USE OF ARTIFICIAL WATER SOURCES BY MULE DEER IN MOJAVE NATIONAL PRESERVE.

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BACKGROUND

Anthropogenic water sources have been used extensively to support wildlife populations for nearly a century. Many of the first water catchments were developed to improve distribution and resource use of small game species such as the California Quail (*Lophotoryx californinus*), mourning dove (*Zenaidura macroura*), and the non-native chukar partridge (*Alectoris chukar*) in water-limited areas (Brigham and Stevenson 1997). The first water developments designed for use by large mammals were created by the United States Fish and Wildlife Service and Arizona Game and Fish Department in 1941 (Brickler et al. 1986). These developments were created, in part, to help improve declining desert bighorn sheep (*Ovis canadensis latrans)* populations in southwestern Arizona, USA. Presumably, these developments would have also benefited additional ungulate species such as mule deer (*Odocoileus hemionus*) and pronghorn (*Antilocapra americana*; Rosenstock 1999), as well as other species of wildlife. More recent water developments have been instituted to mitigate the impacts of the loss of natural water sources (Brigham and Stevenson 1997, Longshore et al. 2009).

Mule deer are widely distributed throughout western North America and occupy a variety of habitat types, including the Canadian boreal forest, the Great Basin, the Colorado Plateau shrubland and forest, and the Mojave/Sonoran desert (Wallmo 1981). Habitats in the most extreme North American desert ecosystems are often thought of as desolate, hot, barren and inhospitable, which is a common misconception. In reality, desert vegetation, such as Y*ucca* and *Opuntia* (Cacti) spp., as well as summer and winter annuals, can be just as productive for mule deer as the aforementioned habitat types. However, the productivity of these vegetation types, especially annual plants, is intimately linked to seasonal precipitation (Urness 1981). Although succulent forage can provide adequate water to meet such metabolic processes as hydration and thermoregulation in regions with temperate, moist climates, distribution and abundance of mule deer in the arid southwestern United States are more closely correlated to the availability of free-drinking water (Wallmo 1981, Rosenstock et al. 1999). Additionally, during times of water scarcity, such as the hot-dry season, mule deer have been shown to remain closer to available water rather than ranging widely to browse (Rautenstrauch and Krausman 1989, Marshal et al. 2006). Therefore, in desert ecosystems where forage quality is adequate to meet nutritional requirements but water is scarce, it has long been assumed that humans may be able to provide permanent water sources in the form of guzzlers or catchments to improve distribution and abundance of mule deer.

Despite the widespread use of artificial water sources in wildlife and range management for over half a century, few empirical studies have investigated the effects of these water sources on wildlife ecology (Krausman et al. 2006). Broyles (1995) in an opinion paper, specifically questioned the benefit of water developments by suggesting that "…surface water is neither necessary nor a sufficient condition for the subsistence and perpetuation of most desert wildlife"; although those claims were made with virtually no data. Conversely, others, such as Rosenstock et al. (1999), contend that water developments do provide intrinsic benefits to wildlife populations in the arid west. Although the provision of water for wildlife has developed into a contentious subject, more empirical studies are needed to settle this on-going debate (Broyles 1995, Broyles and Cutler 1999, Rosenstock et al. 1999, Krausman et al. 2006).

Researchers at the University of Nevada in Reno, in collaboration with the National Park Service, California Fish and Game, and extensively supported by Safari Club International, are attempting to shed light on this topic by examining the response of mule deer to manipulation of water sources in the Mojave National Preserve (MNP), California, USA. Additionally, interactions between mule deer and vegetation, as influenced by availability of surface water, are also being addressed. Several hypotheses have been developed and are currently being tested related to demography (e.g. adult and juvenile survival, pregnancy rates, and body condition) and movement responses of mule deer, effects of deer use on habitats surrounding those water sources, and availability and quality of forage for mule deer at available water sites compared to sites where water has been removed or is no longer available.

The following progress report presents updates on current datasets, as well as a recent analysis of mule deer survival. Although our analysis was largely exploratory in nature, we did predict that survival of mule deer would be higher in areas where water sources are permanently available. We predicted that nutritional condition of individuals also would influence survival. Finally, we predicted that survival may also be affected by environmental conditions.

STUDY AREA

Mojave National Preserve (MNP) is a 650,000 ha federally protected Preserve managed by the National Park Service and located in southern California (Fig. 1). MNP encompasses three of the four major desert ecosystems in North America: the Mojave, the Sonoran, and the Great Basin. Prior to federal protection status in 1994, lands

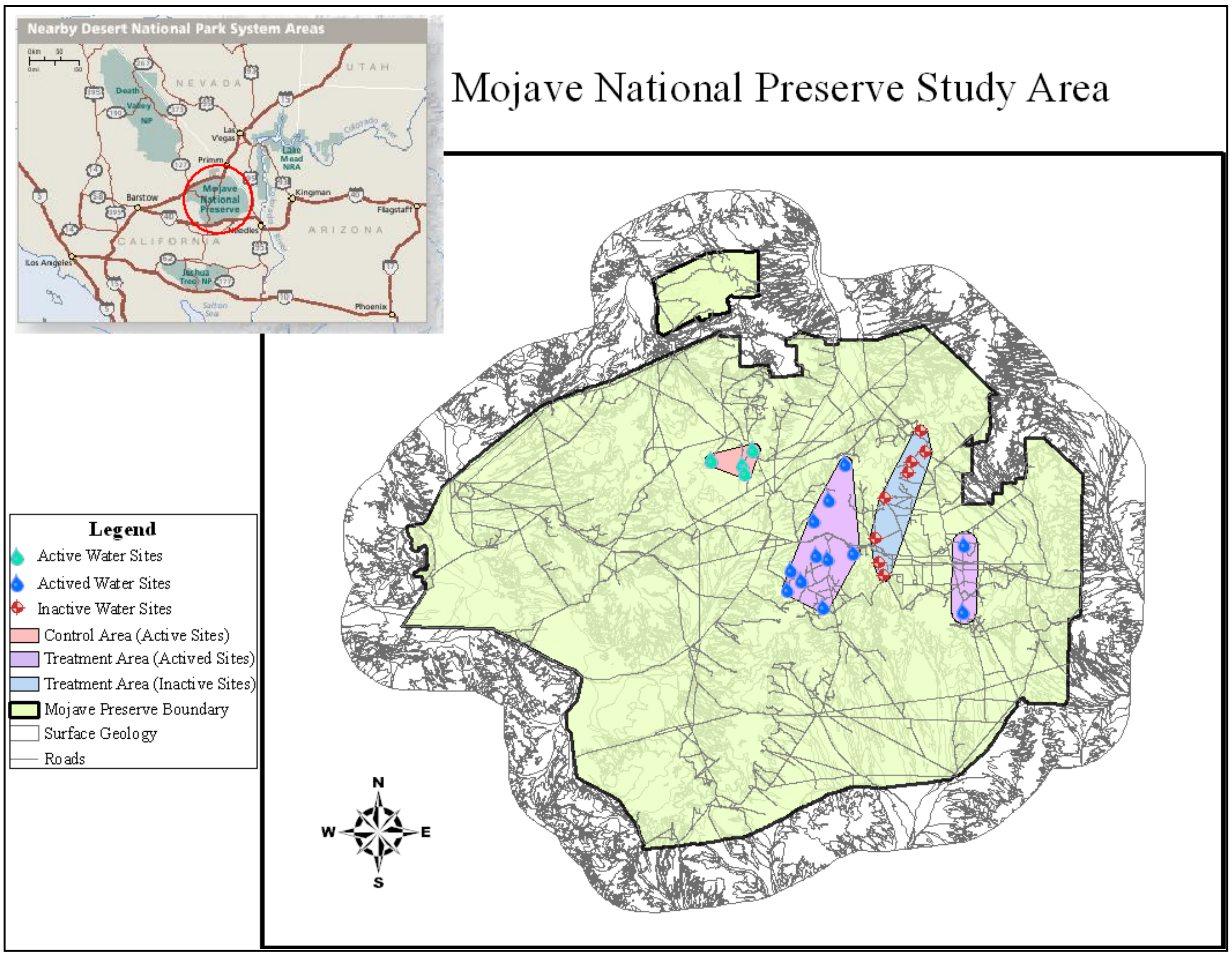

Figure 1. Regional map and boundaries of Mojave National Preserve, located in southern California.

within the MNP were primarily used as rangeland for livestock. During this period of livestock grazing in MNP, several wells were activated prior to the turn of the 20th century to provide water for cattle. Not only did these wells support large herds of permanent source of water for many wildlife species. Systematic reactivation of these water sources provides the foundation of this research.

METHODS

Experimental Design

To evaluate the response of mule deer to reinstitution of water sources (livestock water catchments), the central portion of MNP, where mule deer distribution and presence of wells (both currently activated and deactivated) are highest, was divided into three study areas (Fig. 2). Our study control, hereafter Cima Dome, did not experience well deactivation. Consequently, permanent water developments have been available to wildlife for nearly a century. In study treatment I, hereafter Midhills, livestock wells were reactivated in the fall of 2008 and serves as our water-provided treatment area. In study treatment II, hereafter the New York Mts., wells remain inactive and mule deer access to springs has been limited. The New York Mts. area functions as our water-limited treatment area.

Capture Methods

The State of California temporarily ceased all helicopter operations in January 2010, preventing any capture of mule deer via helicopter until mid-spring. Previous MNP captures occurred in January 2008 and 2009, respectively. Crews from University

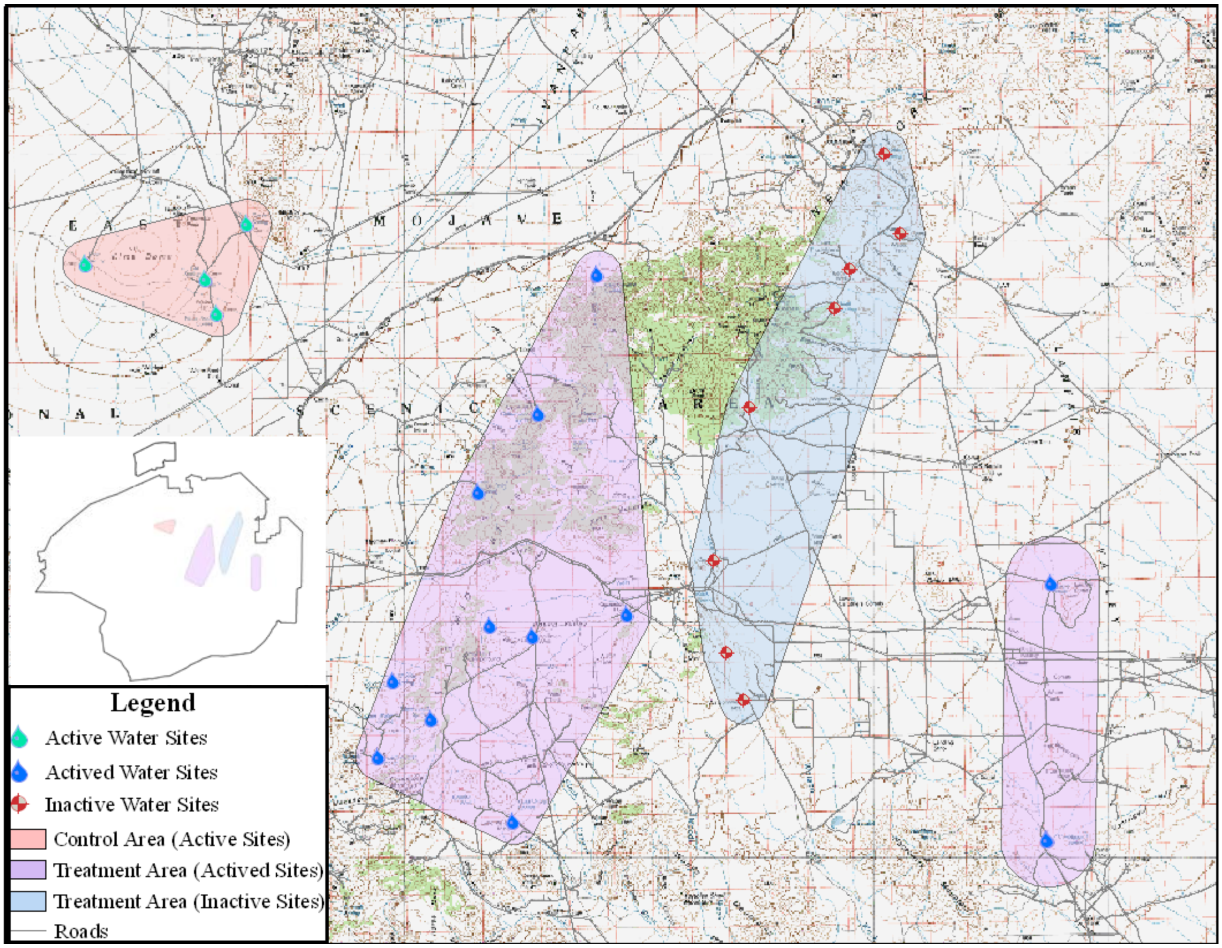

Figure 2. Locations of the 3 Mojave National Preserve study areas: Study Control (unmanipulated water sites), Study Treatment I (activated water sites), and Study Treatment II (inactive water sites).

of Nevada-Reno, California Department of Fish and Game, and the National Park Service attempted to capture mule deer using modified clover traps in addition to chemical immobilization during the helicopter grounding period (February to April 2010). Ground capture efforts were unsuccessful despite hundreds of contributed man-hours.

Special permission was granted by the California Department of Fish and Game to proceed with an aerial capture of mule deer in April 2010, using a private contractor. A total of 15 adult female mule deer were captured and fitted with Sirtrack Global

Positioning Systems (GPS) radiocollars in MNP (Fig. 3). Each individual was uniquely marked with eartags to allow for field identification. Biological samples were collected from most individuals and included fecal pellets for dietary analysis, blood for genetic testing and mineral status, as well as hair for isotope analysis. We did not collect specific morphological data (e.g. chest girth, and metatarsus length) or utilize ultrasonography to estimate nutritional condition and fetal rates, to minimize handling time of females in the third trimester of gestation. Those data, which had been collected during previous captures, are used to assess nutritional condition and pregnancy status of individuals. Collection of these data will be a priority during future capture operations in MNP.

Figure 3. Photo of released female mule deer fitted with a Sitrack GPS radiocollar in the New York Mts. area of Mojave National Preserve. (Photo: K. Stewart)

Survival

Radiocollars have been monitored bi-weekly by fixed wing aircraft, as well as opportunistically by ground crews in MNP since January 2008. Signal status is recorded as either live, mortality, or missing. If a radio-collar is emitting a mortality signal, then a ground crew is dispatched to collect the radio-collar and investigate the signal. A thorough field necropsy is performed on the individual's carcass if a mortality is discovered. Cause of mortality is classified as one of the following categories: natural causes (e.g. old age, malnutrition, or disease), predation, legal hunter harvest, human caused (e.g. automobile accident or wounding loss), or unknown (e.g. investigator unable to locate enough remains needed for adequate necropsy to determine cause of death). We then used the known-fates model in Program MARK 6.0 to estimate annual survival rates and standard errors of mule deer in each study area for 2008 through 2010 (White and Burnham 1999).

In addition to calculating survival rates, Program MARK allowed us to test various models of survival in a multiple-hypothesis framework using Akaike's Information Criterion adjusted for small sample sizes (AICc, White and Burnham 1999). AICc provides an estimate of how well a model fits the relative truth based on maximum likelihood (Anderson et al. 2000). AICc values are ranked to determine model support, where smaller values indicate a better model fit.

We determined the best general models of survival of mule deer in MNP using AICc. We then incorporated individual covariates to determine if individual quality may influence survival rates. In this analysis, we assessed the influence of body mass (kg), rumpfat thickness (cm), and *l. dorsi* thickness (cm), which were collected during capture. Additionally, we incorporated residuals from a linear regression of body mass to body length into our models of survival as a crude estimate of individual body condition. Finally, we modeled the influence of temperature and precipitation patterns from 2008 through 2010, which was obtained from an NOAA weather station located at Mitchell Caverns in MNP. All covariate values were standardized prior to the analysis.

Stealth Cam trail cameras have been placed at water sites to document site use by mule deer and other wildlife (Fig. 4). Along with documentation of site use, this information will be used in a robust capture-mark-recapture framework for estimating mule deer survival and productivity in the three study areas without radiocollars. These estimates depend on the observer's ability to identify unique individuals and require multiple years of capture- mark-recapture data. All captured mule deer have been

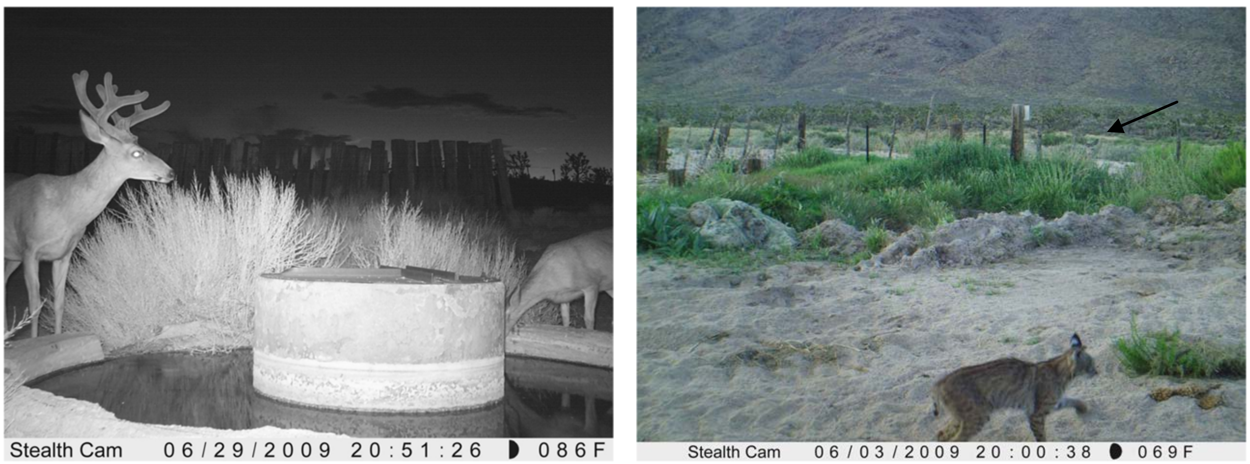

Figure 4. Stealth Cam trail camera photo of mule deer visiting Cut Tank (*left*) and a bobcat (*Lynx rufus*) visiting Kessler Springs (*right*), both water sites are located in the Cima Dome area of Mojave National Preserve. Note deer in the background of the photo at Kessler springs (arrow).

fitted with unique eartags, which remain on the individual after radiocollars are released. Those permanent marks allow for identification of individuals at water sites without the aid of radiocollars. Given sufficient duration of the project, this method can supplant radiocollar monitoring if survival and movement probabilities are the only demographic factor of interest.

Seasonal Movements

In November 2009 and again in February 2010, Sirtrack GPS radiocollars were released from mule deer in MNP. Radiocollars were subsequently collected by ground crews and location data was uploaded into ArcGIS 9.2 (Environmental System Research Institute [ESRI] 2006). We used Hawth's Analysis Tool (ESRI 2006) extension in ArcGIS to determine mean daily movements and minimum convex polygons from 1 June-30 September of all GPS monitored mule deer captured in 2009. Approximately 50% of our April 2010 radiocollars were collected after a scheduled release in November 2010. The remaining April 2010 radiocollars are scheduled for release in March 2010. We have not yet identified trends in movement data from individuals captured in April 2010.

Vegetation Composition and Quality

In the summer of 2009 and 2010, and continuing throughout the duration of the study, field crews from the University of Nevada-Reno began characterizing vegetation composition and quality at water and nonwater sites in the three study areas of MNP (Fig. 5). Field methods included cover class estimates, shrub cover, and point

Figure 5. University of Nevada-Reno technicians David Gonzalez and Nova Simpson measure shrub cover in the Midhills study area of Mojave National Preserve. (Photo: C. McKee)

estimates of herbaceous vegetation. Additionally, shrub, grass, and forb samples were collected at each site to determine forage quality and water content. Data collected from these methods will be used to determine structural and temporal differences in vegetation composition between the three study areas.

PRELIMINARY RESULTS

Pregnancy Status

During January 2009, we collected reproductive data on adult female mule deer captured for application of current year radiocollars or to remove collars from pretreatment data collection during 2008. Percentage of females pregnant was similar in all study areas, although Midhills, where water was provided during late 2008, had a higher proportion of females carrying twins (Table 1). Pregnancy data was not collected in 2010.

Table 1. Pregnancy and fetal rates of adult mule deer captured in the Mojave National Preserve, 2008-2009. Cima Dome (control), Midhills (water provided), New York Mts (no permanent water) study areas.

Study Area	Total Captured	Total Pregnant	Pregnancy (%)	Total Twinning	Twinning (%)
Cima Dome	9	8	88	3	38
Midhills	11	11	100	8	73
New York Mts.	7	6	86	3	50

Cause-Specific Mortality

Since January of 2008, we have experienced 11 known mortalities (out of 51 total captured) of radiocollared individuals in MNP. Unknown mortality has been the dominant fate of radiocollared mule deer in MNP, followed by mountain lion (*Puma concolar*) predation, unknown predation, and illegal harvest (Fig. 6). Cima Dome has experienced the fewest number of mortalities (1 out of 14 individuals), the next fewest was the New York Mts. study area (4 out of 14 individuals), Midhills had the highest total number of mortality events (6 out of 23 individuals; Fig. 7).

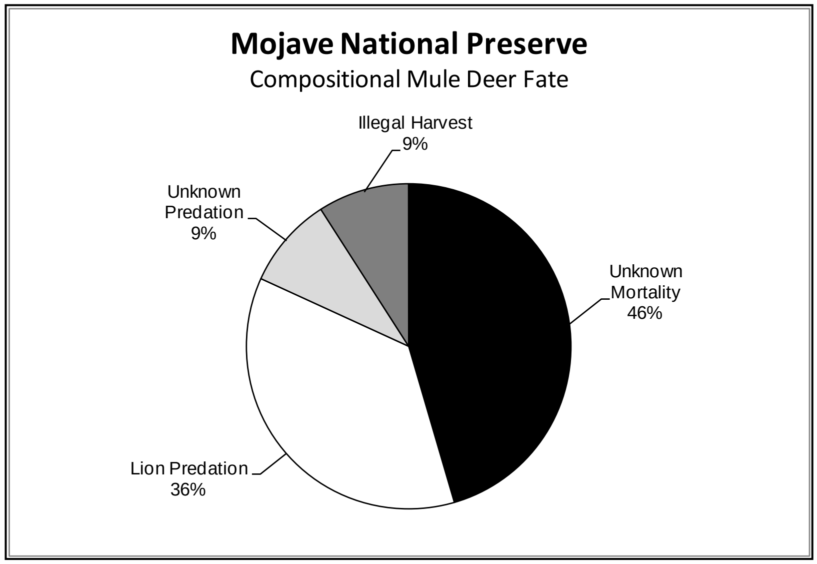

Figure 6. Combined composition of mule deer fates by type in Mojave National Preserve, 2008-2010.

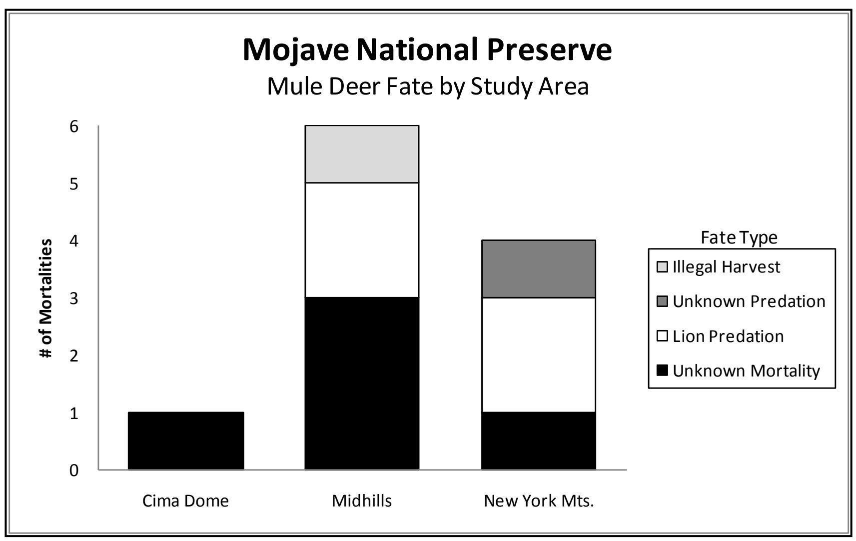

Figure 7. Sources of mortality of mule deer by study area in Mojave National Preserve, 2008-2010.

Movement Patterns

The control area, Cima Dome, has water distributed around it for nearly a century. The large movements by mule deer likely indicate knowledge of location of water that is well distributed in a relatively small study area. Deer in the water provided study area (Midhills) has significantly lower daily distance moved than in the water-limited study area (New York Mountains), likely female mule deer remained in the vicinity of water rather than spending time searching for available water. Deer in the New York Mountains had large daily distances moved, greater than the water provided study area, probably because of increased search time for water.

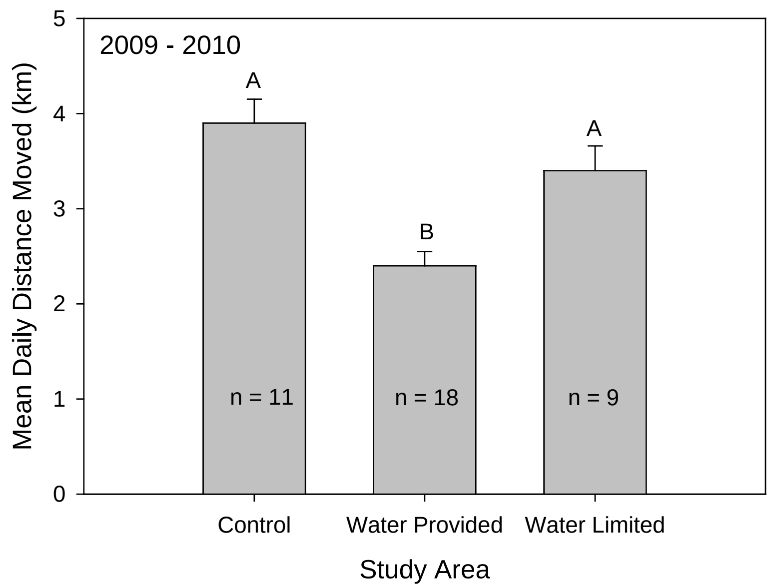

Figure 1. Mean daily distance moved (km) by adult female mule deer equipped with radio collars in East Mojave National Preserve, CA 2009 – 2010. Letters over the bars indicate the results from analysis of variance, different letters indicate significant ($P < 0.05$) differences.

Mule deer in the Control study area, Cima Dome, had the largest home ranges. Mule deer in the water limited study area, New York Mountains, had larger home ranges than in the water provided study area (Midhills). Differences in home range size between water provided and water limited study areas likely results from differences in availability of water, deer in midhills remained close to sources of water and as a result

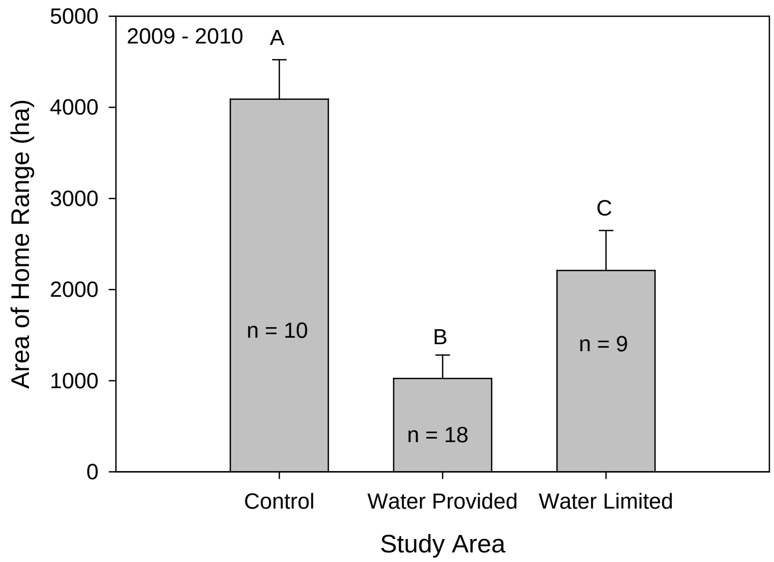

Figure 2. Area of home range (ha) as determined from minimum convex polygons, for mule deer in East Mojave National Preserve, CA 2009-2010. Letters over the bars indicated the results from analysis of variance, where different letters indicate significant (P<0.05) differences.

have smaller home ranges than deer in New York mountains. Those deer in the New York Mountains that likely spent greater amounts of time searching for water sources resulting in greater movements and home range size.

Survival

Model estimates of annual survival for female mule deer in Cima Dome are ~93%, while annual survival in Midhills and the New York Mts. are similar at ~81% (Table 2, Fig. 8). Monthly estimates of survival indicate a general declining trend

Table 2. Model-averaged annual survival estimates of radiocollared mule deer in Mojave National Preserve, 2008-2010.

	2008			2009			2010		
Study Area	Survival (S)	SE	95% CI	Survival (S)	SE	95 % CI	Survival (S)	SE	95 % CI
Cima Dome	0.93	0.02	0.89 to 0.97	0.93	0.02	0.89 to 0.98	0.93	0.02	0.89 to 0.97
Midhills	0.81	0.03	0.75 to 0.87	0.81	0.03	0.76 to 0.87	0.81	0.03	0.75 to 0.87
New York Mts.	0.81	0.03	0.74 to 0.87	0.81	0.03	0.75 to 0.87	0.81	0.03	0.75 to 0.87

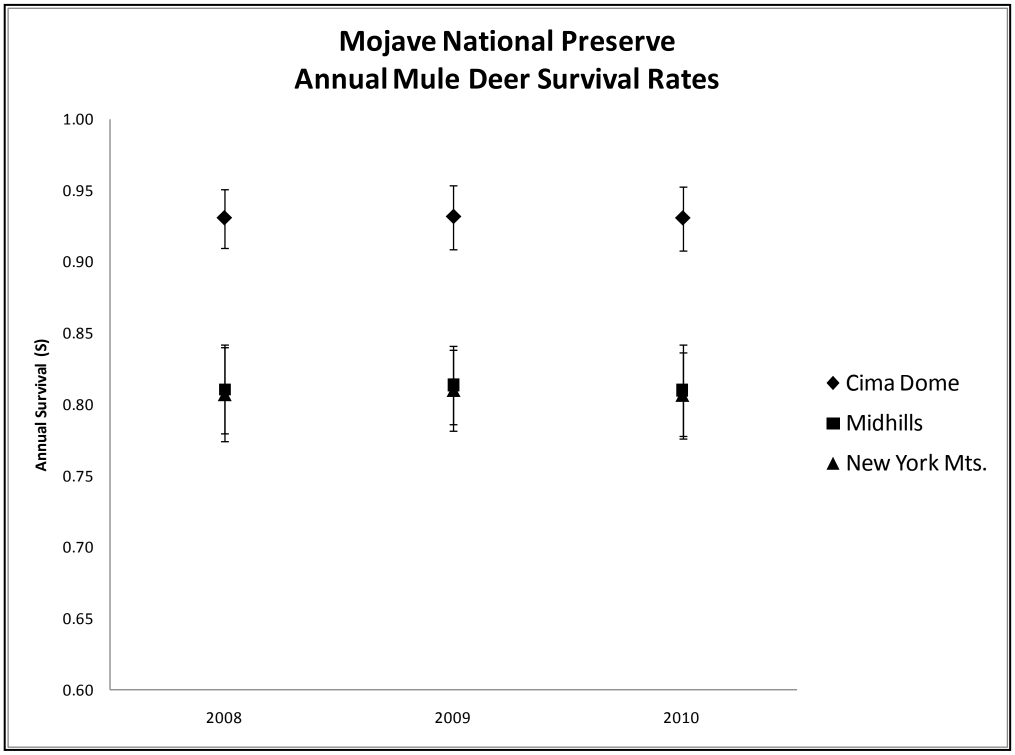

Figure 8. Model-averaged annual survival estimates (± SE) of radiocollared mule deer in Mojave National Preserve, 2008-2010.

during the calendar year from January 2008 through December 2010 in the Midhills and New York Mts. study areas (Fig. 9). Monthly survival rates in Cima Dome remained constant throughout the calendar year from 2008 through 2010 (Fig. 10).

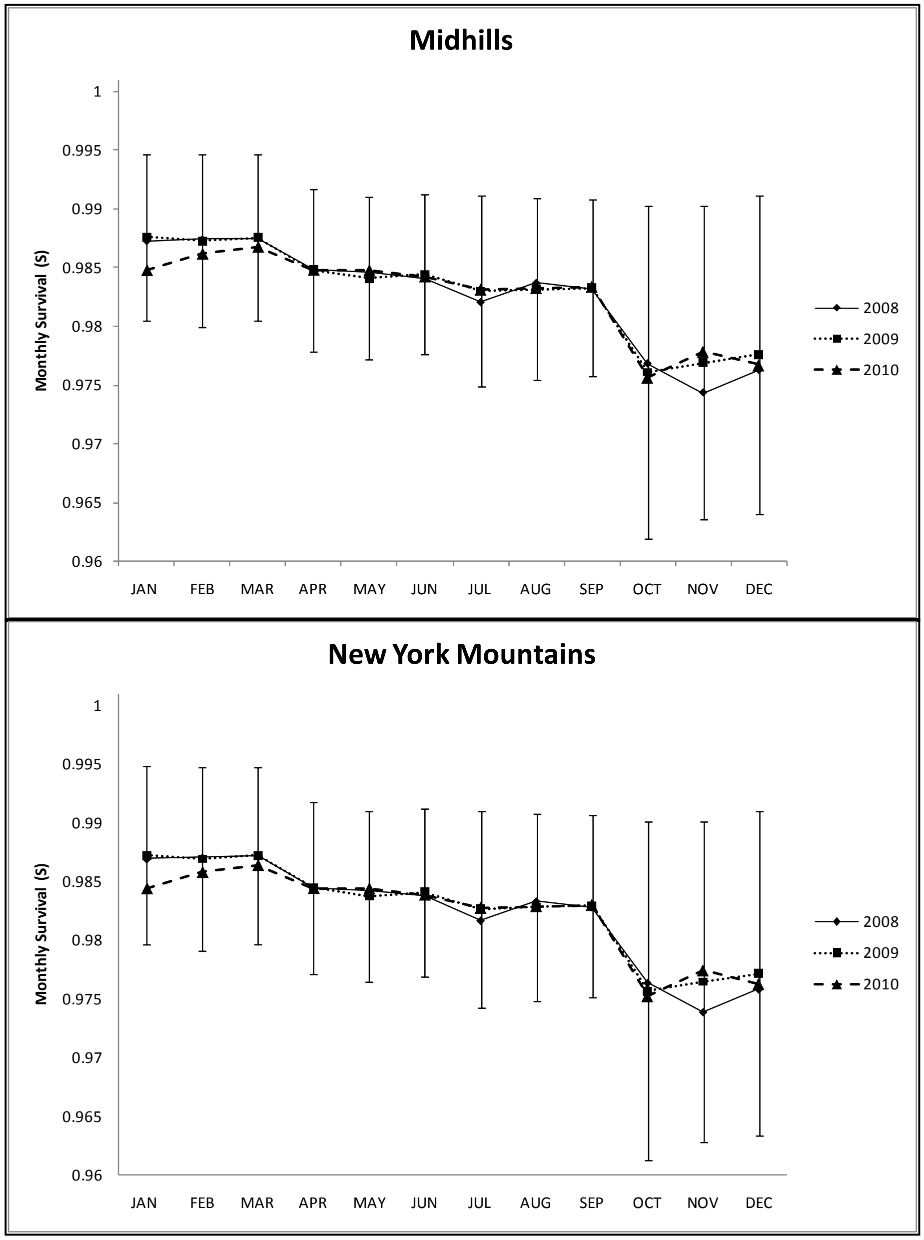

Figure 9. Model-averaged monthly survival rates (+ SE) for mule deer in Midhills (*top*) and the New York Mts. (*bottom*) of Mojave National Preserve, 2008-2010.

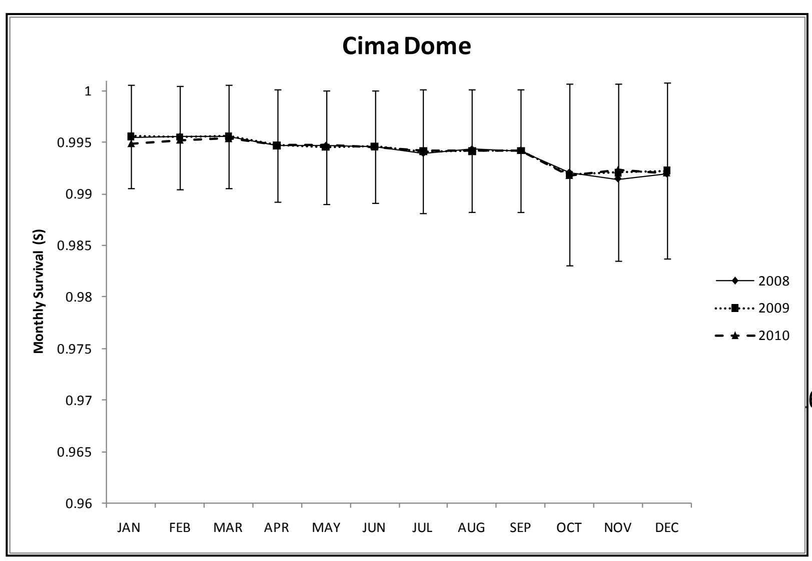

Figure 10. Model-averaged monthly survival rates (+ SE) for mule deer in Cima Dome of Mojave National Preserve

Our best competing general models of survival suggest a positive effect of Cima Dome on mule deer survival (β ± SE; 1.49 ± 1.05), a positive effect of winter (1.19 ± 1.05), and a negative effect of fall (-0.83 ± 0.63; Table 3). A model of individual

Table 3. AICc table of the most competitive general survival models in Mojave National Preserve.

Model	AICc	Δ AIC	AICc Weights	Likelihood	Num. Par	Deviance
S (control vs treat)	116.85	0.00	0.14	1.00	2	112.84
S (control vs treat + winter)	117.11	0.26	0.12	0.88	3	111.08
S (control vs treat + fall)	117.32	0.47	0.11	0.79	3	111.29
S (.)	117.80	0.94	0.09	0.62	1	115.79

covariates containing residual mass, our index of body condition in this analysis, was highly competitive (Table 4). Models containing body mass, rump-fat thickness, and *l. dorsi* thickness were not supported by the data for effects on survival. Finally, models incorporating climatic variables were generally not informative, although a model containing a group effect of precipitation was 1.17 AICc units from the top model, which suggests some support of this variable (Table 5).

Table 4. AICc table of the most competitive survival models containing individual covariates in Mojave National Preserve.

Model	AICc	Δ AIC	AICc Weights	Likelihood	Num. Par	Deviance
S (control vs treat)	116.85	0.00	0.12	1.00	2	112.84
S (control vs treat + fall) ind cov: res mass on fall only	116.93	0.07	0.11	0.96	4	108.88
S (fall) ind cov: res mass on fall only	117.17	0.31	0.10	0.86	3	111.14
S (control vs treat + fall) ind cov: res mass + rumpfat on fall only	117.42	0.57	0.09	0.75	5	107.35
S (control vs treat) ind cov: res mass	117.60	0.75	0.08	0.69	3	111.57
S (control vs treat + winter) ind cov: res mass	117.75	0.90	0.07	0.64	4	109.70
S (.)	117.80	0.94	0.07	0.62	1	115.79

Table 5. AICc table of the most competitive survival models containing climatic variables in Mojave National Preserve.

Model	AICc	Δ AIC	AICc Weights	Likelihood	Num. Par	Deviance
S (control vs treat)	116.85	0.00	0.21	1.00	2	112.84
S (control vs treat + fall) ind cov: res mass on fall only	116.93	0.07	0.20	0.96	4	108.88
S (.)	117.80	0.94	0.13	0.62	1	115.79
S (control vs treat) grp cov: prcp	118.02	1.17	0.12	0.56	3	111.99

It is important to point-out that all measures of precision of effect size and direction overlap zero, indicating a non-significant effect. This lack of significance is likely related to small sample sizes, which will be alleviated as the study duration increases. Despite a lack of significant results, trends do appear to be manifesting themselves in our study.

Overall, our analysis suggests survival of mule deer in all three study areas to be reasonably high. Survival of mule deer in Cima Dome is clearly greater than survival in Midhills and the New York Mts. Long-term availability of water, habitat conditions, or a lack of adequate ambush terrain for local predators may all be reasons for this difference. We expect that with the provision of water, annual survival of mule deer in Midhills and, eventually, the New York Mts. will mirror those currently being exhibited in the Cima Dome study area.

Additionally, we are not surprised that body mass, rumpfat thickness, or *L. dorsi* thickness were not informative in our estimates of survival. These morphological measurements are likely to be better predictors of population productivity. In future analyses, we will investigate the influence of these traits on production of female mule deer in MNP, as well as investigate juvenile survival and recruitment. A firm understanding of juvenile demography, coupled with rates of survival established from this analysis, will help us to better understand the herd status in each study area and in MNP, as a whole.