Mojave National Preserve

National Park Service
U.S. Department of the Interior

Science Newsletter

Responses of Mule Deer to Experimental Manipulation of Water Sources: Preliminary Results from the First Year

Providing water sources for wildlife in arid regions is a method of habitat improvement that has been utilized by managers for many years. At least 122 artificial water sources, known as guzzlers, were in existence when Mojave National Preserve was created in 1994. These are basically tanks that collect runoff and store it underground. A significant population of desert bighorn sheep (*Ovis canadensis nelsoni*) is supported in the Old Dad and Kelso Peaks area by artificial tanks – otherwise ideal sheep habitat that lacks natural water sources.

Two mule deer does, one with collar and ear tags, photographed by a motion-triggered camera at Deer Spring in the Cima Dome area.

The Mojave Desert has a long history of cattle grazing going back to the late nineteenth century. Numerous wells, troughs, and pipelines were developed to support and distribute cattle on the landscape. Near surface groundwater was utilized by constructing shallow horizontal tunnels for gravity flow and by pumping. From 1998 through 2002, grazing allotments in Mojave National Preserve were purchased, retired, and donated to the National Park Service. Approximately 12,000 cattle were removed from 1,260,980 formerly grazed acres along with about 4000 feral burros (*Equis asinus*). Troughs, pipelines, and pumps were removed with the cattle and many wells were abandoned. Loss of these developments generated controversy among hunting and environmental organizations regarding the relationship between livestock watering troughs and viable populations of wildlife species.

In response, Mojave National Preserve, the University of Nevada – Reno, and California Department of Fish and Game initiated research with support from Safari Club International to investigate the effect that water provision has on mule deer (*Odocoileus hemionus*) fecundity, physical condition, and survival. The study area is the northern half of the Preserve from Cima Dome to Barnwell, divided into a control area with permanent natural water sources, a treatment area where water is added, and a dry area. Water was provided at Government Holes, Petit Well, Gold King Well, Eagle Well, and Hogaboom Well in late August to early September of 2008. The experimental design calls for six

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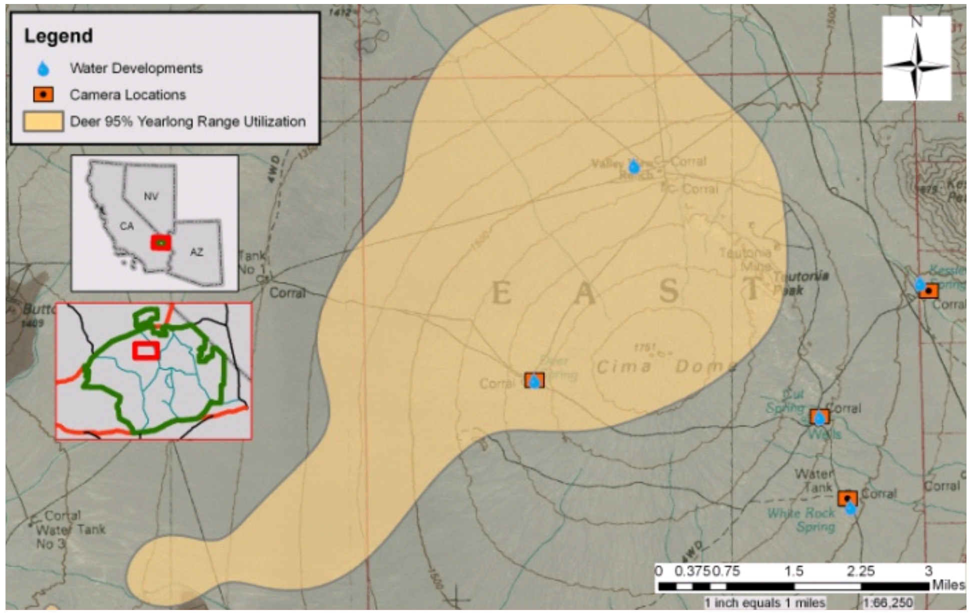
The Mojave Desert is internationally known as a place to conduct scientific research on desert ecosystems. In fact Mojave National Preserve was designated in part to "retain and enhance opportunities for scientific research in undisturbed ecosystems" as stated in the California Desert Protection Act of 1994. Significant research is done 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 of which are located in the Preserve.

The purpose of this newsletter is three-fold. First, we would like to highlight some of the research being done by university scientists in the Preserve and distribute this information to park staff and management. Second, this periodical will allow us to inform the public and research community about science being done by Preserve staff or funded through the National Park Service. And most importantly, 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.

Our intention is to publish this twice per year, once in the spring and again in the fall, in print at our Visitor Centers and electronically on the web. Articles will range from non-technical news stories to highly technical research reports. All material in this newsletter has been peer-reviewed by subject matter experts. In each issue we will discuss a resource management issue or research need along with possible means of obtaining funding. The resource management concern highlighted in this issue is invasive plant species, particularly Sahara mustard.

Debra Hughson, Science Advisor



Mule deer and water distribution on Cima Dome in Mojave National Preserve. A yearlong 95% range utilization estimate was 14,268 acres for five deer combined on Cima Dome. This range included two of five known water sources.

more wells to be added at the five year midpoint of the study. Radio collared mule deer will be located throughout the year and photographed by remote cameras. Survival probabilities will be estimated using known fate analyses implemented in Program Mark (White and Burnham 1999). Information theoretic model selection approaches (Burnham and Anderson 2002) will be used to assess variation in survival.

Vegetation and local precipitation will be monitored in both the treatment and control areas. Shrub cover will be estimated within 200 m of springs and wells in both the treatment and control areas by establishing ten 50 m transects within 200 m of each well and spring site. Shrub cover will be estimated annually within each transect using the line intercept method (Bonham 1989). Cover and biomass of herbaceous plants by forage category (Bonham 1989) will be estimated each season by clipping vegetation inside and outside of moveable exclosures using a one square meter plot frame. These vegetation studies will provide basic information on the spatial and temporal dynamics of vegetation at water sources in Mojave National Preserve.

Mule deer were captured by net gun from a helicopter in January of 2008 and 2009. Physical condition of the captured deer was measured by ultrasound along with standard lengths and weight. Blood, hair, dental, and fecal samples were collected. The animals were equipped with ear tags and radio and Global Positioning Satellite (GPS) collars. The results from this first year of this study, although preliminary and inconclusive, have already significantly increased our understanding, as little is known about this population.

Five mule deer were tracked in the Cima Dome control area and appeared to range along the northwest side of the dome. There are five permanent water sources on Cima Dome: Kessler Spring, Cut Spring, White Rock Spring, Deer Spring, and Valley View Ranch. The range of the deer encompassed Deer Spring and Valley View. Visitation to Deer Spring by the five collared deer was sporadic and inconsistent. Only one collared deer visited throughout the year but disappeared for periods of up to 34 days. The remaining four deer visited for one to three week intervals two or three times during the year. Telemetry location information indicated that at least two deer used the water source at Valley View, which did not have a camera station installed at the time, and that all deer wandered away from Deer Spring for varying lengths of time throughout the year. When deer were consistently around Deer Spring, defined as periods with visitation gaps less than 20 days, all five deer visited on average once every 5.23 days. The highest visitation rates occurred in August with visits once every two days. Deer visited the spring primarily during night-time hours. Marked deer were only photographed at Deer Spring on Cima Dome despite having cameras deployed at springs in the areas where mule deer were collared. Photographs from cameras at three other springs confirmed telemetry results in that no collared deer visited those sites.

We used photographs of collared deer taken with the infrared-triggered cameras to estimate the number of mule deer utilizing Deer Spring. Separate Lincoln-Peterson Index estimates were made during 2 week periods from February 1, 2008 through January 15, 2009 with 95% confidence intervals (CI). We estimated that 26 deer (95% CI 18-44) were using Deer Spring.

In January, 2008 we captured 18 mule deer including 15 does, 2 bucks, and 1 yearling female. We looked at pregnancy of those females and 15 of the 16 (94%), including the yearling were pregnant. Of the 15 pregnant does, 11 (73%) were carrying twins. During 2009, we captured 31 deer, 30 does and 1 6-month old doe and again we examined pregnancy. We examined 28 does for pregnancy, not including the juvenile and 2 does for which we were unable to collect data on reproduction. Of the 28 does 26 (93%) were pregnant, but during the 2009 capture, which reflects the 2008 growing season, only 14 does (50%) were carrying twins. We suspect that because the fall of 2008 was much drier than 2007 the availability of forage was lower and the does were not as able to carry twins. These data are preliminary, but the correlation between late summer and fall weather events and the corresponding response of vegetation likely influences pregnancy and twinning rates in these mule deer. As we collect more data during this study we will be able to examine the effects of weather variation as well as provision of water on physical condition and reproduction mule deer inhabiting this portion of the Mojave Desert.

A Mojave National Preserve Wildlife Biologist releases a mule deer doe freshly equipped with a GPS collar, VHF radio collar, and ear tags near Kessler Spring.

A graduate student from the University of Nevada – Reno, Cody McKee, will be working on this research for a Master of Science degree in wildlife ecology. Cody is supervised by Dr. Kelley Stewart, Assistant Professor in the Department of Natural Resources and Environmental Science and Principal Investigator for this research. Cody and several technicians will spend most of the summer from May through August living in the Preserve, monitoring vegetation, tracking the movements of the collared animals, and collecting and analyzing photographs from the motion-activated cameras.

This study of mule deer and water sources, planned for ten years in two five-year phases, will provide Mojave National Preserve's management with much useful information on resource utilization by mule deer, mule deer reproduction, visitation at springs by mule deer and other animal species photographed by the cameras, and vegetation dynamics correlated with local precipitation variability and herbivory as it effects mule deer reproduction. Although this study is just beginning, experimental manipulation of water in October of 2008 did result in a detectable response when a mule deer buck was photographed at water placed at Eagle Well.

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Mohave Tui Chub: Hybridization and Invasion

The Mohave tui chub is the only animal species in Mojave National Preserve federally listed as endangered under the Endangered Species Act. It was found surviving in two small ponds at Zzyzx, California, on what is now the Preserve, after being extirpated from the Mojave River in the early to mid-twentieth century, reportedly through hybridization with the non-native arroyo chub. Transplants from this relict population were used to establish populations at China Lake near Ridgecrest and Camp Cady near Newberry Springs. The National Park Service is working with the U.S. Fish and Wildlife Service and California Department of Fish and Game to upgrade the status of this species to threatened. To accomplish this we need to establish three more populations and maintain six geographically distinct populations each at a minimum level of 500 adult fish. In this article we describe our work on experimental hybridization and surveys of the Mojave River.

The Mohave tui chub (*Siphateles bicolor mohavensis*), (Pisces: Cyprinidae), was listed as endangered October 13, 1970. The Recovery Plan was published September 17, 1984. At the time of its listing, the extirpation of Mohave tui chub (MTC) from the Mojave River was thought to have resulted from hybridization with arroyo chub (AC) (*Gila orcutti*). The Recovery Plan states, "[t]he exotic species of Gila invaded the Mohave River and subsequently hybridized with the Mohave tui chub. By 1970 genetically pure Mohave tui chubs had been eliminated from the river by hybridization and subsequent introgression." This statement was based on work (Hubbs and Miller 1943, Miller 1969) that assessed hybridization through morphometric comparisons such as scale counts, scale morphology, fin ray counts, and body proportions. More recent work (Chen et al. 2006) found genetically pure AC in the Mojave River and genetically pure MTC in the three extant populations (Zzyzx, Naval Air Weapons Station at China Lake, and Camp Cady). Thus the viability of Mohave tui chub – arroyo chub hybrids is a research question that needs to be addressed prior to reestablishment of MTC in the Mojave River basin, or establishment of recovery populations in off stream waters that potentially could be invaded by arroyo chubs.

Abiotic factors may have contributed to extirpation of MTC from the Mojave River. Castleberry and Cech (1986) argue that physiological responses to high temperatures, rapidly fluctuating temperatures, and high flow velocities give AC a competitive advantage over MTC in predator avoidance, feeding, and escaping stressful environmental conditions. Mohave tui chub, on the other hand, may have a competitive advantage in low temperature and/or hypoxic conditions that typically occur in stratified lake environments, particularly during a winter freeze. Arroyo chubs are better swimmers than Mohave tui chubs and thus less likely to be swept downstream to the Soda Lake terminal playa. In the flood-prone Mojave River, Mohave tui chubs were frequently washed downstream to expire on the exposed terminal playa. A combination of low fertility of hybrids and greater tolerance of high temperatures and higher flow velocities may explain the presence of pure arroyo chubs in the Mojave River drainage. This project seeks to address the issue of hybridization and competition between Mohave tui chub and arroyo chub in an aquarium and an artificial pond environment. A better understanding of the viability of hybrids may be useful in selecting suitable habitats in the upper Mojave River drainage for recovery of the species.

The original objectives of this study proposal were to address the following two research hypotheses.

1. Are *Siphateles bicolor mohavensis* X *Gila orcutti* hybrids viable?
2. Will *Siphateles bicolor mohavensis* out-compete *Gila orcutti* in a still pond subject to seasonal conditions of low temperature hypoxia?

Agency staff survey the Mojave River by electroshocking at the Upper Narrows.

We started this experiment with 10 laboratory spawned MTC, which had been released into the Fire Pond at Camp Cady on March 30, 2007 and which we obtained November 18, 2007 when California Department of Fish and Game was in the process of transferring MTC from the Fire Pond to Bud's Pond, and with 10 presumptive AC which we collected from the Mojave River at Afton Canyon between December 4 and 11, 2007.

We attempted to spawn AC by manipulating photoperiod and water temperature in the aquarium but saw no sign of spawning. These fish collected from Afton Canyon also appeared to be infected with anchorworm (*Lernaea cyprinacea*). Upon close inspection, eight of the ten fish collected in Afton Canyon were found to be non-native hitch (*Lavinia exilicauda*), a minnow from Central California, and only two were arroyo chub.

Prior to this discovery in December, 2007, nearly all fish collected from Afton Canyon had been reported as either Mohave tui chub or arroyo chub or their hybrids, although Timothy Brown did report 7 black bullhead (*Ameiurus melas*) in 1978. Twenty seven fish collected on May 22, 2002 were all identified as arroyo chub with the possible exception of one (Jeffrey A. Seigel, Natural History Museum of Los Angeles County, personal communication). Of another 72 collected from Afton Canyon on April 6-8, 2005, 71 were identified as arroyo chub and one was identified as hitch.

Henkanaththegedara et al. (2004) noted that brown bullhead (*Ameiurus nebulosus*) was the first reported non-native fish species in the Mojave River drainage. By 2002, 23 non-native fishes were reported in the drainage (Marchetti et al. 2004, Moyle 2002). Non-native species richness appears to be highest at the Silverwood reservoir on the West Fork which ties in to the State Water Project.

This invasion of non-native fish led us to organize an interagency collecting expedition in 2008 to update our understanding of fish community composition in the Mojave River. Voucher specimens from this collection are permanently archived at the Natural History Museum of Los Angeles County. We collected seven fish species from the Mojave River above the Upper Narrows near the Lewis Center for Educational Research on May 12, 2008. They were: mosquitofish (*Gambusia affinis*), threespine stickleback (*Gasterosteus aculeatus*), brown bullhead, and green sunfish (*Lepomis cyanellus*). Fifty four cyprinids were collected, vouchered and identified on the basis of fin–ray, gill raker and pharyngeal tooth counts as 27 arroyo chub, 21 hitch, and 6 hitch/arroyo chub hybrids (Jeffrey A. Seigel, personal communication). These numbers may be meaningful in that they show the relative abundance of each minnow at that locality. This at least provides us with a baseline. It may be worthwhile to collect there in the future to see how these numbers change. Certainly hitch is now a dominant part of the river's fish fauna; a new factor influencing any strategy to reintroduce MTC. Twenty each of mosquitofish, threespine stickleback, and hitch were sent to the California Nevada Fish Health Center. The exotic parasite Asian tapeworm (*Bothripcephalus acheilognathi*) was found in 30% of hitch (N=6) and *Schistocephalus spp.* was found in 10% of threespine stickleback (N=2).

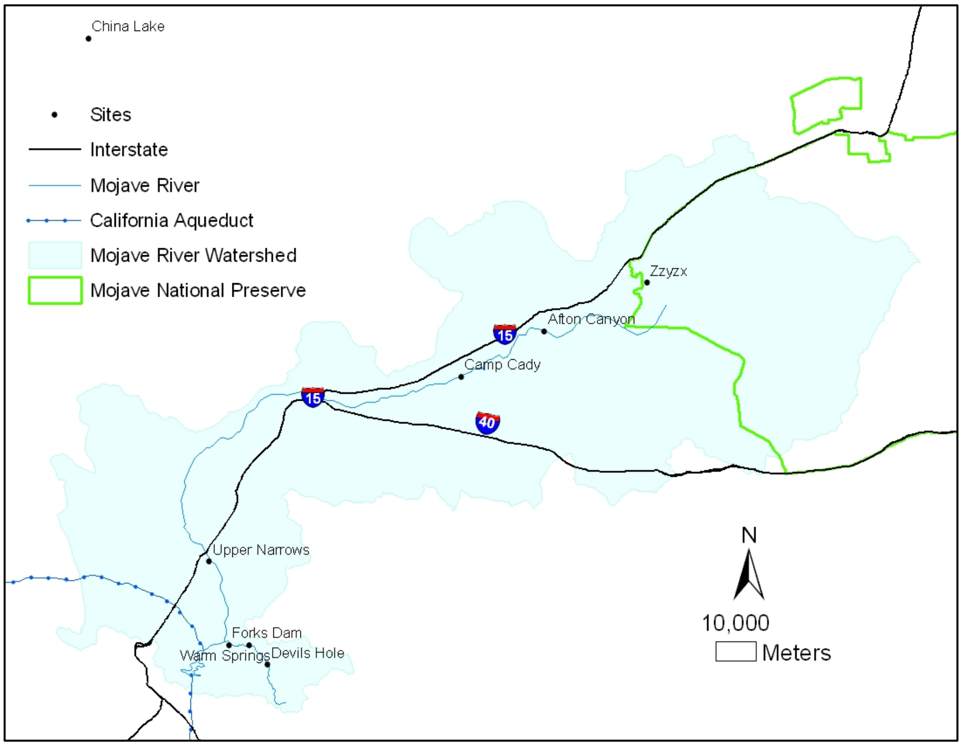
The minnow population in Afton Canyon has seemingly undergone a rapid change in the last 6 years. Of 107 fish collected and vouchered from Afton Canyon on May 13, 2008 there were 69 hitch, 18 arroyo chubs, and 20 hitch/arroyo chub hybrids. Additionally, a small slough south of the Campground and southwest of the first Afton Canyon crossing was also sampled on May 13. A riparian area lies east of Afton Canyon road, south of the turnoff to the Campground. About 0.5 km southwest of the campground is a small, shallow swamp/slough near the main riverbed. Schools of very small fish were noticed in the shallows and collected with dipnets. No larger juveniles or adults were observed. Fifty four small fish were collected, identified and vouchered at Los Angeles County Museum, all identified as arroyo chub.

Three localities along Deep Creek, Devil's Hole, Warm Springs, and above Mojave Forks Dam, were qualitatively electrofished and trapped on September 22-23, 2008 to evaluate species composition. Identification in the field indicated rainbow trout (*Oncorhynchus mykiss*), arroyo chub, and threespine stickleback at Devil's Hole in addition to the Eurasian snail, *Radix auriculata*. This mollusk is not a new or unusual find in California. There were 384 specimens, identified as arroyo chub, collected from Devil's Hole. Arroyo chub (279 specimens collected) and black bullhead were found at Warm Springs. Above the Forks Dam black bullhead, hitch, green sunfish, black bass (*Micropterus salmoides*), arroyo chub, and prickly sculpin (*Cottus asper*) were found.

The apparent absence of hitch and/or hybrids from the upper two sites suggests that hydraulic features between Warm Springs and the Forks may provide an effective natural barrier to upstream fish migration. One possible barrier is a large cataract about 1.7 miles upstream from Mojave Forks dam (Matthew Huffine, Lewis Center for Educational Research, personal communication). The failure to collect trout and stickleback at the lower two sites may result from unsuitable water temperatures in mid-summer. The numbers seem to indicate a shift in the predominate minnow in Deep Creek. The upper Devil's Hole and Warm Springs area is dominated by arroyo chub (663 arroyo chub, no hitch) and the lower Fork's Dam area is dominated by hitch (1 arroyo chub, 37 hitch). It seems unlikely that these numbers are an artifact of seasonality or collecting bias.

Non-native fishes appear to be entering the Mojave River drainage via the California Aqueduct through Silverwood Reservoir. Non-native fish species richness appears to be highest in Deep Creek near the Forks Dam, and in the Mojave River at the Upper Narrows. Hitch appears to be restricted in Deep Creek to the lower reaches directly above the Forks Dam while arroyo chub becomes more common upstream. Black bullhead was found in the lower and middle reaches of Deep Creek whereas trout was found only in the uppermost reach. Arroyo chub and stickleback have been introduced in the upper watershed along with trout (Gar Abbas, U.S. Forest Service, personal communication). Hitch appears to be expanding in the Mojave River and hybridizing with and replacing arroyo chub. In order to better frame the recovery potential of Mohave tui chub, species composition above and below potential migration barriers in Deep Creek, the upstream extent of arroyo chub in the perennial headwaters, and the species composition in all Mojave basin reservoirs should be determined.

Date	Number	Location	Species	Natural History Museum of Los Angeles County
May 22, 2002	27	Afton Canyon	*Gila orcutti*	LACM 55990-1
April 6-8, 2005	71	Afton Canyon	*Gila orcutti*	LACM 56881-1
April 6-8, 2005	1	Afton Canyon	*Lavinia exilicauda*	LACM 56881-2
May 12, 2008	27	Upper Narrows	*Gila orcutti*	LACM 56833-3 (10 specimens) LACM 56834-3 (11 specimens) LACM 56838-2 (6 specimens)
May 12, 2008	21	Upper Narrows	*Lavinia exilicauda*	LACM 56833-5, 4 specimens; LACM 56834-6, 11 specimens; LACM 56838-5, 6 specimens
May 12, 2008	6	Upper Narrows	*Gila orcutti / Lavinia exilicauda hybrids*	LACM 56833-4, 1 specimen; LACM 56834-5, 3 specimens; LACM 56838-4, 2 specimens
May 13, 2008	69	Afton Canyon, ford	*Lavinia exilicauda*	LACM 56880-3
May 13, 2008	18	Afton Canyon, ford	*Gila orcutti*	LACM 56880-1
May 13, 2008	20	Afton Canyon, ford	*Gila orcutti / Lavinia exilicauda hybrids*	LACM 56880-2
May 13, 2008	54	Afton Canyon, S of campground	*Gila orcutti*	LACM 56893-1
September 22-23, 2008	384	Devil's Hole	*Gila orcutti*	LACM 56868-1
September 22-23, 2008	279	Warm Springs	*Gila orcutti*	LACM 56867-2
September 22-23, 2008	37	Above the Forks Dam	*Lavinia exilicauda*	(LACM 56864-3, 23 specimens; LACM 56865-3, 14 specimens)
September 22-23, 2008	1	Above the Forks Dam	*Gila orcutti*	LACM 56864-2, 1 specimen



Mojave River watershed showing survey locations and Mohave tui chub sites mentioned in the text.

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Tortoise on Roads in Mojave Preserve

The Desert Tortoise (*Gopherus agassizii*) is federally listed as threatened under the Endangered Species Act throughout its range in the Mojave Desert west and north of the Colorado River. The tortoise is active in Mojave National Preserve and above ground from mid-March to June with a secondary period of activity from September to October. Tortoises are attracted to paved roads following rainstorms by puddles of water where they are susceptible to being killed by automobiles. Some of the heavily traveled roads in the Preserve pass through high quality tortoise habitat. A north - south stretch of roads is a major thoroughfare connecting the high desert cities of Joshua Tree, Yucca Valley, and Twentynine Palms to Las Vegas, Nevada. We initiated this study to identify “hotspots” where high-speed traffic passes through more densely populated tortoise habitat and to see if warning signs might increase driver awareness.

We used line distance sampling data collected by the U.S. Fish and Wildlife Service (USFWS) in Mojave National Preserve for the years 2001, 2002, 2004, and 2005 to identify potential concentrations of tortoise. We illustrated areas of high live tortoise observations using the kernel density function in ArcMap 9.2 (Figure 1). Note that although this produces units of live tortoises per area it should not be mistaken for actual tortoise densities. Density of tortoises is calculated using the Line Distance methodology for data aggregated by Recovery Unit and is available through the USFWS Desert Tortoise Recovery Office.

The polygons in Figure 1 show transects conducted by contractors for USFWS. The sampling design changed over the years from small squares to paired

Desert tortoises are attracted to highways during rains by puddles of water.

squares (bowties) to large polygons. This was done in an attempt to compensate for very low detection rates of tortoises. Live tortoise observations from the line distance transects are indicated in Figure 1 by green diamond symbols. Contouring of these observations revealed four areas in the Preserve of apparent population concentrations: just north of Kelso, Ivanpah Valley near the northern park boundary, along Essex Road, and near Goffs.

Preserve staff conducted driving and walking road surveys and collected anecdotal observations simultaneously with observations of motorist response to a model tortoise placed along the road edge. Preserve maintenance staff conducted driving transects once per week on all 164 miles of paved roads in the Preserve for the period from April 1 to June 30 and from September 1 to October 31, 2008 during the tortoise active season. Desert Studies Center herpetologist Jason Wallace walked sections of selected road segments in Ivanpah and Fenner Valleys surveying for tortoise and for all signs of road kill. Mojave National Preserve staff has reported anecdotal observations of desert tortoise since 2001 but a significantly increased effort in 2008 resulted in 255 reports, 80 of which had GPS coordinates and could be plotted. These are not scientific since they are opportunistic and depend on where staff tends to go during daily routines, but do give some indication of where tortoises are seen. Our observations as well as contours of the line distance data are shown in Figure 2.

Observations by Preserve staff tend to confirm the area near the intersection of Ivanpah and Morningstar Mine roads as having a concentration of tortoises and also provide supporting evidence for the cluster along Essex Road. But our observations also indicate more tortoises in the area along Kelbaker Road than suggested by the line distance data and fewer tortoises in the Goffs area. In fact the tortoise population near Goffs may have declined significantly over the past few years (Berry 2000).

The sections of paved roads that connect Interstate 40 to Kelso then to Morningstar Mine Road, Ivanpah Road, Nipton Road, and finally to Interstate 15 form a main traffic corridor between Las Vegas and populated areas of Southern California. We collected observations to compare traffic intensity and driver behavior on this heavily traveled thoroughfare, at Morningstar Mine Road, with the more lightly traveled Essex Road that takes visitors to Mitchell Caverns and to the Hole in the Wall Visitor Center. While most of the traffic on Morningstar Mine Road goes through the park from one metropolitan area to another, most of the traffic on Essex Road goes to the park itself.

We gauged motorist response to tortoises on paved roads by placing a medium sized model on the white line along the edge of the pavement in the northbound lane. We observed motorist response to the model tortoise at a point midway on Morningstar Mine Road and on Essex Road. We are confident based on these observations that the model is difficult to distinguish from a real tortoise even up close. We collected 110 observations on Morningstar Mine Road May 5, 2008 and 104 observations on October 11, 2008. Given the fewer cars on Essex Road it took several days to collect a comparable number of observations. We collected 22 observations on May 21, 19 observations on May 22, 29 observations on May 24, 34 observations on May 26, and 13 observations on May 29, 2008. In the fall active season we collected 60 observations on October 12 and 49 observations on October 13, 2008.

These observations are count data of individual automobiles passing the model tortoise placed on the edge of the pavement. If several cars passed in a group only one observation (the lead car) was counted. Motorists that deviated from normal travel either by obvious slowing that was noticed by both of two concealed observers, brake lights coming on, or most commonly, stopping to investigate were counted as reacting to the model tortoise. Several times we observed vehicles pass by without slowing only to turn around and return to investigate. We attached an informational brochure to the bottom of the model and overheard many comments about the issue and our study. Not counting park vehicles, Union Pacific vehicles, or motorcycles, our observations are summarized in the following contingency table.

Contingency Table	Morningstar Mine Road	Essex Road
Reacted to the model	7	34
Did not react to the model	188	172

The difference in motorist behavior between Morningstar Mine Road and Essex Road was significant ($\chi^2 = 16.9$, P = 0.00004).

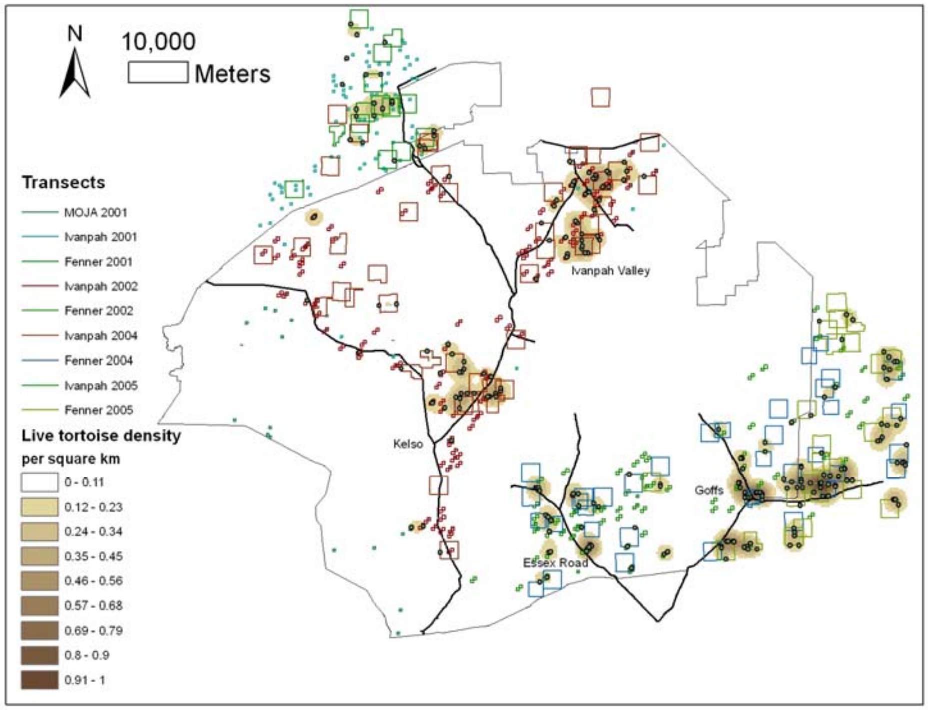

Figure 1. Live tortoise observations taken from U.S. Fish and Wildlife Service Line Distance Sampling data through 2005.

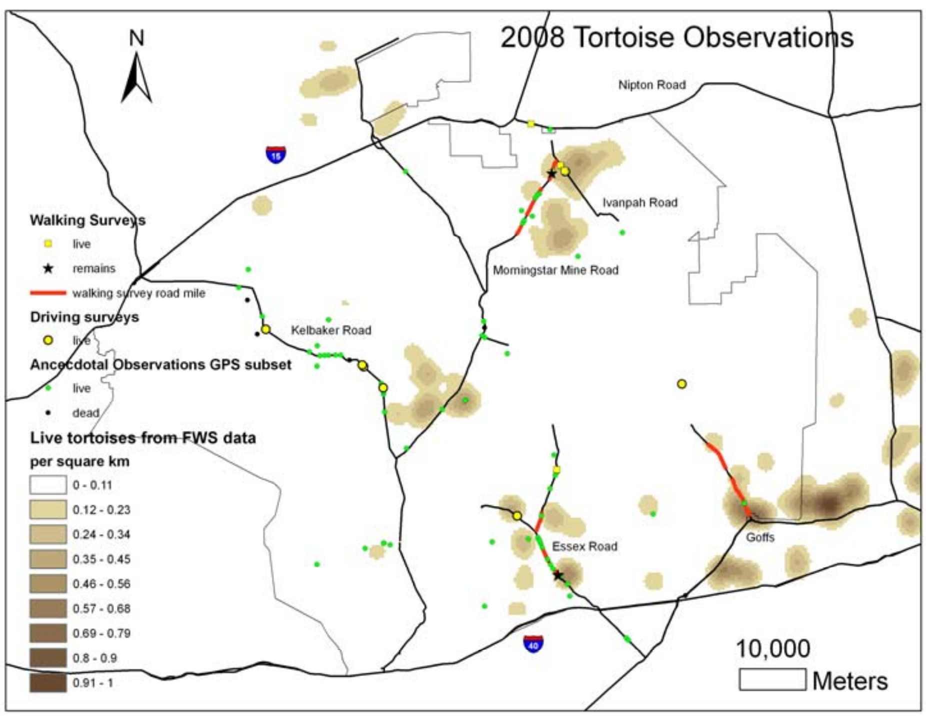

Figure 2. Park observations of desert tortoise in 2008 with contours from U.S. Fish and Wildlife Service Line Distance Sampling data.

The purpose of conducting the model tortoise observations is to test the hypothesis that road signs have an effect on motorist behavior in responding to a tortoise (model) on the road. Starting in April, 2009 we installed warning signs at 4 locations on Kelbaker and Ivanpah roads and will repeat the model tortoise observations.

Figure 3 shows a comparison of traffic speeds on Morningstar Mine Road and Essex Road from Sunday morning, October 12, 2008 through Friday, October 17. During this week 612 cars passed the data collection point on Essex Road at an average speed of 55 mph while on Morningstar Mine Road 2135 cars passed at an average speed of 67 mph. Even more important is the higher speed traffic. On Morningstar Mine Road the 85th percentile was 79 mph with a maximum of 111 mph while on Essex Road the 85th percentile was 71 mph with a maximum of 97 mph. Clearly Morningstar Mine Road is the higher resource protection priority with about three times as much traffic traveling on average 12 mph over the speed limit. Differences between traffic on these roads were reflected in our observations of motorist behavior.

We are also interested in seeing if tortoise populations are depressed adjacent to paved roads and conducted transects parallel to Morningstar Mine Road and Essex Road this spring using the methodology of Boarman and Sazaki (2006).

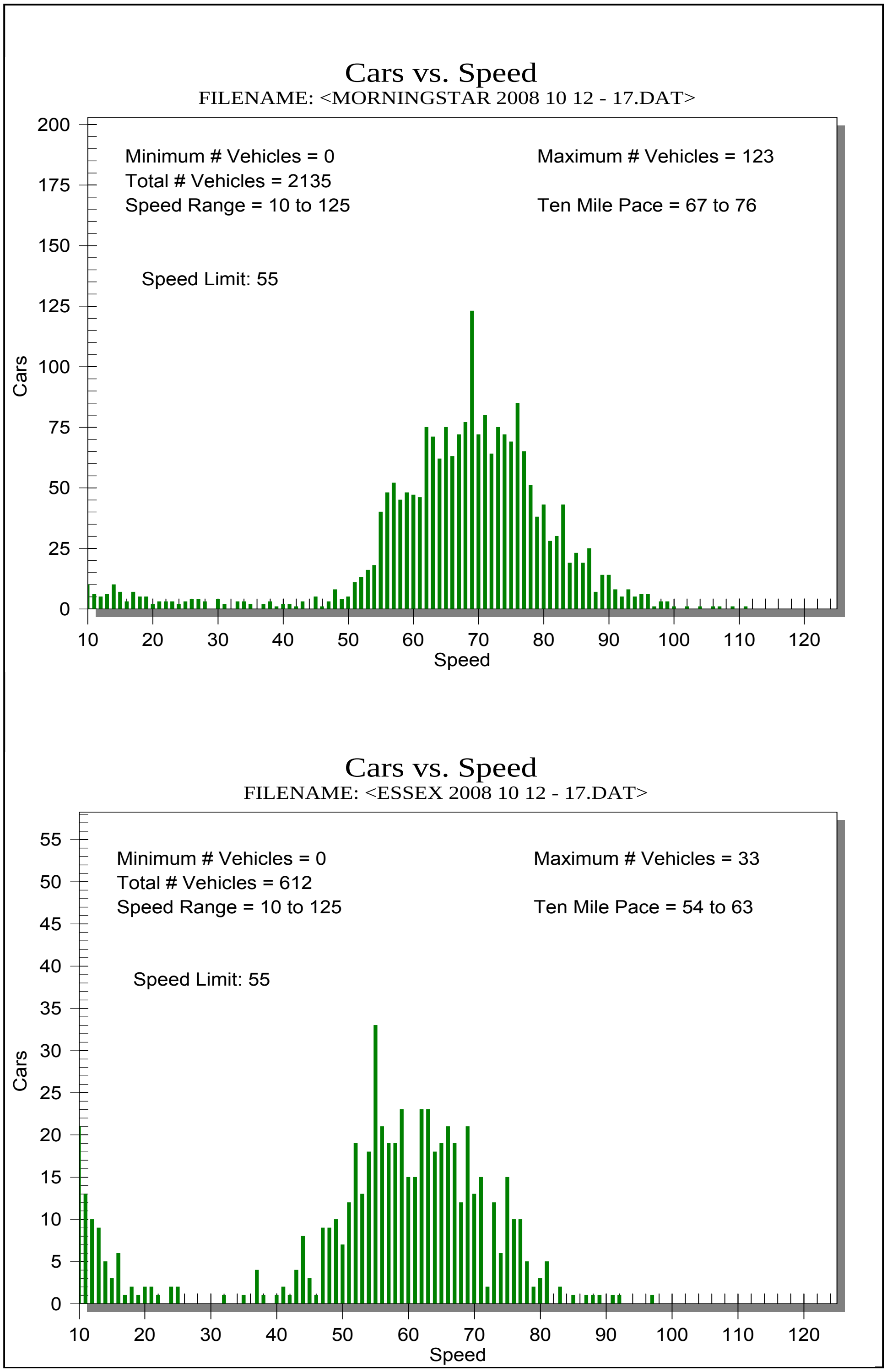

Figure 3. Comparison of traffic speeds on Morningstar Mine Road and Essex Road starting Sunday morning, October 12, 2008 and ending Friday, October 17, 2008.

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Effects of small mammals on post-fire vegetation recovery in the Mojave Desert

The frequency and intensity of fires is increasing in the Mojave Desert driven by invasive annual plants, precipitation variability, and human-caused ignitions. Meanwhile the role that rodents play in vegetation dynamics is becoming increasingly appreciated. The winter of 2004 and 2005 was the wettest on record in the Mojave Desert, followed by a dry summer and strong monsoon. Lightning strikes in late June sparked a wildfire in Mid Hills and Hackberry Mountain that burned over 70,000 acres of Mojave National Preserve. Western National Parks Association funded Dr. Paul Stapp, Associate Professor in the Department of Biological Science at California State University – Fullerton, to study the relationships between small mammals and post-fire vegetation recovery.

Although arid and semiarid ecosystems are usually considered too unproductive to support high fuel loads, episodic wildfires can still have catastrophic effects (Westerling et al. 2003, Brooks et al. 2004, Letnic et al. 2005). In the Mojave Desert, large amounts of rainfall in the winter of 2004-05 resulted in unusually high plant growth, especially at higher elevations. On 22 June 2005, dry lightening strikes ignited a series of large fires in the central Mojave National Preserve (MNP). When these fires, collectively known as the Hackberry Complex Fire (HCF), were finally contained on 27 June, some 31,580 ha had burned, mostly in mixed sagebrush (*Artemesia*)-juniper (*Juniperus*) and other woodland and scrub plant communities.

The Hackberry Complex Fire was the largest recorded for the eastern Mojave Desert, and is expected to have long-lasting effects on the character, management and ecology of this portion of Mojave National Preserve. In particular, there are concerns that fire will facilitate continued invasion by exotic plants (Lovich and Bainbridge 1999). Herbivory by native ungulates and rabbits and granivory by nocturnal rodents may also significantly influence the re-growth of vegetation and, potentially, the spread of exotic annual grasses such as *Bromus rubens* and *Schismus spp.*, which out-compete native plants and are the most important sources of fuels (Brooks 2002). Compared to other arid and semiarid systems (e.g., Schwilk and Keeley 1998, Olson et al. 2003, Letnic et al. 2005), however, the effects of fire on small mammal communities and the role of small mammals in post-fire vegetation recovery in the Mojave Desert are poorly understood. For example, selective granivory can alter local plant communities and the trajectory of desert ecosystems (Brown and Heske 1990). Although rodent species are differentially affected by fire (McGee 1982, Schwilk and Keeley 1998, Esque et al. 2003), individuals that survive the immediate effects of fire may accumulate in remnant unburned patches, resulting in high population densities and a greater impact on local plants and seed resources. In theory, the high densities of rodents may also impose high foraging pressure on plants and seeds in the adjacent burned areas, which, depending on the source of new seeds and the relative preference of rodents for exotic vs. native species, may result in very different plant communities near the edge than farther into the burn. Understanding the effects of fire on species composition and relative abundance of small mammals, and the spatial pattern of foraging behavior and seed removal, may have important implications for the use of fire as a tool to control exotic plant invasions and for the re-establishment of native desert plant communities following catastrophic fire.

I studied the effects of fire-mediated changes in habitat and resources on the abundance and foraging activity of small mammals, and on their possible effects on post-fire vegetation recovery of vegetation in sagebrush-juniper vegetation in Mojave National Preserve. The specific objectives of the project were to determine:

- relative abundance and community attributes of small mammals in burned and unburned areas of sagebrush-juniper vegetation, and examine how these change across the transition (edge) between burned and unburned vegetation;
- the pattern of seed removal by small mammals across the burn edge to estimate potential impact of granivores on the seed bank;
- the effects of small and large herbivores and granivores on vegetation recovery in burned areas compared to the burn edge.

Field work on the project began in May 2006, 11 months after the Hackberry Complex Fire, and, except for the ongoing experimental studies of vegetation recovery, was completed by August 2007. Most of the field work was conducted by a former California State University – Fullerton Master's student (C. Moore).

The research site was in the Mid Hills region of Mojave National Preserve, California (35º9' N, 115º23' W), at elevations between 1500-1600 m. Mean annual precipitation at the nearby Mid Hills Campground is 264 mm, with a mean winter daily minimum and summer daily maximum of 3.2°C and 34.3°C, respectively. Most precipitation falls during the winter months (November–March), although there are often summer thunderstorms as well. The dominant vegetation is big sagebrush (*Artemisia tridentata*) and Utah juniper (*Juniperus osteosperma*). Other abundant perennials include desert bitterbrush (*Purshia tridentata*), Nevada ephedra (*Ephedra nevadensis*), banana yucca (*Yucca baccata*), threadleaf snakeweed (*Gutierrezia microcephala*), and turpentinebroom (*Thamnosma montana*), as well as a number of forbs and grasses. Abundant annuals include western tansymustard (*Descuraina pinnata*), birdnest buckwheat (*Eriogonum nidularium*), storksbill (*Erodium cicutarium*), Fremont's phacelia (*Phacelia fremontii*), bristly fiddleneck (*Amsinckia tessellata*), desert globemallow (*Sphaeralcea ambigua*), desert allysum (*Lepidium fremontii*), rose heath (*Chaetopappa ericoides*), and cushion cryptantha (*Cryptantha circumscissa*).

In May 2006, four study plots were established at edge of the Hackberry Complex Fire. Plots were 1.60 ha (80 x 200 m), with the long axis perpendicular to and centered on the edge of the burn. Plots were at least 100 m away from each other and roads. Trapping grids (5 x 11; 55 stations) were established on each plot to estimate relative abundance and diversity of nocturnal rodents. One extra-long Sherman live-trap was placed at each station, which were 20 m apart (Figure 1). Traps were baited with irradiated birdseed at dusk and checked at dawn. Trapping sessions were 4 consecutive nights. Each individual captured was marked with a uniquely numbered aluminum ear tag and released. All animal handling procedures were approved by the Institutional Animal Care and Use Committee at California State University – Fullerton.

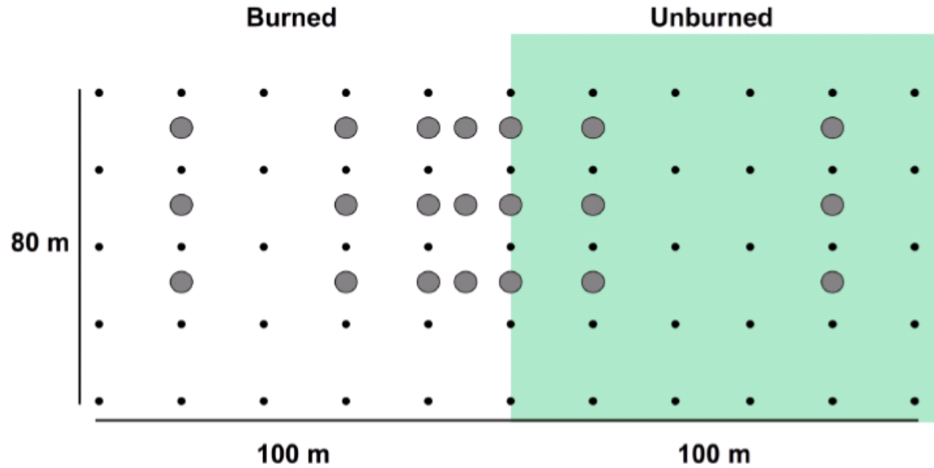

Figure 1. Layout of 1.60-ha plots in sagebrush-juniper vegetation in high-elevation Mojave Desert. The small black circles represent trap stations spaced 20 m apart (80 x 200 m grid), for a total of 55 Sherman live traps per plot. The larger gray circles indicate locations of seed trays placed 80, 40, 20, and 10 m into the burn, at the burn-unburned edge, and 20 and 80 m into the unburned vegetation..

Two trapping sessions were conducted on each plot from June–August 2006 and May–August 2007, for a total of 3,520 trap-nights. On each plot, trapping sessions were conducted during full and new moon periods to account for differences in rodent activity associated with moonlight. I used the number of unique individuals captured in each location (burned, 40-100 m, trap rows 1-4; edge, 0, +20 m, traps 5-7; burned, 40-100 m, traps 8-11) and plot during each trapping session, based on their location of first capture, as an estimate of relative abundance. In addition, four smaller grids (5 x 4 stations at 20-m intervals) were established in an area of Joshua tree woodland that also burned during the Hackberry Complex Fire. Two plots were in burned vegetation and two were in unburned vegetation, with plots approximately 100 m apart. These grids were trapped twice between June and August 2006, with the goal of comparing rodent communities in burned and unburned areas of Joshua tree woodlands to that in sagebrush vegetation.

To determine spatial patterns of seed removal across the sagebrush burn transition, foraging activity was measured in artificial seed trays placed in three parallel transects, 20 m apart and perpendicular to the burn edge, on each of the 4 large study plots. Trays were placed at 80, 40, 20 and 10 m into the burn, at the edge of the burn (0 m), and at 20 and 80 m into unburned sagebrush vegetation (Figure 1), for a total of 21 trays per plot. Seed trays were plastic plant saucers (36 cm diameter, 4 cm deep) filled with 2 L of pre-sifted sand. Trays were set at dusk by mixing 4.00 g of irradiated millet into the sand, and smoothing the surface so that foraging activity could be detected. Trays were collected at dawn and the sand was sieved to collect the remaining seed, which was weighed to estimate the amount of seed removed. On each plot, trays were set for 2 consecutive nights during full and new moon periods in June and July 2006. The difference between the first and second night reflect the time needed for rodents to discover seed trays, which would be expected to be longer on Night 1, i.e. fewer trays would be discovered, especially if moonlight reduced aboveground foraging activity.

To determine the effects of herbivores and granivores on vegetation recovery, in March 2007 exclosures were established on 2 of the sagebrush study plots, as well as one new plot that crossed the boundary of the Wildhorse Fire (WHF), which burned sagebrush-juniper vegetation in July 2002 in the same area. Exclosures were constructed of 1.3 cm mesh hardware cloth and were 60 x 60 cm (0.36 m^2) and 30 cm high. The exclosure walls were buried 10 cm into the ground. Three different types of exclosures were used. One (N) had solid walls and a roof to exclude all herbivores, including rodents, rabbits, deer and cattle. Another (R) was similar to N but had two 8 x 8 cm holes on each wall, which excluded larger herbivores but allowed access to large rodents (*Dipodomys panamintinus, Neotoma lepida*). The third type (C) was a control that was similar to R but without a roof, to permit access to all herbivores while mimicking any effects of the exclosure walls.

Exclosures were placed at the burn edge and 100 m into the burn on each plot. Five stations, each 20 m apart, were established at each location. Each station had one of each type of exclosure, set at random locations approximately 2 m apart. Therefore, there were a total of 10 exclosures of each type at the edge and burn locations of the Hackberry Complex Fire plots, and 5 exclosures of each type at the edge and burned locations on the Wildhorse Fire plot.

Vegetation in exclosures was measured beginning in May 2007 and has continued intermittently since. Percent canopy cover, number of individual plants and species richness was measured in a 40 x 40 cm (0.16 m^2) quadrat in the center of each exclosure. The effects of small and large herbivores was estimated by comparing plant percent cover, plant density and species richness between exclosures and controls that were accessible to all herbivores. The difference between N and C exclosures reflected the effects of all herbivores on vegetation; the difference between R and C exclosures was used to estimate the effects of large herbivores only; and the difference between N and R exclosures estimated the effects of rodents. To account for local effects, differences were calculated for each set of exclosures (station) during each sampling period; statistical analyses were conducted on mean differences. Data from May 2007, only ~1 month after exclosures were in place, were excluded from statistical analyses. Because sample size (n=5 per type) and therefore, power, was low for Wildhorse Fire plots, I used $\alpha = 0.10$ to evaluate whether results were statistically significant. Here, I focus on percent cover and species richness as response variables.

Heteromyid rodents were the most abundant species captured in sagebrush areas, with *D. panamintinus* (DIPA) and *D. merriami* (DIME) representing 65% and 12% of the 428 individuals captured. Three species of *Peromyscus* (*maniculatus, crinitus, truei*), here considered collectively (PESP), were the most abundant cricetids (14% of individuals), followed by *N. lepida* (6%). *Perognathus longimembris* (PELO) and *Onychomys torridus* (ONTO) made up the remaining 3% of individuals. The rodent community in Joshua tree woodlands was similar, except that *D. merriami* was more abundant than *D. panamintinus*, and that a single *Chaetodipus*, identified in the field as *C. penicillatus*, was also captured. No voucher specimens were prepared.
By all three community metrics examined (N0, N1, N2), rodent diversity was highest in unburned vegetation, intermediate at

Table 1. Mean abundance (N) and community diversity indices (species richness N0; Hill's N1; Hill's N2) on 4 1.60–ha study plots that spanned the transition from burned to unburned sagebrush in 2006 and 2007. For comparison, results from trapping in burned and unburned Joshua tree woodlands in 2006 are also included.

Vegetation/ year/variable		Burn (40-100 m)	Edge (±20 m)	Unburned (40-100 m)
Sagebrush (n=4 plots)				
2006				
	N	10.25 (1.80)	7.75 (0.48)	10.75 (1.80)
	N0	3.00 (0.41)	3.00 (0.00)	4.25 (0.48)
	N1	1.91 (0.35)	2.63 (0.15)	3.49 (0.37)
	N2	1.60 (0.25)	2.47 (0.19)	3.12 (0.31)
2007				
	N	12.25 (0.48)	6.25 (0.75)	8.00 (0.82)
	N0	2.00 (0.71)	2.25 (0.25)	3.75 (0.25)
	N1	1.38 (0.22)	1.65 (0.19)	3.31 (0.28)
	N2	1.23 (0.13)	1.45 (0.16)	3.06 (0.29)
Joshua tree (n=2 plots)				
2006				
	N	25.50 (1.50)	-	13.50 (0.50)
	N0	4.50 (0.50)	-	4.00 (0.00)
	N1	2.38 (0.47)	-	3.23 (0.15)
	N2	1.90 (0.38)	-	2.89 (0.11)

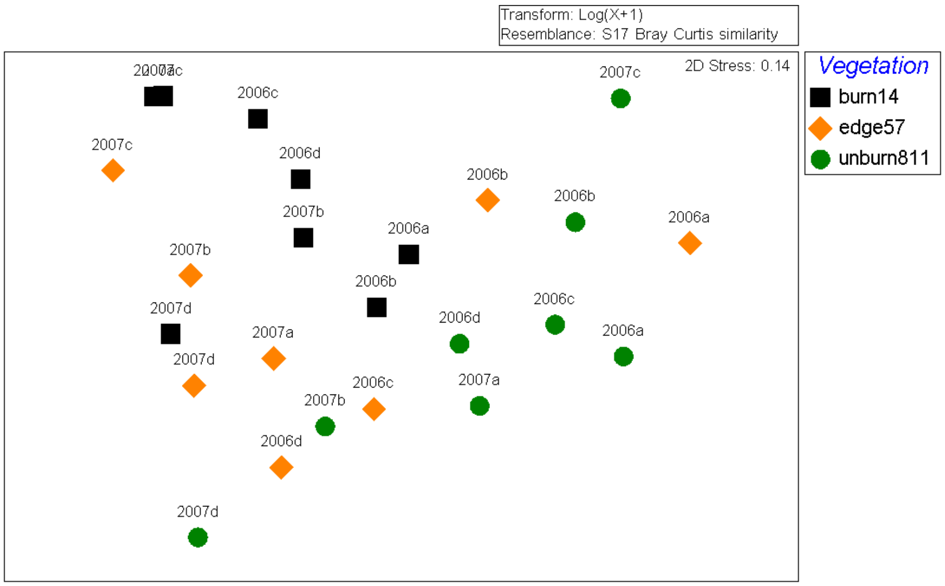

Figure 2. MDS plot showing the relationships between rodent communities in burned, edge and unburned sagebrush in 2006 and 2007. Each point represents a different plot (a-d), taking the mean of numbers of individuals caught during trapping sessions within a year.

the edge, and lowest in the burn (Table 1). For all three indices, diversity was significantly higher in unburned vegetation than at the edge and burned areas (ANOVA, P<0.003), which were not significantly different from each other. Rodent diversity was significantly higher in 2006 than 2007 for all three vegetation types (P<0.020). Graphically, a non-metric multidimensional scaling (MDS) plot, followed by an analysis-of-similarity (ANOSIM) in PRIMER (Clarke and Gorley 2006), indicated significant clustering of rodent communities both by year (P=0.011) and vegetation type (P=0.001; Figure 2), revealing that community structure differed among vegetation types. Rodent diversity in unburned sagebrush was similar to that in unburned Joshua tree woodland (Table 1), but burned areas of Joshua tree woodlands retained higher rodent diversity than in burned sagebrush.

In both years, DIPA was the only species captured in high numbers in burned sagebrush areas (Figure 3), and their abundance generally declined toward the edge of the burn and in unburned vegetation, especially in 2007. DIME was most abundant at the edge and in unburned vegetation (Figure 3). Cricetids were more abundant and widespread in 2006 than in 2007, and tended to be restricted to unburned areas.
Rates of seed removal were usually highest on dark, new-moon nights than on full-moon nights, a pattern that was particularly evident in the more open, burned vegetation (Figure 4). On full-moon nights, the amount of seed removed was lowest in the burn, and increased toward the burn edge. In contrast, on new-moon nights, rodents, presumably DIPA, consumed large amounts of seed in the burn (Figure 4). On the first night of trials, significantly more seed was consumed on new- than full-moon nights (ANOVA, P = 0.021), but there was no significant difference between distance categories (P = 0.145). On the second night, when most trays would have been discovered by rodents, more seeds were eaten on new moon nights (P<0.001) and at the burn edge (P=0.002). On Night 2, a significant interaction between moonlight and distance (P<0.001) also indicated significant differences between distances on full-moon nights (Figure 4), but no distance effects on new moon nights (P>0.05).

At the Hackberry Complex Fire burn sites, the consistently positive differences between plant cover in N and C exclosures (Figure 5, top) indicated that

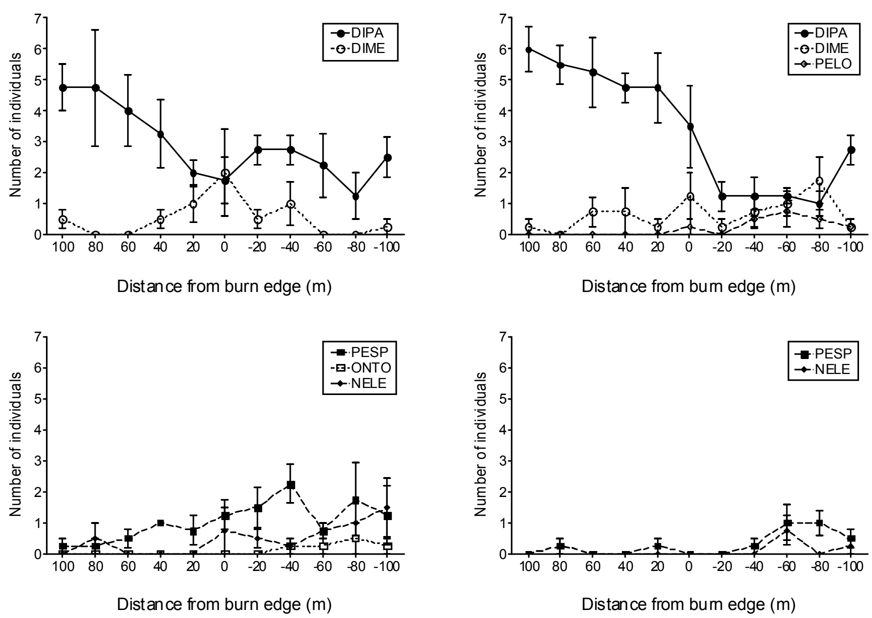

Figure 3. Relative abundance (mean + 1 SE) of rodents with distance along a transition from burned (positive values) to unburned vegetation (negative values) sagebrush vegetation in 2006 (left panels) and 2007 (right panels).

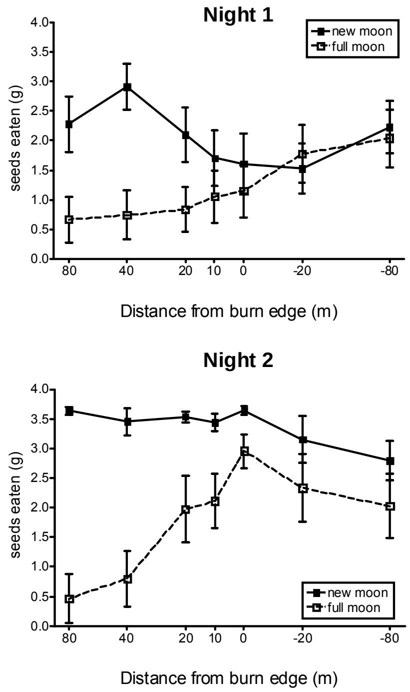

Figure 4. Amounts of seed removed (mean + 1 SE) in 2006 from artificial seed trays with distance from the edge of the HCF burn in sagebrush vegetation. Trials were run for 2 consecutive nights in each season on 4 study plots, with a total of n=9-12 trays per distance class for each moon phase.

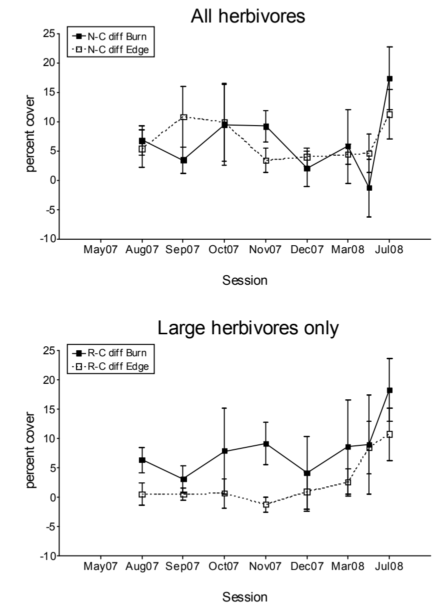

Figure 5. Effects of excluding all herbivores (top) and large herbivores only (bottom) on percent cover of plants 100 m into the 2005 HCF and at the fire's edge. Effects were calculated as the difference between N and C exclosures, and R and C exclosures, respectively. Values are means + 1 SE.

herbivores collectively significantly reduced plant cover by approximately 7% during the study period (paired t-tests, N-C; P<0.05). The effects were similar in the burn and at the edge (P=0.947; Figure 5). In contrast, excluding large herbivores only (R-C) significantly increased plant cover in the burn (P=0.035), but not at the edge (P=0.151; Figure 5, bottom), and the difference in plant cover between R and C exclosures was consistently higher in the burn (P=0.030). This could have resulted from higher foraging activity of large herbivores in the burn; however, the effect of rodents (N-R) was also significantly higher at the edge than in the burn (P<0.001; Figure 6, top left), which likely contributed to lower cover in both R and C exclosures. Excluding both large and all herbivores combined reduced species richness in the burn relative to the edge (P<0.034), suggesting that herbivores may mediate competition between plants. In contrast, rodents had little effect on plant species richness in either the burn or at the Hackberry Complex Fire edge (N-R, P=0.450; Figure 6, top right).

Herbivores, and especially rodents, had markedly different effects at the older, Wildhorse Fire burn site. Excluding all herbivores significantly increased plant cover and species richness vs. controls in the burn (P<0.076), but not at the edge (P>0.209). Excluding only large herbivores had no significant effect on plant cover or species richness, either in the burn or at the edge (P>0.10). Whereas the effect of rodents on plant cover was greater at the edge than in the burn at the Hackberry Complex Fire (Figure 6, top left), at the Wildhorse Fire site this pattern was reversed, with the exclusion of rodents resulting in an increase in cover in the burn, but decreased cover at the edge (P=0.009; Figure 6, bottom left). Similarly, excluding rodents increased plant species richness in the burn, but decreased it at the edge (P=0.012; Figure 6, bottom right).

Because field work on this project began in May 2006, some 11 months after the Hackberry Complex Fire, it is not possible to know how much mortality of small mammals was caused directly by the fire. Nonetheless, despite the near absence of perennial vegetation, rodents inhabited the burned sagebrush areas in relatively high numbers. *Dipodomys panamintinus* was the only species captured consistently far into the burn, although it was also present in lower numbers at the edge and in unburned areas. Assuming that, prior to the fire, rodent communities in the burn were similar to those in the unburned vegetation, cricetids and notably, *N. lepida*, likely suffered most from the fire. This was particularly true in 2007, when populations of most species and rodent diversity were much lower than in 2006. The difference between years may be due to worsening resource conditions during the 2 years after the fire, or may simply reflect inter-annual variation in resource availability and therefore rodent productivity.

By all community indices examined, the Hackberry Complex Fire significantly reduced rodent diversity compared to the unburned sagebrush. Diversity was somewhat higher at the edge than 100 m into the burn, but the edge community more closely resembled that in the burn than in the unburned vegetation, where cricetids were dominant and diversity was consistently highest. *Dipodomys merriami*, a smaller kangaroo rat that would be expected to be competitively subordinate to *D. panamintinus*, tended to be most abundant at the edge, possibly responding to the decline in abundance of its larger congener near the edge, especially in 2007.

Although species composition clearly differed between the edge and burned and unburned areas, combining all

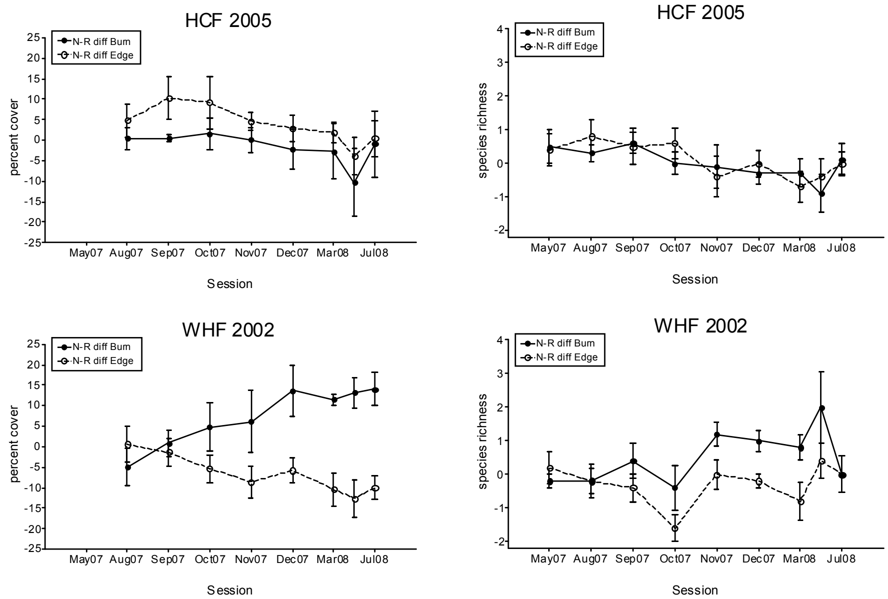

Figure 6. The effect of small rodents on percent cover (left panels) and plant species richness (right panels) in the burn and at the burn edge in the sagebrush vegetation affected by the Hackberry Complex Fire (HCF) in 2005 and the Wildhorse Fire (WHF) 3 years earlier. The effects of rodents were calculated by subtracting values from wire cages excluding large herbivores (R) from those excluding all herbivores (N). Values are means + 1 SE.

species, total rodent abundance varied little across the study plots. Presumably as a result of the high numbers of *D. panamintinus* in the burn, there was surprisingly little variation in seed removal on dark, new-moon nights between burned, edge and unburned vegetation. Even seeds 80 m from the unburned refugia were discovered and consumed on dark nights. However, indirect effects of the Hackberry Complex Fire on rodent foraging activity were apparent on full-moon nights, when significantly fewer seeds were removed in the burn. This difference can probably be attributed to the loss of protective overhead cover as a result of the fire, which could make rodents more sensitive to predation risk on brightly lit nights (e.g. Price et al. 1984, Longland et al. 1991). Because potential granivores were abundant at all distances from the burn edge, it seems likely that the increasing seed removal rates with decreasing distance into the burn reflects the tendency of rodents living at the edge or in unburned vegetation to not wander far from the safety of the edge on full-moon nights.

The extent and mechanisms by which small mammals influence vegetation recovery following fires in high-elevation sagebrush habitats are not yet clear, and this aspect of the project is ongoing. However, results thus far from my exclosure experiments suggest that large herbivores and granivores influence both plant cover and species richness. Excluding herbivores consistently led to increases in plant cover in both the burn and at the edge. The high rates of seed removal observed at the edge during seed tray trials may be translated into larger effects of rodent exclusion on plant cover near the Hackberry Complex Fire edge than in the burn itself, though plant species richness was not different. In addition, the effects of rodents were more pronounced on the 2002 Wildhorse Fire, suggesting that, given the low productivity of the Mojave Desert, it may take several years to observe significant changes in plant responses to herbivores and granivores. In particular, the relative decrease in cover and plant species richness in rodent exclosures at the edge suggests some positive effects of rodents that are only manifest over longer periods.

In conclusion, I found that granivorous rodents continued to live in high numbers in the burned areas of the Hackberry Complex Fire and that, at least on dark nights, rates of seed removal were comparable to those near the edge of the unburned vegetation. This suggests that, for restoration efforts, planting seeds far into a burn does not necessarily make them safer from granivores. Combining across nights, however, the higher rates of seed removal at the edge, combined with the diversity of small mammals in remnant unburned patches, implies that seeds and seedlings planted near the edge of a fire may be at greater risk of consumption or caching. Ultimately, rodents may have a facilitative effect on plant recovery, as suggested by results from the Wildhorse Fire exclosure experiments, though it is not known if these effects benefit native or exotic plant species more. Unfortunately, data on the plant percent cover and density were not collected separately for each species, information that is critical to determine if there are differences in species composition, and especially in the abundance of exotic species, between exclosures. Future sampling of plant responses in exclosures will examine possible differences in plant species composition between exclosures, as well as between the burn and edge.

Acknowledgements

C. Moore collected field data in 2006 and 2007 and erected the exclosures. Y. Atallah and R. Fulton assisted with plant identification. J. Kraft assisted with field work. Funding was provided by Western National Parks Association, California State University, and the Department of Biological Science at California State University – Fullerton.

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Resource Management Issue: Sahara Mustard

Sahara mustard (*Brassica tournefortii*) has become a major threat to rare and endemic sand dune ecosystems in Mojave National Preserve following an exceptionally wet spring in 2005. Sahara mustard may increase fuel loads and fire hazard in desert scrub (Brooks et al. 2003). Dense stands appear to suppress native vegetation and wildflowers. In some areas following a cool, wet spring mustard can become so dense as to be difficult to walk through. Sahara mustard appears to be advancing into the Preserve from the south and west through the sand dunes of Devil's Playground towards Kelso Dunes, one of the most scenic geologic features in the Preserve and habitat for rare and endemic desert vegetation.

Sahara mustard is native to semi-arid and arid deserts of North Africa and the Middle East, as well as Mediterranean lands of southern Europe. It was apparently uncommon in the deserts of southern California until recently. Above average rainfall from 1977 through 1983 may have caused a significant population expansion and the species became abundant in southeastern California (Sanders and Minnich 2000). It is most common in wind-blown sand deposits and disturbed sites. Because of its early phenology, it is a winter annual forb that responds to fall and winter cool season rains, it appears to monopolize available soil moisture as it builds canopy and sets mature seed before many native species have begun to flower. Dependence on the timing and magnitude of winter rain results in highly variable and difficult to predict distributions from year to year.

Mechanical treatments consisting of hand pulling and hoeing are labor intensive, effective only on a small scale, and can cause significant ground disturbance. *Brassica tournefortii* has a taproot which can be pulled with no resprouting but is difficult to hand pull when the plant is in its basal rosette stage. Plants must be bagged and removed if hand pulling is conducted during early to late seed pod development. Partial efforts that result in lower densities of plants, but not complete eradication, may conversely lead to increased net seed production (Trader et al. 2006).

Mojave National Preserve is interested in

Sahara mustard invasion in the sand dunes near Rasor, south of Zzyzx, California. Photo taken March 12, 2008.

research projects that will improve our understanding of the ecological effects of invasive species and lead to effective management techniques. Although many exotic species exist in the Mojave Desert, the rapid expansion of Sahara mustard into sand dune areas with spectacular native wildflower blooms has heightened concern.

Will predicted warming, drying, and increased variability of precipitation resulting from climate change promote a shift from native annuals to exotic annuals, such as Sahara mustard and red brome? Are there control methods that could take advantage of the early seasonal development of this plant while avoiding harm to native vegetation? Mojave National Preserve resource managers would be interested in proposals, ranging from annual monitoring by students and field classes, or volunteer seasonal control efforts, to multiyear research efforts on chemical and biological control agents. Send research ideas and proposals to Debra Hughson (debra_hughson@nps.gov).

As a federal partner of the Cooperative Ecosystem Studies Units (CESU) (http://www.cesu.psu.edu/) we are able to work with academic scientists to seek funding for research on resource related conservation efforts. Contact Angie Evenden (Angela_Evenden@nps.gov) for information about the CESU system.

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