Mojave National Preserve

National Park Service
U.S. Department of the Interior

# Science Newsletter

## Fulton's desertsnail: A new species of *Cahuillus* from Mojave National Preserve

Lance Gilbertson[1]

A new land snail species, *Cahuillus fultoni*, or Fulton's desertsnail, has been described from the Mojave National Preserve (*1*) (Figure 1). The new species belongs to the molluscan gastropod family Helminthoglyptidae Pilsbry, 1939, a large pulmonate group found throughout California, the southwestern states (Arizona, New Mexico, and Texas), and adjacent northwestern Mexico (*2*). In California, helminthoglyptids account for about 46% of the native land snail species (*3*). The first known Mojave species, *Sonorelix baileyi* and *Helminthoglypta fisheri*, were described by Paul Bartsch in 1904 (*4*). They were collected as part of the Death Valley Expedition of 1891.

**Figure 1. *Cahuillus fultoni* n. sp. at type locality. Photo: Jason Wallace.**

*Cahuillus fultoni* is found in the southern Soda Mountains near the Desert Studies Center at Zzyzx and named for Robert Fulton, the long-time manager of the center. Fulton noticed their shells while hiking in the area during the late 1980s and later, in 1993, saw the living snails. Their distinctiveness was not recognized for several years. In February 2009, I observed them while on a weekend field trip to the Desert Studies Center with a group from Orange Coast College. At first, I presumed they belonged to genus *Eremarionta* Pilsbry, 1913, a genus that is widespread in the Mojave Desert, but my dissections and subsequent examinations of stained, slide-mounted reproductive systems led me to assign them to a morphologically similar genus, *Cahuillus* Roth, 1996. Then, after completion of the anatomical studies, I had the unexpected opportunity to send selected ethanol preserved specimens to be sequenced for two mitochondrial DNA genes, COI and 16S, by Cal State Fullerton geneticist Douglas Eernisse.

We were excited to see our DNA sequence analyses agree with our anatomical separation of *C. fultoni* from other similar Mojave Desert species of *Cahuillus* and *Eremarionta*. Our combined gene analysis also provided information about phylogenetic relationships, revealing an especially close relationship between the new species and *Cahuillus unifasciatus* Willett, 1930, (Figure 2, upper left). This species, formerly known as *Eremarionta rowelli unifasciata*, is from the vicinity of Newberry Springs, about 80 km west of Zzyzx.

Snails of the genera *Cahuillus* and *Eremarionta* are some of the most arid adapted snails in the country and the world. They live on rocky desert hillsides

**In this Issue:**



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**This Science Newsletter:**

The Mojave Desert is internationally known as a place to conduct scientific research on desert ecosystems. In fact Mojave National Preserve was designated in part to "retain and enhance opportunities for scientific research in undisturbed ecosystems" as stated in the California Desert Protection Act of 1994. Much of this research is conducted through the Sweeney Granite Mountains Desert Research Center, part of the University of California Natural Reserve System, and the Desert Studies Center, operated by the California Desert Studies Consortium of California State Universities. Both are located in the Preserve.

The purpose of this newsletter is threefold. First, we would like to highlight some of the research being done by scientists in the Preserve and to distribute this information to management and the scientific community. Second, this periodical will allow us to inform the public and research community about science being done by Preserve staff or funded by the National Park Service. And third, we would like to build collaboration between scientists and resource managers so that scientists are made aware of the needs of managers and top quality science is brought to bear on the problems facing resource managers.

This newsletter is published once per year. Copies are available in print at our Kelso Depot Visitor Center, Barstow Headquarters, Desert Studies Center, Sweeney Granite Mountains Desert Research Center, and electronically as pdf documents on the web[1]. Articles range from non-technical news stories to highly technical research reports. All material in this newsletter has been peer-reviewed by subject-matter experts.

Debra Hughson, Science Advisor

[1]http://www.nps.gov/moja/naturescience/sciencenews.htm

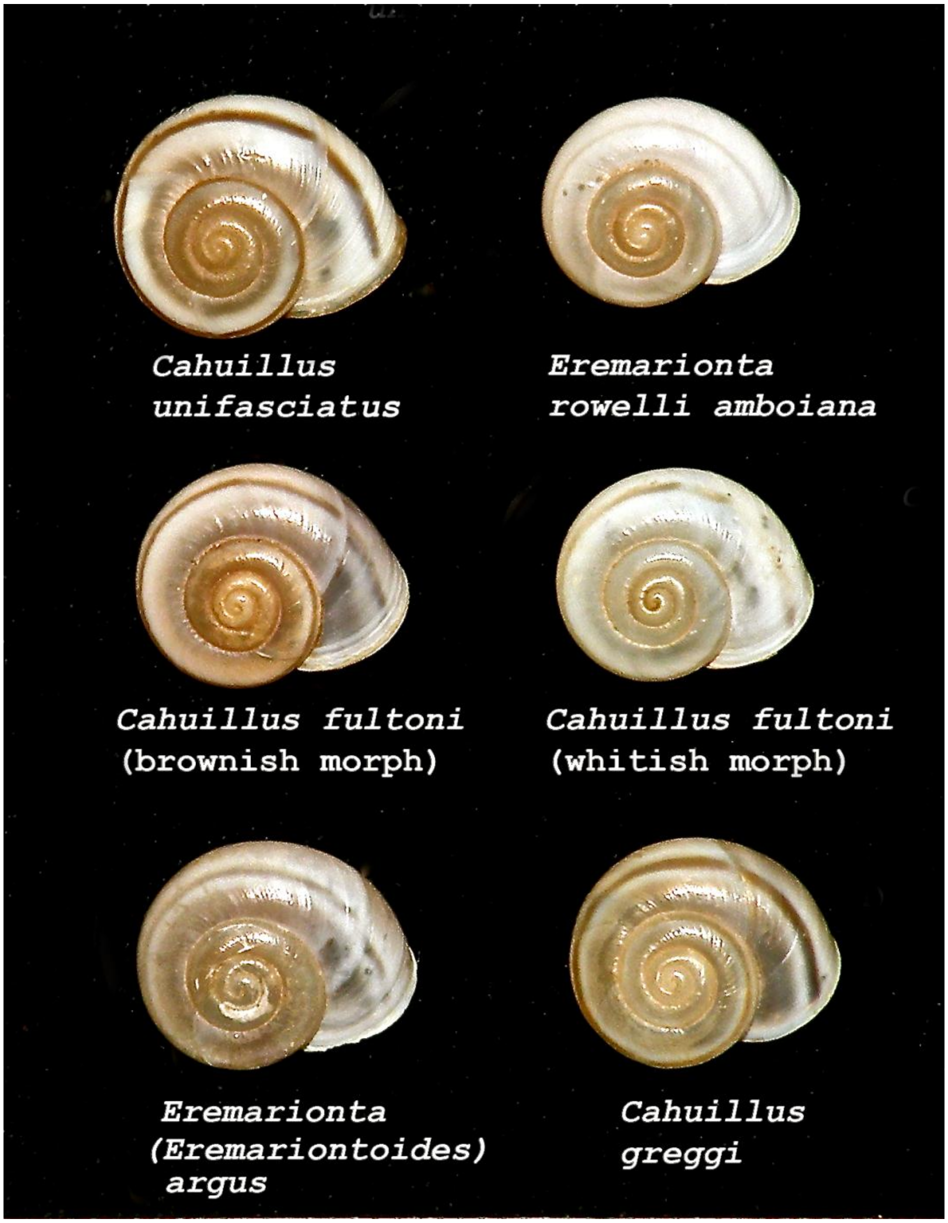


**Figure 2. Apical views of the shells of selected Mojave Desert helminthoglyptid species.**

where they are very secretive and ephemeral, typically being active only a few days to a week or two following winter rainstorms. During this time they feed, mate, and (presumably) lay eggs. They apparently spend the rest of the year estivating, with their aperture firmly sealed to a subterranean rock.

The shells of the new species are small (about 10-12 mm in diameter) compared to the shells of most other members of the family and genus. They are flattened, thin, semi-transparent and range in color from light brown to ivory-white (Figure 2, middle row). By comparison, their bodies, including their tentacles, are jet black. In this species, and a few others such as *Eremarionta rowelli amboiana* Willett, 1930 (Figure 2, upper right), from the more southerly Bristol and Marble mountain ranges, the melanin spreads upward over some of their internal organs located underneath their shell. Because the shell is semi-transparent, the underlying melanin causes it to appear gray, which is fairly cryptic on certain rock surfaces in their habitat (Figure 3).

Interestingly, the new species lacks a structure known as the dart sac and its associated mucus glands normally found on the female system of helminthoglyptid snails including all other members of *Cahuillus* and *Eremarionta*, *sensu stricto*. Except for the large southwestern genus *Sonorella* Pilsbry, 1900, only a few species (primarily members of genus *Sonorelix* Berry, 1943) have secondarily lost this structure. In species where it is present, such as *C. unifasciatus*, the dart sac makes a calcareous dart about a millimeter in length (Figure 4), which is explosively shot into the flesh of its mating partner as part of the courtship ritual. It is, therefore, known as the “love dart.” Since the dartless condition is found almost exclusively in (certain) desert species/species groups, it may be a recent (post-Pluvial) adaptation for water conservation in an increasingly arid environment.

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*Acknowledgements*


For valued assistance and encouragement, I wish to thank Debra Hughson at Mojave National Preserve; William Presch, Robert Fulton and Jason Wallace at the Desert Studies Center; Douglas Eernisse at Cal State Fullerton; and Gary James, Dennis Kelly and Mark Perkins at Orange Coast College.



**Figure 3. *Cahuillus fultoni* at type locality showing cryptic coloration.**

**Figure 4. Side view of mucus glands (top) and dart sac (containing dart) of *Cahuillus unifasciatus*.**

# Way to co-exist! Reciprocal predation mediates the co-existence of endangered Mohave tui chub with invasive western mosquitofish: A case study from Mojave National Preserve

Sujan M. Henkanaththegedara[1] and Craig A. Stockwell[1]

Mohave tui chub (*Siphateles bicolor mohavensis*) is a federally and California State protected endangered minnow (Cyprinidae; Figure 1) that once occurred in the deep pools and slow moving areas of main-stem Mojave River (*1*). However, river populations were extirpated by the late 1960s (*2*) due to a combination of threats, including presumed hybridization with introduced arroyo chub (*Gila orcutti*) (*3, 4*), a severe flash flood in 1938 (*3*), impacts of introduced brown bullhead (*Ameiurus nebulosus*), and habitat modification and degradation (*5*). A relict population was discovered in a spring-fed pool near Soda Dry Lake at the settlement of Zzyzx (*6*), where two extant Mohave tui chub populations, one in Lake Tuendae and the other in MC Spring, persist.

Mohave tui chub populations were subsequently established by extensive translocations in the 1960s and 1970s (*2, 7*). Fish were introduced from Lake Tuendae to a variety of sites, but only two populations persisted, one at Bud's Pond at Camp Cady State Wildlife Area and the other in the seep system in China Lake Naval Air Weapons Station near Ridgecrest. More recently, managers transplanted Mohave tui chubs from China Lake and Lake Tuendae to establish populations at the Deppe Pond/Tui Slough system at the Lewis Center for Educational Research in 2008, and Morning Star Mine pit lake in 2011, respectively (Figure 2). Lake Tuendae, MC Spring, and Morning Star Mine are all located within Mojave National Preserve.

**Figure 1. An adult Mohave tui chub from Lake Tuendae, total length 135 mm. Photo: Sujan Henkanaththegedara ©.**

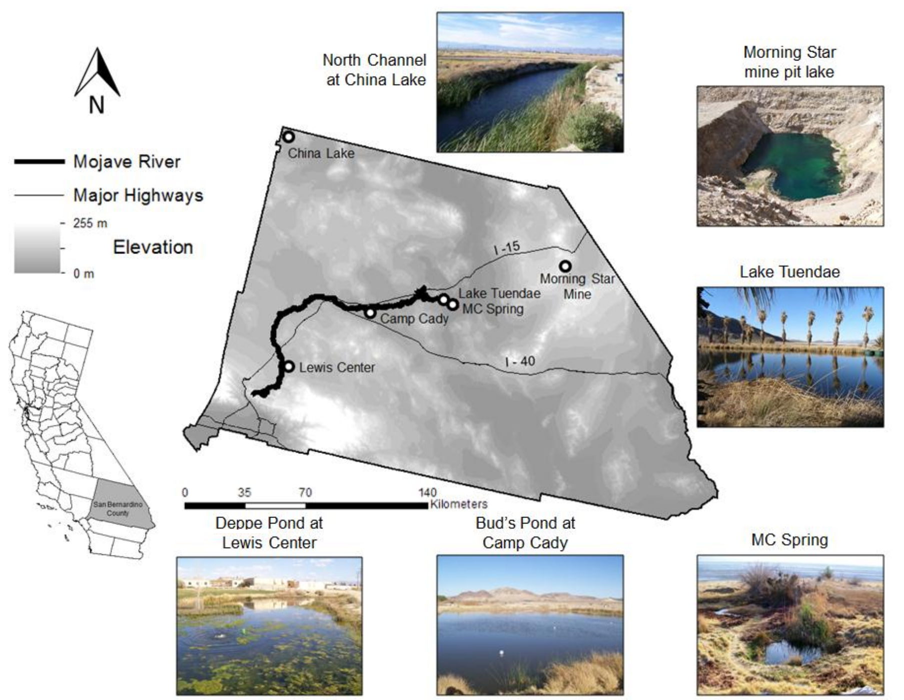


**Figure 2. Current distribution of endangered Mohave tui chub. Map: Justin Fisher ©. Photos: Sujan Henkanaththegedara ©.**

The motivation for the current study was to evaluate potential impacts of invasive western mosquitofish (*Gambusia affinis*) on endangered Mohave tui chub, because two of four established refuge Mohave tui chub habitats (i.e. Lake Tuendae and China Lake) are inhabited by western mosquitofish. Mosquitofish has been identified as one of the world's "worst 100 invasive species" (*8*) due to its negative impacts on a variety of native species via predation and competition (*9*). Furthermore, mosquitofish has been identified as one of the largest threats for native desert fishes, including Mohave tui chub in the southwestern United States (*10, 11, 12*).

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We conducted field mesocosm experiments using thirty 320 gallon cattle tanks that were set up adjacent to Lake Tuendae at the California State University–Fullerton, Desert Studies Center at Zzyzx, California (Figure 3). Mesocosm experiments allowed us to study species interactions between Mohave tui chubs and western mosquitofish under a semi-natural condition. We filled the mesocosms with water from Lake Tuendae and stocked both adult tui chubs (8 / tank) and adult mosquitofish (25 males and 50 females / tank) mimicking natural densities and sex ratios of fish in Lake Tuendae. Tanks were randomly assigned to one of three treatments; 1) Mohave tui chub only (MTC), 2) Mohave tui chubs with mosquitofish (MTC + WMF), and 3) mosquitofish only (WMF), with 10 replicates for each treatment. We fed the fish daily with ground pelleted food at a ration of 4% of fish biomass to limit competition. Mesocosm water quality closely mimicked the water quality of the Lake Tuendae throughout the study period (*13*). We ran the experiment for 70 days and at the conclusion, all surviving fish including larval stages, were counted.

**Figure 3. Thirty 320 gallon plastic cattle tanks were used for the field mesocosm experiment. Mesocosms are a good way to study species interactions under semi-natural conditions. Each mesocosm was filled with Lake Tuendae water, provided with 3 m of plastic "plant" material, and covered with poultry fence to avoid fish suicidal jumps and bird predation. Lake Tuendae is visible to the right and Soda Dry Lake can be seen in the background. Photo: Sujan Henkanaththegedara ©.**

As expected, western mosquitofish had significant negative impacts on Mohave tui chub recruitment ($W = 142.0$; $P < 0.01$) by reducing the larval survival due to mosquitofish predation on tui chub eggs and/or larvae (Figure 4). Surprisingly, Mohave tui chub presence also negatively impacted western mosquitofish populations ($W = 155.0$; $P < 0.001$). Mosquitofish populations maintained alone increased rapidly and doubled the total mosquitofish population size in less than 10 weeks. By contrast, the presence of tui chubs caused mosquitofish populations to decrease by approximately 70%, with complete extirpation in one mesocosm. These effects on mosquitofish populations were due to reduced adult survival and reduced larval production (Figure 5). Tui chubs apparently preyed on juveniles and small adult mosquitofish. Male mosquitofish, which are notably smaller than female mosquitofish, had higher survival in the mosquitofish only tanks (90% survival), but significantly lower survival in the presence of Mohave tui chub (3% survival; Figure 5). Further laboratory predation trials (*14*) and fish diet analyses (*15*) provided direct evidence for the reciprocal predation between Mohave tui chub and western mosquitofish.

Collectively, our results provide evidence for reciprocal predation between endangered Mohave tui chub and invasive western mosquitofish (Figure 6). This case of reciprocal predation appears to be size structured. Adult Mohave tui chub prey on adult (and juvenile) mosquitofish, while adult mosquitofish prey on tui chub eggs and/or larvae. We suggest that reciprocal predation plays an important role in co-existence of Mohave tui chub and western mosquitofish. In fact, mosquitofish and tui chubs have co-existed for at least 29 years in China Lake (*12*) and 11 years in Lake Tuendae (*16*).

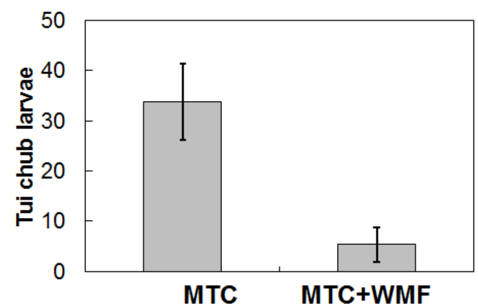


**Figure 4. Mohave tui chub recruitment in the presence (MTC+WMF) and absence (MTC) of mosquitofish is shown. Mosquitofish presence had a significant negative impact on Mohave tui chub recruitment ($W = 142.0$; $P < 0.01$). Tui chub populations with mosquitofish had low tui chub larval production (mean 5.4 ± standard error (SE) 3.4 larvae/mesocosm), with 6 sympatric mesocosms producing no tui chub larvae. By contrast, Mohave tui chub by themselves produced 33.8 (SE ± 7.6) larvae/mesocosm with only a single mesocosm producing no tui chub larvae. Error bars represent 1 ± SE.**

Prior to our work, sites that had been invaded by mosquitofish were deemed

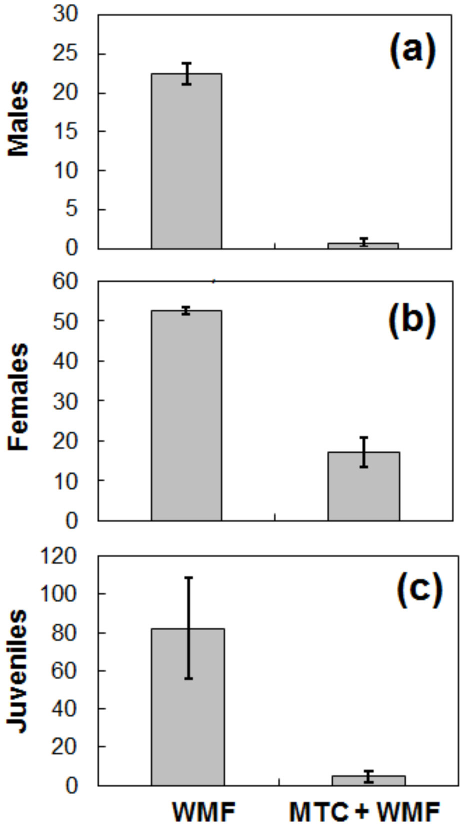


**Figure 5. Average mosquitofish survival for adult male (a), adult female (b), and juveniles (c) in the presence (MTC + WMF) and absence (WMF) of Mohave tui chubs. Mosquitofish population size was significantly lower (W = 155.0; P < 0.001) in the presence of tui chubs (22.1 ± 4.0 mosquitofish/mesocosm) compared to mosquitofish by themselves (157.2 ± 26.9 mosquitofish/mesocosm). Male mosquitofish survival was significantly lower (W = 155.0; P < 0.001) in the presence of tui chubs (0.8 ± 0.5) compared to male survival in mosquitofish only tanks (22.5 ± 1.3). Female mosquitofish survival was also significantly reduced in the presence of Mohave tui chubs (17.2 ± 3.6), compared to female mosquitofish survival from mosquitofish only tank (52.5 ± 0.9; W = 155.0; P < 0.001). Error bars represent 1 ± SE.**

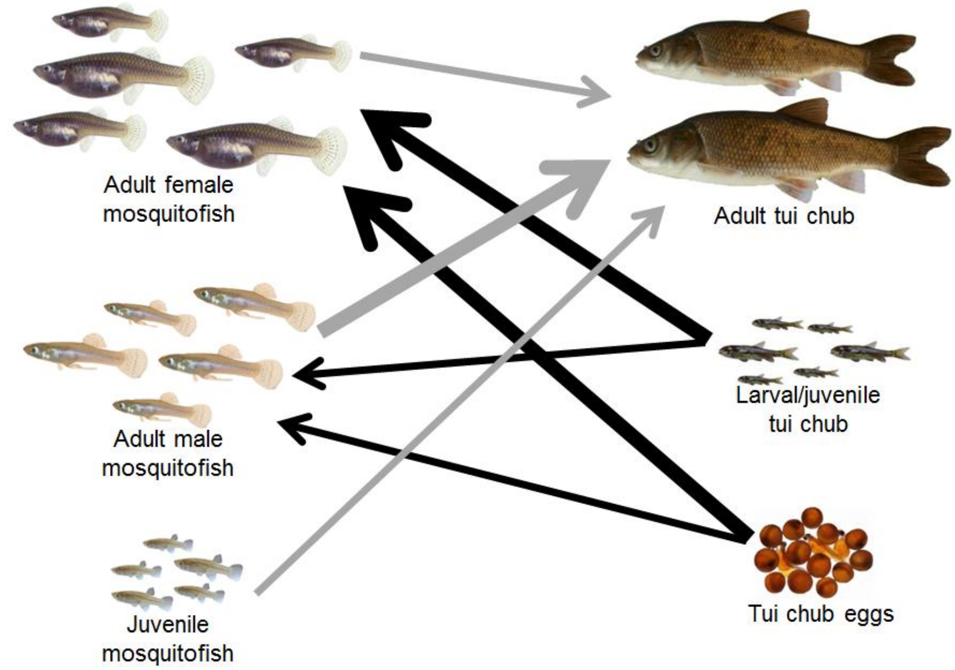


**Figure 6. A conceptual representation of reciprocal predation between endangered Mohave tui chub and invasive western mosquitofish. Arrowheads point toward the predator and the thickness of the arrows indicates the relative intensity of the predation.**

inadequate as refuge sites for Mohave tui chub recovery. Our research suggested that mosquitofish presence does not necessarily exclude the suitability of a site for colonization by Mohave tui chub. These findings led managers to establish a fifth population of Mohave tui chub at a site inhabited by mosquitofish (i.e. Deppe Pond/Tui Slough system) (*17*).

Invasive species often impact native species via predation; thus it seems likely that reciprocal predation could be important for many systems harboring invasive predators. Thus, understanding complex interactions among native and non-native species in the whole-ecosystem context may help conservation practitioners identify novel management options.

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*Acknowledgements*

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# Use of Artificial Water Sources by Mule Deer in Mojave National Preserve

Kelley M. Stewart[1]

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 by small game species such as the California Quail (*Lophotoryx californinus*), mourning dove (*Zenaidura macroura*), and the nonnative chukar partridge (*Alectoris chukar*) in water-limited areas (*1*). 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 (*2*). Those developments were created, in part, to help improve declining desert bighorn sheep (*Ovis canadensis nelsoni*) populations in southwestern Arizona, USA. Those developments may have also benefited additional ungulate species such as mule deer (*Odocoileus hemionus*) and pronghorn (*Antilocapra americana*) (*3*), as well as other species of wildlife. More recently, water developments have been instituted to mitigate the loss of natural water sources (*1, 4*).

Mule deer are widely distributed throughout western North America and occupy a variety of habitat types, ranging from the Canadian boreal forest to the Mojave and Sonoran deserts (*5*). Deer habitat in Mojave National Preserve is often thought of as desolate, hot, barren and inhospitable, which is a common misconception. Desert vegetation, including *Yucca* and *Opuntia* (Cacti) spp., and a variety of summer and winter annuals, can be just as productive for mule deer as other areas in the Western U.S. (Figure. 1). However productivity, especially of annual plants, is closely linked to seasonal precipitation (*6*). Although succulent forage can provide adequate water to meet metabolic processes (e.g. 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 drinking water (*3, 5*). Additionally, during times of water scarcity such as the hot-dry

**Figure 1. Landscape of Cima Dome study area, Mojave National Preserve. Photo: Riley Heater.**

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season, mule deer have been shown to select areas closer to water rather than ranging widely to browse (*7, 8*). In desert ecosystems where forage quality is adequate to meet nutritional requirements but water is scarce, it has long been assumed that provisioning permanent water sources in the form of guzzlers or catchments may improve distribution and abundance of mule deer (Figure 2).

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 (*9*). In an opinion paper, Broyles (*10*) 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.* (*3*), contend that water developments provide intrinsic benefits to wildlife populations in the arid west. Empirical studies are needed to settle this on-going debate (*3, 9, 10, 11*).

Researchers at the University of Nevada in Reno, in collaboration with the National Park Service, California Fish and Wildlife, and supported by the California Deer Association and Safari Club International, are attempting to shed light on this topic by examining the response of mule deer to manipulation of water sources in Mojave National Preserve, California. We are addressing several hypotheses related to effects of provisioning water on mule deer and the corresponding effects on: 1) population demography, including survival of adult and juvenile mule deer as well as pregnancy rates and nutritional condition; 2) selection of resources and movement patterns of mule deer; and 3) availability and quality of forage at water sources.

Mojave National Preserve is a 650,000 ha unit of the National Park Service in southern California (Figure 3). It includes

**Figure 2. Mule deer at Kessler Springs on Cima Dome, Mojave National Preserve. Note the female on the left with a radio collar. Photo: Neal Darby.**

components of three of the four major desert ecosystems in North America: Mojave, Sonoran, and Great Basin. Prior to the California Desert Protection Act in 1994, lands within the Preserve were used as rangeland for livestock and also by wildlife. A number of wells were developed prior to the turn of the 20th century to provide water for cattle. These wells supported large herds of cattle and also benefitted many species of wildlife. In 2001 and 2002, cattlemen sold their grazing permits and most of the wells were either dismantled or not maintained, removing sources of water for wildlife. Reactivation of these water sources provides the foundation of this research.

We are evaluating the responses of mule deer to reactivation of water sources in two of three study areas of the Preserve. One study area, Cima Dome, did not experience loss of well water. Consequently, permanent water developments have been available to wildlife for nearly a century. Our second study area, hereafter referred to as Mid Hills, had livestock wells that were reactivated in the fall of 2008 and served as a water-provided treatment area. Our third study area, hereafter referred to as the New York Mountains, has wells that remain inactive. The New York Mountains area functioned as a water-limited treatment area for the first half of the study, with plans to provision water there during the second half. We captured 20 to 30 mule deer per year (2008 to present), about equally distributed among study areas, using a net gun fired from a helicopter. Each animal was equipped with a Global Positioning Satellite radio collar and colored ear tags for field identification (Figure 4). Infrared-triggered trail cameras were placed at water sites to document site use by mule deer and other wildlife (Figure 5). All captured mule deer were fitted with unique ear tags, which remained on the individual after radio collars were released. Those permanent marks allow for continued identification of individuals photographed at water sites.

We calculated 95% home range and 50% core areas used by radio collared mule deer in each of the study areas. Our analyses indicated that areas of both the home range and core areas were smallest in the Mid Hills, or water provided treatment, likely indicating that mule deer did not spend as much time searching for water or other resources in that study area. Daily movements were greatest in the Cima Dome area and were smaller in the other two study areas. Smaller home ranges likely provide benefits for females raising offspring and lactating during summer because restricted movements by females also means shorter movements for juveniles and less energy expended in searching for resources.

Adult survival was high across all 3 study areas during 2009-2011 at about 86%, with no variation between areas. This finding is not surprising because adult survival is generally high with mule deer and is often less variable than that of juveniles. Unknown mortality was the largest source, although illegal harvest and predation by mountain lions also were sources of mortality in the Mid Hills and New York Mountains. Mule deer are generally a long-lived species with relatively high adult survival. Other regions in the western United States typically have adult survival rates of 85%. Juvenile survival is often more variable than adult survival and likely will better reflect different availability of resources among the study areas.

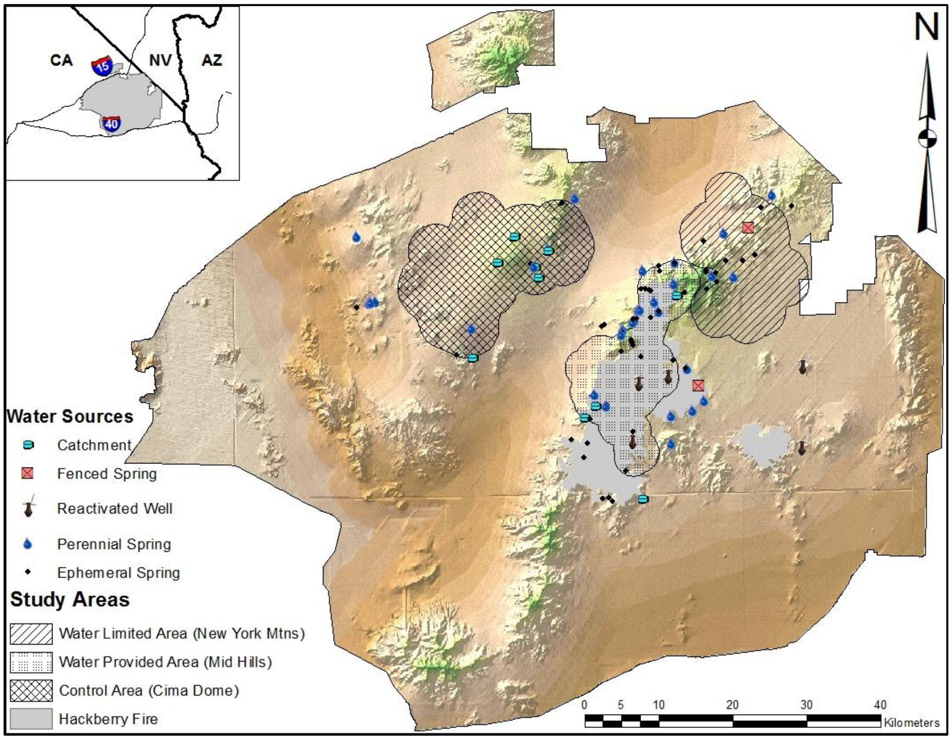


**Figure 3. Mule deer study areas within Mojave National Preserve.**

The Mid Hills area also was impacted by a wildfire that occurred during 2005. The burned area that had previously been dominated by pinyon-juniper woodland has responded with native forbs such as globemallow (*Sphaerelcea spp.*) and four o'clock (*Mirabilis spp.*) and shrubs such as bitterbrush (*Purshia tridentata* var. *glandulosa*) that are more palatable for mule deer (Figure 6). Thus wildfire appears to have resulted in improved habitat for mule deer. In addition, several springs have appeared that were not identified prior to the burn. The Mid Hills area currently has about 23 water sites documented to be available to mule deer. Two of those water sites are wells that were reactivated for this research and where water is now available to mule deer and other wildlife. Although mule deer were the target species of this research, many other species of wildlife have been photographed using those water sources, including passerine birds, small mammals, upland game birds, and some carnivores.

**Figure 4. Female mule deer fitted with a Sirtrack GPS radiocollar released in the New York Mountains area of Mojave National Preserve. Photo: Kelley Stewart.**

Cody McKee, the first graduate student on the project, completed his Masters' Degree in May 2012 (Figure 7). Anthony (Tony) Bush (Figure 8) began his graduate work on this project in May 2012. Tony will focus on juvenile survival and recruitment in each of the 3 study areas. Cody's portion of the project indicated that adult survival is high overall, which is consistent with results of adult survival from other studies of mule deer. In general, survival and recruitment of juveniles are more variable and more likely to be affected by availability of water. Tony will investigate juvenile survival and continue monitoring and collaring mule deer in these study areas for 2-3 more years before initiating the second phase of the project, which entails reactivating livestock wells in the water-limited study area to examine the effects of water provisioning.

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**Figure 5. Mule deer at a water source in the Cima Dome area of Mojave National Preserve. Note adult female with radio collar. Photo: Neal Darby.**

**Figure 6. The post-wildfire landscape is now dominated by annual and perennial herbaceous vegetation (e.g. globemallow and four o'clock) as well as some perennial shrubs, e.g. bitterbrush and desert almond (*Prunus fasciculata*). Photo: Cody McKee.**

**Figure 7. From left to right, Cody McKee, Ian Knight, and Neal Darby prepare to release a mule deer in Mojave National Preserve. Photo: Cody McKee.**

**Figure 7. Tony Bush tracking radio collared mule deer. Photo: A. Bush.**

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