RESPONSES OF MULE DEER TO EXPERIMENTAL MANIPULATION OF WATER SOURCES IN A MOJAVE DESERT ECOSYSTEM

Proposed Start and Completion Date: 1 July 2013 – 30 June 2019

Executive Summary: The proposal represents the second of two parts of a long-term investigation. Phase 1, a period during which baselines have been established with respect to demography, habitat selection, and effects of mule deer on forage resources has just been completed. This proposal is presented to ensure that phase 2, during which water sources will be manipulated, will be adequately funded. This investigation, planned for a total of 10-12 years, has been underway since 2007, and has been designed to answer very basic questions addressing the demographic, behavioral, and distributional responses of large mammals (in this case, mule deer) to the availability and provision of surface water in a Mojave Desert Environment. In the absence of research of this type, future habitat enhancement activities in areas managed by the National Park Service, or in wilderness areas managed by other federal agencies, are in jeopardy as a result of advocacy by special-interest groups and political processes. During this period of changing climates, accelerated fragmentation of arid systems, and a rapidly increasing human population, definitive answers to management questions are needed if large mammals in arid environments are to continue to thrive. This project is the most comprehensive to date.

Statement of Need: Benefits to large mammals in arid environments are among the least understood aspects of habitat management actions involving the development of water sources. As a result they are, in part, among the most controversial habitat management actions carried out by management agencies. Previous efforts to elucidate the responses of large mammals to the development of wildlife water sources have fallen short of expectations and yielded largely equivocal results. This has occurred largely because (1) delayed responses by wildlife or unanticipated weather events compromised experimental designs; or (2) because the investigations lacked a manipulative component. These problems largely were the result of the short temporal scale at which the investigations occurred. Further, previous investigations have centered primarily on the behavioral responses or effects on distribution of large mammals, and have not incorporated an effort to assess demographic responses.

This project has two phases, the first of which extended over a period of 6 years, and served as a control for the manipulative phase. Phase 2, which will begin in 2013, involves the restoration of water to one of three areas from which it previously had been removed by MNP management. Project collaborators and, the National Park Service in particular, are deeply committed to expanding the understanding of the benefits or detriments of water provisioning in desert environments. In the absence of results emanating from this investigation, critics — both inside agencies and among the general public — of water development on lands managed by the National Park Service or within wilderness areas managed by the Bureau of Land Management or the U.S. Forest Service will continue to demand the removal of unnatural sources, and will continue to question the benefits associated with proposed new developments. This will occur despite other activities on public lands, including development of renewable energy projects, that may dictate intervention to ensure the persistence of large mammals in desert ecosystems.

The increasingly evident impacts of climate change associated with global warming further dictate an assessment of the demographic and behavioral responses by

large mammals to the "unnatural" provision of surface water. Thus, information resulting from this project will have important implications for the continued provision of water for use by wildlife in a unit of the National Park Service that is open to recreational hunting — on average, deer harvested in D-17 are among the largest taken in California on an annual basis (Bleich and Pauli 1999). Further, there are important ramifications for the persistence of deer and other large mammals at the level of the landscape in the eastern Mojave Desert. For example, these results will have overall implications for the continued provision of water for mountain sheep in units of the National Park Service, as well as in wilderness areas administered by the Bureau of Land Management, both of which are critically important to the persistence of those specialized ungulates in southeastern California. In the absence of rigorous evidence that intervention, in the form of habitat enhancements, is a meaningful technique with implications for the continued persistence of large mammals in arid systems, efforts to remove "artificial" water sources will continue and, likely, expand in scope.

Introduction: This project had its origins in the decision by the National Park Service to remove artificial (i.e., man-made) sources of water from the Mojave National Preserve (MNP), and the ensuing public outcry. In response to public concern, personnel at the MNP, in collaboration with the California Department of Fish and Wildlife (CDFW) and the University of Nevada (UNR) worked cooperatively to design and implement an experimental approach to the assessment of responses by mule deer, the large mammal primarily affected by the aforementioned decision to remove the water sources. Subsequently, a proposal (Stewart et al. 2007) was prepared and implemented with funds provided largely by Safari Club International, National Park Service, University of Nevada Reno, California Deer Association, and a number of smaller nongovernmental organizations. Although CDFW participated in this investigation at its inception, funding from CDFW has been limited to about $40,000 of the $450,000 expended during the initial phase of the investigation.

As noted by Simpson et al. (2011; and references therein), previous efforts to ascertain the responses of large mammals to water development in arid systems have fallen short of expectations. Further, and with few exceptions (e.g., Cain et al. 2008), those investigations have not included a demographic component but, rather, have emphasized the effects of water provisioning on the distribution of wildlife (e.g., Marshal et al. 2006). Indeed, long-term investigations extending over numerous years — years that include drought as well as years of greater than normal precipitation — and with strong experimental designs (control, replication, and treatments) are needed to fully understand the influences of water developments on population performance (Ballard et al. 1998, Brown 1998). It is up to managers and researchers to implement repeatable, experimental manipulations to further elucidate the benefits or detriments of water developments for wildlife (deVos 1998).

The removal of water sources occurred in the absence of any environmental assessment of the potential influences of that action on wildlife, including mule deer, which are widely distributed within MNP (Bleich and Pauli 1999). The original Environmental Assessment produced by the National Park Service described several additional issues regarding reinstatement of wells in Mojave Preserve. Because addressing each of those issues in this proposal would have substantially increased the length of this document, we incorporate by reference material included in Simpson et al. (2011), which provides an updated review of the current literature on those subjects.

This project consists of two phases: Phase 1, which has been completed, involved establishing baselines with respect to demographics and habitat selection by mule deer in three separate parts of the Mojave National Preserve over a period of 5 years. Products

produced include a M.S. Thesis (McKee 2012), and three (McKee et al. *in review*$_a$, McKee et al. in *review*$_b$), and the aforementioned literature review (Simpson et al. 2011).

Objectives: The purpose of Phase 2 of the investigation is to

1) assess responses of mule deer inhabiting the eastern Mojave Desert to the provision of water at locations where it had been, but is no longer, available. We have again placed emphasis on demographic and distributional responses to the importance of surface water to those ungulates.
2) , We address interactions between mule deer and vegetation as influenced by availability of surface water. Rosenstock et al. (1999) emphasized several areas where research should focus with respect to water developments, including (1) effects of water developments on population performance; (2) distribution and habitat use of game and non-game wildlife species; and, (3) secondary effects of water developments on adjacent plant communities.

Following the challenges posited by Rosenstock et al. (1999), we are testing four hypotheses related to responses of mule deer to provision of water, effects of deer use on habitat conditions adjacent to those water sources, and the availability and quality of forage for mule deer with available water compared with similar areas where water sites had been removed (see Marshal et al. [2006] for review). These hypotheses center on demography (survival, reproduction, and physical condition), habitat selection and movement patterns, and influences of ungulate use on habitat associated with point sources of water. We are making these comparisons among three large study areas inhabited by mule deer — one with perennial sources of surface water, one from which previously available surface water has been removed, and one area that serves as an unmanipulated control.

H1: Provision of permanent, year around water will be beneficial to mule deer populations.

H1a: Fecundity of mule deer will be higher in areas with permanent year-round available water, developed springs and reinstated wells.

H1b: Physical condition of mule deer will be greater in areas with available water.

H1c: Annual survival will be greater in areas where surface water is provided.

H1d: Population density of deer will be greatest in areas with permanently available water.

Rationale: Water is thought to be an important limiting resource for wildlife species that rely at least partially on free water to meet their requirements for water in desert habitats (Turner 1973). If water is in fact limiting under some circumstances, then provision of water must increase survival or fecundity for individuals in areas with permanent available water compared to those relying only on ephemeral sources of water. Under this hypothesis, it is also possible that provision of artificial water will attract individuals from areas lacking that resource. Thus, we may observe changes in survival and reproduction in areas with permanent, available water and our experimental area without permanent water, or changes in distributions of mule deer away from areas without water to those with water available. These changes in distributions, home range size, and movement patterns are most likely during the hot-dry season, which coincides with high water demands, particularly of lactating females.

H2: Provision of water at historic wells will not be detrimental to habitat for other wildlife species.

Rationale: Vegetation represents a key aspect of the habitat for many wildlife species,

because vegetation provides either cover or food (Bowyer et al. 1998). Water alone does not sustain ungulate populations in areas where forage availability is insufficient; thus, forage availability near water sources could be a significant draw for mule deer in those areas (Marshall et al. 2006). Increased numbers of mule deer using reestablished wells have the potential to impact shrubs through their browsing activity or physical disturbance. In years of adequate rainfall, forbs are an important part of the diet for many wildlife species, including mule deer (Marshal et al. 2004). Increased numbers of mule deer at wells might lead to increased interspecific competition for herbaceous plants near these sites. In addition, graminoids present near sources of water also may be suitable forage for mule deer, particularly during early stages of growth. Thus we will sample abundance and nutritional quality of shrubs and herbaceous plants occurring near water sources and sites without available water.

H3: Availability and quality of forage for mule deer and other species will be greatest in areas around developed water, seeps, and springs than away from sources of water or water catchments that are not functional.

Rationale: During conditions when water is most scarce in arid environments, water content of forage is also at its lowest (Marshal et al. 2005). Levels of crude protein in plant material are generally associated with higher rates of forage growth and are associated with the anabolic processes that occur during the production of plant tissues, which decrease as plants reach maturity (Greenwood and Barnes 1978, Marshal et al. 2005). Desert trees and shrubs responded quickly (<1 week) to adequate rainfall by producing new foliage and died back during dry periods (Marshal et al. 2005). Thus, it is likely that shrubs located near sources of water are higher in quality and maintain growth longer than those not associated with sources of water. Moreover, springs, seeps, and developed catchments, with overflow, likely have more forbs and graminoids nearby. Water catchments that are no longer functional will no longer have secondary effects on the surrounding vegetation. When those sites are redeveloped, however, forage quality of the surrounding vegetation will likely increase and maintain higher moisture content through the dry season, provided there is some additional water available to the plant community.

H4: Mule deer will actively select areas near permanent sources of water and home range size of mule deer will be smaller in areas with permanently available water.

Rationale: Habitat selection is defined as areas used greater than their availability (Krebs 1999). Mule deer may select areas with permanent sources to fulfill their needs for free water and to obtain forage that is more available and of greater quality (Marshal et al. 2006). In addition, movement patterns of mule deer likely differ seasonally and home ranges may be smallest during the hot-dry season when deer remain closer to permanent sources of water as ephemeral sources become less available (Rautenstrauch and Krausman 1989). In the control area, without permanent sources of water, mule deer likely move farther and have larger home ranges to include several ephemeral sources of water, and spend more time searching for available water. Conversely, in areas with permanent sources of water, home ranges of mule deer likely are smaller as deer remain close to those water sources, particularly during the hot-dry season when physiological demands for water are greatest (e.g., lactation). In addition, home range size likely differs among males and females and some water sources may used more by one sex than the other during the period of sexual segregation outside the mating season (Bleich et al. 1997, Whiting et al. 2010).

Methods: Deer occupy suitable habitat throughout much of the Mojave Desert where Mojave National Preserve, a 6,500 km^2 unit of the National Park Service is located, and an area in which deer are widespread and are an important game animal (Bleich and Pauli

1999). Areas occupied by mule deer generally are above 1,500 m in elevation. Primary habitat types within MNP include Creosote Bush Scrub, Yucca-Ephedra Scrub, Pinyon-Juniper Woodland, Great Basin Sagebrush, Joshua Tree Woodland, and Desert Wash (Thorne et al. 1981).

During the initial 5 years (Phase 1) we compared a large area with year-round available water including established wells and developed springs with a large area without permanent (i.e. ephemeral) sources of surface water. The area at Cima Dome in MNP functioned as a control and included developed springs (Deer, Cut, Kessler, and White tank); water sources in this area were not manipulated during Phase 1, nor will they be manipulated in Phase 2. Our study area with year-around available water includes reestablished wells (Pettit Well, Government Holes Well, Granite Well, Eagle Well, and Vontrigger Well) and five developed springs (Live Oak, Cottonwood, Clark, Cliff Canyon, and Silver Lead). These wells and springs were monitored and maintained with permanent sources of water during Phase 1, and will remain as such for the duration of the study. The study area without permanent sources of water included sites of 6 wells that were deactivated (Watson's Well, Payne Well, Caruther's Canyon Well, Lecyr Well, Barnwell, and Slaughterhouse Well), and two developed springs (Bathtub and Matt) located within our water-free study area that were made unavailable to mule deer. Springs and wells in each of the three study areas were equipped with ≥1 remote camera to monitor use by mule deer and other wildlife during Phase 1, and remote monitoring will continue for the duration of Phase 2. There are many natural springs occurring throughout the preserve, but most are ephemeral. Data sensors will continue to be used to record the presence or absence of water in a substantial sample of these recorded springs.

In Phase 2 of this long-term investigation we will reinstate the wells in the water-free study area while maintaining the status quo in the other two areas. We will compare responses of mule deer to availability of water in this study area, and make comparisons of that study area before the wells are reinstated (Phase 1) with 6 years after water is made available in that study area (Phase 2). In addition, we will test the hypotheses comparing the area that had permanent water available the first 5 years of the study and will continue as an area with available water during Phase 2. We will also compare differences in habitat selection and home range size as well as changes in demographics within and among all three study areas.

Mule deer have been, and will continue to be, captured by helicopter net-gun and transported to a base camp location for processing. If the base camp is >3 km from the capture site, animals will be returned to the capture site for release. During processing we will collect blood by jugular venipuncture in serum, EDTA, and specialty (i.e., "clean" for trace nutrient analyses) tubes; collect hair and fecal samples for further analyses; and, obtain standard morphometrics. We will continue to use ultrasonography to measure maximum subcutaneous fat thickness on the rump and a body condition score again will be determined; total body fat will be estimated according to methods of Stephenson et al. (2002) and Cooke et al. (2010). Pregnancy will be determined by ultrasonography and serum assay for pregnancy-specific protein B (Stephenson et al. 1995).

We will continue to mark each captured animal with unique combinations of numbered and colored ear tags to facilitate identification of individuals by remote photography (Hughson et al. 2010). Each individual will receive a store-on-board GPS collar as well as a VHF collar. The store-on-board collar will be pre-programmed to drop off approximately one year after deployment. GPS will continue to be programmed to obtain multiple locations throughout the day. VHF transmitters will be monitored from

the ground ≥1 time each week, and ≥1 time from an aircraft on a monthly basis for the duration of the investigation.

We will continue to use, multiple logistic regression models (Manly et al. 1993) to explore relationships among pre-determined parameters and to derive their relevance to habitat selection by mule deer (McKee 2012; McKee et al. *in review*$_a$, *in review*$_b$). Additionally, we will continue to use, the known-fates module in Program MARK (version 6.1, Cooch and White 2009) to analyze monthly patterns of survival of mule deer (McKee 2012; McKee et al. *in review*$_a$, *in review*$_b$).

We will continue to use the Akaike Information Criterion (AIC; Akaike 1973) to compare candidate models and to select the most appropriate models. We will use similar techniques to explore relationships between availability of water and population-level indicators of performance, to include body condition, pregnancy rates, fetal rates, and recruitment rates, based on data obtained from the three study areas during Phase 1 and this phase of the investigation.

Needed equipment is largely in hand, but funds to refurbish collars each year will be necessary. This investigation (i.e., Phase 2 of the long term study) will extend from 1 July 2013 through 30 June 2019, a period of 6 years. Data bases currently are housed at, and are managed by Professor Stewart at the University of Nevada and are readily retrievable. Information on disease status, blood chemistry, and capture records also is maintained at UNR, and also is available at the Wildlife Investigations Lab.

Products and estimated dates of completion: A master's thesis (McKee 2012) that summarized results for Phase 1 of the investigation has been completed. Two manuscripts based on that thesis (McKee et al. *in review*$_a$ and McKee et al. *in review*$_b$) have been completed and submitted to be considered for publication in professional journals. Additionally, a third paper (Simpson et al. 2011), which updated and explored the current literature on responses of wildlife to water developments — and that emphasizes the absence of demographic considerations in previous research — has been published in the professional literature. Further, results have been presented at three professional meetings, including the annual meeting of The Wildlife Society (2011), the annual meeting of the Nevada Chapter of The Wildlife Society (2011), and the annual meeting of the American Society of Mammalogists (2012). C. J. McKee received the "Best Student Paper" Award at the annual meeting of TWS in 2011.

To date, at least three popular articles (Darby et al. 2009, Horner et al. 2009, Stewart et al. 2009) have appeared in the popular press, and one video presentation describing the ongoing research (Nine Caribou Productions 2012) have been produced. We have placed an emphasis on providing information and updates in the form of unpublished progress reports to the organizations that have provided the bulk of the funding for Phase 1, including Safari Club International, California Deer Association, Boone and Crockett Club, Nevada Bighorns Unlimited, and other sponsors, and will continue to do so.

We have met every request and expectation of the Deer Program regarding capture activities in a timely and expedient manner, as specified in approved capture plans. Further, we have provided copies of all publications to the Deer Program and the Wildlife Investigations Lab via Dr. Bleich, and to the University of Nevada via Dr. Stewart. Although annual reports were not required by any agency other than the National Park Service, we have provided them to each of the sponsoring organizations; Dr. Stewart has assumed the primary responsibility for that effort.

Assuming that Phase 2 (i.e., this request) is funded, we will provide a semi-annual report by 1 January each year beginning in 2014 and continuing through 1 January 2019, and completion of an annual report by 30 June each year through 2018. We anticipate

that a final report will be completed by 30 June 2019. Additionally, we will continue to work closely with Deer Program personnel regarding annual capture activities and to provide summaries of results of capture efforts as they occur. We anticipate that the final report will consist of at least one M.S. thesis and several professional publications based on that thesis.

Collaborators: CDFW: Dr. Vernon Bleich, Mr. David Elms, and Dr. Ben Gonzales
UNR: Dr. Kelley Stewart and Dr. James Sedinger
NPS: Mr. Neal Darby and Dr. Debra Hughson

Dr. Bleich is a retired annuitant with CDFW, and has been involved with this project since its inception; he has been the CDFW liaison with researchers from UNR and NPS, has been the project leader for all capture efforts to date, and has been responsible for the preparation and submittal of all requisite reports. Dr. Bleich holds a faculty appointment in the Department of Natural Resources and Environmental Science (DNRES) at UNR and has served, or is serving, on the graduate committees of students working on the project.

Mr. Elms is an Environmental Program Manager in Region 6 of CDFW. Mr. Elms recently assumed that position and, thus, is new to the project. Nevertheless, he brings strong organizational skills, logistical expertise, and supervisory responsibilities to the project. With concurrence from the Regional Manager, Mr. Elms provides direction for CDFW personnel working in the majority desert regions in southeastern California, the participation of whom is critically important to this project.

Dr. Gonzales is a Senior Wildlife Veterinarian with the Wildlife Investigations Lab, and has assumed the responsibility for animal welfare during capture operations, as well as animal processing, biological sampling, and interpretation of results. Dr. Gonzales has participated in this project since its second year.

Dr. Stewart is an Associate Professor in the DNRES at UNR, with expertise in research design, habitat modeling, population ecology, and data management. She serves as the graduate committee chair for three students working on the project, and has been involved with this project since its inception.

Dr. Sedinger is a Professor in the DNRES at UNR, and has been affiliated with this project since its inception. He contributed substantially to the design of this project, and has vast expertise in population ecology and development of habitat selection models. Further, Dr. Sedinger serves on the graduate committees of the students working on this project.

Mr. Darby is the wildlife biologist at Mojave National Preserve, is located on site and is involved primarily with day-to-day project activities. Mr. Darby has been fully involved in this project since its inception, and plays a critically important role in resolving logistical issues, in data acquisition, and the maintenance of water sources included in this investigation. Additionally, he has provided personnel in the form of student workers over the past 5 summers, and is the individual largely responsible for the remote monitoring aspect of the project.

Dr. Hughson is the Science Advisor at Mojave National Preserve, collaborated with Drs. Bleich and Sedinger on the original funding proposal, and has been involved in all aspects of the investigation. Dr. Hughson was responsible for the preparation of the environmental assessment necessary to move this project forward, and brings substantial mathematical, modeling, and analytical skills to the effort. Additionally, Dr. Hughson has been tasked with ensuring that all NPS policy issues are complied with, and that the project continues to meet NPS expectations in terms of productivity and quality.

Program Planning: The collaborators meet face-to-face at least once each year to review progress and to assess, and correct as necessary, any issues that developed during

the prior year. In the event of unforeseen, urgent problems, telephone conferences are arranged; otherwise, collaborators communicate by e-mail on a regular basis.

Other Resources Requested from CDFG: None at this time.

Issues to be Resolved: Other than funding to complete Phase 2 of the long-term investigation, no issues remain to be resolved. Administrative approval has been obtained from Mojave National Preserve, and all environmental requisites have been met. An Institutional Animal Care and Use Permit for this project has been approved by the University of Nevada. As noted previously, approximately $450,000 was expended on Phase 1 — virtually all of it from non-governmental organizations, the National Park Service, and the University of Nevada Reno. It is important to note that collaborators will continue to seek outside funds to support this project, but a solid funding base is necessary to move forward, and also will help generate additional outside funds.

Personnel Requirements and Commitments from CDFG: Annual participation by regional personnel will continue to involve 3-4 person-weeks, primarily during capture operations. Participation by WIL staff will continue to involve approximately 3 person-weeks of time, primarily during capture operations. Seasonal personnel will be needed for 1 person-year each year for the duration of Phase 2, as will 1 person-month of time to oversee the entire project, prepare necessary reports, prepare and implement capture plans and capture events, and to carry out other duties associated with the project.

Budget Detail:

	Fiscal Year						
Anticipated Expense	2013	2014	2015	2016	2017	2018	Totals
CDFW Staff (months)[1]	*3.0*	*3.0*	*3.0*	*3.0*	*3.0*	*3.0*	
Seasonal Staff (months)[2]	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	*12.0*	
Capture Contracts	$40K	$40K	$40K	$40K	$40K		$200K
Collar Refurbishment	$20K	$20K	$20K	$20K	$20K		$100K
Lab Contracts	$2K	$2K	$2K	$2K	$2K	$2K	$12K
Travel	$5K	$5K	$5K	$5K	$5K	$5K	$30K
CDFW Air Services	$5K	$5K	$5K	$5K	$5K		$25K
Publication Costs	$2K	$1K	$1K	$1K	$1K	$10K	$16K
Total Seasonal Costs[2]	$22K	$22K	$22K	$22K	$22K	$22K	$132K
Total Staff Costs[1]	$6K	$6K	$6K	$6K	$6K	$6K	$36K
Annual Project Costs	$102K	$101K	$101K	$101K	$101K	$45K	$551K[3]

[1] Italicized staff costs are estimated in total person-months; regular font indicates out-of-pocket cost in dollars for 1 person-month of time for a Staff Environmental Scientist each year, and assumes other staff time is covered by existing Regional and WIL budgets.

[2] Italicized seasonal staff costs are estimated in person-months; regular font indicates out-of-pocket cost for 12 months of time for a Scientific Aid each year.

[3] Phase 1 of this long-term project has been completed and was funded in the amount of ~$450,000, >90% of which came from non-CDFW sources, as detailed elsewhere. The products produced to date have been previously described, and citations are included among the references. A change of personnel, and hence priorities, within Region 6 of CDFW has resulted in strong support for this project. The collaborators will continue to solicit funds from other resources to offset the costs to CDFW, but continued support from outside sources cannot be guaranteed.

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