance that reduces cover (Webb et al., 2009), so this covariate is measured the first year of data collection and then at 5-year intervals, based on the duration of the study.

3. Ephemeral Plant Species Cover and Species Richness: Desert tortoises forage on a wide range of species, primarily annual plant species but also perennial grasses, woody perennials, and cacti (especially cactus flowers) (USFWS, 2011). Specific annual plant species have been shown to be preferred by the tortoise and perhaps provide greater nutrient benefit or moisture (Esque, 1994).

   - Hypothesis: The presence of desert tortoises is related to greater cover and diversity of food resources provided by ephemeral plant species.

   - Sampling Method: The cover of grass and forb species are visually estimated in 1 m x 2 m quadrats placed systematically along the line intercept transect in each subplot. Quadrats are placed at the 10 m and 20 m points on the 25 m transect, with the longer side of the quadrat paralleling the transect and with the transect bisecting the quadrat (see Figure 3). Three grass species will be recorded separately – red brome (*Bromus rubens*), split grass (*Schismus barbatus),* and sixweeks grass (*Vulpia octoflora).* All other grass species will be recorded in a group, and a single group will be used to record all forb species. Total ephemeral plant species cover is also estimated. Cover is estimated in 10 cover classes that are designed to be more sensitive for lower percent cover. These cover classes are trace, 0-1%, 1-2%, 2-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, and 95-100% (Peet et al., 1997). Species richness in each quadrat is determined by identifying all the grass and forb species in the quadrats, including all recognizable taxonomic units described and identified as unknown species.

   - Sampling Frequency: The presence and cover of ephemeral plant species change annually in relation to fall and winter precipitation. This covariate is sampled only in years that have adequate precipitation, a threshold that is determined by the prediction of El Nino conditions using the ENSO Alert System (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/enso-alert-readme.shtml). Sampling will occur during years with an El Nino Watch or an Advisory, determined at an appropriate time or at six months before field sampling is initiated (S. Wainscott, DCP; personal communication). In years without these conditions, the assumption is there would not likely be any ephemeral plant species to measure. During any year of no sampling, a random subset of 10 of the 4 ha plots that are located within 1 km of an access road will be visually assessed by DCP staff to verify the assumption.

4. Vegetation Index of Perennial and Ephemeral Plant Cover: This covariate uses remote sensing to measure a vegetation index that can be interpreted to represent total plant cover and the green-up of spring ephemeral plant cover. The best available aerial or satellite imagery is used for this covariate. In general, the vegetation indices are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation (Weier & Herring, 2005). The vegetation index, Normalized Difference Vegetation Index (NDVI) is calculated from the visible (VIS) and near infrared (NIR) light reflected by vegetation (NIR - VIS)/(NIR + VIS), and is the relative difference in the reflectance of near infrared and photosynthetically active radiation. This results in a measure of greenness and photosynthetic capacity. Aerial and satellite imagery are routinely used to generate NDVI products. To produce the ideal baseline NDVI

products, three temporal dates are used – a drought year, a wet year, and an average year. During each year, several NDVI products are produced to detect the green-up of vegetation and the brown-down of the ephemeral vegetation (L. Mata, DCP, personal communication).

- Hypothesis: The presence of desert tortoises is related to higher levels of perennial and ephemeral plant cover at the scale of the plot, 40 ha and 400 ha (see Section 4.0 for description of plot size and scale).
- Sampling Methods: ASTER imagery is preferred imagery but Landsat, NAIP 2006/2010, and Quick-Bird 2006 are evaluated for usefulness. Other ancillary products such as ortho/aerial photography and Google Earth/Bing imagery may be used to assist to generate these products.
- Sampling Frequency: This covariate is generated annually.

3.2 Substrate Covariates

Desert tortoises spend much of their lives in burrows during every life history stage. Burrows provide protection against cold and extreme heat and protection from predators. The essential role that burrows play in the survival of the species means that soil structure is an important environmental (ecological) variable (USFWS, 2011). Soils must be soft enough for digging yet firm enough to maintain burrow structure. Burrows are found in sandy-loam soils but not extremely sandy soils. They are also found where there is a hardpan layer, where the underlying softer soils are exposed by erosion, and in rocky soils where rocks provide a ceiling structure over a softer soil. Nussear et al. (2009) found that on a range-wide scale the distribution of the species was best explained by several factors, including the soil variables of bulk density, depth to bedrock, and average percentage of rocks greater than 254 millimeters on the B-Axis (intermediate) diameter. The following covariates were selected based on a review of studies by Nussear et al. (2009; 2010), Natural Resources Conservation Service (NRCS) publications, and personal communications (D. Merkler, NRCS). The substrate covariates measured in the field or derived from GIS include:

1. Soil Series and Soil Suitability for Burrows: The NRCS has mapped the soils of the BCCE to the association level and has provided summaries of the soil series found in each association (http://soils.usda.gov/technical/classification/osd/index.html). For each soil series, NRCS can provide a rating of soil suitability for burrowing by the desert tortoise, if requested. The soil series are rated as: (1) well suited with no restrictions to use and are favorable for burrows; (2) suitable with few restrictions for use as burrows or for burrowing; and (3) poorly suited with many limiting factors for use as burrows or for burrowing (USDA, 1993).

   - Hypothesis: The presence of desert tortoises is related to the soil series and their suitability for burrows in the subplots.
   - Sampling Method: This covariate is sampled in the field, visually assessing the soil series by completely surveying each subplot. Identification is primarily based on geomorphic position and surface features. There are five soil series (Bluepoint, Grapevine, Hypoint, Searchlight, and Tipnat) found within the BCCE that are well suited or suitable for tortoise burrows, but the majority of the BCCE is not comprised of these soil series. The two options for collecting this data are to train the field collection team to identify the soil series in the subplot or to contract with a local soil expert.

- **Sampling Frequency:** This covariate does not change so the field data is recorded one time prior to the end of the third year of the study.

2. **Presence of Petrocalcic Horizon or Duripan:** The presence of an exposed petrocalcic horizon (a calcium cemented layer) or duripan (a silica cemented layer), commonly referred to as "caliche", in areas with some topographic diversity provide potential burrow locations for tortoises.

   - **Hypothesis:** The presence of desert tortoises is related to the presence of an exposed petrocalcic horizon or duripan.
   - **Sampling Method:** This covariate is sampled in the field, recording the presence of an exposed petrocalcic horizon or duripan by completely surveying each subplot. A petrocalcic horizon or duripan is identified by an exposed layer of cemented or indurate soil that does not allow root penetration and creates ledges and overhangs (Soil Survey Staff, 2006).
   - **Sampling Frequency:** This covariate does not change so the field data is recorded one time prior to the end of the third year of the study.

3. **Total Length of Washes:** Washes are shallow to deep, narrow to wide temporary water courses that concentrate surface flow during rain events and generally have greater cover, biomass, diversity, and consistency of food resources, and provide potential burrow locations for tortoises.

   - **Hypothesis:** The presence of desert tortoises is related to total length of washes on the alluvial fan.
   - **Sampling Methods:** The total length of washes within the plots and within 40 ha and 400 ha areas centered on and surrounding each plot is determined from digitizing the length of this feature on the whole BCCE and appropriate surrounding area using the best available imagery. Criteria for identifying washes are developed based on the imagery and methods used.
   - **Sampling Frequency:** This covariate does not change for the plot and surrounding area so it is generated one time prior to the end of the third year of the study.

3.3 Precipitation Covariate

Precipitation is an important covariate for understanding the current presence of desert tortoises within landscapes. Winter precipitation has a major influence on the ephemeral plant species that are the food resources for tortoises and spring rainfall provides water for tortoises. Precipitation patterns over short (5 to 6 years) and long (30 years) time periods influence the abundance and density of tortoises. Nussear et al. (2009) found that the mean wet and dry season precipitation over a 30-year normal period to be an important environmental layer that helped define desert tortoise habitat across the total range of the desert tortoise. Nussear et al. (2010) used cumulative winter (October-April) precipitation over a small geographic area for the six most recent years to model tortoise habitat.

1. **Precipitation Amount and Occurrence:** Data from Prism and BioClim datasets and National Weather Service precipitation data (2005-2011) will be used for this covariate. The National Park Service assembled these datasets under a Clark County MSHCP project (2005-NPS-525) from January 2005 to October 2011. The DCP has created datasets that present total precipitation, average precipitation, and monthly precipitation totals. Preliminary results of total precipitation within the BCCE from January 2005 to October 2011

range from 16.46 to 26.01 inches. Preliminary results of average precipitation in the BCCE range from 2.35 to 3.72 inches. Data across the BCCE indicate that December, January, and February have the highest monthly precipitation totals.

- Hypothesis: The presence of desert tortoises is related to higher levels of precipitation over time periods of 1 year and longer (7 years).
- Sampling Methods: The GIS staff at DCP has compiled the precipitation data needed to assess this covariate from 2005 to 2011. The DCP will inquire about receiving 2012 data from the National Park Service when it becomes available, and will explore the best methods to utilize these data for correlation tests and occupancy statistics.
- Sampling Frequency: This covariate is generated annually.

3.4 Disturbance and Habitat Alteration Covariates

Studies have shown that the Mojave desert tortoise population has declined and continues to decline throughout its range. Threats to the species survival and fecundity include mortality by vehicles, disease, habitat loss, and habitat degradation due to invasive species, fire, and other disturbances. In the BCCE the primary threats are habitat loss from expansion of energy production facilities, construction and maintenance of energy transmission lines and gas pipelines, habitat degradation caused by invasive species and off-highway vehicles, and mortality by vehicles. Linear disturbances and energy facility sites are the two covariates described; invasive species are included in the vegetation covariates.

1. Distance to and Density of Linear Disturbances: Linear disturbances (roads, transmission lines, and pipelines) are a primary causal factor of change for populations of Mojave desert tortoise (USFWS, 2011) and cause a range of ecological effects (Brooks & Lair, 2009). The conceptual ecological model (see Figure 2 and Appendix C) displays these changes and effects. Brooks and Lair (2009) characterize these ecological effects at three spatial scales: (1) direct local effects within route corridors; (2) indirect local effects distributed along gradients radiating outward from the route corridor; and (3) dispersed landscape effects resulting from the cumulative effects of multiple routes across landscapes.

   Direct local effects include mortality caused by collisions with vehicles or an increase in predators, such as ravens, due to structures (e.g., transmission lines, utility buildings) within the corridor. Few studies, however, have documented the ecological effect of roads (von Seckendorff Hoff & Marlow, 2002; Boarman & Sazaki, 2006; USFWS, 2011). The rate of mortality is most likely variable and dependent on the type of road, traffic speed, barriers to movement (e.g., tortoise fences), and surrounding vegetation types and the distribution of food resources, which in turn is dependent on rainfall that is also variable across years (Brooks & Lair, 2009). Linear disturbances also cause a direct loss of habitat and an alteration of habitat on road shoulders and median areas. Indirect local effects are more numerous and include the introduction of invasive species, alteration of surface water flow, and the addition of nitrogen, heavy metals, dust, and noise (Lovich & Ennen, 2011).

   Measuring the effects of linear disturbances is complex due to the variation in the type of road, speed of traffic, road surface, extent of shoulders and berms, and presence of culverts and fences. It is even more complex if these linear disturbances are considered at different spatial scales (Brooks & Lair, 2009). There are no studies that integrate the effects of different types of linear disturbances with tortoise presence or densities at a range of spatial scales. To assess this covariate, categories of linear disturbance effects were developed that integrate the different characteristics and relate them to their likely negative effect on the desert tortoise. The ecological criteria used for developing these categories included mortality potential, areal extent of disturbance to vegetation and substrate in the right-of-way, limitations to movement, and deterrents to use of the area impacted by the linear disturbance. The categories are described in Table 2.

- Hypothesis: The presence of desert tortoises will increase as the distance to linear disturbances increases and density of linear disturbances decreases.
- Sampling Methods: The Euclidian distance from the center point of the 4 ha plot to the border of the nearest category of linear disturbance is measured using GIS and/or remote sensing. The density of linear disturbances in each category within the 40 ha and 400 ha areas centered on and surrounding the plot is measured using GIS.
- Sampling Frequency: This covariate is generated during the first year of the study, reviewed annually, and then generated every study year there are new vehicular incursions or other new linear disturbances.

TABLE 2. CATEGORIES OF LINEAR DISTURBANCES

Category	Description
High	Paved road, two or more lanes, or divided highway without tortoise fencing to limit mortality or movement. Moderate to heavy use with traffic speeds generally greater than 25 miles per hour (mph). Moderate to extensive areal disturbance to vegetation and soil within the right-of-way. Example in the BCCE is Eldorado Valley Drive providing access to the energy production and transmission facility sites.
Medium	Paved road, two or more lanes, or divided highway with tortoise fencing that limits mortality and movement. Heavy use with traffic speeds greater than 25 mph. Moderate to extensive areal disturbance to vegetation and soils within the right-of-way. Examples in the BCCE are U.S. Highway 95 and State Route 165.
Low	Unpaved open public road and open right-of-way roads. Moderate to little use with traffic speeds at 25 mph or less. Minimal disturbance to vegetation and soil adjacent to the road.
Very Low	Unpaved closed public roads, right-of-way roads, or one- or two-track trails. Little to no use with traffic speeds less than 25 mph. Minimal to no disturbance to vegetation and soil adjacent to the road or trail.

2. Distance to Energy Production and Transmission Facility Sites: Sites that produce and transmit energy are located within and adjacent to the BCCE (see Figure 1). These sites include solar facilities (photovoltaic, concentrated-trough generation), natural gas-fired facility, substations, and switching yards. The sites are surrounded by chain-link fencing without tortoise exclusion fencing, and many have flood-control berms on one or more sides. The energy transmission lines associated with these facilities are addressed under the linear disturbances covariate.

- Hypothesis: The presence of desert tortoises will increase as the distance to energy production and transmission facility sites increases.

- **Sampling Methods:** The Euclidian distance from the center point of the 4 ha plot to the nearest energy production and transmission facility site is measured using GIS.
- **Sampling Frequency:** This covariate is generated during the first year of the study, reviewed annually, and then generated in any study year if there are changes in the footprint of the energy production and transmission facility sites.

3.5 Management Action Covariate

The DCP is responsible for managing the BCCE for the benefit of the Mojave desert tortoise, native flora and fauna, and other natural resource values on the easement. The DCP can implement several different types of management actions to meet this responsibility.

1. **Distance to Management Actions:** Management actions could include road closures, law enforcement actions (patrols, warnings, citations), restoration actions (restoring degraded habitat), and enhancement actions (improving existing habitat). Tortoise relocation within the BCCE to remove them from harm's way (construction project sites within the BCCE or Energy Zone) is also included as a management action. Released tortoises have unique tag numbers to track and potentially analyze their occupancy separately from the rest of the BCCE tortoise population.

   - **Hypothesis:** The presence of desert tortoises will increase after management actions reduce disturbances and habitat alteration.
   - **Sampling Methods:** The Euclidian distance from the center point of the 4 ha plot to the nearest management action in the classes of road closures, law enforcement actions, restoration actions, enhancement actions, and tortoise relocations is measured using GIS.
   - **Sampling Frequency:** This covariate is generated annually whenever management actions are taken.

3.6 Summary

Table 3 presents a summary of the different covariates with sampling method and frequency for each covariate.

TABLE 3. SUMMARY OF COVARIATES

Covariate	Field/GIS	Method	Sample Unit	Frequency
Vegetation Covariates				
Vegetative Cover of Perennial Shrub and Succulent Vegetation	Field	Line intercept	Subplot	First year of sampling, then at 5-year intervals
Percent Shade Cover of Perennial Shrub and Succulent Vegetation	Field	Line intercept	Subplot	First year of sampling, then at 5-year intervals
Ephemeral Plant Species Cover and Species Richness	Field	Visual estimates of cover and identification of species	Quadrat	Annually during predicted El Nino Watch and Advisory years
Vegetation Index of Perennial and Ephemeral Plant Cover	GIS	NDVI using the best available imagery	Plot (4 ha), 40 ha and 400 ha areas centered on and surrounding plot	Annually

TABLE 3. SUMMARY OF COVARIATES				
Covariate	Field/GIS	Method	Sample Unit	Frequency
Substrate Covariates				
Soil Series and Soil Suitability for Burrows	Field	Visual assessment	Subplot	One time before the end of the 3rd year of the study
Presence of Petrocalcic Horizon or Duripan	Field	Visual assessment	Subplot	One time before the end of the 3rd year of the study
Total Length of Washes	GIS	Digitize using best available imagery	Plot (4 ha), 40 ha and 400 ha areas centered on and surrounding plot	One time before the end of the 3rd year of the study
Precipitation Covariate				
Precipitation Amount and Occurrence	GIS	Compilation of precipi-tation data for short (1 year) and long-term (7 years) periods	Plot	Annually
Disturbance and Habitat Alteration Covariates				
Distance to and Density of Linear Disturbances	GIS	Euclidian distance and density measured by GIS	Plot (4 ha), 40 ha and 400 ha areas centered on and surrounding plot	First year of sampling, then only with changes in linear disturbances
Distance to Energy Production and Transmission Facility Sites	GIS	Euclidian distance measured by GIS	Plot	First year of sampling, then only with changes in site footprint
Management Action Covariate				
Distance to Management Actions	GIS	Euclidian distance measured by GIS	Plot	One time and with imple-mentation of management actions

4.0 SAMPLING DESIGN

A good sampling design minimizes data variability and maximizes the detection of condition and change over time, including maximizing precision and repeatability. There are five major sampling design decisions that are made:

1. What "population" is inferred?

   This covariate monitoring protocol, coordinated with the desert tortoise occupancy sampling monitoring protocol, will be tested in the BCCE (see Figure 1). The BCCE is physically stratified into two sections that have different human impacts and adjacent land designations:

   - The north section nearest the populated area of Boulder City and east of U.S. Highway 95 has an extensive road network, several above and below ground utility line rights-of-way, and significant recreational uses, such as historic off-highway vehicle race courses, past and current hunting, current casual motorized recreation, and other uses. Shown on Figure 4, the study area within this section is 15,213 ha (37,593 acres). State Route 165 crosses the south part of this section and cuts off 589 ha (1,455 acres) from the core area of the easement. Because the road has a tortoise exclusion fence, the cut-off acres are excluded from the study area.

- The south section includes the area west of U.S. Highway 95 but excludes the Energy Zone. Although this section experiences less impact from recreation activities than the north section, it is adjacent to solar and natural gas power facilities within the Energy Zone and includes an extensive network of above ground utility line rights-of-way and electrical substations. Shown on Figure 4, the study area within this section is 16,567 ha (40,937 acres). U.S. Highway 95 and tortoise exclusion fencing cut off 2,605 ha (6,438 acres) of the BCCE so these acres will be excluded from the study area.

2. What sample unit size and shape best obtains data?

The covariate monitoring sample unit size and shape were determined by the needs of the Mojave desert tortoise occupancy sampling, which is 4 ha square plots (Clark County, 2011). Figure 3 shows the layout of a sample unit. Plots are numbered 1-80; subplots are numbered clockwise 1-4 from the northwest corner.

Covariate data are obtained at a variety of scales; some are obtained by measuring the characteristics of the entire 4 ha plot and others from sampling within 1 m x 2 m quadrats. Four subplots are systematically placed at the center point of each 1 ha quarter section within the randomly placed 4 ha plot. Starting 5 m from the center point of the subplot, four 25 m transects radiate toward the corners of the subplot at 45, 135, 225, and 315 degrees. Line intercept data for some covariates are taken along these transects. Line intercept is an efficient and precise method of measuring cover for shrubs that are widely dispersed.

A quadrat (1 m x 2 m) is established at the 10 m point and 20 m point along each 25 m transect. The longer side of the quadrat parallels the transect and the transect bisects the quadrat. There are eight quadrats per subplot and 32 quadrats per plot. The quadrats are used to sample the covariates of plant species cover and diversity of grasses and forbs. The quadrats are small enough to easily and effectively assess visual cover, and the rectangular shape captures more variability in species richness than a square shape.

There are several covariates measured by remote sensing at multiple scales. These covariates are measured in 40 ha and 400 ha areas surrounding and centered around the 4 ha plots. The larger scales help determine if the covariates in adjacent areas have an influence on the presence of tortoises in the 4 ha plots.

3. Are the sample units permanent or temporary?

The sample units are permanent across years to maximize the ability to relate changes in the covariates to the occupancy of tortoises. The northwest corner of the plots and center point of the subplots are permanently marked with stakes. Quadrats are not marked and are relocated along the transects in each subplot.

4. How will the sample units be spatially allocated?

The occupancy sample units (4 ha plots) are randomly placed within the study areas. Random placement of the plots was done by using the Generalized Random Tessellation Stratified (GRTS) sampling approach (see Figure 4). The GRTS is a form of probability sampling that results in greater spatial balance (i.e., less clumping) in the sample draw, while decreasing the variance about sample estimators and thus increasing statistical power (Stevens & Olsen, 2004). As with a simple random sample, a GRTS draw results in independent, random site selection. However, the resulting draw is more evenly spread across the study area with fewer pairs of very close points. The full range of environmental variability can thus often be better captured with a GRTS design. As described above, the covariate sample units are systematically placed within the randomly placed 4 ha plots.

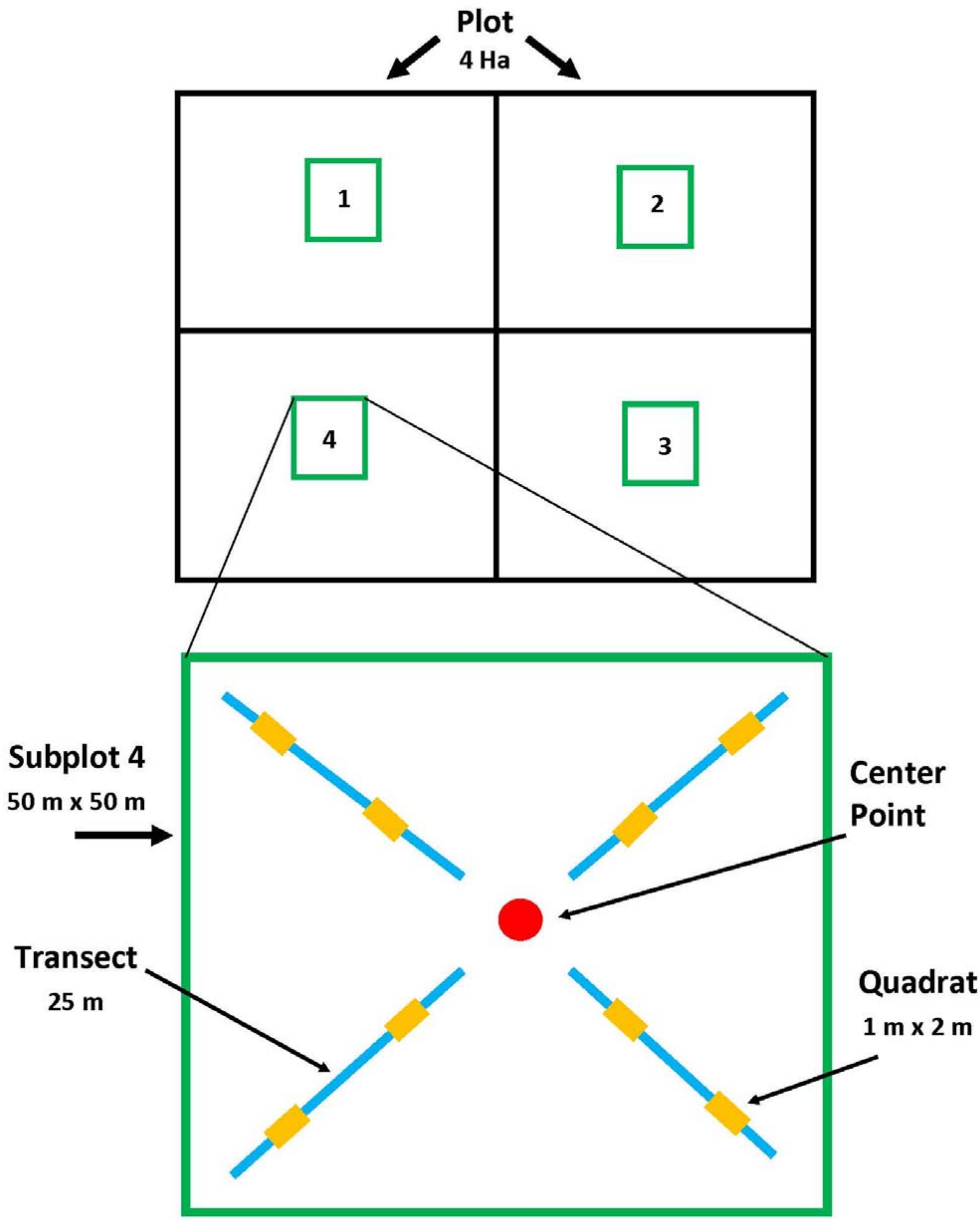

Figure 3. Layout of a Sample Unit (Not to Scale)

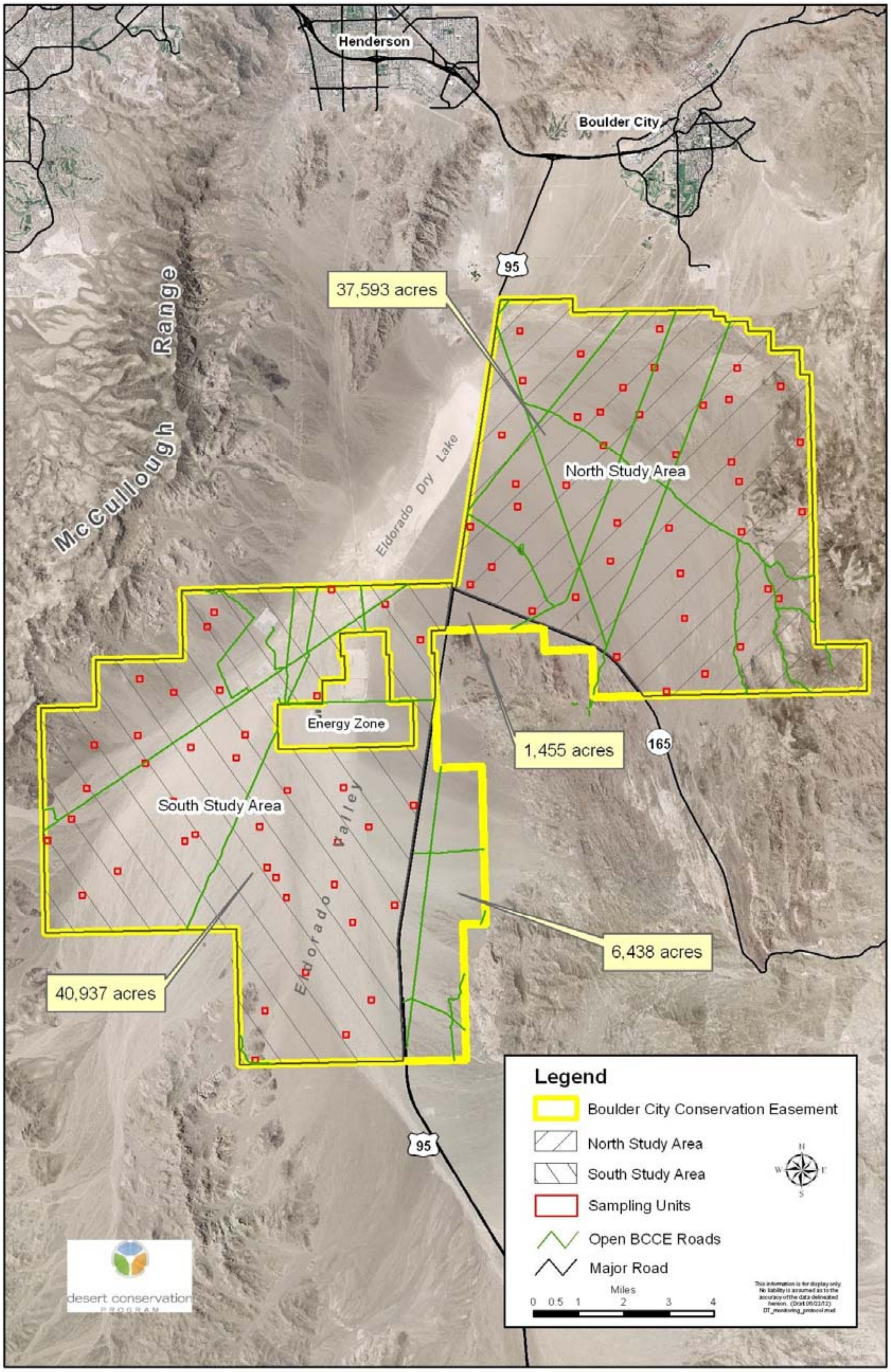

Figure 4. GRTS Placement of Occupancy Sample Units in the Study Areas

5. How often will the sample units be sampled (What is the frequency of sampling)?

   How often each sample unit is sampled is determined by the pattern of change in the covariate indicator. See Table 3 for a summary of the sampling frequency.

5.0 DATA MANAGEMENT PLAN

An essential component of a successful monitoring project is the quality of the data. Quality data is required for results that meet the objectives of the project. This section provides guidance for ensuring data collection is complete and of desired quality, available for analysis and sharing, and archived for future use. Errors, however, are common in data collection and many projects are compromised by incomplete, poor, or missing data. This section describes the data collection process, data management, and quality assurance.

The guidelines presented are supplemented by a spreadsheet (see Appendix A) listing the specific covariates identified for data collection. The covariates are accompanied by their definition, standard operating procedures, and how each is verified and validated. The field data sheets are included in Appendix A.

These data management guidelines will be reviewed and followed by all project staff involved in data collection or data management for the environmental indicators portion of the occupancy sampling pilot study for the Mojave desert tortoise on the BCCE.

5.1 Assessment of Detail Needed for Data Management

Not all data management plans need to contain the same detail, and there is not a “one-size-fits-all” approach to developing data management plans for the wide diversity of long-term monitoring projects. A graded approach is used to identify the level of detail and comprehensiveness needed for project-level data management and quality control (C. Palmer, UNLV, personal communication). The graded approach assesses the scope and impact of the study, complexity, duration, staffing, project costs, and intended use of the data.

This covariate monitoring study is of significant regional and local interest due to the status of the Mojave desert tortoise as a federally listed endangered species and as a species covered by the MSHCP. The complexity of the study is high, collecting a range of field and GIS data. Due to the duration of the study (3 to 5 years), involvement of multiple staff and potential for staff change, the data management plan comprehensively covers all aspects of the study.

Because the Mojave desert tortoise occupancy covariate study is supported by public funds, a high level of accountability is necessary. Also, the data can be used by other desert tortoise researchers and conservation practitioners for both scientific defensibility and in combination with other research, and therefore, the data management plan for this protocol includes a high level of detail.

5.2 Project Teams, Roles, and Data Flow

The roles of data collection and data management are divided among five distinct teams. The detailed responsibilities of each of these teams are described in Section 5.7 Roles and Responsibilities. Briefly, the teams and roles are:

- Project Lead (Adaptive Management Coordinator) is responsible for administering the project, making sure project objectives are met, and responsible for interim and final reports.

- Project Management Team (or management team) is responsible for designing, directing, and reporting on the pilot study.
- Field Data Collection Team (or field team) collects the data in the field and provides it to the Project Management Team.
- GIS Data Collection Team (or GIS team) compiles and generates the GIS data and provides it to the Project Management Team.
- Data Analyst completes the analyses, assists with interpretation and report writing, and provides it to the Project Management Team.

The data flow in the project is illustrated in Figure 5. Field collected data is entered on data sheets that are transferred daily to the Covariate Database. The GIS data is also entered into the Covariate Database. The Project Management Team develops and manages the Master Covariate Database, collecting the data from the field and GIS teams. The Master Covariate Database is the source for analysis and archiving.

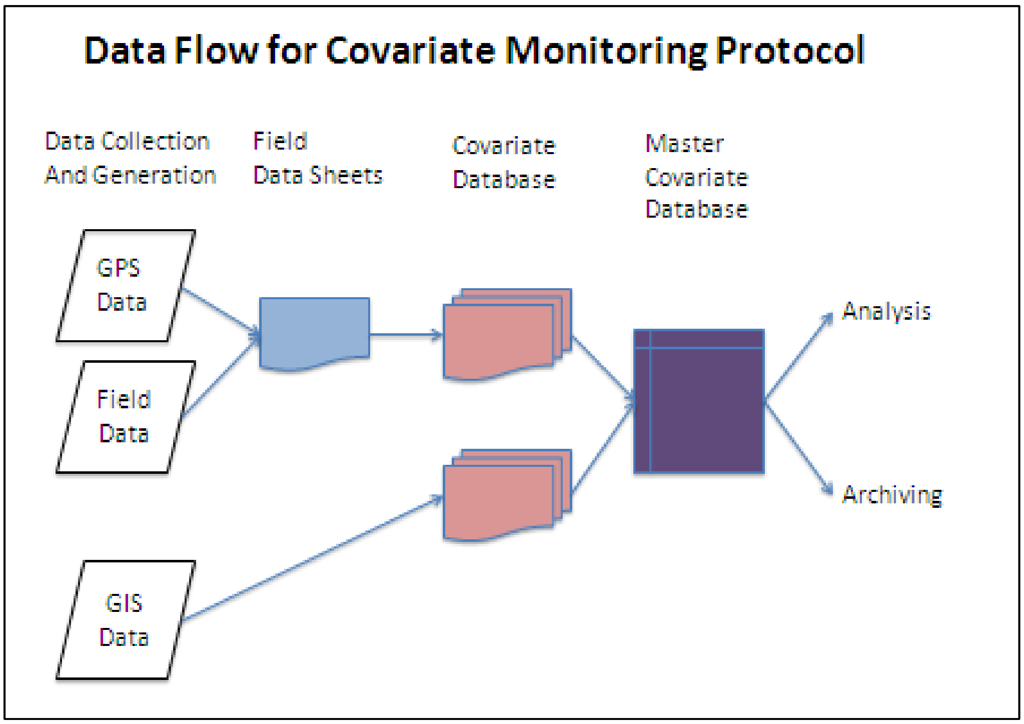

Figure 5. Data Flow

5.3 Data Acquisition

The section explains the different parts of the data collection process.

5.3.1 Field Data Collection

A field data sheet is developed to record information on vegetation and substrate in the four subplots nested in the 4 ha plots. The order of data entry parallels the logical approach to collecting data in the field, from general subplot data to data collected on vegetation and substrate in quadrats. Definitions of all terms are provided in the data collection and management spreadsheet (see Appendix A). The data sheet and the data collection and management spreadsheet are provided in the field team training materials.

5.3.2 Spatial Data

Field collected spatial coordinates are recorded on the field data sheet and obtained from a global positioning system (GPS) unit with 1 to 5 m accuracy. Accuracy less than 1 m is not necessary to relocate the plot and subplot markers, influencing the GPS unit used in the protocol, but still requiring a unit that differentially corrects GPS values. The coordinate values estimated by the GPS unit are recorded directly onto the field data sheet provided the “position dilution of precision” or “PDOP” values are suitably low (PDOP less than 6), logging a minimum of 30 positions per point feature (location) collected. Data is recorded in UTM zone 11 projection and NAD83 datum. The spatial coordinates are entered on the field data sheet at the time of data collection.

5.3.3 Photographic Data

Digital photographs (images) are taken of each transect using a digital camera with a minimum of five megapixel capacity. A GPS location point is recorded for each photograph and an entry is made on the photo log (see Appendix A). The purpose of the transect photographs is to provide documentation of the vegetation in each subplot. The photographs are taken from the center of each subplot when transects are established, at the height of approximately 1.5 m from the ground surface. The photo is of the vertical (portrait) view with the transect line bisecting the frame with one of the field crew standing at the end of the 25 m transect at the top of the frame. Optional photographs may be taken of observations of rare and unique species, examples of biodiversity, and tortoises.

5.3.4 Maintenance and Calibration of Equipment

The Field Data Collection Team maintains all field equipment in perfect working condition and ensures the GPS unit and camera time stamps are synchronized and have a full or adequate charge for each day in the field. The field survey crew’s camera clock is synchronized each morning with the date and time of the crew’s GPS receiver to assist with data verification.

5.3.5 Training on Field Data Acquisition and Data Quality

Training individuals on the Field Data Collection Team is essential for data quality. The DCP staff will provide a training manual and copy of the protocol, and instruct the field team on the specific items (see Section 8.3 Training for details).

5.3.6 Acquisition of GIS Data

GIS data is used to generate six covariates – perennial plant cover, length of washes, precipitation, distance to and density of linear disturbances, distance to energy production and transmission facility sites, and distance to management actions. The datasets for these covariates are developed internally by DCP staff or by a contractor. For each covariate the process for developing the spatial products and the procedures for quality assurance will be described. Documentation of each spatial product includes the dataset objectives, data source, data resolution, data time period, specific spatial representation (points, lines, polygons, and rasters), assessment of valid attribute values, and development of metadata. These components are described with the covariates and in the data acquisition and management spreadsheet in Appendix A.

5.4 Data Completeness and Quality

The overall system of management activities designed to ensure the quality of the data generated by a project or program is commonly known as QA/QC, or Quality Assurance and Quality Control. For the purpose of this data management plan, QA/QC is being described by its two major components, data verification and data validation.

5.4.1 Data Verification

Data verification ensures that all required data have been collected and recorded. This is accomplished by reviewing the field data sheets and the Covariate Database for blank fields. The verification process occurs within a time frame after data collection that allows for accessing the recollection of the data collectors (e.g., Field Data Collection Team) and, if needed, the potential recollection of data.

The Field Data Collection Team reviews the data sheets at the end of each transect to ensure that all data has been collected. This also occurs at the end of each field day when the field team reviews all paper data sheets and the photo log, checking data while field team memories are most accurate. This review includes making notations on paper field data sheets of any corrections made. The Field Data Collection Team enters the field data in the Covariate Database spreadsheet and reviews the completed Covariate Database spreadsheet after entry of each day's data to ensure that all data have been collected and entered.

The GIS Data Collection Team reviews each project to ensure that data is present for each plot location at the time that the data is generated.

The Project Lead conducts separate data verification after receipt of each day's data entry or completion of a GIS project before pasting it into the Master Covariate Database. The Project Lead maintains the Master Covariate Database.

5.4.2 Data Validation

Data validation assesses the quality of each data entry, checking its structural integrity and logical consistency. For example, it includes comparing the expected and entered GPS coordinates, assessing the expected percent cover of each species or species group (e.g., all forbs), and comparing field identification of soils series with potential soils series present. Data validation requires the reviewer to understand each of the covariates and their range of values. The validation method used for each data field is listed in the data acquisition and management spreadsheet of metrics for the field data sheet. The Project Management Team completes the data validation process.

The data spreadsheet automates some data validation steps using three automated processes:

- Checking ranges highlights values that are outside of the expected range of the value. An example is if a distance measurement between a plot and the nearest road is greater than is possible for the size of the BCCE. This validation method requires that the appropriate ranges are known in advance. The range for any value is iterative as data is reviewed and can be adjusted by the Project Management Team.
- Sorting entries by date or plot numbers and checking for the logic of the entries.
- Comparing new data with already validated data to identify values that are new or beyond the current range of the data.

Aspatial data is graphed and assessed for patterns and outliers. Spatial data is also validated. The GIS Team maps all field and GIS generated spatial data on the base map of the study areas and survey plots, and all data points are matched with plots and areas surveyed.

Field data is validated by the Project Management Team twice weekly for the first three weeks of the annual sampling period, and then at least weekly for the rest of the sampling period. Data generated by the GIS Data Collection Team is validated by the Project Management Team within 30 days of its completion. Errors in more than two percent of the entries in any data field triggers a review of the data collection and verification protocols and may require additional field survey crew or GIS team training.

5.5 Data Management

Data management covers the topics of logistics of entering and/or downloading the data, developing and maintaining data files, and archiving data.

5.5.1 Entering and Downloading Data

Field survey crew members enter data on paper field data sheets. One member of the Field Data Collection Team is assigned as the Data Sheet Recorder and maintains that responsibility for a complete plot.

After each field survey day, the data on the field sheets is entered into a spreadsheet for the Covariate Database and the digital images and scanned datasheets are downloaded to a local computer by the Field Data Collection Team. Paper field data sheets are scanned at 300 dpi (dots per inch) resolution and saved in Adobe Acrobat (.pdf) format according to the file naming convention described below. Images are downloaded for that day's data collection and stored in .tif or an equivalent lossless image file format with file names updated as described in the file naming convention below.

Data generated by the GIS Data Collection Team is compiled into a spreadsheet and provided to the Project Management Team.

5.5.2 Preparing Data for Upload

<u>Covariates Database:</u> The Covariates Database from each field survey day is named according to the following naming convention:

BCCE_Field_Covariates_<PN-PN-PN-PN-PN-PN>_<QC step>_<date>.xls

Where,

- <PN> is the plot number 01 through 80 with each number separated by a dash
- <QC step> represents the QA/QC version control level (described in the section below) as fieldverified, officeverified, validated, or master
- <date> is the field survey date as yyyymmdd

The underscore symbol separates the identifying features in the file name. The file extension (.xls) indicates the file is the Covariate Database using Microsoft Excel™ software.

Data Sheets: The paper copy field data sheets from each survey day are scanned, compiled into one file, and named according to the following naming convention:

BCCE_Field_Datasheets_<PN-PN-PN-PN-PN-PN>_<date>.pdf

Where,

- <PN> is the plot number 01 through 80 with each number separated by a dash
- <date> is the field survey date as yyyymmdd

The underscore symbol separates the identifying features in the file name. The file extension (.pdf) indicates the file is the field data sheets. Note that data sheets from multiple plots can be in the same daily scanned file.

Images – Transects: Digital images taken during a survey day are identified by plot, subplot, and transect compass direction. One photo of each transect is named according to the following naming convention:

BCCE_Field_Covariates_Photo_<PN>_<SPN>_<CD>_<date>.tif

Where,

- <PN> is the plot number 01 through 80
- <SPN> is the subplot number 1 through 4
- <CD> is the compass direction of the transect
- <date> is the field survey date as yyyymmdd

The underscore symbol separates the identifying features in the file name. The file extension (.tif) indicates the file is a digital image.

Images – Observations: Only one photo of a transect is submitted. Any additional photos have an observation number associated with the image. Observation photos can be of unique plants, geologic features, etc. These images are named according to the following naming convention:

BCCE_Field_Covariates_Photo_<ON>_<date>.tif

Where,

- <ON> is the sequential number of the observation from 01 through XX
- <date> is the field survey date as yyyymmdd

The underscore symbol separates the identifying features in the file name. The file extension (.tif) indicates the file is a digital image.

Images – All: The Field Data Collection Team verifies the digital images from one survey day and then compiles and compresses all images into one zip file to submit with the database and data sheets. The image zip file is named according to the following naming convention:

BCCE_Field_Covariates_Photos_<PN-PN-PN>_<QC step>_<date>.zip

Where,

- <PN> is the plot number 01 through 80 with each number separated by a dash
- <QC step> represents the QA/QC version control level (described in the section below) as fieldverified
- <date> is the field survey date as yyyymmdd

The underscore symbol separates the identifying features in the file name. The file extension (.zip) indicates the file is the compressed (zipped) file of the digital images.

GIS Data: For GIS data, files are named according to the following naming convention:

BCCE_GIS_<covariate>_<QC step>_<date>.zip

Where,

- <covariate> is covariate or covariates for which the GIS data represents
- <QC step> represents the QA/QC version control level (described in the section below)
- <date> is the date the completion date of the data compilation as yyyymmdd

The GIS team completes metadata records for all data and attributes tables following ISO 19115 Geographic Information – Metadata, North American Profile metadata register, or another appropriate standard.

5.5.3 Uploading Data

The data files (Covariate Database, data sheets, digital images) for a complete field day from the Field Data Collection Team(s) is saved as a single compressed (.zip) file and uploaded to an ftp site maintained by the Field Collection Team. Paper field data sheets are delivered to the Project Management Team on a weekly basis. The GIS data is uploaded to the Covariate Database.

5.5.4 Version Control

Version control is the process of managing copies of changing files over the course of a project. Any alteration or update to a file is considered a change and is reflected in the complete file name. Version control includes developing file-naming guidelines that include the file name, the QA/QC status, and the date of the file.

Version control is required for the Covariate Database and the image files. The categories of QA/QC versions are *_fieldverified_* for the data sheets and Covariate Database that have been verified by the Field Data Collection Team, *_officeverified_* for data that have been verified by the Project Management Team, *_validated_* for data that have been validated by the Project Management Team, and *_master_* for the master compilation of data for which all QA/QC steps have been completed. For example, the validation of the Covariate Database from the field survey completed April 17, 2013 of plots 3, 12, and 24 is named:

BCCE_Field_Covariates_03-12-24_validated_20130417.xls

5.5.5 Data Storage

Data is retrieved from the ftp site each workday morning by the Project Management Team and stored by the DCP on network servers that are backed up nightly with a series of backup tapes stored in a secure off-site location. Paper field data sheets are stored by the Field Data Collection Team for up to one week prior to delivery to the Project Management Team. The field team maintains a complete copy of tabular data, scanned data sheet files, and image files for the term of each annual sampling period.

Ideally, tortoise indicator data and environmental (covariates) indicator data from the occupancy sampling pilot study should be stored in one directory titled "BCCE Occupancy Sampling". If necessary, or to maintain a DCP standard operating procedure, establish separate project number directories with links to the one consolidated BCCE Occupancy Sampling data directory. First tier sub-directories are the separate projects for "Tortoise Indicators" and "Environmental Indicators" data collection. At a minimum, second tier sub-directories are created for databases, data sheets, and digital images. Naming of data files should be tied to the directory structure established by DCP.

5.5.6 Data Compilation

The Project Management Team compiles all data from a field season and provides them to the Adaptive Management Coordinator for analysis. This compilation is a new file or set of files and no prior files are overwritten.

5.5.7 Data Archiving

Data archiving is the long-term (multi-year/multi-decade) management of the data once it is received by the DCP. It acts as a backup to the active datasets managed by the project team during the life of the project, and is the location of the datasets after the project is complete. The pilot study adheres to Clark County records management policy and record retention schedule for archiving data. Data is stored on lossless and non-proprietary software in multiple locations with appropriate metadata. The DCP provides periodic verification of the archived data. Academic archives, such as University of Nevada, Las Vegas, will also be assessed to permanently house copies of the data, protocol, and training materials.

5.6 Data Quality Review

The process of data verification and validation often highlights ways to improve the data collection through changes in the data sheets, types of menus used, or by providing additional training. The Project Management Team meets with the Project Lead periodically and as needed to review the outcomes of the data verification and validation process and reviews all aspects of data collection for the pilot study.

5.7 Roles and Responsibilities

There are five distinct teams of individuals involved in data collection and data management for the pilot study – the Project Lead, Project Management Team, Field Data Collection Team, GIS Data Collection Team, and Data Analyst. It is important that each member of these teams understands their role and specific responsibilities to ensuring good data management and data quality.

5.7.1 Project Lead (Adaptive Management Coordinator)

The Project Lead is within the DCP and has responsibilities to:

- Administer the project.
- Track project objectives, budget, and progress toward meeting objectives.
- Coordinate and ratify revisions to protocol.
- Ensure project compliance with County, MSHCP, and USFWS requirements.
- Manage and maintain the active master database.
- Oversee analysis of data.
- Maintain and archive project records.
- Complete reports, metadata, and other products according to schedule.
- Communicate status of project and project results to appropriate audiences and decision-makers.

5.7.2 Project Management Team

The Project Management Team is within the DCP and includes those individuals involved in designing, directing, and reporting on the pilot study. This team will:

- Develop and provide training to Field Data Collection Team and GIS Data Collection Team members.
- Communicate the importance of good data management and quality data to both data collection teams.
- Ensure compliance of both data collection teams with monitoring protocols and data verification.
- Work with both data collection teams to identify sources of errors and lead efforts to reduce sources of errors.
- Work with Project Lead and Science Advisor to refine the monitoring protocol.
- Develop the Covariate Database.
- Perform data validation.
- Provide compiled data for analysis to the Project Lead who will oversee the analysis of the data.
- Ensure proper transfer of interim data to the Project Lead for archival of final data.

5.7.3 Field Data Collection Team

The Field Data Collection Team includes the contracted individuals who collects data in the field and provides it to the Project Management Team. This team will:

- Participate in the initial and ongoing training for the project.
- Follow the established protocols for data collection, entry, and verification.

- Coordinate among themselves on a weekly basis on identifying soil series and species, and assessing vegetative cover. Coordination includes testing and discussing with each other to ensure consistent and accurate data collection across collectors.
- Transfer data from data sheets to the Covariate Database on a daily basis and verify the data collected each day.
- Maintain the functional condition and calibration of data collection equipment.
- Provide each day's data to the Project Management Team.
- Work with the Project Management Team to identify sources of errors and assist in developing solutions to reduce sources of error.

5.7.4 GIS Data Collection Team

The GIS Data Collection Team includes the DCP staff and potential contracted individuals who compile and generates GIS data and provides it to the Project Management Team. This team will:

- Participate in the initial and ongoing training for the project.
- Generate GIS data for covariates as defined in the protocol.
- Enter and update metadata for all spatial and aspatial data.
- Enter GIS generated data into the Covariate Database and provide the compiled GIS data to the Project Management Team.
- Work with the Project Management Team to identify sources of errors and assist in developing solutions to reduce sources of error.

5.7.5 Data Analyst

The data analyst is a contracted individual or team who will:

- Complete data summaries and analysis.
- Assist in interpretation and report writing.

6.0 Data Analysis

The analysis of the data consists of the following components:

- Exploratory Data Analysis: This analysis assesses each covariate for its precision and variability (including mean, standard deviation, standard error, confidence interval, coefficient of variation), including a graphical display of the data. This step in the analysis helps detect any errors in data entry, ensure the assumptions of the analysis are met, and detect unusual values (outliers). This step includes any transformation of the data for further analysis. Acceptable values are determined after the first year of data collection.
- Correlation Analysis: This analysis describes the relationship between two or more continuous or categorical variables by the use of an index of relationship called the co-efficient of correlation. The analysis as-

sesses different models of relationship (linear, curvilinear, and quadratic). While the rule of thumb suggests that a correlation greater than 0.7 is significant, this is interpreted in the context of the data. An understanding of the correlation between covariates assists in selecting covariates for the Occupancy and Random Forests analyses and identifies covariates that could be removed from the project.

- Occupancy Analysis: The Mojave desert tortoise occupancy model selected for this protocol requires the use of occupancy covariate data. The Program PRESENCE 3.1 (Hines, 2006) used to assess the detectability of desert tortoise is used to assess the covariate data. This program uses logistic regression to assess covariates, with the assumptions that covariate values are fixed and known without error, the covariate values do not need to be normally distributed, and linearly distributed (MacKenzie et al., 2006). The covariates are analyzed using Akaike's Information Criterion, a measure of the relative goodness of fit of a statistical model. However, Akaike's Information Criterion penalizes models with a greater number of parameters, and thus, is biased to more simple models of covariates. Additionally, analyzing many covariates in any one model in PRESENCE creates extensive output, leading to the recommendation to include one or a few covariates in each model (Darryl MacKenzie, Proteus Consulting, personal communication). More information is found in MacKenzie et al. (2006) and in the analysis draft manual developed by Darryl MacKenzie for this project. The final manual will be completed by November 2012 and available on the DCP website for public review.
- Random Forests: Another method of analysis used to assess the covariates to the occupancy data is Random Forests (RF), a multivariate analysis method that provides a more accurate classification of the covariates (Prasad et al., 2006; Cutler et al., 2007; Evans & Cushman, 2009). The RF is a powerful technique that can handle large datasets, complex data distributions, and interactions. Using this additional method of analysis is recommended because RF does not assume a linear relationship between the covariate and the dependent variable (desert tortoise presence), provides a direct measure of covariate significance, has no penalty for higher numbers of covariates, and is quick and inexpensive to run (less than a day). While RF does not account for imperfect detection probability, it can be used to explore the relationship of the covariates to different desert tortoise occupancy patterns. The results from this analysis will provide greater accuracy in the interpretation of the covariate assessment from PRESENCE. More information on RF is provided below.

Random Forests is a multivariate analysis method that can provide more accurate classification of the variables that best account for the differences between groups. For this study the differences are where desert tortoises are present versus where they are not present, with "present" being defined as different patterns of detection histories for single season models (e.g., once within season or all three sampling periods during a season) or of occupancy for multi-season models (e.g., all years, half of the years, and none of the years of sampling). The RF also provides an assessment of correlated variables, thus it is not necessary to remove them before the analysis. To outline the RF analysis method, a background on Classification and Regression Trees (CART) is provided. CART is the predecessor to RF and provides context for the selection of RF.

The CART analysis (Breiman, et al., 1984; Clark & Pregibon, 1992; Ripley, 1996) is a collection of algorithms used to explore and model the response of a dependent variable based on one or more predictor variables. CART models are nonparametric, make no assumptions about the type of response (i.e., linear), and can be used with a variety of variable types. A classification tree is used when the response variable is categorical, while a regression tree is used if the response variable is continuous.

CART uses rules to recursively split the dataset into increasingly homogenous groups. The splitting rules can be thought of as questions with “yes” or “no” answers. The root node, which corresponds to the entire dataset before partitioning, is first split into two nodes according to a rule that determines the best predictor variable to initially divide the data, based on the Gini index (Breiman et al., 1984). The two resultant nodes can themselves be further split into two more nodes. This binary recursive partitioning is repeated until the dataset can no longer be split. The nodes that can no longer be subset are referred to as terminal nodes. The resultant output is a tree diagram that presents a set of decision rules based on one or more of the predictor variables most strongly associated with the dependent variable.

There is no formal test of significance to evaluate a tree’s goodness-of-fit. Rather, the rate at which samples are misclassified into groups is used to assess classification trees. As CART models tend to overfit the data, it is often necessary to “prune” the initial classification tree to reduce the number of decision rules (McCune & Grace, 2002). A large tree with many decision nodes will likely have a low misclassification rate but will also capture noise in the data-set and potentially obscure important patterns. Pruning techniques seek to balance the misclassification rate and the size of the tree. If the dataset is large enough, the data can be divided into a training sample and a testing sample. The training sample is used to build the tree, while the testing sample is used to determine the misclassification rate of different sized trees.

The RF analysis is a machine-learning extension of CART in which many decision trees are grown (i.e., a forest) to produce a more accurate classification. While commonly used in bioinformatics, RF has only recently begun to be used in ecological studies for specific distribution models and has proven to be a robust classification method (Prasad et al., 2006; Cutler et al., 2007; Evans & Cushman, 2009). The RF has been shown to have greater accuracy than CART and due to internal cross-validation, does not overfit. In summary, RF is a powerful technique that can handle large datasets, complex data distributions, and interactions.

The algorithm works by first randomly selecting many observations from the data with replacement, a technique known as bootstrapping. The bootstrap samples serve as the training data and a classification tree is fit to each sample. In each bootstrap sample, approximately 33% of the observations are not used and are referred to as out-of-bag (oob) data. The oob data is used for calibration and validation of the classification trees and to estimate predictor variable importance. For each node in each tree, a subset of the predictor variables is randomly selected and used in the binary partitioning as described above for the single classification tree in a CART analysis. Each tree is grown as large as possible and no pruning is necessary.

The predicted classification of an observation is determined by the majority of oob trees in the forest with ties split randomly. Classification accuracies are calculated for each observation using the oob predictions and are then averaged over all observations (Cutler et al., 2007). Variable importance is calculated by randomly permuting the predictor variables for the oob observations, and then subtracting the misclassification rate for the permuted data from the original oob misclassification rate to determine how much predictive accuracy decreases when the permuted data is used (Cutler et al., 2007). This is not an exhaustive explanation of RF or all the issues to consider when using RF. The references should be reviewed for more details on the technique, parameter considerations, and applications.

The RF is available in a commercial program (Salford Systems) and a number of open source programs, with R seemingly the most popular. R is a free software environment for statistical analyses and graphics that can be run on the UNIX (uniplexed information and computing system) platforms, Windows, and MacOS. A general workflow and a generic script to illustrate how one might run RF and CART in R are provided as Appendix B.

7.0 DECISION-MAKING, MANAGEMENT RESPONSE, AND COMMUNICATION

Data from the covariate analysis will be used by the DCP to interpret spatial patterns and trends in the desert tortoise occupancy data, including areas to focus protection and management and areas that cannot be improved by management actions. Additionally the data will be used to evaluate and recommend management actions to improve desert tortoise habitat or mitigate the effects of past and current human impacts.

Management responses could include, but are not limited to:

- Immediate responses – those that can likely be accomplished within existing budgets and authorities:
  - Conduct localized weed treatments.
  - Post new or additional signs within a local area.
  - Increase frequency of signage inspections and repair within a local area.
  - Remove trash/debris in a local area.
  - Increase law enforcement patrols within a local area by decreasing patrols in some other area(s).
  - Assign a volunteer monitor to a local area or request current volunteer monitor to conduct additional visits.
- Long-term Responses – those that require approval of Plan Administrator, Permittees, and/or USFWS or may require additional budget approvals:
  - Conduct a restoration/rehabilitation project.
  - Close, relocate, or open a road.
  - Remove an allowable use from a local area, avoid issuing use permits within a local area, allow a new use or increase concentration of an existing use.
  - Increase overall law enforcement within the easement.
  - Conduct outreach to key neighbors or user groups to request voluntary actions (or avoidances) on their part to benefit the easement.
  - Develop new outreach to achieve focused goal.
  - Update easement management documents or legal agreements.

The communication of monitoring data is the essential link to improving decision making and conservation. Data communication answers these questions:

- Who are the appropriate decision makers that need to know the results of monitoring? How will the data be presented to them?

- How and to whom will the monitoring results be communicated to improve the work of others?
- How and to whom will the monitoring results be communicated to facilitate peer review and the improvement of the work?

Decision makers and stakeholders impacted by the results of this study include, but are not limited to, the DCP, MSHCP Permittees, USFWS, U.S. Geological Survey, and Nevada Department of Wildlife. The results of the study will be presented in a written final technical report that will receive peer review as described below. Once the outcomes of the peer review are addressed in the final report, it will be shared with the above key decision makers. Other local land managers may also benefit from the outcomes of this study and the technical report will be shared with them. This pilot study report may also be formatted for submittal to a peer reviewed journal for publication. The protocol, data, technical report, and publication will be part of the public records of Clark County, Nevada, and available for inspection by anyone who requests them. In addition, the report will be posted on the DCP public website and the DCP may seek opportunities to deposit the technical report and publication in open access repositories such as the Nevada State Library and local university repositories.

The draft version of this protocol received peer review from individuals familiar with occupancy modeling. Assuming funding is secured and after a maximum of five seasons of the pilot test of the protocol and data analysis, a report on the results of the pilot study will be prepared and the report will receive peer review.

8.0 IMPLEMENTATION

This section summarizes the logistical issues related to implementing the Mojave desert tortoise occupancy covariate monitoring protocol.

8.1 Staffing

The protocol is implemented over several years and by five working teams (Project Lead, Project Management Team, Field Data Collection Team, GIS Data Collection Team, and Data Analyst). The Project Management Team consists of DCP staff and it oversees the other teams' activities related to this protocol. A single Field Data Collection Team consisting of at least two people collects all field data. The field team has at least one qualified botanist with experience with Mojave Desert plants in both flowering and non-flowering condition and experience with the field sampling methods used in the protocol. The GIS team consists of DCP GIS staff and/or contractors. The Data Analyst is anticipated to be a contractor.

8.2 Equipment

Each field survey team has a GPS receiver (a model with 1 to 5 m accuracy and differential correction) for locating points, and a field kit containing data sheets, clipboards, pens, handheld radios (for communication between DCP staff and field survey crews), four 50 m tapes, one 1 m x 2 m collapsible quadrat, pins, compass (with 1 degree accuracy and resolution), camera, and spare batteries for the camera. Field data sheets are provided to field survey crews by DCP staff.

8.3 Training

The Project Management Team conducts a training program and provides a training manual and copy of the protocol to each team member. The field team is instructed on the following items:

- Background on the project and covariate protocol monitoring objectives.
- Summary description of the desert tortoise occupancy sampling protocol and interrelationship with the co-variates sampling.
- Overview of the study area.
- Safety and access issues and permits and authorizations for the study area.
- Sampling design, randomly placed plots, the subplot and transect placement with each plot, and the survey timeframe.
- Standardized procedures and instrumentation for locating subplots, collecting data, completing data sheets, and taking photos.
- Standardized procedures for identifying species, measuring vegetative cover, and identifying soil series (unless assigned to others with appropriate expertise).
- Data verification and validation methods, data management, and data transfer.
- Roles and responsibilities of field survey crew members.
- Protocol comments and feedback

Training is completed within two weeks of the initiation of data collection. Training time is an appropriate length to adequately cover the material, anticipated to be approximately one day with additional time (1 to 2 days) for soil series identification if not collected by others with appropriated expertise

8.4 Landowner Authorizations

The DCP staff makes a formal request for permission to conduct the study from the County as the holder of the conservation easement, the City of Boulder City as the landowner of the BCCE, and from USFWS as a signatory to the BCCE agreement. Written approval must be received from the County, City, and USFWS. Additionally, field monitoring activities are coordinated with the entity that provides law enforcement for the BCCE.

If any sample units are on lands that were reserved to the U.S. during the 1995 transfer of land to the City of Boulder City, permission must also be sought from the appropriate federal agency. The DCP staff reviews sample unit locations and initiates any request(s) for permission from the federal agency(ies).

9.0 DOCUMENT HISTORY

A draft of this protocol was peer reviewed by an independent set of reviewers in June 2012. The final report was submitted to the DCP in August 2012. Any changes to this document will be maintained by the DCP as separate versions.

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APPENDIX A

Data Sheet, Photo Log, Data Management Spreadsheet

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Field Data Sheet for Assessing Environmental Covariates for Desert Tortoise Presence

version: 13 September 2012

Page ___ of ____

Plot #: **Recorder:** **Date (yyyy/mm/dd):**

Field Team: **Time (0000-2400):**

Subplot #:

1 ☐	^North ☐ 2
4 ☐	☐ 3

circle subplot sampled

Subplot GPS Coordinates: **UTMs: N:** ________ **E:** ________

Transect Compass Direction: **NW** **NE** **SE** **SW** **Photo?** Yes No

Perennial Shrub and Succulent Species -- Percent Vegetative and Basal Cover on Line Intercept (25 m transect, 20 cm gap rule)

Ambrosia dumosa	Veg Cover												
	Basal Cover												
Ephedra nevadensis	Veg Cover												
	Basal Cover												
Grayia spinosa	Veg Cover												
	Basal Cover												
Krameria grayi	Veg Cover												
	Basal Cover												
Larrea tridentata	Veg Cover												
	Basal Cover												
Lycium andersonii	Veg Cover												
	Basal Cover												
Opuntia species (acanthocarpa,	Veg Cover												
basilaris, ramosissima)	Basal Cover												
Yucca species (brevifolia,	Veg Cover												
schidigera)	Basal Cover												
Other:	Veg Cover												
	Basal Cover												
Other:	Veg Cover												
	Basal Cover												
Other:	Veg Cover												
	Basal Cover												
Other:	Veg Cover												
	Basal Cover												
Bare Ground	Cover												

Ephemeral Plant Species: Cover and Diversity in 1 m by 2 m quadrats (with 1 m side centered on line intercept transect)

	at 10m point on transect Cover	at 20m point on transect Cover
Bromus rubens		
Schismus barbatus		
Vulpia octoflora		
All other grass species		
All forb species		
All ephemeral plant species		

Cover Categories

1	trace
2	0-1%
3	1-2%
4	2-5%
5	5-10%
6	10-25%
7	25-50%
8	50-75%
9	75-95%
10	95-100%

List of species or recognizable taxonomic units present in quadrats:

Total Number

Tortoises Encountered	1	2	3	4	5	6	7	8
Tag Number								
Tag Color								
Unreadable Tag								
No Tag								

PHOTO LOG
Desert Tortoise Occupancy Covariate Monitoring
Clark County Desert Conservation Program

Date: _____________　　**Photographer(s):**
Log Sheet ___of ___　　**Field Team Names:**

Photo #	Camera Time	UTMs N	UTMs E	Photographer Facing Direction[1]	Plot-Subplot-Transect #s or Subject

[1] **N, NE, E, SE, S, SW, W, NW, Ground, Sky**

Covariate Data Acquisition and Management Plan Spreadsheet for the Desert Tortoise Covariate Monitoring Protocol					
MEASUREMENT	COVARIATE DEFINITION	COLLECTION STANDARD OPERATING PROCEDURE	DATA VERIFICATION	DATA VALIDATION	FREQUENCY
Field Collected Data					
Plot #	Unique number assigned to each plot by GRTS methodology	Enter on data sheet	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Graph plot number by date and time entries to ensure plot number is correctly entered. In database, program cells to only accept a certain range of numbers.	Whenever any data is collected in the field.
Recorder	Name of the person recording the data on the data sheet.	Enter on data sheet	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Compare to team members present for that plot and date stamp.	Whenever any data is collected in the field.
Field Team	Names of team members collecting data and making observations	Check off on data sheet	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Compare to team members present for that plot and date stamp.	Whenever any data is collected in the field.
Date	The day of the data collection	Entered on data sheet in format YYYY/MM/DD	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Dates within the range of possible dates, check consecutive nature of dates.	Whenever any data is collected in the field.
Time	The time that data collection is started in the plot	Entered in military time format (0000-2400)	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Times within range of possible times (0500 to 1500), graph date and times.	Whenever any data is collected in the field.
Subplot #	Unique number assigned to each subplot in the plot	Enter on data sheet in format: Plot Number-Subplot Number	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Graph plot number and opportunistic data by date and time entries to ensure plot number is correctly entered.	Whenever any data is collected in the field.

Covariate Data Acquisition and Management Plan Spreadsheet for the Desert Tortoise Covariate Monitoring Protocol					
MEASUREMENT	COVARIATE DEFINITION	COLLECTION STANDARD OPERATING PROCEDURE	DATA VERIFICATION	DATA VALIDATION	FREQUENCY
Subplot Coordinates UTMs: N and E	Coordinates automatically generated with use of GPS	Coordinates automatically generated with use of GPS function	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Spatial data mapped and visually inspected for within boundaries of plot, correlated with correct plot and the daily survey route. Post processing will be within 1 to 3 m of recorded location.	Whenever any data is collected in the field.
Transect Compass Bearing	Compass bearing of transect taken from the center point of the subplot	Use compass to obtain bearing	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Compare compass bearings for logical sequence.	Whenever any data is collected in the field.
Photo Taken	Indicate if the required photo is taken for the transect	Circle Y or N on data sheet	Verify that photos are taken for each transect.	Verify against digital photo files with that date and time stamp in each plot location.	Whenever any data is collected in the field.
Vegetation Covariates – Field Data Collection					
Vegetative Cover of Perennial Shrub and Succulent Vegetation	Perennial and succulent plants are present above ground throughout the year and provide cover and food resources for tortoises. The vegetative cover of these species provides a measure of the influence these plants have on the system.	Line intercept is used to measure the vegetative cover of the perennial shrub and succulent species. Line intercept is the length of the transect that is covered by each species. A gap of 20 cm of cover is required before it is recorded as cover or no cover. Species can overlap in cover.	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the covariate was collected.	Data spreadsheets are reviewed and data graphed to ensure logical values and to look for outliers.	First year of sampling, then at 5-year intervals.

Covariate Data Acquisition and Management Plan Spreadsheet for the Desert Tortoise Covariate Monitoring Protocol					
MEASUREMENT	COVARIATE DEFINITION	COLLECTION STANDARD OPERATING PROCEDURE	DATA VERIFICATION	DATA VALIDATION	FREQUENCY
Shade Cover of Perennial Shrub and Succulent Vegetation	Perennial and succulent plants are present above ground throughout the year and provide cover and food resources for tortoises. The shade cover of these species provides a measure of the value of each species for tortoises to escape the intense sun of the desert.	Line intercept is used to measure the vegetative and basal cover of the perennial shrub and succulent species. Shade cover is derived by subtracting basal cover from vegetative cover. Line intercept is the length of the transect that is covered by each species. A gap of 20 cm of cover is required before it is recorded as cover or no cover. Species can overlap in cover.	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the covariate was collected.	Data spreadsheets are reviewed and data graphed to ensure logical values and to look for outliers.	First year of sampling, then at 5-year intervals.
Bare Ground	Bare ground is the absence of any vegetation, and includes soil, rocks, stones, pebbles, etc. The inverse of bare ground is total vegetation cover.	Line intercept is used to measure bare ground. Gap of cover of 10 cm is required before recorded as cover or no cover.	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the covariate was collected.	Data spreadsheets are reviewed and data graphed to ensure logical values and to look for outliers.	First year of sampling, then at 5-year intervals.
Ephemeral Plant Species Cover, Biomass, and Diversity	Ephemeral species are either annuals or perennials that occur above ground during one time of the year or across several years. To assess their abundance and value as a food resource for the desert tortoise, cover and species richness are measured.	The cover of grass species and forb species as a single group are visually estimated in 1 m x 2 m quadrates placed systematically at the 10 m and 20 m points along the line intercept transect in each subplot. The grass species include red brome (*Bromus rubens*), split grass (*Schismus barbatus*), and sixweeks grass (*Vulpia octoflora*), and a grouping of all other grass species. Total ephemeral plant cover is also measured. Cover is estimated in 10 cover classes that are designed to be more sensitive for lower percent cover. These cover classes are trace, 0-1%, 1-2%, 2-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, and 95-100%. Species richness is determined through the identification of all species in the plot.	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the covariate was collected.	Data spreadsheets are reviewed and data graphed to ensure logical values and to look for outliers.	Annually during predicted El Nino Watch and Advisory years.

Covariate Data Acquisition and Management Plan Spreadsheet for the Desert Tortoise Covariate Monitoring Protocol					
MEASUREMENT	COVARIATE DEFINITION	COLLECTION STANDARD OPERATING PROCEDURE	DATA VERIFICATION	DATA VALIDATION	FREQUENCY
Data Collected if Tortoise Encountered					
Tortoise Encountered	Circle number of tortoises encountered	Circle the number of tortoises encountered	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the information was collected.	None	Whenever any data is collected in the field.
Tag #	The number of the tag on the tortoise if visible	Noted on data sheet	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the information was collected.	Tag number within range of possible numbers.	Whenever any data is collected in the field.
Tag Color	The color of the tag on the tortoise if easily visible	Noted on data sheet	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the information was collected.	Tag color within range of possible colors.	Whenever any data is collected in the field.
Unreadable Tag	The presence of a tag on which the number is unreadable.	Noted on data sheet	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the information was collected.	Check that Tag Number and Tag Color fields have no data entered.	Whenever any data is collected in the field.
No Tag	No tag is present on the tortoise	Noted on data sheet	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the information was collected.	Check that Tag Number, Tag Color and Unreadable Tag fields have no data entered.	Whenever any data is collected in the field.
Photo Log Datasheet					
Date	Enter day photo taken which should be same as data collection day.	Entered on photo log in format YYYY/MM/DD	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Dates within the range of possible dates, check consecutive nature of dates.	Whenever any data is collected in the field.

Covariate Data Acquisition and Management Plan Spreadsheet for the Desert Tortoise Covariate Monitoring Protocol					
MEASUREMENT	COVARIATE DEFINITION	COLLECTION STANDARD OPERATING PROCEDURE	DATA VERIFICATION	DATA VALIDATION	FREQUENCY
Log Sheet Number	Enter the number of the log sheet if more than one sheet is used.	Noted on photo log	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Photo log sheets are checked to see that all numbered pages are accounted for and match with the photos uploaded to the DCP.	Whenever any data is collected in the field.
Field Team Names	Names of team members collecting data and making observations	Enter on log sheet, or if names are listed on datasheet, check off names of those present on datasheet	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Compare to team members present for that plot and date stamp.	Whenever any data is collected in the field.
Camera Time	Enter the time the photo was taken as recorded by the camera.	Entered in military time format (0000-2400)	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Times within range of possible times (0500 to 1500), graph date and times.	Whenever any data is collected in the field.
Subplot Coordinates UTMs: N and E	Coordinates automatically generated with use of GPS	Coordinates automatically generated with use of GPS function	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Spatial data mapped and visually inspected for within boundaries of plot, correlated with correct plot and the daily survey route. Post processing will be within 1 to 3 m of recorded location.	Whenever any data is collected in the field.
Photographer Facing Direction	Compass bearing of the direction of the photo or camera facing towards the ground or sky.	Use of compass to obtain bearing or enter sky or ground direction.	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	None	Whenever any data is collected in the field.
Plot-Subplot-Transect # or Subject	Identify photo by subject matter or plot, subplot, and transect number.	Describe subject of photograph in enough detail for others to understand, using key words related to the objects that are the focus of the photo.	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	None	Whenever any data is collected in the field.

Covariate Data Acquisition and Management Plan Spreadsheet for the Desert Tortoise Covariate Monitoring Protocol					
MEASUREMENT	COVARIATE DEFINITION	COLLECTION STANDARD OPERATING PROCEDURE	DATA VERIFICATION	DATA VALIDATION	FREQUENCY
Photographer	Enter name of person taking photo.	Enter on photo log.	Data sheets and data spreadsheets are checked at the end of each field day to ensure this information was collected. Data spreadsheets are reviewed by the Project Lead to ensure this information was collected.	Compare to field team names present for that plot and date stamp.	Whenever any data is collected in the field.
GIS Collected Data					
Vegetation Covariate					
Vegetation Index of Perennial and Ephemeral Plant Cover	Measures a vegetation index by remote sensing that can be interpreted to represent total plant cover and the green-up of spring ephemeral plant cover.	The best available aerial or satellite imagery is used for this covariate. In general, the vegetation Indices are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation. The vegetation index, Normalized Difference Vegetation Index (NDVI) is calculated from the visible (VIS) and near infrared (NIR) light reflected by vegetation (NIR – VIS)/(NIR + VIS), and is the relative difference in the reflectance of near infrared and photosynthetically active radiation which results in a measure of greenness and photosynthetic capacity. Aerial and satellite imagery is routinely used to generate NDVI products. To produce the ideal NDVI products three temporal dates should be used, representing a drought year, a wet year, and an average year. Therefore, three different biomass products are created.	Data spreadsheets are reviewed by the Project Lead to verify this covariate was recorded.	A subset of data (10%) is checked by another GIS expert to assess accuracy. Data is mapped and reviewed for logic.	Annually

Covariate Data Acquisition and Management Plan Spreadsheet for the Desert Tortoise Covariate Monitoring Protocol					
MEASUREMENT	COVARIATE DEFINITION	COLLECTION STANDARD OPERATING PROCEDURE	DATA VERIFICATION	DATA VALIDATION	FREQUENCY
Substrate Covariates					
Total Length of Washes	Washes are shallow to deep, narrow to wide temporary water courses that concentrate surface flow during rain events. They provide enhanced food resources and burrow sites for 9mplemenes than most of the surrounding landscape.	The linear length of washes within the BCCE and the appropriate surrounding area are digitized from the appropriate imagery. Criteria for the identification of washes is developed using different imagery layers.	Data spreadsheets are reviewed by the Project Lead to check that this covariate was recorded for each scale of analysis (4, 40, and 400 ha) for each plot.	A subset of data (10%) is checked by another GIS expert to assess accuracy.	One time before the end of the 3rd year of the study.
Precipitation Covariate					
Precipitation Amount and Occurrence	The amount of rainfall during selected periods during the year and for a selected time span over years	Precipitation data from Prism and BioClim datasets and National Weather Service precipitation data (2005- 2011) is used for this covariate. The DCP has created datasets that present total precipitation, average precipitation, and monthly precipitation totals.	Data spreadsheets are reviewed by the Project Lead to verify this covariate was recorded for each plot.	A subset of data (10%) is checked by another GIS expert to assess accuracy. Data is mapped and reviewed for logic.	Annually
Disturbance and Habitat Alteration Covariates					
Distance to and Density of Linear Disturbances	Linear disturbances include roads, power lines, and utility corridors.	The Euclidian distance from the center point of the 4 ha plot to the nearest of each category of linear disturbances, and the density of each category of linear disturbances within the 4 ha plot and 40 ha and 400 ha areas surrounding the plot	Data spreadsheets are reviewed by the Project Lead to verify this covariate was recorded for each plot.	A subset of data (10%) is checked by another GIS expert to assess accuracy.	First year of sampling, then only with changes in linear disturbances.
Distance to Energy Production and Transmission Facility Sites	Sites that produce and transmit energy are within the BCCE. These sites include solar facilities (photovoltaic, trough generation), natural gas facility, substations, switching yard, and associated transmission lines.	The Euclidian distance is measured from the center point of the 4 ha plot to the nearest energy production and transmission facility site.	Data spreadsheets are reviewed by the Project Lead to verify this covariate was recorded for each plot.	A subset of data (10%) is checked by another GIS expert to assess accuracy.	First year of sampling, then only with changes to site footprint.

Covariate Data Acquisition and Management Plan Spreadsheet for the Desert Tortoise Covariate Monitoring Protocol					
MEASUREMENT	COVARIATE DEFINITION	COLLECTION STANDARD OPERATING PROCEDURE	DATA VERIFICATION	DATA VALIDATION	FREQUENCY
Management Action Covariate					
Distance to Management Actions	Management actions could include road closures, law enforcement actions, restoration actions (restoring degraded habitat), and enhancement actions (improving existing habitat).	The Euclidian distance is measured from the center point of the 4 ha plot to the nearest management action in the classes of road closures, law enforcement actions, restoration actions, and enhancement actions.	Data spreadsheets are reviewed by the Project Lead to verify this covariate was recorded for each plot.	A subset of data (10%) is checked by another GIS expert to assess accuracy.	One time and with implementation of management actions.
Substrate – Separate Field Collection (not on covariate datasheet)					
Presence of Petrocalcic Horizon or Duripan	A petrocalcic horizon or duripan is a hardened deposit of soil that cements together other materials, including gravel, sand, clay, and silt. It is evident in the field by the formation of ledges around hills and washes.	Visual assessment of the presence of a petrocalcic horizon or duripan by surveying each subplot.	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the covariate was collected.	Data is compared to the soil association map to assess validity of the visual assessment.	One time before the 3rd year of the study.
Soil Series Present	Assess soil series in each subplot. Natural Resource Conservation Service has mapped the soils of the BCCE to the association level and provides summaries of the soil series found in each association at http://soils.usda.gov/technical/classification/osd/index.html. Training will be required to identify the soil series	This covariate is sampled in the field, visually assessing the soil series by surveying each subplot. Training is required to accurately assess the soil series.	Data sheets and data spreadsheets are checked at the end of each field day to ensure this covariate is collected. Data spreadsheets are reviewed by the Project Lead to ensure the covariate was collected.	Data for this covariate is compared against expected data from the NRCS soil survey data, assessing if the soil series is recorded or likely from the soil association.	One time before the 3rd year of the study.

APPENDIX B

Random Forest Implementation in R

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Random Forest Implementation in R

Random Forests software is available in a commercial program (Salford Systems) and a number of open source programs, with R seemingly the most popular. R is a free software environment for statistical analysis and graphics that can be run on UNIX platforms, Windows and MacOS. The following is a general workflow and a generic script to illustrate how one might run Random Forests in R. The statements following the # sign describe the computation action, while the lines without the # sign are the syntax for the computation in R.

Preliminaries

1. Install the R software, http://www.r-project.org/
2. After R is stalled, install the randomForest package as follows:
    a) Open R
    b) In the menu, go to Packages > Install Package(s)…
    c) Select a CRAN mirror
    d) Select "randomForest"

Generic R Script

```
#Set working directory to where the data is stored
setwd("C:/Data/input")

#Load the randomForest library (after the one-time installation of the library as described above)
library(randomForest)

#For randomForest help
help(randomForest)

#Read in the data that contains the response and predictor variables. The following code is for reading in #.csv files,
but R can easily read other file formats.
example <- read.csv("FILENAME.csv",header = TRUE)

#Set random seed (this can be any number)
set.seed(44)

#Run RF **SEE THE NOTES ON RF PARAMETERS AT THE END OF THIS SCRIPT**
data1.rf <- randomForest(DEPENDENT VARIABLE~., data=example, ntree=1000, replace=TRUE, importance =
TRUE, proximity=TRUE, nodesize=2)

#Print RF results, including confusion matrix (classification accuracy)
print(data1.rf)

#Generate the variable importance table
imp1 = round(importance(data1.rf),2)
#If desired, write the importance table to your directory as a .csv file
```

write.csv(imp1, "imp1_tbl.csv")

#If the number of variables is very large, forests can be run once with all the variables, then run again using only the most important variables from the first run. This usually improves model performance.

#Re-run RF after dropping the least important variables based on the importance table above
data.rf2 <- randomForest(DEPENDENT VARIABLE~., data=example_reduced, ntree=1000, replace=TRUE, importance = TRUE, sampsize=ss, proximity=TRUE, nodesize=2)

#Generate the variable importance table
imp2 = round(importance(data.rf2),2)

#If desired, write the importance table to your directory as a .csv file
write.csv(imp2, "imp2_tbl.csv")

#The RF model can then be used to classify new predictor variables to predict the response of interest.
#The RF model could also be used to classify a subset of the data that was not used to build the RF #model.

#Predict the remaining cases or new cases
#Read in new data
read.csv("new.csv",header = TRUE)

#Classify observations using the previous RF model
new.pred = predict(data2.rf,new,type = "response")

#Generate matrix of class probabilities using the previous RF model
new.prob = predict(data2.rf, new,type = "prob")

#See the following web site for help with RF predict
#http://www.stat.ucl.ac.be/ISdidactique/Rhelp/library/randomForest/html/predict.randomForest.html

#Write tables of the results
write.csv(new.pred, file = "new_pred.csv")
write.table(new.prob, "new_prob.csv")

RF Parameters in R

There are numerous parameters that can be set in randomForest as implemented in R. The following are particularly important to understand. For more details, see the R help and the references at the end of this document.

- "~." Tells R to use all the other variables in the dataset as predictor variables
- ntree: the number of trees to be constructed. This should be a relatively large number to ensure that every observation is predicted at least a few times. The default appears to be 500. See Evans & Cushman, 2009 for details on this parameter.

- mtry: number of predictor variables randomly selected for use in the binary partitioning. For classification, the default values are sqrt(p) where p is the number of predictor variables in the dataset. This number can be experimented with to see what values result in the lowest error rates.
- replace: indicates if the samples should be done with replacement. TRUE or FALSE
- importance: indicates whether variable importance should be calculated. TRUE or FALSE
- strata: A factor variable that is used for stratified sampling.
- ndesize: Minimum size of terminal nodes. Setting this number larger causes smaller trees to be grown.
- proximity: Should proximity measure among the rows (observations) be calculated. TRUE or FALSE. If proximity=TRUE, a matrix of proximity measures among the input (based on the frequency that pairs of data points are in the same terminal nodes).
- sampsize: Size(s) of sample to draw. For classification, if sampsize is a vector of the length the number of strata, then sampling is stratified by strata, and the elements of sampsize indicate the numbers to be drawn from the strata. Experiment with this parameter to see what value(s) result in the lowest error rates. See Evans & Cushman, 2009 and Grossman et al., 2010 for two different approaches related to sample size.
    - If the size of the dependent variable classes varies, experiment with setting different sample sizes for each class. For a hypothetical example, the following numbers are the known occurrences for the three species attempting to predict
      Species1: 500
      Species2: 150
      Species3: 200

    Set the sample size before running the RF command as follows in R:

```
#Set sample size for species1, species2, and species3
ss <- c(250, 150, 150)
#run RF with the sample size vector
data.rf <- randomForest(DEPENDENT VARIABLE~., data=example, ntree=1000, replace=TRUE,
importance = TRUE, sampsize=ss, proximity=TRUE, nodesize=2)
```

Simple Example in R

The following example adapted from the randomForest R help uses a sample dataset called “iris” that is readily available in R. The iris dataset gives the measurements in centimeters of the variables sepal length and width and petal length and width, respectively, for 50 flowers from each of 3 species of iris.

Dependent variable: iris species (n=3). The species are *Iris setosa*, *versicolor*, and *virginica*.
Predictor variables: sepal length, sepal width, petal length, and petal width (n=4)

Random Forest Classification in R

```
#Load the randomForest library
library(randomForest)

#load the iris dataset
```

```
data(iris)

#View column names
names(iris)

#Run RF using all predictor variables
iris.rf <- randomForest(Species ~ ., data=iris, importance=TRUE, proximity=TRUE)

#Print the results
print(iris.rf)

Call:
 randomForest(formula = Species ~ ., data = iris, importance = TRUE,      proximity = TRUE)
               Type of random forest: classification
                     Number of trees: 500
No. of variables tried at each split: 2
        OOB estimate of error rate: 4%
Confusion matrix:
           setosa versicolor virginica class.error
setosa         50          0         0        0.00
versicolor      0         47         3        0.06
virginica       0          3        47        0.06

#View importance table
round(importance(iris.rf), 2)

             setosa versicolor virginica MeanDecreaseAccuracy MeanDecreaseGini
Sepal.Length   1.23       1.69      1.77                 1.28             8.88
Sepal.Width    1.01      -0.08      1.26                 0.59             2.20
Petal.Length   3.70       4.42      4.18                 2.49            42.30
Petal.Width    3.83       4.48      4.34                 2.53            45.83
```

See http://www.stat.berkeley.edu/~breiman/RandomForests/cc_home.htm#varimp for more information about the “Mean decrease Accuracy” and “Mean Descrease Gini” variable importance measures

CART Implementation in R

To better understand how a single classification tree is generated and to compare the RF results with a single classification tree, the following is an example of one way to conduct CART in R. There are multiple R libraries that can be used to run CART. The following example uses the “rpart” library, but other options include “tree,” “party”, and “mvpart” libraries.

Preliminaries

1. Install the R software, http://www.r-project.org/
2. After R is stalled, install the randomForest package as follows:
    a) Open R
    b) In the menu, go to Packages > Install Package(s)…
    c) Select a CRAN mirror
    d) Select "rpart" package
    e) Select "party" package

Generic R Script

#Set working directory to where the data is stored
setwd("C:/Data/input")

#Read in the data (the following line is for reading in .csv files, but R can easily read other file formats)
example <- read.csv("FILENAME.csv",header = TRUE)

#Load rpart library
library(rpart)

#Optional - Load party library. This is a library for recursive partitioning with conditional inference trees #for multivariate responses (ctrees). Loading this library in conjunction with rpart seems to result in #nicer graphics for rpart trees.
library(party)

#For rpart help
help(rpart)

#Run Classification Tree Analysis using all predictor variables
data1.cart <- rpart(DEPENDENT VARIABLE ~ ., data=example)

#Print results
printcp(data1.cart)

#Detailed summary of splits
summary(data1.cart)

#Plot un-pruned tree: In rpart trees, move to the left branch when the stated condition is true
plot(data1.cart, margin=0.1)
#Add text to the tree plot
text(data1.cart, cex=0.5)

#Plot complexity parameter to see the cross-validation results that will be used to prune the tree

plotcp(t.cart)
#Prune the tree. For the “cp” parameter, a good choice for pruning is often the leftmost value for which #the mean lies below the horizontal line.
data1.prune <- prune(data1.cart, cp=X)

#Plot the pruned tree
plot(data1.prune, margin=0.1)
#Add text to the pruned tree plot
text(data1.prune, cex=0.5)

# Optional: Create postscript plot of tree
post(data1.prune, file = "c:/tree.ps", title = "XX")

#Can then manually calculate the confusion matrix using the predicted class for each observation or write function in R to do so

Estimated Time

Depending on the user’s familiarity with R and experience with predictive models, estimated time to conduct the RF analysis could range from three days to over a week with the low estimate for experienced R users and/or those with experience in machine learning methods.

References

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APPENDIX C

Conceptual Ecological Model for Mojave Desert Tortoise

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Acronyms and Abbreviations

BCCE	Boulder City Conservation Easement
BLM	Bureau of Land Management
DCP	Desert Conservation Program
Ha	hectares
KEA	key ecological attribute
Km	kilometer
MSHCP	Multiple Species Habitat Conservation Plan
OHV	off-highway vehicle
U.S.	United States
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

1.0 Overview

The Mojave population of the desert tortoise (*Gopherus agassizii)* is a priority species for conservation in Clark County, Nevada and throughout its range in the southwestern United States (U.S.). Studies have shown that the species has declined and continues to decline throughout its range in the Mojave Desert (USFWS, 2011) and the species was listed as threatened under the Endangered Species Act in 1990 (USFWS, 1990).

The Desert Conservation Program (DCP), in conjunction with its Science Advisor, developed a conceptual ecological model for the Mojave desert tortoise to be used with the Adaptive Management Program of the Multiple Species Habitat Conservation Plan (MSHCP) for Clark County, Nevada. The DCP plans to conduct a multi-year pilot study to test the use of occupancy sampling for monitoring tortoise habitat use in smaller desert conservation areas. The primary purpose of the model is to assist with identifying which ecological covariates to measure as part of the occupancy sampling study. The model will also provide a comprehensive and integrated understanding of the factors that influence the life history and survival of the Mojave desert tortoise.

The model was specifically developed for the desert tortoise population present on the Boulder City Conservation Easement (BCCE). The BCCE covers 86,423 acres owned by the City of Boulder City with an easement held by Clark County. The BCCE is managed by the DCP under the MSHCP. The BCCE is located at the upper reaches of the Eldorado Valley and southwest of the populated area of Boulder City. Prior to establishment of the easement in 1995, the site was managed by the Bureau of Land Management (BLM) for multiple uses including mining, energy transmission, telecommunications, off-highway vehicle (OHV) racing, hunting, grazing, and open recreation. The conservation easement specifies that of these historical uses, only limited transmission of energy and telecommunications, hunting, non-speed vehicular events, and non-ground disturbing recreation may occur on the BCCE.

The majority of the information for this report comes from the Revised Recovery Plan for the Mojave Population of the Desert Tortoise (USFWS, 2011). References that were not included in the Revised Recovery Plan that provide significant information on the topic are cited herein.

2.0 Conceptual Ecological Models

Conceptual ecological models have been widely acknowledged as having exceptional value for the conservation and management of natural resources (DeAngelis et al., 2003; Slauson & Zielinski, 2008; Missouri River Independent Science Advisory Panel, 2011). Conceptual models visually depict the complex causal relationships between a species life history and its habitat or an ecological system, and how they relate to threats and management actions. The model allows the identification of predicted pathways between management actions and the response of a species or ecological system. While the components of a conceptual model can be adequately described in text form, the linkages among these components are better communicated visually.

The values of developing a conceptual ecological model include:

1. Facilitates a comprehensive look at factors that influence the status and trend of a species or ecological system.
2. Illustrates the complex linkages between and among key ecological attributes, changes to key ecological attributes, and the causal factors of change.

3. Assists with identification of priority factors or factor linkages for management and monitoring.
4. Identifies aspects of the system that are well understood and where there are substantive uncertainties that limit the application of available knowledge to management.

3.0 Components of the Desert Tortoise Conceptual Model

The conceptual ecological model developed for the desert tortoise shown in Figure 1 consists of four primary components. The components are discussed from right to left and include life history and demographics, key ecological attributes, ecological changes, and causal factors of change. Each component and details on the subcomponents are described in the next sections. Arrows are used to represent the relationship of these subcomponents. The direction of the arrows is from left to right – from causal factors of change to their influence on the life history and demographics of the species.

This conceptual ecological model illustrates current understanding of the desert tortoise as it relates to the abiotic and biotic variables of its habitat, and the causal factors that change those variables. This model does not include every possible factor that could be addressed, but focuses on those determined key to the dynamics of the species and the implementation of management.

3.1 Life History and Demographics (Eggs, Yearlings, Juveniles, Adults)

The desert tortoise lifespan is 50 to 80 years. Tortoises reach sexual maturity at 15 to 20 years of age and reproductive rates have been shown to be low (Tracy et al., 2004). The number of eggs laid at a single time and the number of clutches during the breeding season vary extensively (1 to 10 eggs and 0 to 3 clutches). Additionally, the success rate of clutches is most likely low, with predation and the availability of food resources having the largest impact. Most long-lived species depend on the addition of individuals to the reproducing population to be greater than the mortality of reproductive individuals. Since the rate of clutches is low, the most important life history factor is the survival of large adult females (Doak et al., 1994).

The desert tortoise is a herbivorous terrestrial reptile that may occur at elevations between sea level and 7,300 feet. Suitable habitat for desert tortoise includes areas with sufficient available forage consisting of annual and perennial vegetation, and soils suitable for construction of subterranean burrows for nesting, resting, escaping the heat, and for longer periods of brumation. Tortoises are most active above ground within southern Nevada between March 15 and October 15. During years with low annual plant productivity, tortoises may spend considerably more time below ground.

Tortoise home ranges can be between 25 to 200 acres (10 to 81 hectares), with individuals able to range up to seven miles on a single foray (Berry & Turner, 1986). Males typically have home ranges twice as large as females (Berry & Turner, 1986).

Information about threats to the species is discussed in each component of the conceptual ecological model. Additional information about tortoise biology and habitat requirements is described in the Revised Recovery Plan (USFWS, 2011).

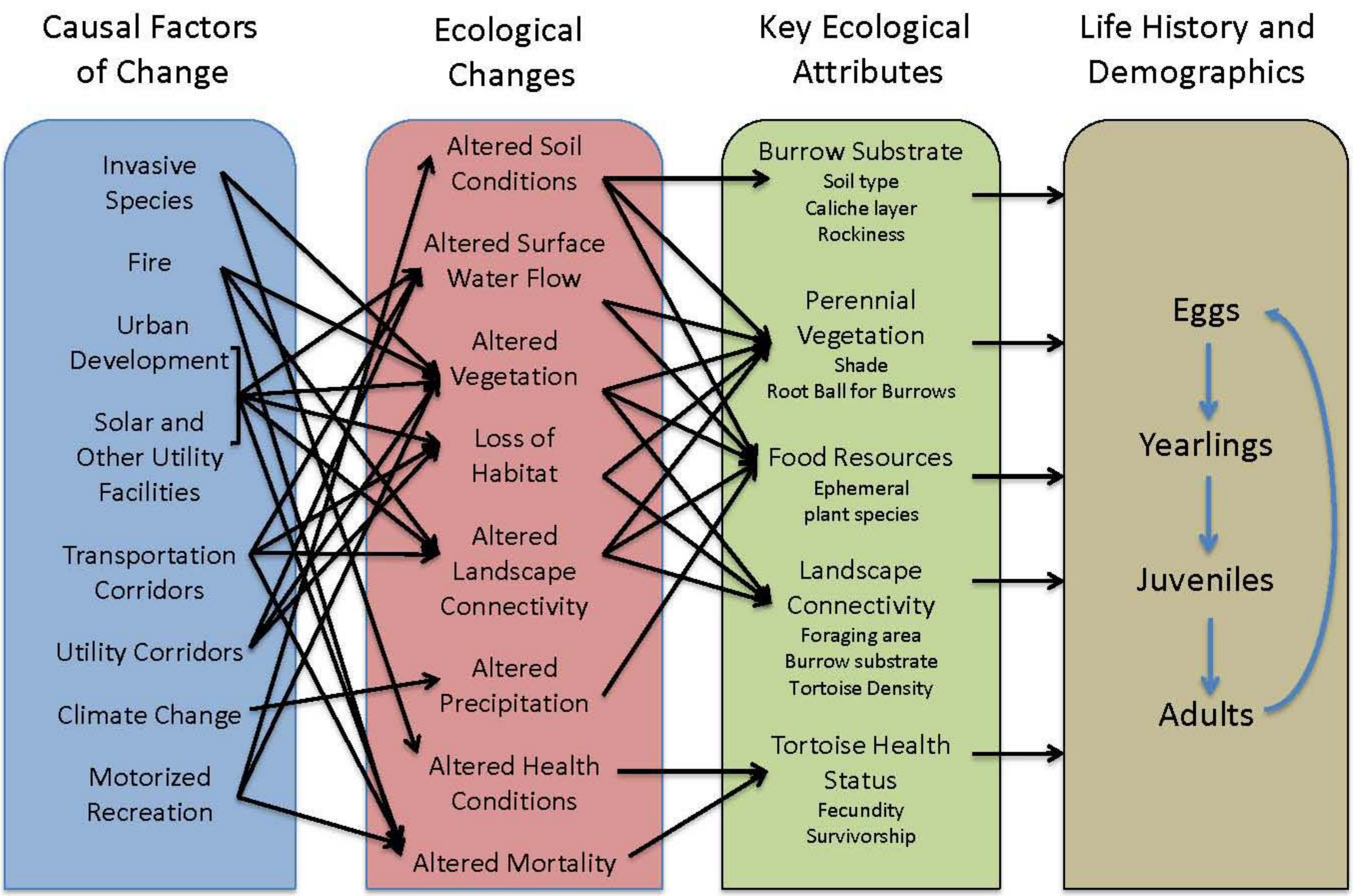

Figure 1. Conceptual Ecological Model for Mojave Desert Tortoise within the BCCE

3.2 Key Ecological Attributes

A key ecological attribute (KEA) is a characteristic of the species' biology, ecology, or physical environment that is critical to the species persistence. KEAs can be physical factors such as the hydrologic regime or fire, or biological factors such as population size or survivorship for a species or structure and composition of vegetation for an ecological system.

While there are many ecological attributes that influence the condition of a species or ecological system, a *key* ecological attribute must strongly influence the species or ecological system's long-term persistence, define or influence its spatial distribution, and contribute highly to resistance and resilience of the species or ecological system. The four categories that provide guidance to the development of a list of KEAs are population size and spatial extent, health condition, ecological processes, and landscape context.

The conceptual ecological model identifies five KEAs for the desert tortoise. These include four environmental attributes (burrow substrate, perennial vegetation, food resources, and landscape connectivity) and one biological attribute (tortoise health status).

1. Burrow Substrate: Desert tortoises spend much of their lives in burrows during every life history stage. Burrows provide protection against cold and extreme heat and protection from predators. The essential role that burrows play in the survival of the species means that soil structure is an important ecological variable. Soils must be soft enough for digging yet firm enough to maintain burrow structure. Burrows are found in sandy-loam soils but not extremely sandy soils. They are also found where there is a caliche layer, where the underlying softer soils are exposed by erosion, in rocky soils where rocks provide a ceiling structure over a softer soil, and near washes, where banks provide burrow locations and additional moisture increases food resources Nussear et al. (2009) found, on a range-wide scale, that the distribution of the species was best explained by several factors, including the soil variables of bulk density, depth to bedrock, and average percentage of rocks greater than 254 millimeters on the B-Axis (intermediate) diameter.

2. Perennial Vegetation: While the species occurs in several different ecological systems, these systems are all open shrub or woodlands. The shrubs provide shade and some plant species have elevated root balls that facilitate their use for burrows. One study found that distribution of the species at large scales was best explained by several factors including perennial plant cover (Nussear et al., 2009).

3. Food Resources (ephemeral plant species): These open desert shrub and woodlands systems are also distinctive in their richness of annual plant species, both in species diversity and in biomass during wet years. These winter annual species provide an important food source for the desert tortoise. The tortoise will forage on a wide range of species, primarily the annual plant species but also perennial grasses, woody perennials, and cacti (especially cactus flowers). Specific annual plant species have been shown to be preferred by tortoises and perhaps provide greater nutrient benefit or moisture (Esque, 1994)

4. Landscape Context: The home ranges of desert tortoises vary in space and time and with the gender of the animal, most likely in response to food resources and reproductive and social interactions. Males have larger ranges, up to 80 hectares (ha) (200 acres) or more, while females may range over an area less than half of the male home range. There is substantial uncertainty about the specific habitat or environmental

factors to determine the size and dimensions of home range and what generates tortoises to move great distances (up to 11 kilometers (km) (7 miles)). It is also unknown what size or connectivity is needed to maintain a population over time. Some research (Longshore et al., 2003) suggests the spatial variability of survival caused by precipitation and the production of food resources set the stage for source-sink dynamics within a meta-population of the species; thus, connectivity within populations or sub-populations is essential for the long-term survival of a sub-population.

5. Tortoise Health Status: The health of a tortoise determines fecundity and survivorship. The desert tortoise has a long lifespan of 50 to 80 years, and requires 15 to 20 years to reach sexual maturity and have a low reproduction rate during its years of reproductive potential. Since the clutch production rate is low, the most important life history factor is the survival of large adult females (Doak et al., 1994).

3.3 Ecological Changes

Ecological changes are altered life history or ecological attributes of the species, which can be either stresses or enhancements to the species. The effects of ecological changes are evaluated in the context of one or more habitat or life history indicators (Noon, 2003). Not all ecological changes are known nor are their relative magnitudes of effects or interrelationships understood a priori (Slauson & Zielinski, 2008). Other terms used in conservation planning for the same concept include stresses.

There are eight key ecological changes illustrated in the conceptual ecological model:

1. Altered Soil Conditions: changes to soil conditions that increase or reduce the ability of soil to provide structure for burrows (increase – roadside disturbance; reduce – soil compaction) or growing conditions for perennial vegetation and ephemeral plant species (nitrogen, density, topography).

2. Altered Surface Water Flow: changes to the land surface that alter surface water flow (increase – impervious surface; reduce – interception of surface water flow).

3. Altered Vegetation: changes to the vegetation that enhance or reduce available shade, root balls of shrubs for burrows, and food resources.

4. Loss of Habitat: changes to habitat that result in it being unsuitable for tortoise occupancy, including the removal of all vegetation and alteration of soil substrate, usually replaced by roads, buildings, and landscaped vegetation.

5. Altered Landscape Connectivity: changes to the landscape context that increase or reduce the ability of tortoises to move among areas with available food resources, burrow substrate, and other tortoises.

6. Altered Precipitation: changes to precipitation amounts and patterns that increase or reduce perennial vegetation, food resources, and connectivity between suitable habitats.

7. Altered Health Conditions: changes in the health of tortoises that affect fecundity and survivorship.

8. Altered Mortality: changes in the demographic condition of tortoises that influence mortality.

3.4 Causal Factors of Change

These causal factors are the factors that cause ecological change, both stresses that alter life history and habitat attributes, and change that can improve the condition of the species. When these causal factors of change focus on negative change, they are also referred to as threats, sources of stress, or stressors. The information for this section came primarily from the Revised Recovery Plan, Appendix A, Threats to the Mojave Population of the Desert Tortoise and its Habitat since the Time of Listing (USFWS, 2011).

The eight causal factors of change considered for the conceptual ecological model are listed below. Each factor is described, the ecological changes shown by arrows in the model (Figure 1) are listed, and the relationship to other casual factors of change is briefly presented.

1. Invasive Species: Invasive species are defined as non-native and native species that have harmful effects on native biodiversity directly or through altering ecological processes. Mojave Desert ecosystems are highly threatened by the presence of many non-native invasive species, including red brome *(Bromus rubens),* split grass *(Schismus barbatus),* and Sahara mustard *(Brassica tournefortii).* These species compete with native plants, primarily annuals and short-lived perennials, reducing their abundance and/or biomass and can possibly extirpate populations. Invasive species also alter ecological processes such as causing fire and reducing soil moisture and altering soil nutrients. Increased levels of nitrogen deposition can increase the abundance and vigor of invasive species. The BCCE currently has few or low levels of infestation of these species (O'Farrell, 2009).

   Ecological Changes: altered vegetation, altered health conditions

   Relationship to Other Causal Factors of Change: invasive species facilitate the ignition and spread of fire.

2. Fire: Fire is defined as the increase in fire frequency and intensity outside of its historically occurring range of variation. Mojave Desert ecosystems have no natural fire regime and the vegetation is not fire-adapted and fire results in a major shift in species composition. Shrub species such as blackbrush (*Colegyne ramosissima*) are completely eliminated by fire and some species rarely establish under natural conditions. With the lack of seed source and past and future climatic change, seedling establishment may not be possible. Herbaceous species are also impacted by having seeds killed in the soil, less appropriate soil conditions for germination and growth, and competition from species (many non-native) that respond favorably to fire. Fire effects on vegetation and soils can reduce landscape connectivity for tortoises. Fire can also kill or seriously injure tortoises. The extent of these impacts is influenced by the timing of fire and the activity of tortoises, the depth of burrows, fire intensity, how quickly fire moves across an area, and the patchiness of fire (Esque et al., 2003). There have been no major fires in or around the BCCE and the fuel loading is currently low (O'Farrell, 2009).

   Ecological Changes: altered vegetation, altered landscape connectivity, altered mortality

   Relationship to Other Causal Factors of Change: invasive species provide fine fuels for fire; climate change can increase lightning caused fires; non-motorized recreation, solar and other utility facilities, urban development, transportation corridors, utility corridors, and motorized recreation facilitate the human ignition sources.

3. Urban Development: Urban development is defined as human development of lands for urban, residential, recreational (golf courses), and industrial purposes resulting in permanent loss of habitat. While urban development is spatially restricted in the Mojave Desert, the areas that are urbanized are growing at rapid rates. For example, the population of Las Vegas nearly doubled between 1995 and 2005. Nye County, NV grew by 97 percent and Mojave County, AZ grew by 66 percent between 2000 and 2006. St. George, UT, at the northeastern most extent of the Mojave Desert, was one of the fastest growing metropolitan areas in the U.S. between 2000 and 2006, with a growth of 39.8 percent. Additionally, urban development is a source for many other causal factors of change. While urban development occurs to the north of the BCCE, it does not directly impact the lands within the BCCE, yet it is a primary source for other causal factors of change.

   Ecological Changes: altered surface water flow, altered vegetation, loss of habitat, altered landscape connectivity, altered mortality

   Relation to Other Causal Factors of Change: collection, motorized recreation, solar and other utility facilities, disease, non-motorized recreation, invasive species, fire, predation, utility corridors, transportation corridors

4. Solar and Other Utility Development Facilities: Solar and other utility development facilities are defined as the facilities and the supporting infrastructure (roads, waste disposal) that produce and transmit any energy source or pump or transmit water, maintenance roads for transmission lines, and access roads to the facilities. In the Mojave Desert, the primary expanding energy source is solar. The U.S. is poised to greatly expand current renewable energy facilities to counter increased costs and demand for traditional energy sources and concern for global climate change (Lovich & Ennen, 2011). Changes in federal and state policy and funding have supported this change. The Mojave Desert has some of the highest potential for solar development (Lovich & Ennen, 2011). A recent environmental impact statement identified alternatives ranging from 115,335 to 39,972,558 ha for development (Lovich & Ennen, 2011). With the increase in renewable energy development and the need to provide better connectivity within the U.S. electrical grid, several major transmission projects are planning to connect with the existing substations inside the BCCE (Sue Wainscott, personal communication). Included in these projects are some that would require upgrades and expansion of the substation yards and development of switching stations for direct current transmission lines. The impacts of these facilities are included in this causal factor of change.

   Ecological Changes: Construction phase: altered vegetation, loss of habitat, altered mortality; Operation phase: altered surface water flow, altered landscape connectivity, altered mortality. Potential secondary stresses include altered dust and toxins levels, altered noise regime, altered electromagnetic regime, alter microclimate, altered light regime (Lovich & Ennen, 2011).

   Relation to Other Causal Factors of Change: transportation corridors, utility corridors, fire, invasive species

5. Transportation Corridors: Transportation corridors are defined as linear corridors consisting of paved roads and railroads. Transportation corridors affect desert tortoises and desert tortoise habitat by: (1) increasing mortality through collisions; (2) fragmenting habitat and reducing connectivity across habitat; and

(3) indirectly by facilitating access by humans. The effect of transportation corridors varies by road type (high speed divided highways roads to paved secondary roads) and by the presence of tortoise exclusion fencing. Whether transportation corridors have an effect on the density of tortoise populations is unknown, but studies have shown that they do have an effect on abundance of tortoises adjacent to a quarter mile from high traffic roads (von Seckendorff Hoff & and Marlow, 2002; Boarman & Sazaki, 2006). In contrast to these studies, the increased sheet-flow from roads often results in more robust and diverse ground cover that may be an attractant to tortoises. The paved roads that cross the BCCE have tortoise exclusion fences.

Ecological Change: altered surface water flow, loss of habitat, altered landscape connectivity, and altered mortality.

Relation to Other Causal Factors of Change: transportation corridors can assist in the dispersal of invasive species, provide ignition sources for fire, increase predation (through structures such as signs, fences, telephone and electric lines), increase disease (through the release of diseased pets or abandoned tortoises) and provide access for non-motorized recreation, motorized recreation, collection.

6. Utility Corridors: Utility corridors are defined as linear corridors disturbed and maintained for energy transmission lines, natural gas pipelines, water lines, and communication lines. Utility corridors are common features in the Mojave Desert and are present in most critical habitat units. While the permanent disturbance to soil and vegetation is often limited to the footprint of structures, some of these linear features in the BCCE include established maintenance roads that develop berms that can alter surface water flows. Also, the linear corridor disturbed for underground utilities and access roads can provide access for people and the towers provide perches for opportunistic predatory bird species. However, some of these disturbances may provide suitable burrow locations for desert tortoises.

   Ecological Change: altered surface water flow, altered vegetation, loss of habitat

   Relation to Other Causal Factors of Change: utility corridors can assist in the dispersal of invasive species, provide ignition sources for fire, and provide access for non-motorized recreation, motorized recreation, collection, and increase predation. The presence of utility corridors is related to the distribution of Solar and Other Energy Development Facilities.

7. Climate Change: Climate change is defined as changes in ambient temperatures and altered amounts and patterns of precipitation that directly influences species and altered key ecological processes. Regional changes in temperature and precipitation may result in more frequent and/or prolonged droughts. Annual summer temperatures may increase by 6.3 to 7.2 degrees Fahrenheit. Annual precipitation may decrease 5 to 15 percent, with winter precipitation decreasing from 5 to 20 percent. The ecological impacts from climate change are in many instances intensified by the human responses to climate change, such as great need and use of water and higher levels of energy use. There are no withdrawals of water in the basin occupied by the BCCE for municipal uses.

   Ecological Changes: altered precipitation.

   Relationship to Other Causal Factors of Change: invasive species provide fine fuels for fire and climate change can increase lightning caused fires.

8. Motorized Recreation: Motorized recreation is defined as the activities of a range of vehicle types, active individually or in large groups, which travel off of paved and improved roads. Motorized off-road vehicles commonly use desert environments, especially playas and washes. While a quantitative relationship between motorized off-road vehicles and reduced tortoise densities is lacking, qualitatively the likelihood of direct mortality, collapsed burrows, and reduced food resources (from both direct elimination to indirect changes in soil condition – compaction, soil moisture and reduction in soil crusts) suggest that this factor has an impact on population size. A comparison between areas used for motorized off-road vehicles and those that are unused provide support for this impact (Bury & Luckenbach, 2002).

   Ecological Changes: altered soil conditions, altered vegetation, altered mortality,

   Relation to Other Causal Factors of Change: motorized off-road vehicles can facilitate the dispersal of invasive species and ignite fires.

The following causal factors of change have a minor or potentially minor role in changes affecting desert tortoise in the BCCE, and therefore, are not included in the conceptual ecological model.

1. Grazing: Grazing is defined as the use of natural desert habitat to support grazing animals. The impacts of grazing on arid lands are well documented, with grazing causing substantial changes in vegetation and soils including the reduction of native species and an increase in invasive species. Grazers can cause direct mortality (above ground and while tortoises are in burrows) and competition and reduction in food resources can alter the health conditions of tortoises. Grazing is not occurring on the BCCE at this time and is not an allowed use in the easement agreement. While feral cattle remain in the uplands adjacent to the BCCE in the McCullough Range, there are no water sources or other attractants likely to bring the cattle into the BCCE (Sue Wainscott, personal communication).

   Ecological Changes: altered soil conditions, altered vegetation, altered health conditions, altered mortality.

   Relation to Other Causal Factors of Change: grazing can facilitate the dispersal of invasive species, and when invasive species are present, grazing may be able to control biomass.

2. Non-motorized Recreation: Non-motorized recreation is defined by the activities such as hiking, biking, horseback riding, hunting, camping, and target practice. These activities can directly damage soil, altering soil structure and disrupting the soil crust, and damage and reduce vegetation. These activities are minimal within the total range of the desert tortoise, but in some places can be quite intense. In the BCCE, the occurrence rates of these activities are minor (Sue Wainscott, personal communication). No data exist correlating these activities to impacts to desert tortoise. More important may be the indirect impacts of non-motorized recreation such as ignition of fire, introduction of invasive species, increased predators, and the handling or poaching of tortoises.

   Ecological Changes: altered soil conditions, altered vegetation.

Relationship to Other Causal Factors of Change: increase in invasive species, fire, predation and collection, and urban development through the development of recreational facilities and transportation corridors serving trail heads and recreational facilities.

3. Disease: Disease is defined as natural phenomena that increase mortality within populations and occasionally have epidemic outbreaks that could have catastrophic effects on small or declining populations. Several diseases have been identified in desert tortoise populations, including upper respiratory tract disease (probably the most important infectious disease), shell disease, and herpesvirus. The Revised Recovery Plan calls for additional research to clarify the role and importance of disease in the demographics of desert tortoise populations.

   Ecological Changes: altered health conditions, altered mortality.

   Relation to Other Causal Factors of Change: none.

4. Predation: Predation is defined as the mortality of tortoises by species other than humans. Natural predation rates are not considered a threat, but current predation has been enhanced by increased populations of predators through changes in trophic structure, increase in food and water sources and nesting substrates (billboards, utility towers, buildings), and the introduction of non-native predators. Desert tortoise is preyed upon by several native species such as the common raven (*Corvus corax*) (the best documented predator) and coyotes (*Canis latrans*), and introduced species such as dogs. Juvenile tortoises are the most likely size class of tortoises that are predated. The contribution of predation to the survivorship/demographic impacts of desert tortoises has not been quantified and is complicated by spatial and temporal variability and difficulty of monitoring juvenile tortoises. This is currently assumed to be a minimal impact in the BCCE (Sue Wainscott, personal communication).

   Ecological Changes: altered mortality.

   Relation to Other Causal Factors of Change: none.

5. Collection/Take: Collection is defined as the removal of individual tortoises for commercial pet trade, food, and research, while take is defined as the deliberate maiming or killing of tortoises by humans. Both collection and take were more common in the past and little evidence exists to support it as a significant causal factor of change.

   Ecological Changes: altered mortality.

   Relation to Other Causal Factors of Change: none.

Other causal factors of change found within the range of the Mojave desert tortoise were not considered in this conceptual ecological model because they were not present in the BCCE. These factors include mineral development, agriculture, and military activities.

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