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Effects of Geophysical Survey Energy Sources on Kangaroo Rat Abundance

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Abstract.—We assessed the effects of geophysical (i.e., seismic) survey energy sources on local kangaroo rat abundance on study sites in the Lokern area of California. Seismic surveys are routinely conducted in this region where several rare kangaroo rat species occur. We monitored kangaroo rat abundance by live-trapping on three study plots: one subjected to a "vibroseis" energy source, one subjected to a "shot-hole" energy source, and one control. Compared to capture rates prior to the simulated seismic surveys, rates were higher immediately after and one month later on all plots. Trends in rates were nearly identical on all three plots indicating that the seismic energy sources had no detectable effects on abundance. Although we did not detect adverse effects during this simulated survey, potential impacts also should be assessed during an actual full-scale seismic survey.

Key Words.—capture rate; *Dipodomys*; gas; oil; seismic survey; shot-hole; vibroseis

Introduction

Over 95% of the San Joaquin Valley floor in California has been converted from native habitat to urban sprawl or agricultural land (USFWS 1998). A large portion of the remaining area has been developed by the petroleum industry for oil and gas production (US Fish and Wildlife Service [USFWS] 1998). Since the early 1900s, the San Joaquin Valley has experienced substantial physical alteration of its natural environment from oil and gas exploration, drilling, and extraction.

Oil and gas exploration often occurs in the form of geophysical, or seismic, surveys. Geophysical surveys are routinely conducted in areas with potential hydrocarbon resources in an effort to locate crude oil and natural gas reserves. These surveys are conducted by generating energy waves that reflect off of subterranean strata (Milligan 2004). Two common methods of creating these energy waves include generating strong vibrations ("vibroseis") and detonating a buried explosive charge ("shot-hole;" Milligan 2004). The seismic images produced by the resulting energy waves are recorded by geophones to produce an underground map of oil and gas deposits. Some of these deposits are chosen for drilling and extraction.

The effects of drilling and resource extraction processes on wildlife have been well documented. Such effects can include habitat loss, disturbances associated with noise and activity from production operations, exposure to toxins, and entrapment and drowning in spilled oil or waste water from wells (Flickinger 1981; Kaplan et al. 1996; Cypher et al. 2000, Lyon and Anderson 2003; Ingelfinger and Anderson 2004; Trail 2006; Ramirez 2010). However, the effects of geophysical surveys have not been well studied. Because these surveys involve the generation of subterranean energy waves, fossorial animals may be particularly vulnerable to effects. The objective of this project was to determine the effects of two common forms of exploratory seismic surveys on semi-fossorial mammals, particularly kangaroo rats (*Dipodomys* spp.). In the San Joaquin Valley, seismic surveys are routinely conducted in habitats occupied by kangaroo rats, including several rare species.

Methods

Study area.— We studied the effects of exploratory seismic surveys in the Lokern Natural Area in western Kern County, California (35.43N, 119.62W; Fig. 1). The study area encompassed approximately 47 ha consisting entirely of the U.S. Bureau of Land Management land. The Lokern Natural Area is within a region considered to be important habitat for federally listed species such as San Joaquin Kit Fox (*Vulpes macrotis mutica*), Blunt-nosed Leopard Lizard (*Gambelia sila*), and Giant Kangaroo Rat (*D. ingens*; USFWS 1998).

Vegetation on the three plots was a mosaic of arid shrubland and annual grassland. The predominant natural community in the study area was Valley Saltbush Scrub (Holland 1986). This community is characterized by open shrublands with a forb understory comprised of annual plants representative of Non-native Grassland (Holland 1986). Common shrubs on the plots included Desert Saltbush (*Atriplex polycarpa*) and Russian Thistle (*Salsola tragus*). Other plant species included Red-stemmed Filaree (*Erodium cicutarium*), Red Brome (*Bromus madritensis* ssp. *rubens*), and Arabian Grass (*Schismus arabicus*).

Field methods.—From 15 October 2008 to 21 November 2008, we conducted small mammal surveys to census and mark small mammals on the study plots. On each plot we established a grid of 60 trap stations (5 × 12 pattern) with 10-m spacing, and placed a 7.6 × 8.9

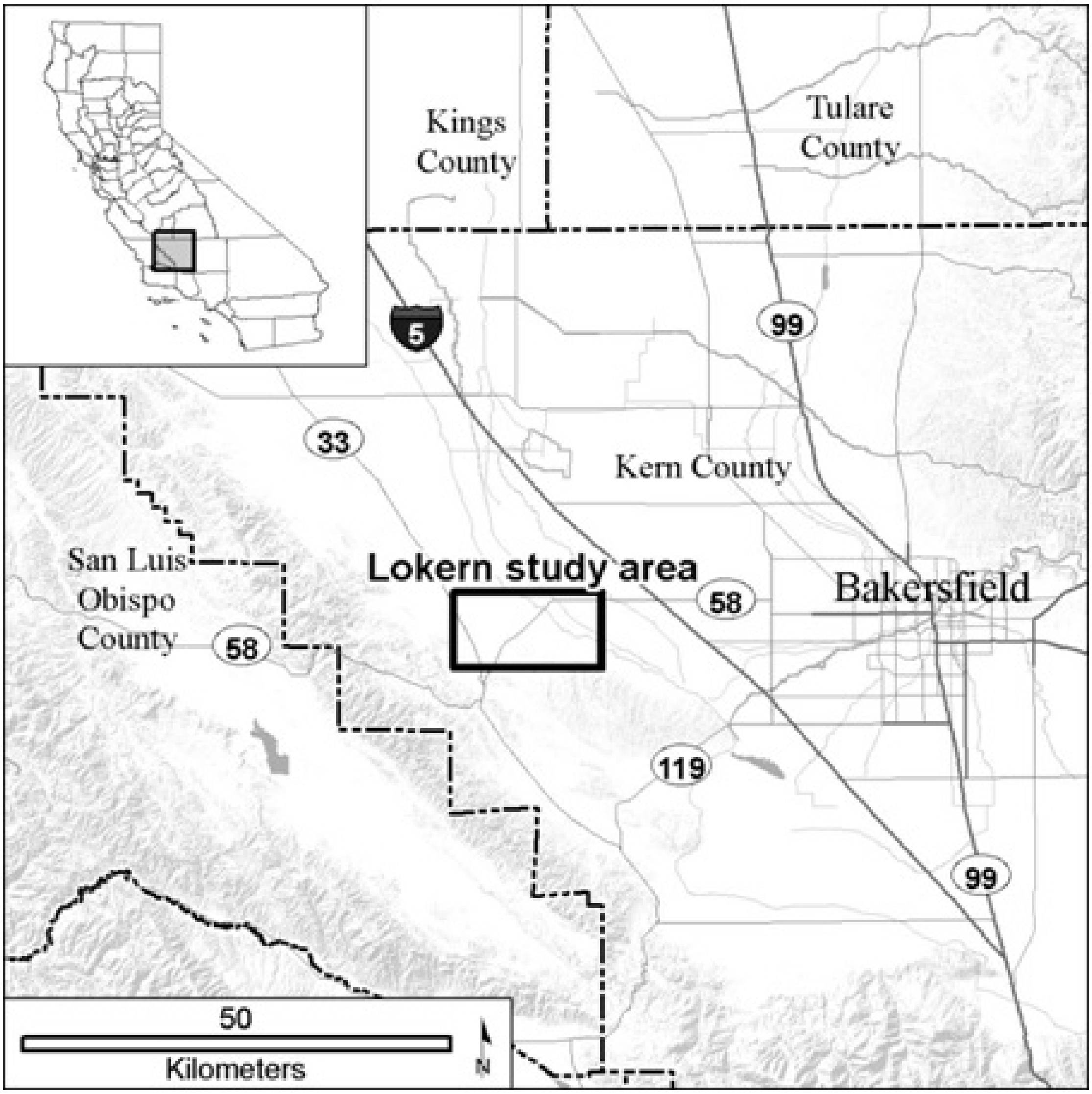

Figure 1. Location of the Lokern study site in the San Joaquin Valley, California used to study the effect of seismic activity on abundances of kangaroo rats (*Dipodomys* spp.).

× 33.3-cm Sherman live trap (model XLKR; H.B. Sherman Traps, Tallahassee, Florida) at each station. The grids were approximately 100 m apart to reduce the potential for treatments to affect other plots and for individual rodents to use more than one plot. We trapped small mammals on each plot for four nights just prior to vibroseis and shot-hole activities (beginning 14 October 2008), two nights immediately after (beginning 22 October 2008), and four nights four weeks after (beginning 18 November 2008) seismic activities. We marked all individuals captured for the first time with a numbered eartag (1005 size 1 monel; National Band and Tag Co., Newport, Kentucky).

Seismic exploration events (shot-hole and vibroseis) were simulated by personnel of Occidental Petroleum on two of the study plots with the third site serving as a control where no activity occurred. Shot-holes were drilled to a depth of 6.1 m and a 1-kg charge of Geoprime dBX pentolite (Dyno Nobel Inc., Salt Lake City, Utah) was placed down hole to be detonated. A total of 10 shot-holes were drilled at 34-m spacing along the edge of one study plot. Charges were detonated sequentially at ca. 5-min intervals. We established 10 vibroseis points at 34-m spacing along the edge of a second plot. One 22,246-kg vibroseis truck was used operating at an 80% drive level for 10 s at each point. Each linear sweep was 10 s in duration and ranged from 8-100 Hz. We located the lines of shot-holes and vibroseis points ca. 10 m from the edge of their respective trapping plots. Shot-hole detonations and vibroseis were conducted between late-morning and mid-afternoon when small mammals were down in burrows. We watched for any animals appearing above-ground during the activities. After the conclusion of the simulated seismic surveys, we immediately inspected nearby small mammal burrows for collapse or damage.

Statistical analysis.—We compared the abundance of kangaroo rats between trapping before seismic activity and one month later and among vibroseis, shot-hole, and control plots using contingency table analysis ($\alpha = 0.05$).

Results

We restricted our analyses to kangaroo rat species because we did not capture the other small mammal species in sufficient numbers to include them. Kangaroo rat species we captured included Giant Kangaroo Rats (federally and state-listed as endangered), Heermann's Kangaroo Rats (*D. heermanni*), and Short-nosed Kangaroo Rats (*D. nitratoides brevinasus*; federal species of concern, state Species of Special Concern). Other species we captured were North American Deermice (*Peromyscus maniculatus*) and Tulare Grasshopper Mice (*Onychomys torridus*).

Across all trapping sessions, we caught 39, 63, and 105 individual kangaroo rats on the vibroseis, shot-hole, and control plots, respectively (Table 1). Capture rate trends for the three sessions were virtually identical on all three plots (Fig. 2). Capture rates increased markedly during the "after" trapping session. The capture rates for the "one month" session were slightly higher than the "before" session rates on all three plots. Changes in the number of individuals captured between the initial session and one month later did not differ among plots ($\chi^2 = 0.02$, 2 df, $p = 0.99$). The proportion of recaptured individuals after one month on the vibroseis, shot-hole, and control plots was 60%, 85%, and 79%, respectively, and did not differ among plots ($\chi^2 = 3.22$, 2 df, $p = 0.20$). We did not observe small mammals exiting burrows after shot-hole detonation or during the vibroseis survey, and we did not detect any physical damage to small mammal burrows near the seismic survey sample points, including several burrows that were within 1 m of shot-holes.

Table 1. Total number of individual kangaroo rats captured on each study plot during each trapping session during simulated seismic survey activity in the San Joaquin Valley, California, in 2008. The number of recaptured marked individuals is given in parentheses.

	Trapping session		
Plot	**Before**	**After**	**1 month**
Vibroseis	12	12 (9)	15 (9)
Shot-hole	16	25 (13)	20 (17)
Control	29	37 (34)	38 (30)
Trap nights/plot	240	120	240

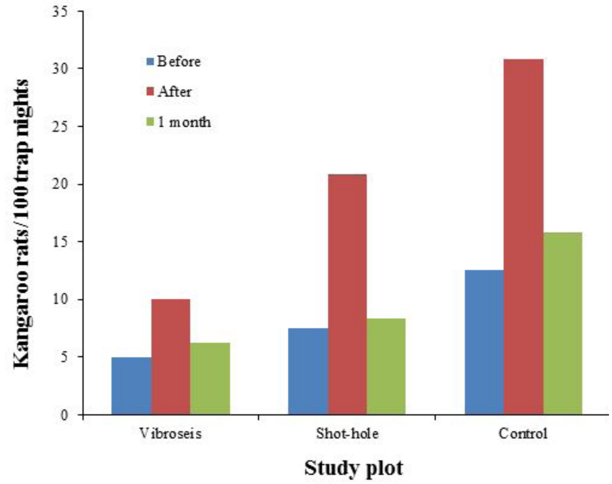

Figure 2. Number of kangaroo rats trapped per 100 trap nights during three trapping sessions on three seismic survey study plots in the Lokern area of Kern County, California, in 2008.

Discussion

We did not detect any immediate or long-term impact to kangaroo rat abundance from the simulated seismic surveys. Population reductions could have resulted from direct mortality due to energy sources or burrow collapse, or from indirect mortality due to physical impairment (e.g., inability to forage, increased predation) or emigration. However, capture rates on all three study plots were higher both immediately after the simulated seismic surveys and one month later. We suspect that the marked increase in rates immediately after the surveys may have been an artifact, as capture rates for kangaroo rats commonly increase during a trapping session as additional animals discover, habituate to, and enter traps. We observed this same trend within sessions. The "after" trapping session commenced just five days following the conclusion of the "before" session, and so animals were probably still habituated to the traps, resulting in the high capture rates. The decrease in rates by the "one month" session likely reflects a decline in habituation and not a decline in abundance because the rates were still higher compared to the "before" session. Regardless of the reasons for the variation in capture rates, the trends were nearly identical on all three plots, indicating that the differences were attributable to factors other than the simulated seismic surveys.

Environmental monitoring studies following geophysical exploration projects that employed vibroseis and shot-hole source methods in the southern San Joaquin Valley reported a decline in the number of small mammal burrows within vibroseis corridors 90 days and one year following surveys compared to control areas, but a substantial increase in burrows two years following the surveys (Steve Tabor and Rex Thomas, unpubl. report). The results of these monitoring studies indicated no long-term impact to the habitat or to the small mammal species following vibroseis activities (Steve Tabor and Rex Thomas, unpubl. report). Similarly, in another unpublished report (George Menkens and Stanley Anderson), vibroseis activity did not impact the physical living space, vegetation structure, or population dynamics of White-tailed Prairie Dogs (*Cynomys leucurus*) in Wyoming.

Other research has suggested that loud noises, such as those from off-road vehicles, can lead to temporary hearing impairment in kangaroo rats and may lead to higher levels of depredation (Brattstrom and Bondello

1983). Several kangaroo rat species use foot-drumming to communicate identity and to advertise territory (Randall 1984; 1989; 1997; Shier et al. 2012). It has been suggested that kangaroo rats, including *D. ingens*, use their acute low frequency hearing to detect and interpret foot-drumming signals from conspecifics and to avoid predation (Webster and Webster 1980; Randall 1984). Shier et al. (2012) found that Stephen's kangaroo rats (*D. stephensi*) foot-drummed in response to low frequency vehicle traffic noise and concluded that such noise potentially disrupted intraspecific communication. We did not attempt to assess physiological impacts from seismic energy sources to kangaroo rat individuals. More research investigating the effects of the seismic energy sources on kangaroo rats at an individual level would be necessary to evaluate potential physiological impacts to these species. If such impacts did occur on our study site, they did not affect kangaroo rat abundance during the monitoring period.

This study was designed to investigate population level effects of the energy sources used in seismic exploration on resident small mammals and not the physical impacts to the habitat. Although we did not detect any adverse effects to kangaroo rat abundance in our study area from simulated vibroseis and shot-hole surveys, actual surveys are more extensive and have the potential to impact small mammal populations both directly and indirectly. To detect petroleum resources further beneath the surface, two to four vibroseis trucks typically are needed, along with support vehicles (Milligan 2004). Shot-hole surveys may produce less environmental impact as fewer and smaller vehicles are required. Anytime vehicles are operated off-road, the tracks created can persist for months or years, particularly in arid areas like the San Joaquin Valley, and there is always a danger of others following these tracks and effectively converting them into roads. Such conversion could further fragment and degrade these already dwindling habitats.

Management implications.—We did not detect any adverse impacts to kangaroo rat abundance from underground vibrations and noise associated with vibroseis and shot-hole survey methods. However, in an actual seismic survey, impacts could result from associated activities, such as extensive off-road vehicle use. In current seismic surveys conducted in the southern San Joaquin Valley, various mitigation measures are required in an effort to reduce or avoid impacts to kangaroo rats and other small mammals. These measures include balloon tires to reduce burrow collapse, avoiding sensitive resources including rodent burrows, and restricting activities to daylight hours when most animals in this region are inactive (William Dixon, pers. comm.). It is important to maintain these mitigation measures to avoid impacts to small mammals as well as other burrow-dependent species such as endangered Blunt-nosed Leopard Lizards and San Joaquin Kit Foxes.

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Craig Fiehler (left) received his Bachelor's degree in Ecology, Behavior, and Evolution from UCLA and his Master's degree in Wildlife Biology from Humboldt State University. He has worked for the California Department of Fish and Wildlife since 2009. His professional interests remain focused on wildlife ecology and management.

Brian Cypher (center) is the Associate Director and a Research Ecologist with the Endangered Species Recovery Program of California State University, Stanislaus. Since 1990 he has been involved in research and conservation efforts for endangered and other sensitive species in the San Joaquin Valley of California. Although his primary research interest is the ecology and conservation of wild canids, he works with a variety of animal and plant species.

Larry Saslaw (right) worked as a Wildlife Biologist in the Bakersfield office of the Bureau of Land Management between 1985 and 2011 where he collaborated on studies that invested the effects of livestock grazing, fire, and oil and gas activities on several San Joaquin Valley listed species. Other work has included monitoring kangaroo rat species distributions and abundance, evaluation kangaroo rat translocations, developing habitat management prescriptions, and restoring previously disturbed habitats in the San Joaquin Desert region. (Photographed by Christine Van Horn Job).