ECOSYSTEM ANALYSIS OF OILFIELDS IN WESTERN KERN COUNTY, CALIFORNIA

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BAKERSFIELD FIELD OFFICE
3801 PEGASUS DRIVE
BAKERSFIELD, CA 93308

Prepared by:
Craig M. Fiehler and Brian L. Cypher

California State University, Stanislaus
Endangered Species Recovery Program
One University Circle
Turlock, CA 95382

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Craig M. Fiehler and Brian L. Cypher

California State University, Stanislaus
Endangered Species Recovery Program

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EXECUTIVE SUMMARY

Surveys were conducted from March 2008 to May 2010 to characterize ecological communities relative to level of oil field development in saltbush scrub habitat in the southern San Joaquin Valley. Sixteen study sites were identified – four each in areas with high, medium, low, and no oil field development, as measured by numbers of active production wells and verified by measuring the proportion of habitat disturbed. Also, sites with low terrain ruggedness and no recent wildfire burns were selected to further control variables that could influence community composition. Surveys were conducted to assess the abundance and diversity of herbaceous plants, shrubs, breeding birds, wintering birds, reptiles, small mammals, and mesocarvinores. Areas with high levels of development had a higher diversity of herbaceous plants, but lower overall cover and also significantly fewer shrubs. Bird species diversity also was higher on sites with medium and high levels of oil field development. This increased diversity in areas with higher levels of development was attributable to the presence of species, both native and non-native, that are not typically found in undisturbed saltbush scrub habitat. The same likely is true for the increased diversity of herbaceous plants in areas of higher development. Similarly, among rodents, generalist species that are more tolerant of disturbance, such as deer mice (*Peromyscus maniculatus*), were more abundant in areas of higher development. Conversely, several special status species declined with increasing development and most were not detected in areas with high levels of development. These included LeConte's thrashers (*Toxostoma lecontei*), burrowing owls (*Athene cunicularia*), San Joaquin antelope squirrels (*Ammospermophilus nelsoni*), short-nosed kangaroo rats (*Dipodomys nitratoides brevinasus*), American badgers (*Taxidea taxus*), and San Joaquin kit foxes (*Vulpes macrotis mutica*).

Our results indicate that ecological communities in saltbush scrub habitat might remain largely intact up to medium levels of oil field development, but that some species typical of this community may not be present in areas with high levels of development. Habitat alterations in areas with higher development may facilitate colonization by species not typically found in saltbush scrub habitat. The absence of certain species at high levels of development, particularly special status species, might indicate that oil field development has exceeded a threshold resulting in significant community alteration. This threshold appears to be at about 70% habitat disturbance. Recommendations include limiting habitat disturbance in high production areas to be around 70%, limiting habitat fragmentation, conducting habitat restoration, controlling invasive non-native species, investigating effects on ecological processes, and investigating habitat enhancement strategies.

ACKNOWLEDGMENTS

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INTRODUCTION

Over 95 percent of the San Joaquin Valley floor has been converted from native habitat to urban sprawl or agricultural land (USFWS 1998). Much of the remaining area has been developed by the petroleum industry for oil and gas extraction (USFWS 1998). The San Joaquin Valley has experienced substantial physical alteration of its natural environment from oil and gas exploration, drilling, and extraction. In Kern County, oil and gas extraction has steadily expanded since the discovery of the McKittrick field in 1898 (Therkelsen 1973). As of 2008, the five largest producing oilfields in California are located in Kern County, making it one of the nation's most important energy resource areas (DOGGR 2009). These oilfields are managed by a variety of public and private entities. Many of these oilfields are in saltbush scrub habitat, which supports a number of rare species but which also has been significantly reduced by conversion to agricultural, industrial, and urban uses (USFWS 1998).

The magnitude of impacts from oil and gas development on wildlife is largely unknown. Unlike severe urbanization or intensive agriculture, oil and gas extraction and its associated infrastructure often retain enough natural habitat components to support wildlife species (Spiegel 1996). However, regular oil production activities such as well, road, and pipeline construction, generation of hazardous materials, and increased human activity are some of the many threats to wildlife species in active oilfields. Despite these threats, many species of wildlife persist in active oilfields (O'Farrell and Scrivner 1987). Studies at the former Naval Petroleum Reserves 1 and 2 have investigated the impacts of an active oil and gas field on various plant and wildlife species, including sensitive species such as Hoover's wooly star (*Eriastrum hooveri*), San Joaquin kit fox (*Vulpes macrotis mutica*), giant kangaroo rat (*Dipodomys ingens*), and blunt-nosed leopard lizard (*Gambelia sila*) (Otten and Cypher 1997, Cypher et al. 2000). However, few studies have investigated the integrity of wildlife and plant communities along a disturbance gradient in active oilfields.

The objective of this project was to determine wildlife community composition, species abundance, and habitat characteristics in high, medium, and low intensity oil fields in western Kern County. This information will assist in the design and implementation of habitat mitigation measures and best management practices within active oil fields. This information will also contribute to assessments of cumulative effects on natural communities and endangered species occurring within oil production landscapes.

STUDY AREA

The study area for this project was located in the southwestern corner of the San Joaquin valley (Figure 1). The study plots were distributed across the valley but were somewhat clustered near the towns of Maricopa (35.06N, 119.40W), Taft (35.14N, 119.46W), Fellows (35.17N, 119.54W), and McKittrick (35.29N, 119.63W). Sixteen 36-ha plots were established in the study area based on the level of surface disturbance and the number of active oil or gas wells on the property (Figure 1). Study plots were selected along a gradient of oilfield development intensity along with several other factors. Overall, plots were selected based on the number of producing oil or gas wells present. Additionally, all plots were required to have a mean slope of less than 10 percent and no recent wildfire events. Plots were organized into the following treatments: control, low, medium, and high. Control plots were required to have no producing oil wells, low plots had 1-10 producing oil wells, medium plots had 11-50 producing oil wells, and high plots had greater than 100 producing oil wells. Four plots of each treatment were selected. Most of the plots were on Federal lands managed by the Bureau of Land Management, while others were owned by private companies such as Chevron Corporation, Occidental of Elk Hills Inc., and Plains Exploration and Production Company (PXP).

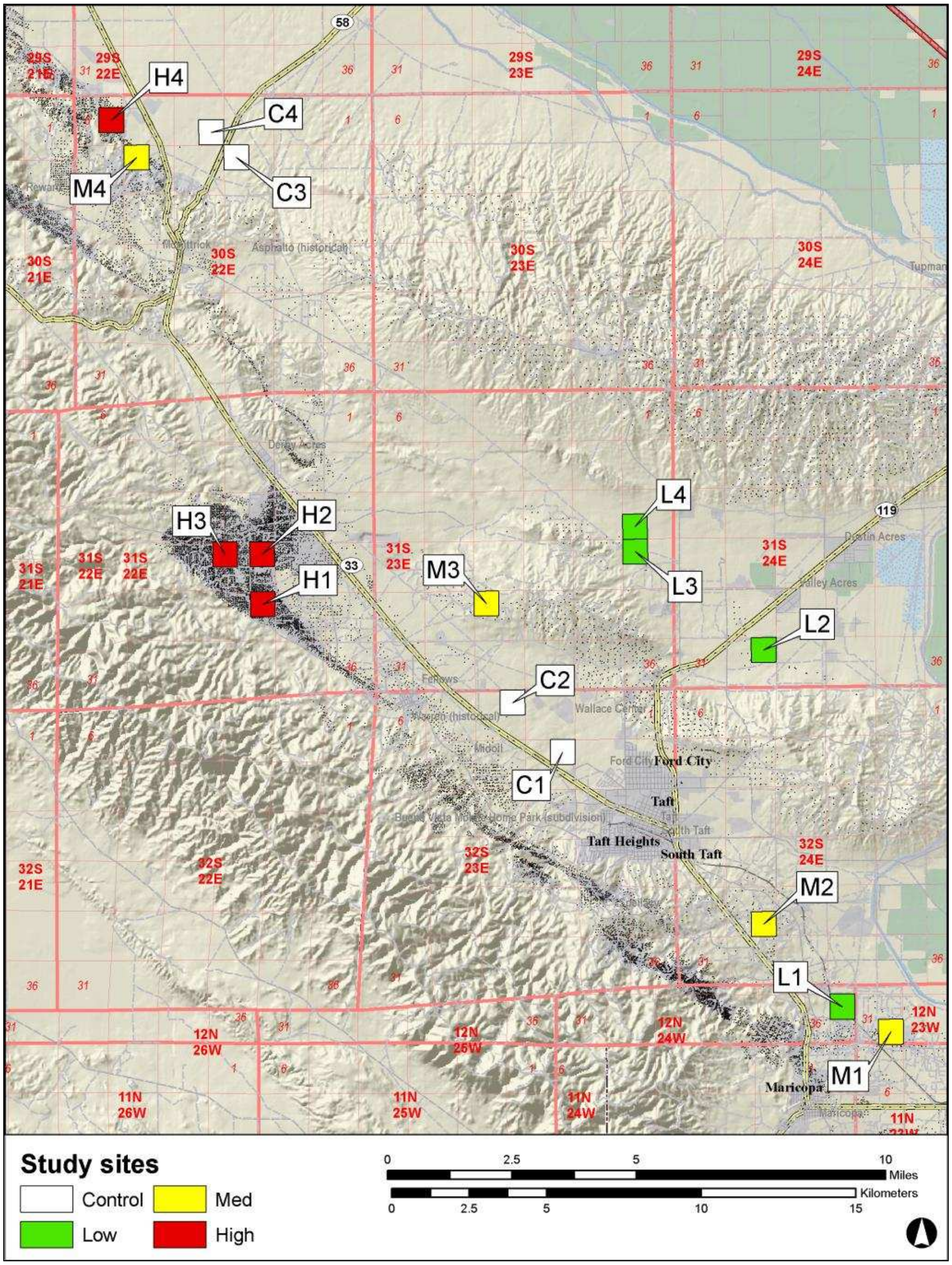

Figure 1. Locations of major roads, towns, Public Land Survey System (PLSS) boundary lines, and the 16 study plots along the southwestern edge of the San Joaquin Valley, Kern County, California.

The vegetation on the plots was a mosaic of arid shrubland, annual grassland, and disturbed oil production areas. The predominant natural community in the study area was Valley Saltbush Scrub (Holland 1986). This community is characterized by open shrublands with a shrub understory comprised of annual plants representative of Nonnative Grassland (Holland 1986). Common shrubs on the plots included desert saltbush (*Atriplex polycarpa*), spiny saltbush (*Atriplex spinifera*), cheesebush (*Hymenoclea salsola*), bladderpod (*Isomeris arborea*), alkali goldenbush (*Isocoma acradenia*), and matchweed (*Guttierezia californica*). Common forbs included red-stemmed filaree (*Erodium cicutarium*), popcorn flower (*Plagiobothrys* sp.), fiddleneck (*Amsinckia* sp.), and shiny peppergrass (*Lepidium nitidum*). Common grasses included red brome (*Bromus madritensis* ssp. *rubens*), barley (*Hordeum murinum* ssp. *glaucum*), and Arabian grass (*Schismus arabicus*).

METHODS

Beginning in March 2008 and continuing through May 2010, comprehensive surveys were initiated to census and describe the predominant wildlife and plant communities present on the various study plots.

BIRD SURVEYS

We conducted variable circular plot (VCP) point counts (Reynolds et al. 1980) at each study plot twice during the breeding season from mid-April to late May 2008 and once during the breeding season from mid-March to mid-April 2009. On each study plot, we established nine point count stations spaced 300 m (Figure 2) apart to avoid potential double counting (Hutto et al. 1986). We began our counts at sunrise and completed each survey by 1000 hours. We recorded all birds seen or heard during a 5-minute period at each station.

We also performed area searches (Ralph et al. 1993) during January 2009 on each study plot. We divided the 36-ha study plots into fourths and randomly chose one of the fourths to be the 9-ha area search plot (Figure 2). Two observers walked throughout the plot for 30 minutes, stopping and investigating sightings and calls when necessary. For unidentified birds, the timer was stopped and the birds were followed to confirm identification. The timer was re-started after positive identification. All birds seen or heard in the search area during the 30 minutes were recorded.

We classified all bird species into 1 of 2 categories: “native” or “cosmopolitan-introduced” species. We considered cosmopolitan species to be birds that were common, abundant, and that often associated with human disturbance (Merola-Zwartjes and DeLong 2005). In this study, the cosmopolitan species included: Killdeer (*Charadrius vociferous*), Rock Pigeon (*Columbia livia*), Mourning Dove (*Zenaida macroura*), Western Kingbird (*Tyrannus verticalis*), Common Raven (*Corvus corax*), Northern Mockingbird (*Mimus polyglottis*), European Starling (*Sturnus vulgaris*), Brewer’s Blackbird (*Euphagus cyanocephalus*), Brown-headed Cowbird (*Molothrus ater*), and House Finch (*Carpodacus mexicanus*). All other species were considered to be native.

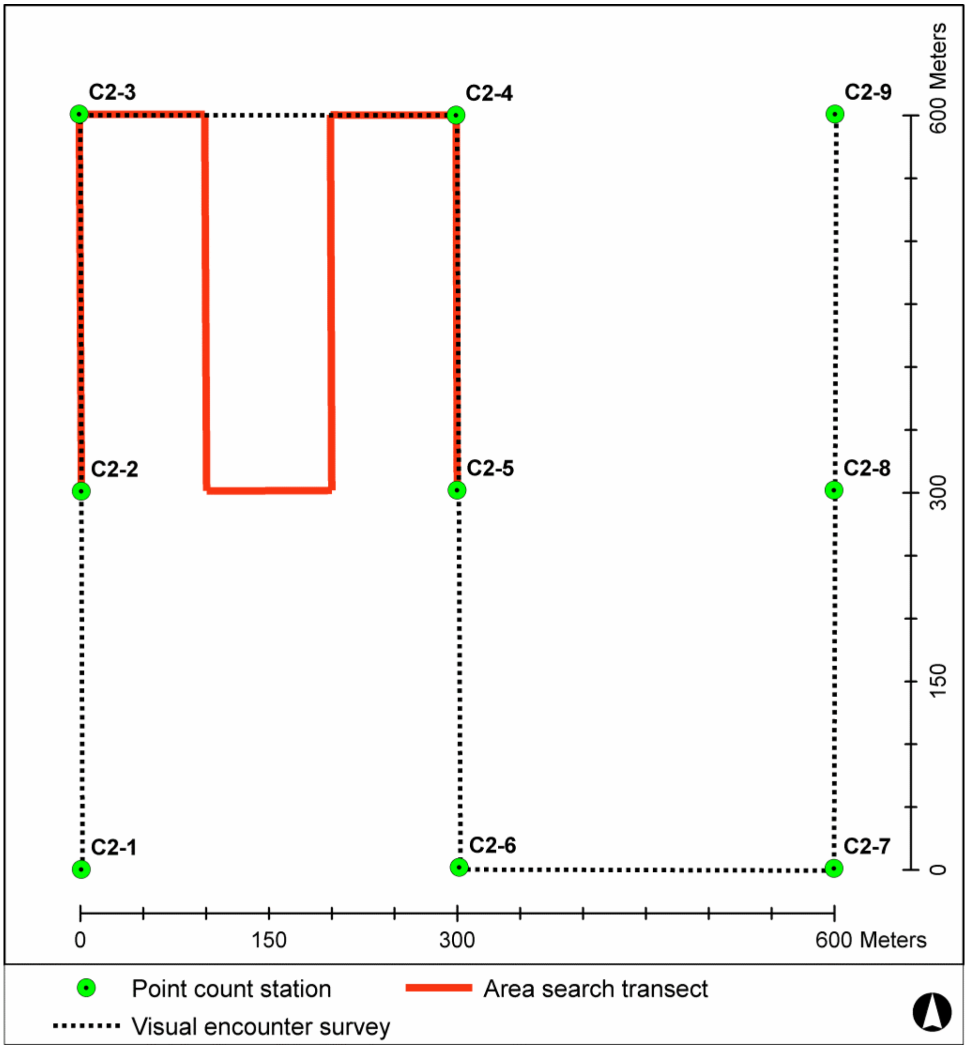

Figure 2. The layout of a typical study plot, in this case, control plot 2 (C2). Nine points were arranged in a 3x3 grid with 300 m spacing. The dotted line shows the visual encounter survey transect. The red line shows the area search transect.

SMALL MAMMAL TRAPPING

We conducted small mammal trapping on each study plot from mid-February to mid-March 2009. We established transects at 5 randomly chosen locations on each plot. Each transect consisted of 10 traps with 10-meter spacing for a total length of 90 meters per transect. We trapped on each transect for 3 consecutive nights. All animals captured were identified to species, aged, sexed, and either ear-tagged or belly-marked with a felt-tipped marker. We applied a numbered ear tag (1005 size 1 monel; National Band and Tag Co., Newport, KY) at the time of first capture for all kangaroo rat species. All other species captured were belly marked with permanent markers (red for females and blue for males) and released.

VISUAL ENCOUNTER SURVEYS

In order to gain a more complete understanding of the diurnal wildlife community on the study plots, we conducted visual encounter surveys (VES). Visual encounter surveys involve walking through an area or habitat for a prescribed amount of time, searching visually and systematically for animals or animals sign (scat, tracks, dens, etc.) (Crump and Scott 1994). These methodical walking surveys allow for the observation of more cryptic mammals, birds, and herpetofauna. We used the point counts stations as the framework for establishing a 2400 m sinuous transect on each study plot (Figure 2). One observer walked the transect recording every animal or animal sign that was encountered along the way and the time of observation. We considered animal sign to include scats, tracks, and burrows. We conducted visual encounter surveys during weather conditions that were optimal for Blunt-nosed leopard lizard (BNLL) activity (25-35º C) (CDFG 2004). Surveys were conducted in spring and fall 2008 and spring 2009.

COVERBOARD SURVEYS

Artificial cover objects are important to herpetofauna by offering shelter from predators and adverse environmental conditions (Hampton 2007). Artificial cover objects offer similar refuge to natural cover objects with the added benefit that they are relatively inexpensive to procure and require little to no maintenance (Fellers and Drost 1994). We placed a 4x4 ft, 0.5-in thick plywood board at each of the nine established point count stations on all treatment plots (Figure 3). The objective of the coverboard deployment was to census less common herpetofauna, particularly snakes. Therefore, due to extreme surface temperatures, the boards were allowed to season for 3 months before being checked in September 2008. The boards were allowed to season additionally over winter 2008-2009 before being checked in May and October of 2009. Coverboards were checked once more in April-May 2010.

Figure 3. Typical coverboard placement in valley saltbush scrub habitat on Plot L1, Kern County, California.

Camera Trapping

In September 2008, eight automated digital field cameras (Stealth Cam 3.0 MP Digital Scouting Cameras, Stealth Cam LLC, Bedford, TX) were deployed in an effort to opportunistically detect the presence and relative abundance of carnivorous mammals on the study plots, particularly canids, felids, and mustelids. The cameras were secured to 4-ft U-posts in the vicinity of two randomly selected point count stations per plot. A fatty acid scent-tab (USDA Pocatello Supply Depot, Pocatello, ID) and a cotton pad soaked in Canine Call scent lure (Carman's Superior Animal Lures, New Milford, PA) were placed near each camera to attract animals. Cameras were deployed for approximately 4 weeks at a time. In October 2009, camera trapping was resumed on the study plots. A can of cat food was staked to the ground using a tent stake and cotton balls soaked in fish oil were scattered in the nearby area. Cameras were deployed for no less than 29 days at each site. We measured camera success as the total number of captures divided by the number of active survey days (one camera active for 24 hours = one survey day). Consecutive photographs of wildlife species were considered independent if taken ≥ 5 minutes apart.

Disturbance Estimation

For each study plot, we estimated shrub cover and disturbance on each plot using a dot count method. Each 36-ha plot was digitally overlayed with a dot grid containing 100 dots. We used recent high quality aerial photographs of the plots for disturbance estimation. Each dot was classified as disturbed or undisturbed. If the dot fell in an area with human-made structures or areas without shrubs or any vegetation, it was classified as disturbed. Any dot that was on vegetative cover was classified as undisturbed.

Vegetation Surveys

We used a modified Daubenmire cover method to sample the shrub understory community during April 2009 (Daubenmire 1959). Vegetation composition around each point count point was obtained using a frame modified from Daubenmire (1959). At each point count station, a 35.5 x 70-cm quadrat (inside dimensions) was placed 10 meters away in each of the cardinal directions. The canopy coverage of each plant species inside the frame was estimated using the following cover classes:

Cover Class	Range of Coverage
1	1 - 5%
2	5 - 25%
3	25 - 50%
4	50 - 75%
5	75 - 95%
6	95 - 100%

The quadrat frames were observed from directly above and canopies that extended into the quadrat were counted even if the plants were not rooted in the quadrat. Canopy coverage data were collected during a time of maximum growth for the predominant species.

Live and dead shrubs were counted in 30 x 1-m belt transects that radiated from the point-count points. At each point-count point a random bearing between 1 and 360° was chosen and a meter tape was pulled out 30 m in the chosen direction. The observer then walked the belt transect and recorded number of live and dead shrubs of each species that fell within or contacted the transect in any way. Any surface disturbance such as well pads, roads, or pavement were also noted and the amount of the transect occupied by the disturbance was recorded.

DATA ANALYSIS

A standard t-test was used to compare all pairs of means. For multiple samples, we used one-way ANOVA to compare means. We also used the non-parametric Kruskal-Wallis test for comparing data that did not fulfill the assumption of normality.

Species diversity was calculated using the Shannon Diversity Index

$$(H' = -\sum p_i \log_e p_i)$$

where p_i is the proportion of the community made up of species i (Shannon and Weaver 1963). For each survey we calculated the Shannon Index and averaged them over the two surveys for each site.

RESULTS

BIRD SURVEYS

Overall, we observed 33 bird species in total during point counts in 2008 and 2009 (Table 1). We detected 12 species on control plots, 14 on low plots, 23 on medium plots, and 22 on high plots. Birds were more abundant on Medium and High intensity plots than on Control and Low plots in 2008 but not 2009 (Figure 4, Figure 5). The total number of species observed on each plot over two surveys (species richness) was higher on Medium and High intensity plots in 2008 and 2009 (Figure 6, Figure 7). However, number of native species were proportionally higher compared to cosmopolitan species on Control, Low, and Medium plots. On high intensity oilfield plots, native species were outnumbered by cosmopolitan species in 2008 but the trend was weaker in 2009 (Figure 8, Figure 9). In 2008, the high intensity oilfield plots had greater species diversity (H') than any other plots while control plots had the least diversity ($F_{3,12} = 10.9$, $P = 0.001$) (Table 2).

Seven additional species were detected during area searches that were not detected during point counts: American goldfinch (*Carduelis tristis*), Lesser goldfinch (*Carduelis psaltria*), Long-billed curlew (*Numenius americanus*), Mountain bluebird (*Sialia currocoides*), Northern flicker (*Colaptes auratus*), Savannah sparrow (*Passerculus sandwichensis*), and Yellow-rumped warbler (*Dendroica coronata*). Three additional species were detected during point counts in 2009: Common Yellowthroat (*Geothlypas trichas*), Violet-green swallow (*Tachycineta thalassina*), and Sage Thrasher (*Oreoscoptes montanus*).

Table 1. All bird species observed on the study plots, based on breeding season point counts in 2008 and 2009 and winter bird surveys in 2009. Species in bold are considered cosmopolitan species for this study.

Northern Harrier (*Circus cyaneus*) *****	Cliff Swallow (*Petrochelidon pyrrhonata*)
Red-tailed Hawk (*Buteo jamaicensis*)	Bewick's Wren (*Thryomanes bewickii*)
American Kestrel (*Falco sparverius*)	Mountain bluebird (*Sialia currucoides*)
Prairie Falcon (*Falco mexicanus*) *****	**Northern Mockingbird (***Mimus polyglottis*)
California Quail (*Callipepla californica*)	Sage Thrasher (*Oreoscoptes montanus*)
Killdeer (*Charadrius vociferous*)	Le Conte's Thrasher (*Toxostoma lecontei*) *****
American Avocet (*Recurvirostra americana*)	**European Starling (***Sturnus vulgaris*)
Long-billed Curlew (*Numenius americanus*)	Yellow-rumped Warbler (*Dendroica coronata*)
Rock Pigeon (*Columbia livia*)	Common Yellowthroat (*Geothlypis trichas*)
Mourning Dove (*Zenaida macroura*)	Western Tanager (*Piranga ludoviciana*)
Greater Roadrunner (*Geococcyx californianus*)	Lark Sparrow (*Chondestes grammacus*)
Burrowing Owl (*Athene cunicularia*)	Sage Sparrow (*Amphispiza belli*)
Lesser Nighthawk (*Chordeiles acutipennis*)	Savannah Sparrow (*Passerculus sandwichensis*)
Anna's Hummingbird (*Calypte anna*)	White-crowned Sparrow (*Zonotrichia atricapilla*)
Northern Flicker (*Colaptes auratus*)	Red-winged Blackbird (*Agelaius phoeniceus*)
Western Wood-Pewee (*Contopus sordidulus*)	Western Meadowlark (*Sturnella neglecta*)
Say's Phoebe (*Sayornis saya*)	**Brewer's Blackbird (***Euphagus cyanocephalus*)
Western Kingbird (*Tyrannus verticalis*)	**Brown-headed Cowbird (***Molothrus ater*)
Loggerhead Shrike (*Lanius ludovicianus*) *****	Bullock's Oriole (*Icterus bullockii*)
Common Raven (*Corvus corax*)	**House Finch** (*Carpodacus mexicanus*)
Horned Lark (*Eremophila alpestris*)	American Goldfinch (*Spinus tristis*)
Violet-green Swallow (*Tachycineta thalassina*)	Lesser Goldfinch (*Carduelis psaltria*)
N. rough-winged Swallow (*Stelgidopteryx serripennis*)	

***** California Species of Special Concern (California Department of Fish and Game 2008).

Table 2. Comparison of the number of species detected on each plot and the Shannon Index for each plot in 2008 and 2009.

Plot	Species	2008 H'	2009 H'
C1	8	0.668	1.18
C2	7	0.696	1.30
C3	6	0.647	1.11
C4	5	0	1.34
L1	11	1.52	1.05
L2	7	0.549	1.46
L3	7	0.591	1.13
L4	6	0.693	0.606
M1	13	1.35	1.54
M2	15	0.972	1.40
M3	21	1.62	1.15
M4	19	1.60	1.18
H1	15	1.51	1.77
H2	14	1.50	1.28
H3	20	1.85	2.10
H4	17	2.09	1.91

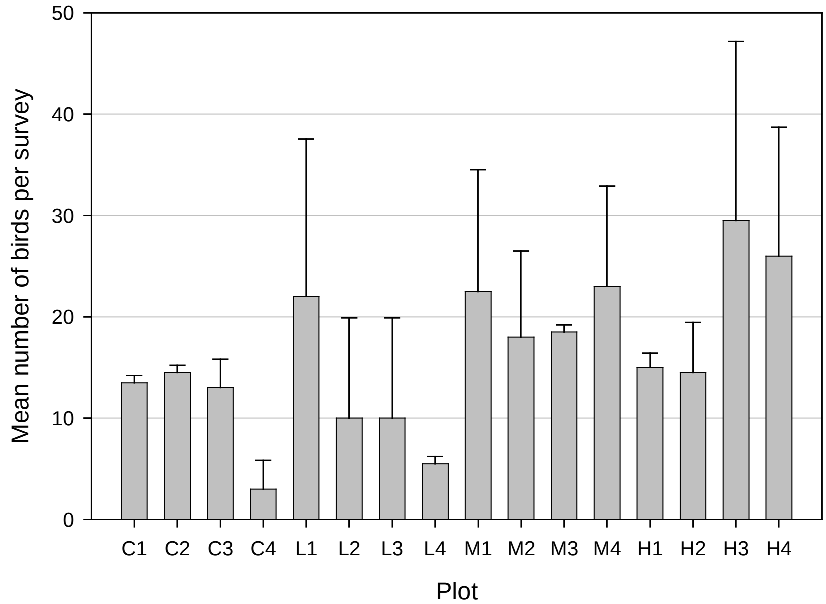

Figure 4. Index of abundance for all bird species observed during n = 2 surveys on each of 16 study plots in the southwestern San Joaquin Valley, California in 2008, represented as mean number of individuals detected per survey (± SD, n = 16).

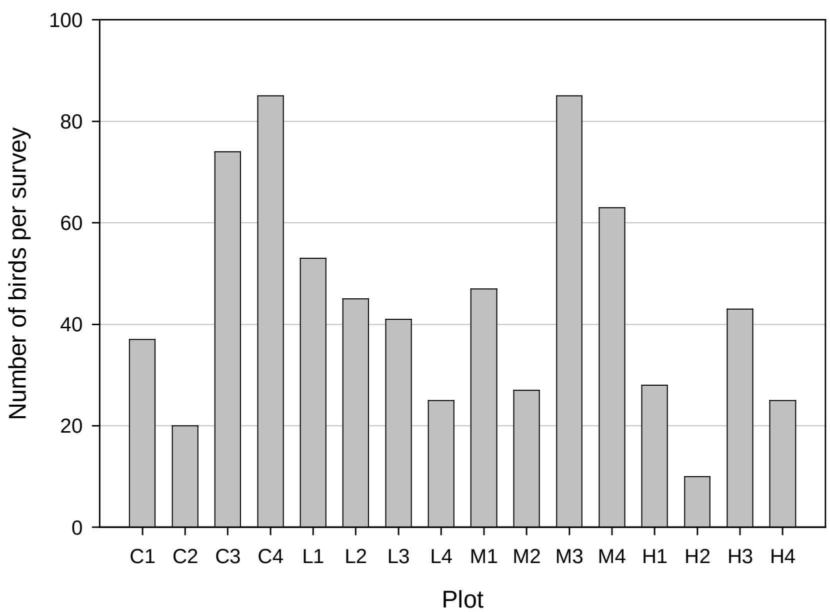

Figure 5. Index of abundance for all bird species observed during n = 1 survey on each of 16 study plots in the southwestern San Joaquin Valley, California in 2009, represented as mean number of individuals detected per survey (± SD, n = 16).

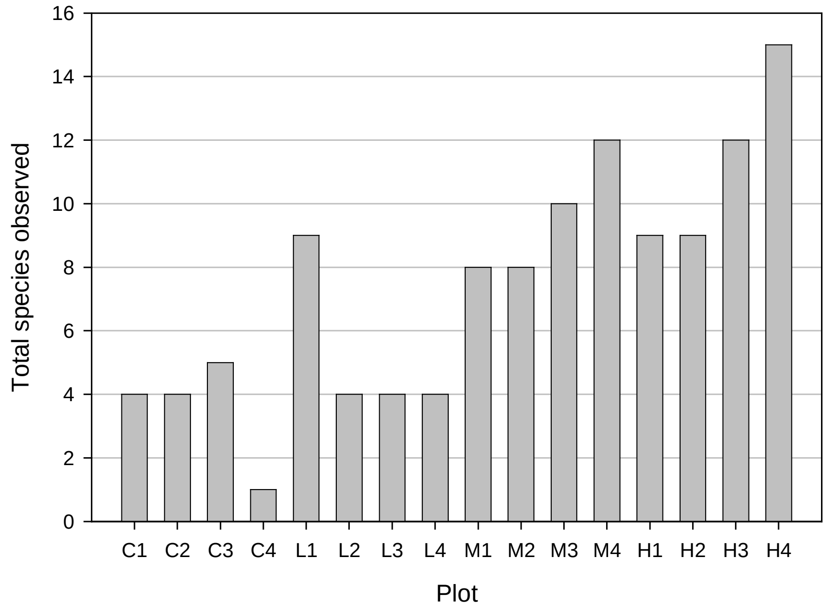

Figure 6. Species richness for all bird species on 16 study plots in the southwestern San Joaquin Valley, California in 2008, represented as total species observed during n = 2 surveys.

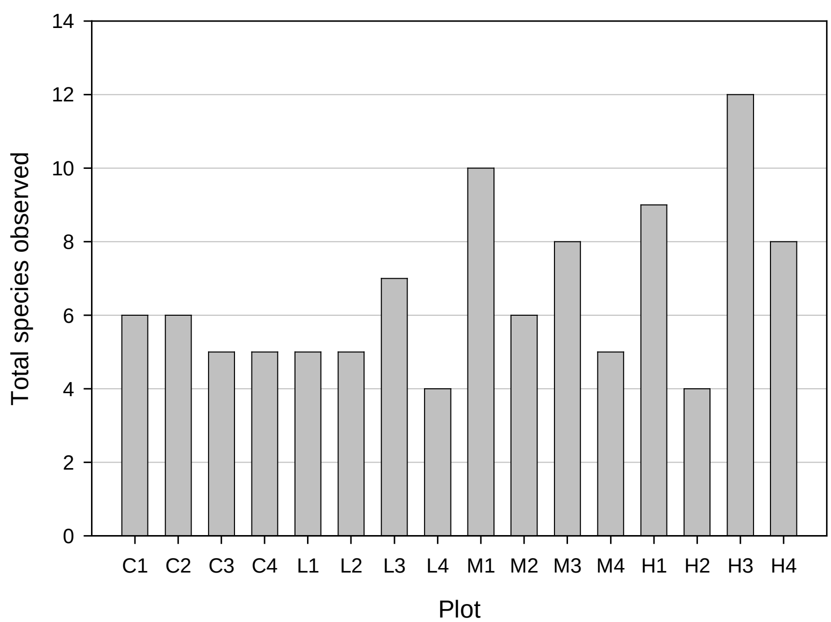

Figure 7. Species richness for all bird species on 16 study plots in the southwestern San Joaquin Valley, California in 2009, represented as total species observed during n = 1 surveys.

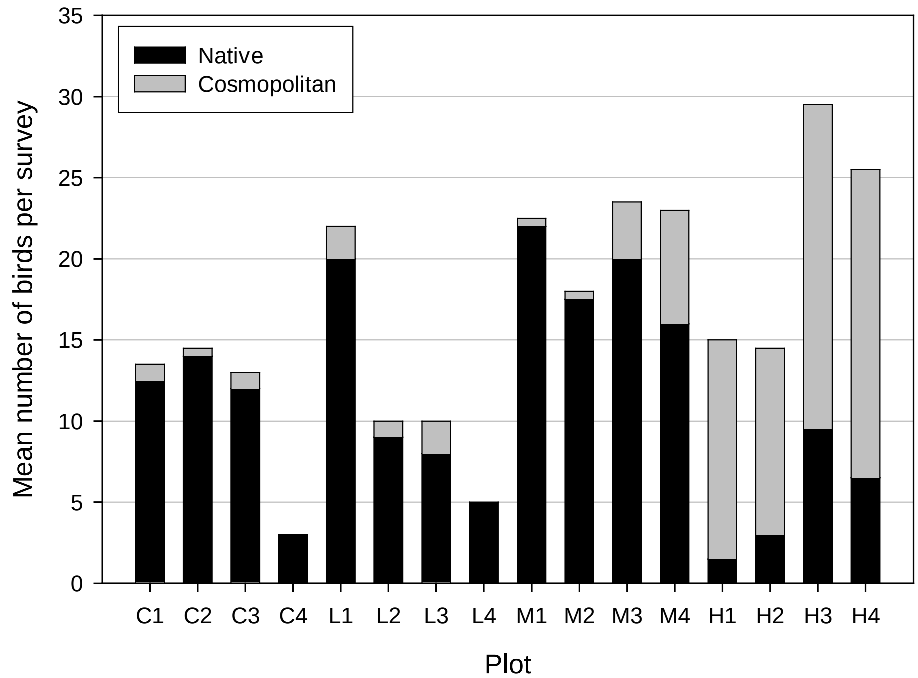

Figure 8. Mean number of native birds compared to cosmopolitan species on 16 study plots in the southwestern San Joaquin Valley, California in 2008.

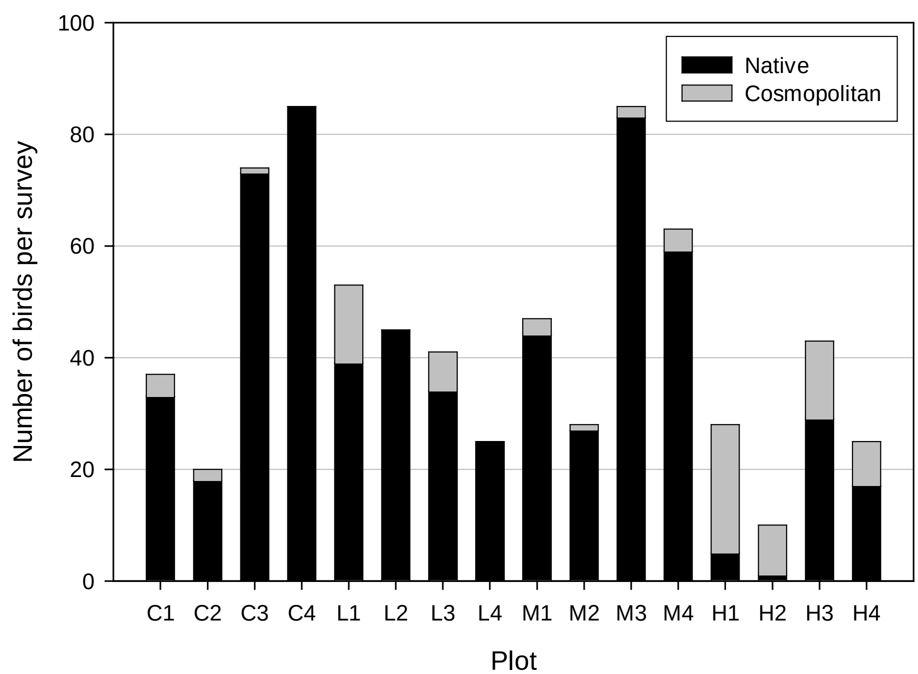

Figure 9. Number of native birds compared to cosmopolitan species on 16 study plots in the southwestern San Joaquin Valley, California in 2009.

SMALL MAMMAL TRAPPING

In 2400 trap nights, on 80 transects, we captured 324 individuals of 8 small mammal species (Table 3). Deer mice (*Peromyscus maniculatus*), Short-nosed kangaroo rats (*Dipodomys nitratoides brevinasus*), and California pocket mouse (*Chaetodipus californicus*) were the 3 most common species captured in order of descending abundance (Figure 10). Special status species such as Short-nosed kangaroo rats and San Joaquin antelope squirrels were found on all treatment plots except for the high intensity oilfield plots. Other species captured included Heermann's kangaroo rats (*Dipodomys heermanni*), California pocket mice (*Chaetodipus californicus*), San Joaquin pocket mice (*Perognathus inornatus*), Western harvest mice (*Reithrodontomys megalotis*), and a House mouse (*Mus musculus*). One way ANOVA analysis indicates that differences in relative abundance of small mammals (captures/100 trap nights) were marginally significant (F=2.91; df=3, P=0.078) and no difference in mean number of individuals (F=1.97; df=3; P=0.173) (Figure 11a,b). However, across treatments there was significantly more species present on the high intensity plots (F=4.62, df=3, P=0.023) (Figure 11c). The highest number of species caught on a plot was 5 and the lowest was 0. The Shannon diversity index did not differ among the 4 treatments (Kruskal Wallis test; df=3; P=0.065). However, diversity was greatest on high intensity plots (mean H'= 0.90), followed by low intensity (mean H'= 0.45), medium intensity (mean H'= 0.42), and control plots (mean H'= 0.13).

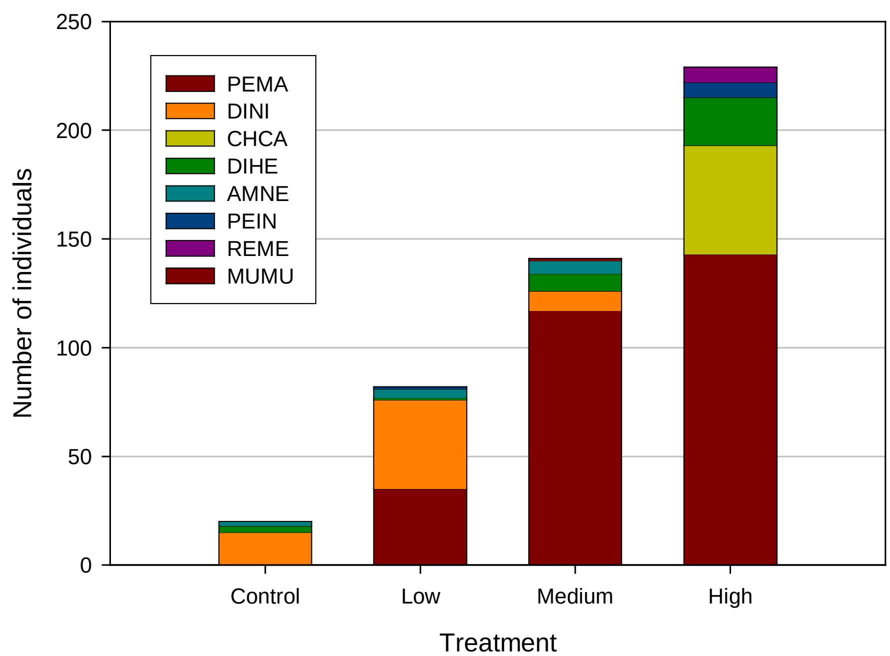

Figure 10. Capture frequencies for small mammals captured on 80 transects of varying oilfield disturbance in the southern San Joaquin Valley during 2009. PEMA = *Peromyscus maniculatus*, DINI = *Dipodomys nitratoides brevinasus*, CHCA = *Chaetodipus californicus*, DIHE = *Dipodomys heermanni*, AMNE = *Ammospermophilus nelsoni*, PEIN = *Perognathus inornatus*, REME = *Reithrodontomys megalotis*, and MUMU = *Mus musculus*.

Table 3. Summary of individual species captured on oilfield plots on a disturbance gradient (from no oil and gas development to high development).

Species	Control	Low	Medium	High	Total
Deer mouse	-	30	86	95	211
Short-nosed kangaroo rat[a]	12	27	5	-	44
California pocket mouse	-	-	-	25	25
Heermann's kangaroo rat	1	1	5	15	22
San Joaquin antelope squirrel[b]	2	3	5	-	10
San Joaquin pocket mouse	-	1	-	4	5
Western harvest mouse	-	-	-	6	6
House mouse	-	-	1	-	1
Totals	15	62	102	145	324

[a] California species of special concern (CADFG 2008)

[b] California threatened (CADFG 2008)

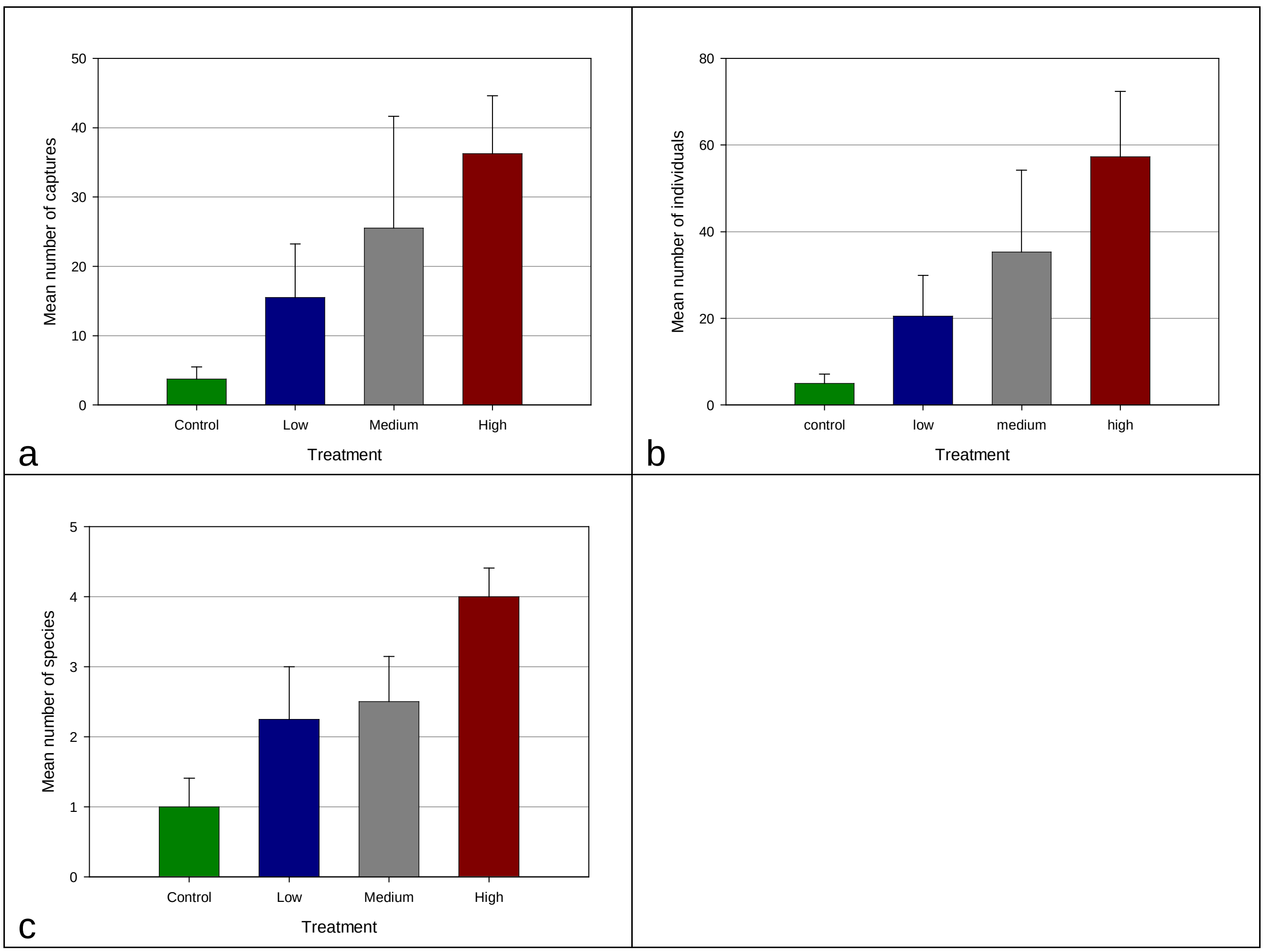

Figure 11. Means and standard errors for (a) total number of small mammals captured, (b) total number of individuals captured, and (c) mean number of species captured for each category of oilfield disturbance in the southern San Joaquin Valley in 2009.

VISUAL ENCOUNTER SURVEYS

A total of 10 species and species sign were observed on the 16 study plots from 2008 to 2010 (Table 4). The most commonly encountered species were side-blotched lizards *(Uta stansburiana)* and California whiptails (*Aspidoscelis tigris munda*) (Table 4). The highest observations per kilometer occurred on plots of medium disturbance levels. We also observed San Joaquin kit fox (*Vulpes macrotis mutica*) scat and dens and American badger (*Taxidea taxus*) digs and dens during VES surveys. No Blunt-nosed leopard lizards were observed during the VES surveys, but one individual was observed on Plot L3 during coverboard deployment in 2008. One California ground squirrel (*Spermophilus beecheyi*) was observed on Plot H3 during a VES survey.

Table 4. Selected species observed during visual encounter surveys conducted May and September 2008 and May 2009 and April and May 2010 on 16 study plots in the San Joaquin Valley, Kern County, California.

	2008				2009				2010				Total Observations
Species	**C**	**L**	**M**	**H**	**C**	**L**	**M**	**H**	**C**	**L**	**M**	**H**	
Black-tailed jackrabbit	4	2	9	5	2	3	6	1	3	3	4		42
Burrowing owl*		1			1								2
California ground squirrel				1				1					2
California whiptail	12	11	20	15	7	14	12	9	4	1	12	6	123
Common side-blotched lizard	33	65	66	58	32	17	22	30	26	23	37	36	445
Coyote		1	5									1	7
Le Conte's thrasher*	1	3	4		2	2	2		1	2	1		18
Loggerhead shrike*	1		1				1		3			6	12
Pacific rattlesnake		1											1
San Joaquin antelope squirrel*	2	1	6		5	1	9		5	2	5		36
Total Observations	**53**	**85**	**111**	**79**	**49**	**37**	**52**	**41**	**42**	**31**	**59**	**49**	
Distance Surveyed (km)	**19.2**	**19.2**	**19.2**	**19.2**	**9.6**	**9.6**	**9.6**	**9.6**	**9.6**	**9.6**	**9.6**	**9.6**	
Total Obs./km	**2.8**	**4.4**	**5.8**	**4.1**	**5.1**	**3.9**	**5.4**	**4.3**	**4.4**	**3.2**	**6.1**	**5.1**	

***** California Species of Special Concern (CDFG 2008).

COVERBOARD SURVEYS

The first coverboard checks occurred in September 2008 after approximately 3 months of deployment. Though the 144 boards had not seasoned sufficiently yet, 10 side-blotched lizards were detected. In 2009, 15 side-blotched lizards and one deer mouse were observed under the coverboards. In 2010, 10 side-blotched lizards and one whiptail were observed under the coverboards.

CAMERA TRAPPING

We captured 4 black-tailed jackrabbits and 3 coyotes in 288 camera-nights in 2008. Camera trapping resumed in September 2009 and continued until February 2010. For the 2009-10 trapping session, we placed cameras in 31 different locations. During the session, 83.8% of those camera stations captured at least 1 carnivore. Standardized for 100 sampling days, we captured 2.7 kit foxes, 0.47 badgers, 8.1 coyotes, and 2.2 lagomorphs per 100 sampling days (Table 5). We captured a total of 29 kit foxes

(Figure 12), 5 American badgers (Figure 13), 87 coyotes (Figure 14), 1 bobcat, 6 San Joaquin antelope squirrels (Figure 15), 24 lagomorphs, 2 humans, and 10 birds in 1073 sampling days on control, low, medium, and high plots.

Table 5. Summary of camera trap surveys by species and level of oilfield development, conducted from September 2009-February 2010 within the southern San Joaquin Valley. Camera data are expressed as number of individuals photographed divided by number of sampling days.

			Taxon								
Treatment	Plot	No. samplin g days	Kit fox[1]	Badger[2]	Coyote	Bobcat	Antelope Squirrel[3]	Lagomorph	Human	Bird	Carnivore species richness
Control	C1	70	0.01		0.03						2
	C2	68	0.15		0.13			0.01			2
	C3	82	0.02		0.05					0.01	2
	C4	82	0.02		0.09			0.01			2
Low	L1	72	0.01		0.04		0.01	0.13			2
	L2	70							0.03		0
	L3	70	0.01		0.01					0.01	2
	L4	70									0
Medium	M1	72	0.08		0.01		0.03	0.04			2
	M2	72	0.08	0.01	0.25		0.04			0.07	3
	M3	72		0.01	0.04						2
	M4	41			0.1						1
High	H1	58			0.22			0.05			1
	H2	58			0.03			0.07			1
	H3	58		0.05	0.29			0.05		0.02	2
	H4	58			0.05	0.02				0.02	2

1. San Joaquin kit fox
2. American badger
3. San Joaquin Valley antelope squirrel

Figure 12. Two San Joaquin kit foxes photographed on plot C2 on November 11, 2009.

Figure 13. Badger photographed on plot M3 on December 18, 2009.

Figure 14. A coyote photographed on plot C2 on November 27, 2009.

Figure 15. A San Joaquin antelope squirrel photographed on plot M2 on December 24, 2009.

DISTURBANCE ESTIMATION

Distubance values ranged from 1% disturbed on plot C4 to 83% disturbed on H1 (Table 6). The dot grid overlay reinforced our a priori evaluation of disturbance based on the number of active oil or gas wells. On average, the high intensity plots were the most disturbed, the control plots were the least disturbed, and the low and medium plots were moderately disturbed. Mean area disturbed was 3.3%, 9.0%, 33.0%, and 71.8% for the Control, Low, Medium, and High plots, respectively. Mean disturbance differed significantly among the 4 plot categories ($F = 19.03$, df = 3, $P < 0.001$).

Table 6. Disturbance values (%) calculated for each study plot from 2008 aerial imagery.

Plot	Disturbed	Undisturbed	Total
C1	2	98	100
C2	5	95	100
C3	5	95	100
C4	1	99	100
L1	14	86	100
L2	9	91	100
L3	6	94	100
L4	7	93	100
M1	30	70	100
M2	17	83	100
M3	15	85	100
M4	70	30	100
H1	83	17	100
H2	81	19	100
H3	64	36	100
H4	59	41	100

VEGETATION SURVEYS

In 2008 and 2009, high intensity oilfield plots had significantly less total shrubs (live and dead combined) than control, low, and medium plots ($F_{3,28} = 3.76$, $P = 0.022$). However, high intensity oilfield plots had the highest total number of forb and grass species ($F_{3,12} = 4.8$, $P = 0.020$). Control plots exhibited the highest total percent cover of forbs and grass ($F_{3,12} = 5.3$, $P = 0.015$). Across all plots in 2008, non-native species cover was higher than native species cover in the shrub understory ($t = 4.2$, $P = 0.001$, n = 16). In 2009, control plots again exhibited the highest total percent cover of forbs and grass ($F_{3,12} = 5.68$, $P = 0.012$) and there was no difference in species richness among the four treatment plots ($F_{3,12} = 0.68$, $P = 0.58$). Total cover was again greatest on control plots ($F_{3,12} = 5.68$, $P = 0.012$). Across all plots in 2009, there was no difference between non-native species cover and native species cover in the shrub understory ($t = -1.4$, $P = 0.181$, n = 16). No special status plant species were found on any of the study plots.

DISCUSSION

Bird Surveys

Our results from the 2008 and 2009 field seasons indicate that bird communities differ along a gradient of oilfield disturbance. High and medium intensity oilfield plots exhibited higher avian species richness and species abundance than control and low intensity plots. However, it is important to differentiate between the quality and quantity of species that occur in these disturbed areas. This increase in avian species on more disturbed plots came in the form of cosmopolitan species and at the expense of locally adapted native species. The fragmented landscape and heavy human presence that characterize the more disturbed study plots likely favored human-commensal bird species such as Brewer's blackbirds and European starlings as well as nest predators and nest parasites such as Common ravens and Brown-headed cowbirds.

Previous studies have documented an increase in cosmopolitan bird species at intermediate levels of urbanization (Blair 1996, 1999). However, unlike in urban settings, species richness and abundance peaked at the highest levels of disturbance in oilfields. This difference is probably due to the intensity of the disturbance. Highly disturbed urban areas have lost almost all native habitat as most of the land is covered in pavement and buildings, thereby supporting few species (Blair 1996). In contrast, in many cases high intensity oilfields still retain some natural habitat components including unpaved areas, patches of shrubs, and natural topography. There was an abundance of habitat edges in the disturbed oilfields. In general, habitat edges typically support a higher diversity of species due to increased vegetative complexity, and increased access to a variety of habitat types (Yahner 1988, Harris 1988, Andren 1994).

Valley saltbush scrub obligate species such as Le Conte's thrasher and Sage sparrows were greatly reduced or completely absent in high intensity oilfield plots. This is most likely due to lack of shrubs for nest sites and cover on these heavily impacted areas. Loggerhead shrikes were commonly seen in high density oilfields, usually perched on overhead powerlines or other anthropomorphic structures. The presence of these perch sites may compensate to some degree for the fragmented habitat, allowing shrikes to persist in highly disturbed oil production landscapes.

Le Conte's thrashers along with other saltbush scrub obligate species may be important indicators of ecosystem health in Valley saltbush scrub habitat. Changes in the population levels of such "indicator species" could possibly be used to assess long-term regional habitat condition.

Small Mammal Trapping

Our results from our 2009 trapping session indicate that the small mammal community differed along a gradient of oilfield disturbance. In general, the four treatments did not differ significantly in species diversity or species abundance. Species diversity did not differ by habitat and many of the small mammals found in contiguous habitat were also found in highly fragmented habitat. However, higher levels of disturbance seemed to favor habitat generalists such as deer mice. Habitat specialists such as San Joaquin antelope squirrel and Short-nosed kangaroo rat were present on all but the most disturbed plots. Relative abundance of small mammals increased as disturbance increased.

Previous studies have shown that small mammal generalists benefit from habitat disturbance while specialists suffer (Getz 1978, Adams and Geis 1983, Goosem 2000). Habitat loss and fragmentation in the southern San Joaquin valley has negatively impacted sensitive rodent species such as the San Joaquin antelope squirrel and Short-nosed kangaroo rat (Harris and Stearns 1991, USFWS 1998). However, the results of our study indicate that these sensitive species can persist in disturbed systems that retain contiguous patches of intact habitat.

As with specialist avian species, small mammal species such as San Joaquin antelope squirrel and Short-nosed kangaroo rats may be important indicators of ecosystem health in Valley saltbush scrub habitat. Presence or absence of such "indicator species" could possibly be used to assess long-term regional habitat condition.

VISUAL ENCOUNTER SURVEYS

Using visual encounter surveys, we were able to detect several species that were not detected by other standardized methods. We were able to successfully characterize lizard and diurnal mammal species composition on the plots. We observed the lizards species side-blotched lizards and California whiptails on all of the study plots, further supporting that these species are habitat generalists that can tolerate a wide range of habitat conditions (Tinkle 1967, Heaton et al. 2006). Similarly, Black-tailed jackrabbits were observed on all of the treatment plots at least once over the course of the study. Endangered species or California species of special concern such as San Joaquin kit fox, American badger, San Joaquin antelope squirrel, Burrowing Owl, and Le Conte's thrasher were not observed on high intensity oilfield plots. These species or their sign were observed along the entire gradient of disturbance including control, low, and medium intensity oilfield plots with the exception of high intensity locations. Though kit foxes have been known to persist in heavily developed oilfields (Berry et al. 1987, Spiegel 1996, Cypher et al. 2000), other sensitive species with narrower habitat requirements may be excluded in areas of increased petroleum development.

COVERBOARD SURVEY

Side-blotched lizards, California whiptails, and deer mice were the only vertebrate species observed under the coverboards after 23 months of deployment (June 2008-May 2010). Numerous invertebrates such as scorpions, ants, beetles, and centipedes were noted under the coverboards. However, blunt-nosed leopard lizards and snakes were not observed under coverboards from 2008-2010. Much of the year, the soil surface temperatures may have been too extreme to allow herpetofauna to use the coverboards as refugia. Natural cover objects are rare in saltbush scrub habitat and rodent burrows may act as preferred refugia for diurnal herpetofauna. Further studies employing coverboards in conjunction with drift fencing would provide more information about the herpetological community in saltbush scrub habitat.

CAMERA TRAPPING

Few target animals were captured on digital camera traps during Fall 2008. The only predator species captured in 288 camera-nights was one coyote. Most of the plots that cameras were deployed upon had documented sign of mesopredators such as badgers and kit foxes from the VES surveys. Possibly, the cameras possibly were not deployed for a sufficient amount of time to capure those species with larger home ranges, or the attractants used were not sufficient to persuade these wary species to investigate the camera stations. The camera trapping resumed in Fall 2009 and the use of canned cat food as an attractant increased camera success. The endangered San Joaquin kit fox was captured with regularity along with coyotes on control, low, and medium plots but not on high intensity oilfields. Generalists such as coyotes and lagomorphs were captured on all of the study plots. However, with the exception of the American Badger, all special status species were absent from high intensity oilfield plots. Though kit foxes have been known to persist in heavily developed oilfields (Berry et al. 1987, Spiegel 1996, Cypher et al. 2000), we did not capture them on camera in the high intensity areas in this study. Perhaps the relatively high levels of coyote activity on these plots deterred kit foxes from using them.

DISTURBANCE ESTIMATION

The dot overlay method further confirmed the accuracy of our classification of oilfield plots of differing development pressure. Control plots featured contiguous habitat and almost no disturbance except for roads and reclaimed well pads. Low and medium plots showed moderate to severe disturbance. High plots were extremely disturbed with very small patches of habitat distributed across a highly impacted landscape. Overall, this method accurately classified disturbance levels on the study plots.

VEGETATION SURVEYS

Plant surveys revealed a pattern of increased forb and grass species richness on higher intensity oilfield plots. However, non-native forb and grass species were present on all plots and percent cover of non-natives was higher than that of natives across all plots. We found that shrub density also decreased with increased oil and gas activity. All types of disturbance tend to favor nonnative plants (Hobbs and Huenneke 1992, Cypher 2005). Constant oil and gas production activities have resulted in repeated brush clearing, road construction, grading, and increased brushfire frequency. Overall, these activities have likely resulted in perpetual loss of shrubs and the proliferation of non-native species on these landscapes.

CONCLUSIONS

The overall results of this study have yielded some interesting and useful trends. For example, it appears that ecological communities, particularly species assemblages, may remain relatively intact up to “medium” oil field development levels, based on comparison with control sites. Communities appear to be substantially altered at high levels of development, where 70% or more of habitat is disturbed. Interestingly, some assemblages, particularly plants and birds, actually are more diverse at high levels of development. However, this increased diversity likely results from an increase in species, native as well as non-native, that are not endemic to saltbush scrub habitat. At high levels of development, factors such as greater structural diversity (from facilities and landscape plantings), greater amount of edge habitat, and the availability of water create additional niches that are colonized by these opportunistic, non-endemic species. One potential concern is that in addition to site-specific displacement of endemic species, areas of high development could serve as refugia for non-endemics resulting in possible adverse impacts to nearby areas of intact natural habitat.

Additionally, our research suggests that certain "specialist" species could potentially function as indicator species for rapid assessment of oil field effects in saltbush scrub habitat. For example, LeConte's thrashers, San Joaquin antelope squirrels, and San Joaquin kit foxes were not found in areas with high levels of development. Thus, for cumulative impact assessments, surveys for these species could quickly indicate whether development levels in a given area had exceeded a threshold such that the ecological community had been significantly altered. Colonization or establishment of these specialist species could also be useful in assessing the success of ecological restoration, remediation, and land retirement projects.

In this study, we were able to assess the effects of level of oil field development on the composition of ecological communities in saltbush scrub habitat. This assessment primarily focused on the presence and relative abundance of various plant and vertebrate species. However, other potential impacts associated with oil field activities would not have been detected during this study, particularly impacts on ecological processes. These could include effects on long-term survival, reproductive rates, condition, and population turnover. Such effects could result from altered behavioral or physiological states resulting from noise, vibrations, chemical inputs (e.g., contaminants, water runoff), human disturbance, or other factors. These effects would be more subtle and therefore not easily detected without specific targeted study.Recommendations

1. Limit habitat disturbance to 70% or less

Habitat disturbance in active oilfield areas should be restricted to a maximum of 70%. This limit should be applied even in dedicated production areas where conservation of natural biological communities is not a priority. The reason for this is that with the retention of 30% or more of natural habitat, the landscape still provides sufficient habitat values to support at least occasional use by species that are rare in the southern San Joaquin Valley. Thus, by restricting habitat disturbance to a maximum of 70%, some rare species may persist in these areas. However, even more important, the retention of suitable habitat values increases the potential for these areas to function as movement corridors. Given the current extensive fragmentation of natural habitats in the San Joaquin Valley, maintaining connectivity between remaining habitat blocks is critical. Such connectivity will facilitate genetic and demographic exchange between remaining populations of rare species thereby reducing the probability of local extinctions.

2. Limit habitat fragmentation by clustering facilities

Oilfield production in the southern San Joaquin Valley generally is characterized by an abundance of roads and widely dispersed facilities, largely facilitated by the relatively "open" structure of natural habitats, which facilitates the construction of facilities. To the extent possible, facilities in production areas should be clustered to minimize sprawl and the number of roads should be limited to the minimum necessary. These actions will result in larger blocks of remaining habitat and will help reduce habitat fragmentation as well as risks to wildlife associated with facilities and related vehicle traffic. Clustering facilities also will help limit the distribution, and therefore the deleterious effects, of non-native species.

3. Conduct habitat restoration on areas no longer needed for operations

In many oilfields in the southern San Joaquin Valley, previously disturbed areas are no longer needed for production activities. This is particularly true in older oilfields. Roads, well pads, and other facilities that are no longer in use could be restored to provide habitat values for wildlife. Minimally, any contaminants should be cleaned up, and compacted soils should be ripped or disked to facilitate natural revegetation. Seeding or shrub planting might speed the pace of restoration. The BLM currently is implementing this strategy on some of its lands in oil production areas.

4. Control the distribution and abundance of invasive non-native species

Highly disturbed areas provide colonization opportunities for non-native species. Some of these species are aggressive and can rapidly invade and dominate native communities, thereby reducing habitat quality and even excluding some native species. Such species might include tocalote (*Centaurea melitensis*) or non-native mustards. Control efforts might help limit the distribution and abundance of such species and reduce their impacts on natural communities.

5. Conduct additional studies to examine oil field effects on ecological process

Community composition is one approach to evaluating impacts from oil field activities. However, although composition may appear relatively unimpacted, underlying ecological processes may be significantly affected. For example, survival or reproductive rates could be lower, and the presence of a species in a given area could be largely reliant on immigrants from surrounding natural lands. In such a situation, the area would be functioning as a biological “sink”, and could also be adversely affecting communities on adjacent natural lands. Thus, additional studies are recommended to determine the affects of oil field activities, particularly at higher levels of development, on ecological processes. Such studies could include:

- plant productivity (e.g., effects of water and nutrient inputs)
- analysis of invertebrate communities
- contaminants bioaccumulation via isotope analysis
- breeding bird nesting success
- turnover rates in small mammal populations

6. Conduct investigations on habitat enhancements for rare species

Habitat enhancements might facilitate use of oil fields by rare species. Such enhancements should be conducted in a manner that permits quantitative evaluation so that the efficacy of these strategies can be determined. Potential strategies include:

- artificial dens for kit foxes (being implemented by BLM in some areas)
- artificial burrows for burrowing owls
- shrub restoration for species such as antelope squirrels and Le Conte’s thrashers
- establishment of special status plants, where appropriate, such as Hoover’s wooly star or Kern mallow (*Eremalke kernensis*)

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