CHAPTER 5

RANGE MANAGEMENT AND ECOLOGICAL RELATIONSHIPS IN THE APWRA

5.1 INTRODUCTION

Historically, range management practices have significantly altered California's landscape. By the mid-1800s, most of the native perennial grasslands had been converted to cismontane annual grass species. This conversion was in large part the result of introducing livestock and grazing practices that allowed the introduced grass species to eventually out compete and replace the natives.

Today, range management and livestock grazing practices in the APWRA play a significant role in the ecological relationships between producers, consumers, and various predators. This is most certainly true for the relationship between grazing cattle and rodent populations, both of which bear on raptor activity in the APWRA. As our study progressed, it became evident that cattle grazing practices and the presence of cattle among the wind turbines affected common rodents, such as pocket gophers, California ground squirrels, and other raptor prey items, which likely played a significant role in bird fatalities, as well.

In the APWRA, we observed that cattle spend a disproportionate amount of time grazing and resting near wind turbine towers (Photos 5-1 A and B). During hot days, they congregate around the towers and often rest in the shade, or in the shadow cast by the towers. Because these towers vary in heights and configuration, the resulting shadows vary in dimension and intensity. We suspected that cattle selected certain tower designs over others because of their shading capabilities, although we did not test whether this was the case in this study. Also, we suspected that towers might be more or less favored by cattle due to their physiographic features.

Where cattle congregate, the vegetation tends to be more intensively grazed and cattle pats (i.e., fecal droppings) dot the landscape much more so than in areas less used by cattle. Typically, areas with relatively open vegetation canopy favor certain small mammal species over others. Some of these mammalian benefactors of intense cattle grazing are prey for raptors that frequent the APWRA.

Similarly, increased cattle pat abundance fuels a food web that attracts certain bird species that are more prone to colliding with wind turbine blades. At certain times of the year, cattle pats are inundated by grasshoppers as a readily available food source and possibly a source of moisture. These readily available grasshoppers are preyed upon by multiple predators, including loggerhead shrike, burrowing owl, American kestrel, and red-tailed hawk. Several locally abundant lizard species also prey on grasshoppers and thus also might proliferate. In general, lizards are prey species for numerous raptorial bird species that are killed more frequently than others in the APWRA.

Desert cottontails often occur in relatively high abundance near wind turbines in the APWRA, especially those constructed on old concrete pads (Photo 5-2) or when rock piles are nearby (Photos 5-3 through 5-4).

In this chapter, we present some fundamental information relating to range management practices. From this early work, it is clear that much remains to be done to fully understand how cattle grazing may affect bird fatalities.

Photos 5-1 A and B. Cattle congregate near wind turbines, where they leave more pats and graze the grass more intensively.

Photo 5-2. Desert cottontails burrow under concrete pads of wind turbines and are concentrated around the turbines.

Photo 5-3. Desert cottontails use rock piles that were originally created near turbine laydown areas as a mitigation measure for San Joaquin kit fox.

Photos 5-4 A and B. Desert cottontails use rock piles created as a mitigation measure for San Joaquin kit fox nearby turbine laydown areas.

5.2 METHODS

For this effort, we visited 1,526 wind turbines that had been sampled through August 2002. During September 2002, we rated the laydown areas at each of these turbine towers for their lateral and vertical edge, which also relates to the abundance of species that are prey of bird species commonly killed. Vertical edge consists of a vertical change in physiography, such as a berm or artificial levee on an otherwise flat landscape. Lateral edge consists of a sharp change in plant cover or soil condition on a flat landscape, such as the boundary between a dirt road and a grassland. Vertical and lateral edges are often found to be used disproportionately more often as burrow sites by fossorial mammals.

We also counted lizards and cattle pats. We estimated the average vegetation height, and by counting fecal pellets, we collected data that yielded an index of desert cottontail abundance.

Between 0830 hours and 1400 hours each day we visited each wind turbine and recorded the data representing the variables described below. One observer walked one transect along the string of turbines (string transect) and returned 20 m to one side of the turbines (grass transect).

The edge index was measured from the string transect while viewing the 40-m radius from the wind turbine: 0 = no vertical or lateral edge within 40 m of wind turbine; 1 = some lateral edge such as the presence of a dirt road other than just the service road found at all of the wind turbines, or cleared area adjacent to vegetated area, or area tilled for pipeline, etc.; 2 = lots of lateral edge; 3 = some vertical edge such as road cut, road embankment, or cut into the hillside for creating a flat laydown area; 4 = lots of vertical edge, covering half or more of the area within 40 m of the wind turbine; and 5 = lots of both vertical and lateral edge.

The cottontail abundance index was recorded along the string transect and grass transect. We recorded the presence or absence of cottontail fecal pellets along 40-m transects and within 5 m of the observer (the same 5 m strip transects used for cattle pats, as well as a 5 m strip transect along the turbine string). We also noted whether or not cottontail fecal pellets were especially abundant.

Lizards were counted along the string transect and the grass transect and within 5 m of the observer.

We estimated the numbers of reasonably fresh cattle pats along the string transect and within 5 m of the observer, and we did the same along the grass transect. Reasonably fresh cattle pats were those that had not been broken up yet and were clearly identifiable as cattle pats.

The vegetation height index was measured only along the grass transect. We estimated the average height (cm) of the vegetation along each grass transect. Wherever the grass had fallen down, we estimated the height that would have been standing a month or two before when the grass had not yet fallen.

The locations of wind turbines were classified as physical features composing the relief, including plateaus, peaks, ridge crests, ridgelines, convex slopes, concave slopes, convex break in slope, concave break in slope, saddles in ridges, and ravines. Wind turbines were also classified as whether inside or outside of “canyons,” which really were the largest watersheds in the APWRA and the boundaries subjectively delineated. Their locations were also classified by slope aspect, including flat, north, northeast, east, southeast, south, southwest, west, and northwest. Rodent control intensity at the site of the wind turbine was classified as none, intermittent, and intense. All of these variables and others appearing in the results section are described further in Chapter 7.

5.2.1 Statistical Analysis

Our analysis was restricted to the 1,526 wind turbines we searched from through September 2002. We used analysis of variance mean comparisons and least significant difference tests. We relied on an alpha level of significance of 0.05, but considered P-values between 0.10 and 0.05 as indicative of trends.

5.3 RESULTS

5.3.1 Vegetation Height

String Level of Analysis

Vegetation height per wind turbine was 18% greater on ownerships where rodenticides were intermittently deployed, which tended to be significant in one-way ANOVA (ANOVA $F = 2.83$; $df = 2, 191$; $P = 0.061$) and was significant in an LSD test (mean difference from heavy rodenticide use = 4.28 cm, $P < 0.05$). It varied significantly by type of physical relief characteristic of the turbine string (ANOVA $F = 2.72$; $df = 10, 191$; $P = 0.003$), and post-hoc LSD tests showed that vegetation was higher on ridge crests compared to other types of relief (Table 5-1).

Table 5-1. LSD test results comparing vegetation height per turbine string to physical relief

Type of Relief	Other Types of Relief	Mean difference (cm)	P-value
plateau	Peak and slope	-12.35	0.040
ridge crest	Plateau	13.66	0.000
	Plateau and slope	11.60	0.002
	Ridgeline	8.76	0.048
	Slope	9.48	0.001
	Slope and ridgeline	7.35	0.009
	Convex slope	7.37	0.005

It also varied significantly by the dominant slope aspect characteristic of the turbine string (ANOVA $F = 2.07$; $df = 11, 191$; $P = 0.025$), and post-hoc LSD test showed vegetation was taller on south-facing and northwest-facing slopes (Table 5-2).

Table 5-2. LSD test results comparing vegetation height per turbine string to slope aspect

Slope Aspect	Other Slope Aspects	Mean difference (cm)	P-value
south	Flat	10.84	0.003
	Northeast	13.15	0.004
	East	12.90	0.002
	Southeast	12.33	0.009
	Southwest	19.00	0.005
northwest	Flat	6.07	0.044
	Northeast	8.38	0.037
	East	8.13	0.020
	Southwest	14.24	0.026

Vegetation height also correlated positively with percent of the string in canyons, steepness of slope, and with the number of cattle pats along the grass transect (Table 5-3).

Table 5-3. Correlation test results between vegetation height and independent variables (n = 192)

Independent Variable	Vegetation height (cm)
Cottontail abundance on grass transect	$r_p = -0.15$*
Mean elevation	ns
Change in elevation	ns
Elevation change per turbine	$r_p = 0.20$**
Percent in canyon	$r_p = 0.46$**
Variation in physical relief	ns
Cattle pats per turbine on grass transect	$r_p = 0.19$**
Cattle pats per turbine on string transect	ns
Edge index per turbine	ns

Wind Turbine Level of Analysis

Vegetation height varied significantly by physical relief (ANOVA $F = 6.391$; $df = 10, 1489$; $P < 0.001$), and post-hoc LSD tests showed that it was tallest on slopes and ridge crests (Table 5-4).

Table 5-4. LSD test results comparing vegetation height per wind turbine to slope aspect, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Physical Feature	Other Physical Features	Mean difference (cm)
Ridge crest	Plateau	5.32**
	Ridgeline	5.57**
	Concave slope	8.29*
	Breaking concave slope	11.60*
	Convex slope	5.75**
	Saddle	5.55*
	Ravine	7.05^{t}
Slope	Plateau	5.64**
	Ridgeline	5.89**
	Concave slope	8.61*
	Breaking concave slope	11.92*
	Convex slope	6.07**
	Saddle	5.87*
	Ravine	7.37^{t}

Vegetation height varied significantly by slope aspect (ANOVA F = 8.388; df = 8, 1486; P < 0.001), and post-hoc LSD tests showed that it was tallest on southern and northwestern-facing slopes (Table 5-5).

Table 5-5. LSD test results comparing vegetation height per wind turbine to slope aspect, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Slope Aspect	Other Slope Aspects	Mean difference (cm)
South	Flat (no aspect)	6.51**
	North	4.61*
	Northeast	5.85*
	East	7.09**
	Southeast	5.44**
	Southwest	6.61*
Northwest	Flat (no aspect)	8.11**
	North	6.21**
	Northeast	7.45**
	East	8.68**
	Southeast	7.03**
	Southwest	8.21*

It was significantly taller in canyons (ANOVA F = 218.561; df = 1, 1499; P < 0.001), averaging 68% taller. It varied significantly by edge index (ANOVA F = 4.231; df = 4, 1499; P < 0.005), and post-hoc LSD tests showed that vegetation height was greatest around wind turbines with lots of vertical edge (Table 5-6). It did not vary significantly by position of the tower in the string (ANOVA F = 1.225; df = 3, 1498; P = 0.299).

Table 5-6. LSD test results comparing vegetation height per wind turbine to edge index, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Slope Aspect	Other Slope Aspects	Mean difference (cm)
Some vertical edge	No edge	3.57[t]
Lots of vertical edge	No edge	6.29**
	Some lateral edge	2.53*
	Lots of lateral edge	3.61**
	Some vertical edge	2.71*

5.3.2 Cattle Use Intensity

String Level of Analysis

The cattle pat abundance index along the grass transect averaged 5 pats more on ownerships where rodenticides were intermittently deployed (ANOVA F = 3.09; df = 2, 191; P = 0.048; LSD mean difference from none = 5.15, P = 0.023), as depicted in Figure 5-1. Along the turbine string transect, it was more than twice as great where rodenticides were intermittently deployed (ANOVA F = 20.02; df = 2, 191; P = 0.000; LSD mean difference of intermittent deployment = 19.1 and 14.5 pats from none and heavy deployment, respectively). Cattle pat abundance did not differ significantly between the grass and turbine string transects on ownerships with no use of rodenticides, but it was significantly greater along the turbine string transect where owners intermittently and heavily used rodent control (Table 5-7).

Table 5-7. Mean comparisons of the number of cattle pats by rodent control intensity, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Intensity of Rodent Control	Mean	SD	Paired-sample t	df	P (2-tailed)
None					
Grass	10.58	8.67			
Turbine string	11.97	10.34	-0.984	35	0.332
Intermittent					
Grass	15.73	10.52			
Turbine string	31.10	19.60	-7.318	65	0.000
Heavy					
Grass	12.44	11.75			
Turbine string	16.62	16.76	-3.176	89	0.002

The abundance of cattle pats along the string transect correlated positively with steepness of slope, percent of the string in canyons, and vegetation height, but none of these were strong (Table 5-8).

Table 5-8. Correlation test results between number of cattle pats and independent variables (n = 192), where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Independent Variable	Cattle pats on grass transect	Cattle pats on string transect
Mean elevation	$r_p = 0.16*$	ns
Change in elevation	ns	ns
Elevation change per turbine	ns	$r_p = 0.26**$
Percent in canyon	ns	$r_p = 0.30**$
Variation in physical relief	ns	$r_p = -0.16*$
Vegetation height (cm)	ns	$r_p = 0.19*$
Edge index per turbine	ns	ns

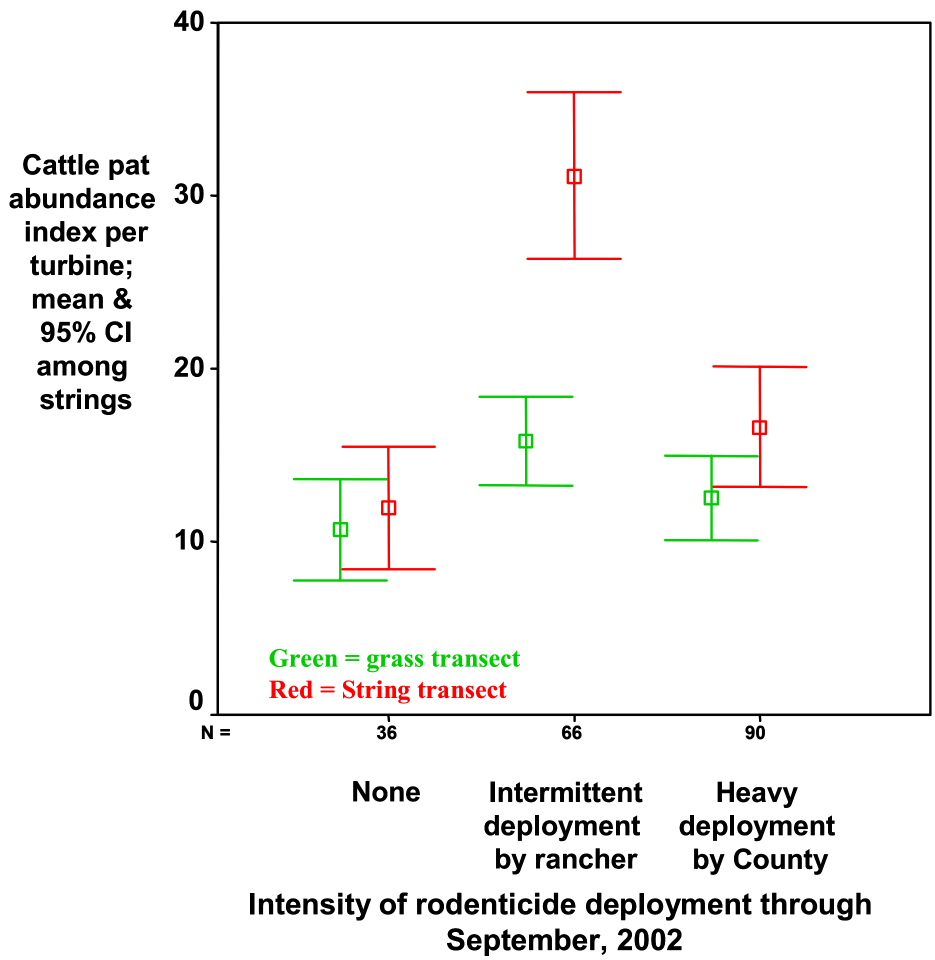

Figure 5-1. Cattle pat abundance was greatest along transects at wind turbine strings where rodenticide was deployed intermittently.

The abundance of cattle pats varied significantly by type of physical relief along both the grass transect (ANOVA F = 2.960; df = 10, 191; P < 0.001) and the turbine string transect (ANOVA F = 4.120; df = 10, 191; P < 0.005), and post-hoc LSD tests showed that cattle pats were generally more abundant on ridge crests and ridgelines, especially along the turbine string transects (Table 5-9).

The abundance of cattle pats did not differ significantly by the dominant slope aspect along both the grass transect (ANOVA F = 1.161; df = 11, 191; P = 0.318) and the turbine string transect (ANOVA F = 1.735; df = 11, 191; P = 0.069), but post-hoc LSD tests showed that cattle pats were generally more abundant on flat terrain with no particular aspect, and on western slopes compared to eastern slopes (Table 5-10).

Table 5-9. LSD test results comparing mean number of cattle pats per turbine string to physical relief, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Physical Feature	Other Physical Features	Mean difference (cm) on Grass transect	Mean difference (cm) on String transect
Plateau	Concave slope	7.43*	ns
Ridge crest	Peak and slope	ns	22.81*
	Plateau	ns	16.20*
	Plateau and slope	7.50*	20.39**
	Slope	6.78*	15.58**
	Slope and Ridge	5.82*	12.91*
	Convex slope	9.26**	18.39**
	Concave slope	ns	23.81*
	Saddle	ns	22.17*
Ridge crest/Ridgeline	Convex slope	10.24*	
Ridgeline	Peak and slope	ns	23.69*
	Plateau	ns	17.07*
	Plateau and slope	11.69*	21.26*
	Slope	10.97*	16.46*
	Slope and Ridge	10.01*	13.79*
	Concave slope	15.91*	24.68*
	Convex slope	13.44**	19.27*
	Saddle	ns	23.05*

Table 5-10. LSD test results comparing mean number of cattle pats per turbine string to slope aspect of the string of turbines, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Slope Aspect	Other Slope Aspects	Mean difference (cm) on Grass transect	Mean difference (cm) on String transect
Flat (no aspect)	Northeast	7.49*	ns
	East	6.21*	ns
West	Northeast	12.25*	ns
	East	10.97[t]	ns
Northwest	Northeast	ns	15.57*
	East	ns	12.50*

It varied significantly by tower type along both the grass transect (ANOVA F = 6.773; df = 8, 191; P < 0.001) and the turbine string transect (ANOVA F = 12.531; df = 8, 191; P < 0.001), and post-hoc LSD tests showed that cattle pats were generally more abundant nearby vertical axis, tubular, and horizontal lattice towers—especially along the string transect (Table 5-11).

Table 5-11. LSD test results comparing mean number of cattle pats per turbine string to tower type, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Type of Tower	Other Tower Types	Mean difference (cm) on Grass transect	Mean difference (cm) on String transect
Bonus tubular	Diagonal lattice	8.53**	21.47**
	Horizontal lattice	ns	13.08**
	Micon 65	6.60*	22.78**
	Enertech	8.14*	24.89**
	Windmatic	11.04*	27.48**
Vertical axis	Bonus tubular	7.15*	ns
	Diagonal lattice	15.68**	25.16**
	Horizontal lattice	5.59*	16.77**
	KVS-33	14.84*	19.81[t]
	Danwin tubular	10.46*	13.21[t]
	Micon 65	13.75**	26.47**
	Enertech	15.29**	28.58**
	Windmatic	18.20**	31.17**
Horizontal lattice	Diagonal lattice	10.09**	8.39 [t]
	Micon 65	8.16*	9.70*
	Enertech	9.70**	11.80*
	Windmatic	12.61*	14.40*
Danwin tubular	Enertech	ns	15.37*

Wind Turbine Level of Analysis

Cattle pat abundance did not differ significantly between the inside and the outside of canyons along the grass transect (ANOVA F = 0.00; df = 1, 1533; P = 0.966) but it did differ along the turbine string transect (ANOVA F = 67.734; df = 1, 1532; P < 0.001). Survey results indicated that cattle pats were twice as numerous inside the canyon compared to outside. The number of cattle pats varied significantly by edge conditions along the grass transect (ANOVA F = 7.964; df = 4, 1533; P < 0.001) and the turbine string transect (ANOVA F = 5.467; df = 4, 1532; P < 0.001). Post-hoc LSD tests showed cattle pats were least abundant around towers with extensive vertical edge (Table 5-12).

Table 5-12. LSD test results comparing mean number of cattle pats per wind turbine to edge condition, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Edge Condition	Other Edge Conditions	Mean difference (cm) on Grass transect	Mean difference (cm) on String transect
Lots of lateral edge	Some vertical edge	2.41*	ns
Lots of vertical edge	None	-6.31**	ns
	Some lateral edge	-5.12**	-6.80*
	Lots of lateral edge	-5.51**	-7.70**
	Some vertical edge	-3.10*	-5.44*

Cattle pat abundance varied significantly by position of the tower in the string along the grass transect (ANOVA F = 6.838; df = 3, 1532; P < 0.001) and the turbine string transect (ANOVA F = 36.859; df = 3, 1531; P < 0.001). Post-hoc LSD tests showed that interior towers had fewer cattle pats than other towers, towers at the edges of gaps had more than those at the ends of strings, and non-operational towers had more pats than did end and interior towers (Table 5-13).

Table 5-13. LSD test results comparing mean number of cattle pats per wind turbine to position of the tower in the string, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Tower position	Other Tower positions	Mean difference (cm) on Grass transect	Mean difference (cm) on String transect
Gap	End	3.37*	17.61**
Interior	End	-2.02*	-3.77*
	Gap	-5.39**	-21.38**
	Non-operational	-8.51*	-28.60**
Non-operational	End	ns	24.83**

5.3.3 COTTONTAIL ABUNDANCE

String Level of Analysis

The cottontail abundance index along the grass transect was twice as great on ownerships where no rodenticides were deployed (ANOVA F = 5.94; df = 2, 191; P = 0.003; LSD mean difference from none = 0.30 and 0.31 for intermittent and heavy, respectively), as depicted in Figure 5-2.

Along the turbine string transect, cottontail abundance was also twice as great where no rodenticides were deployed (ANOVA F = 4.53; df = 2, 191; P = 0.012; LSD mean difference from none = 0.34 and 0.27 for intermittent and heavy, respectively). Cottontail abundance did not differ significantly between the grass and turbine string transects on ownerships with no or intermittent deployment of rodenticides, but it was significantly greater along the turbine string transect where owners heavily attempted rodent control (Table 5-14).

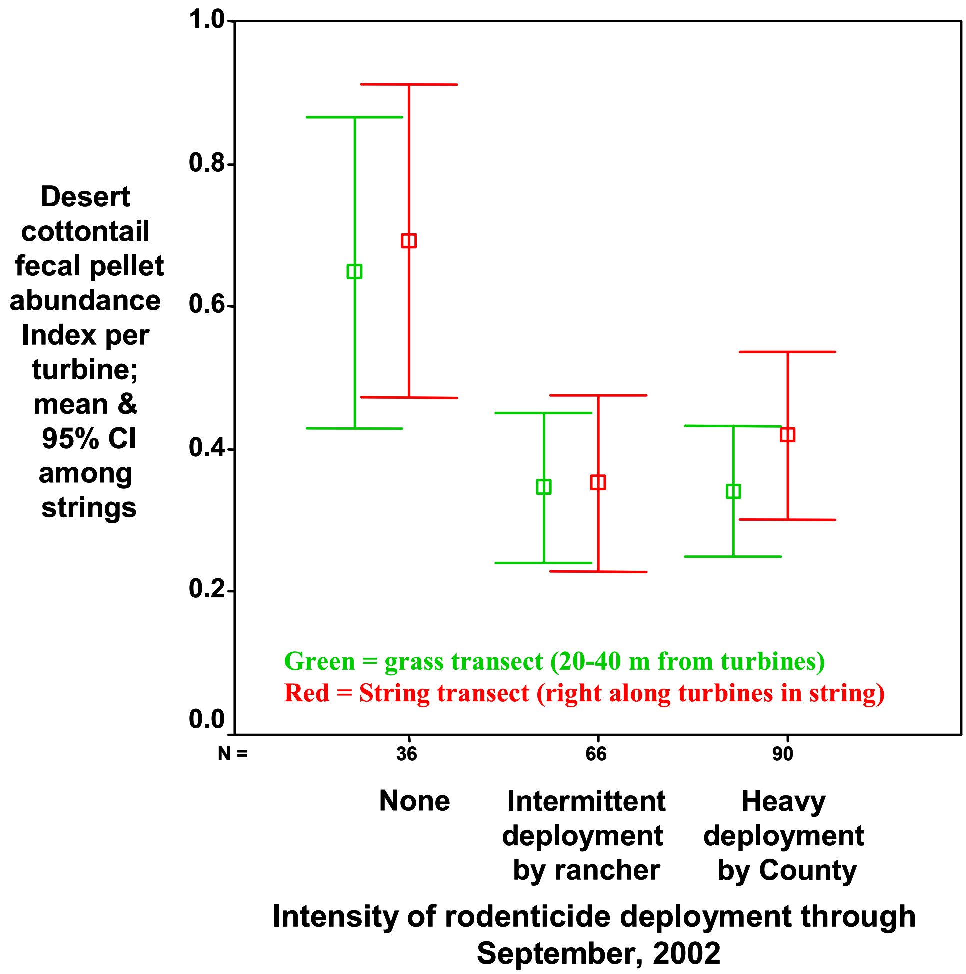

Figure 5-2. Desert cottontail abundance near wind turbines was greatest where no rodenticide was deployed, and it was greater at wind turbines more than 40 m away where rodenticide was heavily deployed.

Table 5-14. Mean comparisons of the cottontail abundance index by rodent control intensity

Intensity of Rodent Control	Mean	SD	Paired-sample t	df	P (2-tailed)
None					
Grass	0.64	0.64			
Turbine string	0.69	0.65	-0.91	35	0.368
Intermittent					
Grass	0.34	0.43			
Turbine string	0.35	0.50	-0.292	65	0.771
Heavy					
Grass	0.33	0.44			
Turbine string	0.42	0.56	-2.18	89	0.032

Cottontail abundance correlated inversely with elevation, steepness of slope along the turbine string, percentage of the string in canyons, vegetation height, and cattle pats found along the transect. However, none of these correlations were strong (Table 5-15).

Table 5-15. Correlation test results between cottontail abundance index and independent variables (n = 192), where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Independent Variable	Cottontail abundance index on grass transect	Cottontail abundance index on turbine string transect
Mean elevation	r_p = -0.23**	r_p = -0.28**
Change in elevation	r_p = -0.21**	r_p = -0.17*
Elevation change per turbine	r_p = -0.20**	r_p = -0.14*
Percent in canyon	r_p = -0.23**	ns
Variation in physical relief	ns	ns
Vegetation height (cm)	r_p = -0.15*	ns
Cattle pats on grass transect	r_p = -0.26**	r_p = -0.26**
Cattle pats on String transect	r_p = -0.33**	r_p = -0.31**
Edge index per turbine	ns	ns

Cottontail abundance varied significantly by tower type along both the grass transect (ANOVA F = 19.75, df = 8, 191, P < 0.001) and the turbine string transect (ANOVA F = 19.92; df = 8, 191; P < 0.001). Post-hoc LSD tests showed that cottontails were generally more abundant around vertical axis, Micon-65, and Enertech towers (Table 5-16).

Cottontail abundance varied significantly by type of physical relief along both the grass transect (ANOVA F = 3.345; df = 10, 191; P < 0.001) and the turbine string transect (ANOVA F = 4.092; df = 10, 191; P < 0.001). Post-hoc LSD tests showed that cottontails were generally more abundant on plateau/slope combinations, slopes, and saddles (Table 5-17).

Cottontail abundance varied significantly by the dominant slope aspect along both the grass transect (ANOVA F = 1.890; df = 11, 191; P =0.043) and the turbine string transect (ANOVA F = 2.144; df = 11, 191; P =0.019). Post-hoc LSD tests showed that cottontails were generally most abundant on southwest slopes and least abundant on northwest slopes (Table 5-18).

Table 5-16. LSD test results comparing mean cottontail abundance index values per turbine string to tower type, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Type of Tower	Other Types of Tower	Mean difference (cm) on Grass transect	Mean difference (cm) on String transect
Vertical axis	Bonus tubular	0.25*	0.30*
	Diagonal lattice	0.38**	0.32*
	Horizontal lattice	0.26*	0.35*
	Enertech	-0.56**	-0.71**
	Windmatic	-1.09**	-0.94**
Micon 65	Bonus tubular	0.32**	0.50**
	Diagonal lattice	0.45**	0.52**
	Horizontal lattice	0.33**	0.55**
	KVS-33	ns	0.72*
	Enertech	-0.49**	-0.51**
	Windmatic	-1.02**	-0.74**
Enertech	Bonus tubular	0.81**	1.01**
	Vertical axis	0.56**	0.71**
	Diagonal lattice	0.94**	1.03**
	Horizontal lattice	0.82**	1.06**
	KVS-33	0.92**	1.23**
	Danwin tubular	0.83**	0.68**
	Micon 65	0.49**	0.51**
	Windmatic	-0.52*	ns

Table 5-17. LSD test results comparing mean cottontail abundance index values per turbine string to physical relief, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Physical Feature	Other Physical Features	Mean difference (cm) on Grass transect	Mean difference (cm) on String transect
Plateau and slope	Plateau	0.56*	0.58*
	Ridge crest	0.61**	0.65**
	Ridge crest/Ridgeline	0.68**	0.83**
	Ridgeline	0.69**	0.65*
	Slope	0.43*	0.35^{t}
	Slope and Ridge	0.62**	0.74**
	Convex slope	0.42*	0.47*
Slope	Ridge crest	ns	0.30*
	Ridge crest/Ridgeline	ns	0.49*
	Slope and Ridge	ns	0.39*
Saddle	Plateau	ns	1.07*
	Ridge crest	ns	1.14**
	Ridge crest/Ridgeline	ns	1.32**
	Ridgeline	ns	1.14*
	Slope	ns	0.83*
	Slope and Ridge	ns	1.22**
	Concave slope	ns	0.89*
	Convex slope	ns	0.96*

Table 5-18. LSD test results comparing mean cottontail abundance index values per turbine string to physical relief, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Slope Aspect	Other Slope Aspects	Mean difference (cm) on Grass transect	Mean difference (cm) on String transect
Southwest	Flat (no aspect)	ns	0.70*
	East	ns	0.63*
	Southeast	ns	0.63*
	South	ns	0.72*
	West	0.82*	1.13*
	North	ns	0.67*
	Northwest	0.72*	1.06*
Northwest	Flat (no aspect)	-0.32*	-0.36*
	North to South	-0.34*	-0.56*
	North	-0.41*	-0.39*
	Northeast	-0.41*	-0.47*
	East	-0.38*	-0.43*
	Southeast	-0.35*	-0.43*

Wind Turbine Level of Analysis

Cottontail abundance at the wind turbine-level of analysis decreased significantly with increasing elevation, vegetation height, and with the number of cattle pats present near the wind turbines (Table 5-19).

Table 5-19. Correlation test results between cottontail abundance index and independent variables (n = 1325), where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Independent Variable	Cottontail abundance index on grass transect	Cottontail abundance index on turbine string transect
Mean elevation	r_p = -0.17**	r_p = -0.25**
Vegetation height (cm)	r_p = -0.12**	r_p = -0.06*
Cattle pats on grass transect	r_p = -0.09*	r_p = -0.13**
Cattle pats on String transect	r_p = -0.13**	r_p = -0.14**

Cottontail abundance was significantly greater (95% greater) outside the canyons along the grass transect (ANOVA F = 14.09; df = 1, 1533; P < 0.001), but not along the turbine string transect (ANOVA F = 2.83; df = 1, 1533; P = 0.093). Within canyons, cottontail abundance averaged 83% greater along the turbine string than 20–40 m away, which was a significant difference (matched-pairs t-test: t = -3.970, df = 174, P < 0.001). Cottontail abundance also differed significantly between transects outside canyons (matched-pairs t-test: t = -2.893, df = 1356, P = 0.004), but less so (11% greater along string transect).

Cottontail abundance varied significantly among edge conditions surrounding the towers, both along the grass transect (ANOVA F = 5.28; df = 4, 1533; P < 0.001) and the turbine string transect (ANOVA F = 3.33; df = 4, 1531; P < 0.01). Post-hoc LSD tests showed that cottontail abundance was greatest at turbines surrounded by some lateral edge and least at those surrounded by vertical edge or no edge (Table 5-20).

Table 5-20. LSD test results comparing mean cottontail abundance index values per wind turbine to the edge index, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Edge condition	Other Edge conditions	Mean difference (cm) on Grass transect	Mean difference (cm) on String transect
Some lateral edge	No edge	0.24*	0.22*
	Lots of lateral edge	0.16*	0.13*
	Some vertical edge	0.18*	0.17*
	Lots of vertical edge	0.27**	0.22**
Lots of lateral edge	Lots of vertical edge	0.11*	0.10*
Some vertical edge	Lots of vertical edge	0.09*	ns

Cottontail abundance did not vary significantly by position of the tower in the string along the grass transect (ANOVA F = 0.79; df = 3, 1323; P = 0.506) or the string transect (ANOVA F = 1.61; df = 3, 1322; P = 0.186).

5.3.4 Lizard Abundance

String Level of Analysis

Lizard abundance per wind turbine tended to vary among turbine strings based on intensity of rodenticide deployment (ANOVA F = 2.54; df = 2, 191; P = 0.081), and post-hoc LSD tests suggested that lizard abundance was 50% to 60% greater on ownerships that deployed no rodenticides compared to those that heavily and intermittently deployed them, respectively (P < 0.05 for both LSD tests), as depicted in Figure 5-3.

Lizard abundance correlated slightly positively with the edge index, and slightly negatively with the number of cattle pats per turbine along the string transect (Table 5-21). It varied significantly by type of physical relief (ANOVA F = 3.04; df = 10, 191; P < 0.001). Post-hoc LSD tests suggested that lizard abundance was especially greater on saddles (Table 5-22). It did not vary significantly by dominant aspect of the slope (ANOVA F = 1.188; df = 11, 191; P = 0.298). Post-hoc LSD tests suggested that lizard abundance was generally greater on southeast and southwest slopes (Table 5-23). It varied significantly by tower type (ANOVA F = 4.187; df = 8, 191; P < 0.001). Post-hoc LSD tests suggested that lizard abundance was greater under and around wind towers that lacked concrete pads, such as lattice towers and those installed for Windmatic turbines (Table 5-24).

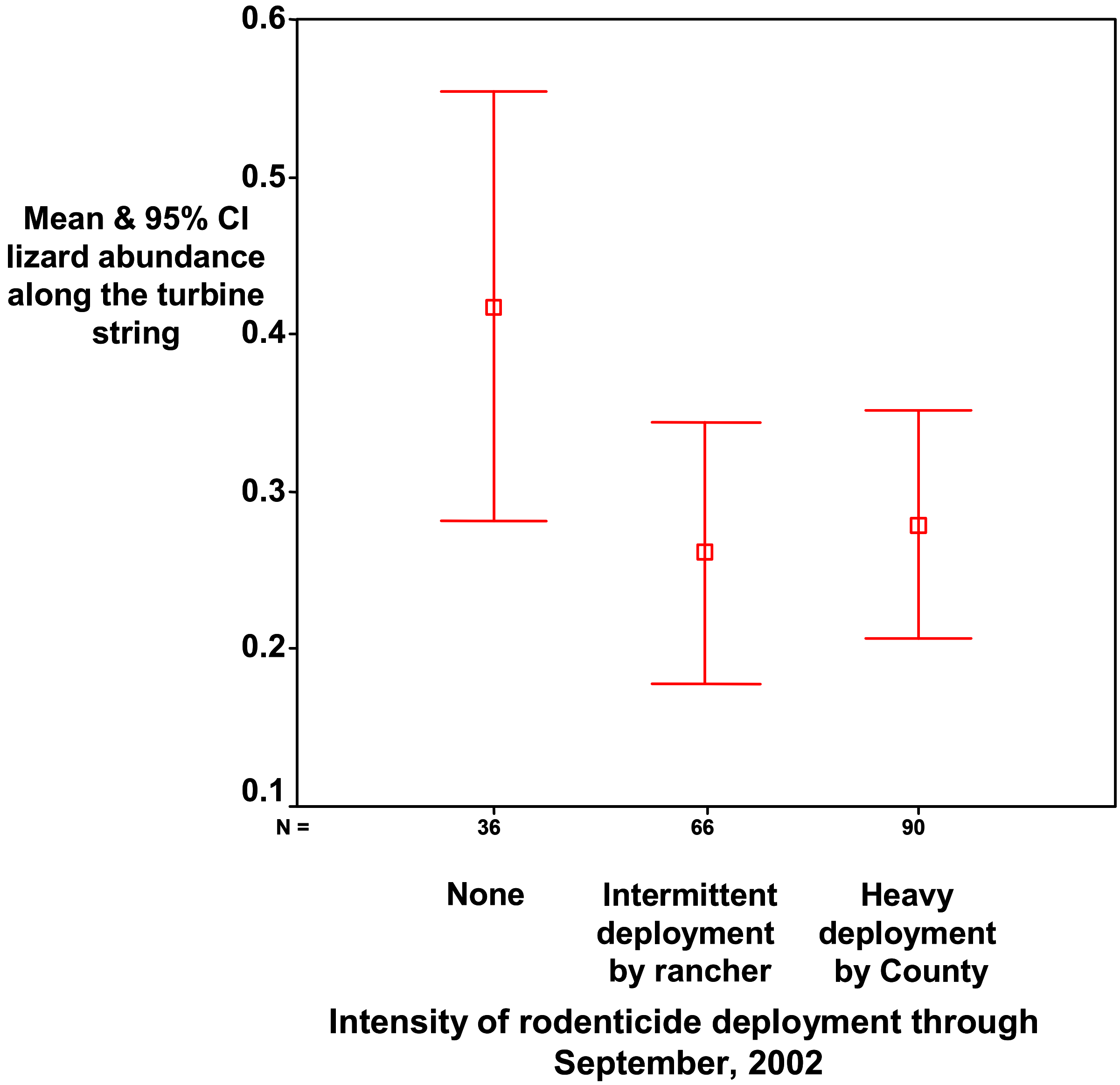

Figure 5-3. Lizard abundance near wind turbines was greatest where no rodenticide was deployed.

Table 5-21. Correlation test results between lizard abundance and independent variables (n = 192), where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Independent Variable	Lizard abundance
Vegetation height (cm)	ns
Mean elevation	ns
Change in elevation	ns
Elevation change per turbine	ns
Percent in canyon	ns
Variation in physical relief	ns
Cattle pats per turbine on grass transect	ns
Cattle pats per turbine on string transect	r_p = -0.21**
Edge index per turbine	r_p = 0.17*

Table 5-22. LSD test results comparing lizard abundance per wind turbine to physical relief, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Physical Feature	Other Physical Features	Mean difference (cm)
Slope and Ridge	Ridge crest	0.22*
Convex slope	Ridge crest	0.16*
Saddle	Peak and slope	0.78*
	Plateau	0.84**
	Plateau and slope	0.71**
	Ridge crest	0.92**
	Ridge crest/Ridgeline	0.92**
	Ridgeline	0.96**
	Slope	0.87**
	Slope and Ridge	0.70**
	Concave slope	0.67*
	Convex slope	0.92**

Table 5-23. LSD test results comparing mean lizard abundance per wind turbine to dominant slope aspect of the string of turbines, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Slope Aspect	Other Slope Aspects	Mean difference (cm)
Southeast	Flat (no aspect)	0.30*
	North	0.32*
	Northwest	0.31*
Southwest	Flat (no aspect)	0.34^t
	North	0.37^t
	Northwest	0.35^t

Table 5-24 LSD test results comparing mean lizard abundance per wind turbine to tower type, where t denotes 0.10 > P > 0.05, * denotes P < 0.05, and ** denotes P < 0.005

Type of Tower	Other types of Tower	Mean difference (cm)
Vertical axis	Bonus tubular	0.20*
	Horizontal lattice	0.24*
Diagonal lattice	Bonus tubular	0.28*
	Horizontal lattice	0.32**
	KVS-33	0.43 t
Micon-65	Horizontal lattice	0.17 t
Windmatic	Bonus tubular	0.61**
	Vertical axis	0.41*
	Diagonal lattice	0.33*
	Horizontal lattice	0.65**
	KVS-33	0.77*
	Danwin tubular	0.53*
	Micon 65	0.48*
	Enertech	0.52**

Wind Turbine Level of Analysis

Lizard abundance correlated significantly with only one continuous variable, but the coefficient was not large enough to warrant reporting. It did not vary significantly by edge conditions surrounding the wind towers, or by position of the tower in the string.

5.4 DISCUSSION

This study resulted in many statistically significant tests, but many of which were somewhat redundant due to shared variation among variables. Table 5-25 summarizes the strongest associations that we believed were also more orthogonal in their expressions of underlying factors. The remainder of this discussion focuses on these associations.

Vegetation height near the wind turbines was greater on ridge crests than most of the other types of physical relief considered. It was greater on steeper slopes and on south-facing and northwest-facing slopes. Vegetation height also was greater in canyons, and where vertical edge was particularly evident near towers. It correlated positively with the number of cattle pats present along a transect 20 m from the turbine string.

Table 5-25. Highlighted associations between variables based on level of statistical significance and shared variation with other associations

Dependent Variable	Relationship with Association Variable
Vegetation height	Taller on ridge crests and slopes
	Taller in canyons
	Taller on south- and northwest-facing slopes
	Taller where vertical edge is greater around tower laydown areas
Cattle pats	More in area of intermittent rodent control
	More at turbines than 20 m away in areas of rodent control
	More in canyons and on steeper slopes and greater vertical edge
	More on ridge crests and ridgelines
	More by vertical axis, tubular and horizontal lattice towers
	More by non-operational towers and those at edges of gaps in string
Cottontail abundance	More in areas of no rodent control
	More at turbines than 20 m away in areas of intense rodent control
	More at lower elevations
	More on shallower slopes outside canyons
	More where there are fewer cattle pats
	More on southwest-facing slopes
	More by wind tower laydown areas with some lateral edge
Lizard abundance	More in areas without rodent control
	More on southeast and southwest slopes
	More on saddles of ridges
	More at wind towers with no concrete pads

The intensity of cattle use of laydown areas, as inferred from the number of cattle pats along two transects, was greatest on the ownership where rodenticide was deployed intermittently, and likely reflected the stocking rate and control methods of the single rancher who controlled this area. Another possible explanation was that this ownership included more of the tubular towers, which cattle appear to use for shade, and another was that the intermittent control may have resulted in greater clustering of rodents around wind turbines, which perhaps fostered a greater growth of plants preferred by cattle. At sites where rodenticides were applied, cattle pats were significantly more abundant immediately around turbines than they were 20–40 m away; however, there was no difference in abundance where rodent control programs were not implemented.

Cattle use intensity in the immediate area surrounding wind turbines was also greatest on ridge crests and ridgelines, and on west- and northwest-facing slopes and on flat areas with no slope aspect. It was greater nearby Bonus tubular towers and vertical axis towers, and least where tower laydown areas were surrounded by lots of vertical edge. Based on these associations, it appears that some factors, such as rodent control, steepness of slope, ridge crests, and northwest-facing slopes, cause cattle to spend more time closer to the wind turbines. This association was especially true for Bonus tubular towers, perhaps because these towers provided more shade during the hot days of summer and early fall. When concentrated among the wind turbine towers, cattle appeared to spend more time within gaps of the turbine string and next to non-operational turbines than elsewhere, perhaps offsetting some aspect(s) of the wind turbines cattle might find annoying, such as the noise or motion of moving blades.

Cottontail abundance was twice as great on ownerships where no rodenticide was deployed, and there was no apparent clustering of cottontails near the wind towers. However, where rodenticide was heavily deployed, cottontails were more abundant at the wind towers than they were 20 m away. Cottontail abundance correlated negatively with cattle pat abundance. It correlated positively with plateaus, slopes, and saddles, on southwest-facing slopes, and where some lateral edge was evident.

Lizard abundance was greatest on ownerships that deployed no rodenticide, and was greater on saddles and on southeast- and southwest-facing slopes. It was also greatest at wind turbines lacking concrete pads.

Rodent control corresponded with greater clustering of cattle and cottontails at the wind turbines, whereas it corresponded with less abundance of cottontails and lizards and greater abundance of cattle pats. Some of these relationships might be confounded with other variables, such as differential stocking rates of cattle by ownership, or more or less availability of rock piles for cottontails to find den habitat.

The distribution of cattle, cottontails, lizards, and grass height appear to associate with physical relief and range management practices, as well as according to the types of wind turbine deployed by the wind industry. The interrelationships between grass height, cattle use intensity, cottontail abundance, and lizard abundance are complex, and not always intuitive. Each varies with range management practices, but each of these relationships is moderated by other factors, such as physiographic conditions. Therefore, it is inherently difficult to predict the effects of new range management practices on bird mortality caused by wind turbines because the ecological relationships affected by such practices are complex. In the chapter on fatality associations (Chapter 7), we test whether cattle pat abundance, cottontail abundance and vegetation height relate to bird fatalities.