Reestablishment of a Rodent Community in Restored Desert Scrub

Michael A. Patten[1]

Abstract

I conducted small-mammal trapping surveys on a desert scrub restoration site in Palm Springs, California, to document concomitant recovery of the rodent community. These surveys were conducted following quantitative vegetation sampling efforts that indicated that a predefined successful restoration criterion of 15% total shrub cover had been met throughout most of the area. But shrub cover, native shrub cover, herb cover, native herb cover, total cover, and total native cover remained significantly lower in the restoration area than in undeveloped desert scrub immediately surrounding the site. Native herb species richness was also generally lower in the restoration area. Despite these vegetation differences, rodent diversity, evenness, and abundance were very similar between the restoration and natural areas (they were consistently slightly higher in the restoration area). More diverse microhabitats, proximity to water, and reduced competition with harvester ants may have contributed to this outcome. If ecosystem restoration is the goal, reestablishment of a faunal community in restored habitat, rather than surpassing a predefined percent cover of vegetation, may be a better indicator of success, because plant cover proved to be a poor predictor of mammal success.

Introduction

Vegetation restoration is a common mitigation measure for areas heavily degraded by construction projects. Virtually all "success criteria" designated for such restoration efforts involve a study only of physiognomy—and at times richness—of restored vegetation. By contrast, little attention has been devoted to use of restored vegetation by fauna, although ecosystem establishment in a restored area should be prerequisite to considering any restoration effort a "success." I compared rodent diversity and abundance of such a restored area with like data gathered in surrounding undeveloped natural habitat. My goal was to determine whether a small-mammal community had recovered from construction impacts at a site for which successful revegetation criteria had been met. Specifically, vegetation sampling indicated that a predefined, project-specific success criterion of 15% shrub cover (set by the U.S. Army Corps of Engineers when they issued a wetlands alteration permit) had been met for most of the restored vegetation. Nevertheless, restored areas, particularly those adjacent to constructed channels, tended to have lower species richness and percent cover than did desert scrub immediately surrounding the site that was not degraded by this construction. Because of these vegetation differences, I expected lower rodent diversity, evenness, and richness in restored desert scrub than in surrounding natural desert scrub.

Methods

Site. The study site was located along Tahquitz Creek at the northern edge of Palm Springs, Riverside County, California (Township 4 South, Range 4 East, Section 22, San Bernardino Baseline and Meridian, U. S. Geological Survey 7.5′ Palm Springs quadrangle). The Riverside County Flood Control and Water Conservation District completed construction of flood control structures along Tahquitz Creek in February 1991. These structures consisted of a debris basin downstream from two unlined, channelized streams (Tahquitz Creek and Fern Canyon) and upstream from a single channel lined with rock and concrete. During construction of the dam and associated access roads and channels, approximately 20 acres of desert scrub was either scraped bare or heavily degraded; topsoil was replaced after construction. In the spring of 1991, vegetation restoration was initiated in degraded areas with direct seeding of shrubs and planting of shrub seedlings; no herb species were seeded. Seeded and planted species consisted mainly of *Encelia farinosa* (brittlebush), *Larrea tridentata* (creosote), *Eriogonum fasiculatum* (California buckwheat), *Prosopis glandulosa* var. *torreyana* (honey mesquite), and *Salvia apiana* (white sage) (taxonomy and nomenclature follow Hickman 1993); furthermore, some cacti were salvaged and replanted.

Vegetation Sampling. Vegetation cover was quantified in natural and restored areas by sampling of randomly selected 3.3 × 3.3–m plots within restored desert scrub and in surrounding desert scrub that was not affected by construction. Species, number, and canopy diameter

[1] Department of Biology, University of California, Riverside, CA 92521, U.S.A., and Tierra Madre Consultants, 1159 Iowa Avenue, Suite E, Riverside, CA 92507, U.S.A.

at the widest point of each shrub were recorded. Shrubs and infrequent annuals were counted, but numbers of common annuals were only estimated. Diameter of total vegetation for annuals was recorded as an estimated average for all individuals of that species growing within plot boundaries. All sampling was conducted between 27 August 1993 and 2 November 1993. A total of 132 plots was sampled, with 30 plots in the natural vegetation area and 102 in the restoration area. With the richness and cover results for each plot, for both native species only and for all species, the following were calculated for each area: mean number of shrub species, mean shrub cover, mean number of herb species, mean herb cover, mean total species, and mean total cover.

Small-Mammal Trapping. Trapping was conducted in restored desert scrub and surrounding desert scrub that was not affected by construction. Sherman live traps were used, with 180 set each of eight nights at 1-week intervals from 29–30 March 1995 through 17–18 May 1995, for a total of 1440 trap-nights. A different portion of the site was trapped each week so that the effects of trap habituation, the tendency of animals to be recaptured on successive trap-nights when trap-lines are repeated (M. V. Price, personal communication), could be safely ignored. Traps were laid in 18 lines of 10 traps each, with each line about 10 m apart. Traplines were centered on the border between the restored and natural areas, with each trap set about 5 m from the centerline, and thereafter 5 m from the nearest trap. This trapping grid was moved each night of the study so that the entire restoration area was sampled. Like bait of oats and bird seed was used in all traps on a given trap night. Trapped animals were identified, measured (sometimes), and released (several vouchers were taken and were donated to the San Bernardino County Museum, Redlands, California). Mammals were identified by means of keys in Ingles (1965) and Jameson and Peeters (1988), and from information supplied by R. J. Baxter and M. V. Price, University of California, Riverside. Setting 90 traps each in natural and restored areas on a given night avoids bias because the effects of moon phase and weather conditions affected all traps in the same way. The 5-m spacing was considered sufficient given the small foraging radii of many rodents.

Statistical Analyses. Percent cover of shrubs, herbs, and total vegetation, both for all species and for native species only, was compared between restored and natural vegetation by means of Welch's separate variance t tests (BMDP 1990) on arcsine-transformed data. Shrub, native shrub, herb, and native herb species richness was compared by means of Mann-Whitney U two-sample rank tests.

Rodent data were analyzed by calculating and comparing rodent diversity (Hill 1973) between restored and natural desert scrub, and by comparing Shannon's indices with the t test described by Hutcheson (1970). Paired t tests were conducted for each species, with number of individuals captured in restored versus natural vegetation during each night of trapping corresponding to a paired observation ($n = 8$ pairs). Because 17 traps were disturbed and/or stolen during the final night of trapping, data for the final 90 traps were excluded; thus, for comparative purposes in pairwise t tests, trapping results from the first 90 traps were doubled for the 17–18 May sample. Actual numbers trapped, with the final 90 excluded, were used in other analyses (e.g., calculation of diversity indices). Finally, rodent data were divided into three categories for foraging guild: granivore (*Chaetodipus* and *Dipodomys*), herbivore (*Neotoma*), and omnivore (*Peromyscus*). A G test of independence with William's correction (Sokal & Rohlf 1995), was conducted to determine if guild differences existed between natural and restored areas.

All statistical tests were performed with BMDP (1990) or SAS (1994) statistical software, or by hand with information from Sokal & Rohlf (1995).

Results

Vegetation Sampling. Vegetation throughout the restoration area and in surrounding natural areas was desert scrub dominated by native species. *Encelia farinosa, Larrea tridentata, Hyptis emoryi* (desert lavender), and *Hymenoclea salsola* (cheesebush), with *Acacia greggii* (catclaw), *Prosopis glandulosa* var. *torreyana, Bebbia juncea* (rush sweetbush), and *Krameria grayi* (white rhatany) more prevalent around washes above the dam (Fig. 1). Understory plants were mostly nonnative grasses, especially *Bromus madritensis* ssp. *rubens* (foxtail chess) and *Schismus barbatus* (Mediterranean split grass). In restored areas, *Encelia farinosa* and, to a lesser extent, *Eriogonum fasciculatum* were the only shrubs that established well, but native shrub richness per plot did not differ significantly between the areas ($U = 1482$, $p = 0.7815$; richness $= 2.54 \pm 0.90$ species/plot in the restoration area and 2.60 ± 1.10 species/plot in the natural area) (Fig. 2).

Although the restoration area met the predefined success criteria for this project of 15% total cover, excepting exotic shrub cover, percent cover differed significantly from the natural area, including native species and exotic species, and including shrub cover, herb cover, and total cover (Table 1). Native shrub, exotic shrub, and native herb species richness did not differ significantly between the natural and restoration areas ($U > 1464$ and $p > 0.28$ in both cases), but exotic herb species richness showed a significant difference ($U =$

Figure 1. Natural desert scrub at Tahquitz Creek, California. This vegetation is dominated by *Encelia farinosa* (the paler shrubs) and *Larrea tridentata* (the tall, very dark shrubs), with occasional *Eriogonum fasciculatum, Hymenoclea salsola, Justicia californica, Krameria grayi*, and *Hyptis emoryi*. February 9, 1997.

2007, $p = 0.0039$), with the natural area having lower exotic herb richness (1.67 ± 0.71 species/plot, compared with 2.08 ± 0.67 species/plot in the restoration area).

Rodent Trapping. Because vegetation structure and distribution plays a major role in rodent distribution and abundance (Price 1978; Munger et al. 1983; Price & Waser 1984; Brooks 1995), I expected to find lower small-mammal diversity and abundance in the restoration area. I consistently captured five species of small rodents: *Chaetodipus fallax* (San Diego pocket mouse), *Chaetodipus spinatus* (spiny pocket mouse), *Neotoma lepida* (desert woodrat), *Peromyscus eremicus* (cactus mouse), and *Peromyscus maniculatus* (deer mouse); there were also single captures of *Dipodomys merriami* (Merriam's kangaroo rat) and *Spermophilus beecheyi* (California ground squirrel), both in the natural desert scrub. In terms of total captures, mean number of captures per trap-night, diversity, and evenness, the natural and restoration areas were very similar (Tables 2 & 3). Except for richness, however, the restored area scored consistently higher than did the natural area, although not significantly so in the case of Shannon's indices; this pattern held even when the two species captured just once were excluded (Table 3). When only captures of juveniles were considered, the restored areas yielded slightly more (Table 4), indicating that these species are likely established and breeding in those areas (i.e., restoration area is unlikely to be a population sink). Of the five species consistently captured, *Chaetodipus fallax* and *Neotoma lepida* tended to be found slightly more frequently in the natural area, although these differences were small and were not statistically significant (Table 2). *Chaetodipus spinatus, Peromyscus eremicus*, and *P. maniculatus* tended to be found more frequently in the restoration area, but not significantly so (Table 2). When grouped by foraging guild, however, the rodent community differed significantly between the restoration area and the natural area ($G_{adj} = 6.036$, $p < 0.05$, $n = 319$, df = 2), principally in that the restored desert scrub had more omnivores (63.64% of the total number of omnivores captured).

Figure 2. Restored desert scrub at Tahquitz Creek, California. This vegetation is dominated by *Encelia farinosa*, the reseeded or replanted perennial that reestablished by far the best on this site. The slightly darker shrubs are *Eriogonum fasciculatum*, the only other perennial that reestablished well. Note the more open vegetation structure compared to the natural desert scrub. February 9, 1997.

Discussion

Even though vegetation in the restoration area at Tahquitz Creek has not yet achieved the same levels of shrub and herb cover, and perhaps of native herb species richness, as those of natural desert scrub surrounding the construction area, rodent communities have recovered in areas with restored vegetation. In fact, the restoration area yielded higher diversity and evenness of small rodents than did surrounding natural areas, and it yielded significantly more captures with rodents grouped by foraging guild. These results were consistent with several previous studies that found fairly rapid recolonization of disturbed sites by small mammals (Frolich & Marion 1984; Hingtgen & Clark 1984; Fowler 1989; but see Kirkland 1976). Rather than calculating only a simple percent cover, monitoring of faunal community recovery likely provides a better measure of restoration success (see Majer 1989 and papers therein). In these terms, restoration efforts at Tahquitz Creek were successful.

Table 1. Results of quantitative vegetation sampling for 132 plots.*

Variable	*Restoration Area*	*Natural Area*	*t*	*P*
	(n = 102 plots)	*(n = 30 plots)*		
Mean exotic shrub cover	0.02% ± 0.14	0.72% ± 3.96	−0.93	0.3622
Mean native shrub cover	29.22% ± 17.80	45.76% ± 30.88	−3.17	0.0030
Mean exotic herb cover	2.13% ± 5.41	9.64% ± 10.30	−5.54	<0.0001
Mean native herb cover	0.50% ± 1.26	1.46% ± 1.75	−3.84	0.0004
Total exotic cover	2.16% ± 5.40	10.36% ± 10.49	−5.29	<0.0001
Total native cover	29.70% ± 18.06	47.22% ± 30.58	−3.38	0.0017
Total cover	31.86% ± 19.84	57.58% ± 31.69	−4.68	<0.0001

* Measured in the fall of 1993, with totals present as mean percent cover/plot ± SD (percent cover was square-root arcsine transformed for *t* tests). Negative *t* values slope into the natural desert scrub.

Nevertheless, it is puzzling as to why small-rodent diversity was not lower in restored areas, particularly considering the lower shrub cover, herb cover, and plant species richness. Indeed, many previous studies have shown that rodent species composition varies with shrub and herb diversity, cover, and density (Rosenzweig & Winakur 1969; Beatley 1976; Price 1978; Munger et al. 1983; Price & Waser 1984; Heske & Campbell 1991; Brooks 1995; Carey & Johnson 1995). Most of these studies were conducted within desert ecosystems in the southwestern United States, and each found generally consistent results: rodent diversity was positively correlated with plant diversity and cover.

Several factors may have influenced the fact that rodent diversity was higher in restored areas, most having to do with microhabitat differences, which can play a major role in shaping rodent community structure and diversity (Price 1978; Price & Waser 1985). On a microhabitat level, the restored area may be more diverse, for it has several habitat types, including creek edge, rock-lined revetments, desert scrub, open dirt roads, and a few natural washes. Natural habitat immediately surrounding the project area is less varied, with more dense desert scrub, more washes, and more grassy (nonnative) flat areas, but with fewer rocky areas and no creek edge. This last habitat may be a key because, in part, rodent numbers were likely higher in restored areas bordering the channel because of their proximity to water (Munger et al. 1983; Mastrota et al. 1989), especially below the debris basin dam. *Peromyscus maniculatus* in particular was trapped in larger numbers near the creek than anywhere else, and the number of captures diminished away from that area. Similarly, those plants in closer proximity to the creek may have higher leaf and seed production, which would in turn positively affect rodent diversity (Reichman & Van De Graaff 1973). The much higher amount of nonnative grass in the natural grass areas (Table 1) may inhibit the use of those areas by rodents because the amount of open ground—foraging area—is reduced. The only expected exception may be *Chaetodipus fallax*, a species often found in grasslands (personal observation). *Neotoma lepida*, a species inhabiting rocky areas with high shrub cover (Jameson & Peeters 1988), may be expected to occur with equal frequency in both areas. By contrast, *Chaetodipus spinatus* prefers rocky areas (Williams et al. 1993), and the many rocks used as revetments along the constructed channel provide more habitat for this spe-

Table 2. Trapping results from restored desert scrub and natural desert scrub.*

	Total Captures		*Mean Number of Captures*			
Species	*Restored*	*Natural*	*Restored*	*Natural*	*t*	*P*
Chaetodipus fallax	23	27	2.9	3.5	−0.691	0.5121
Chaetodipus spinatus	22	10	2.9	1.4	1.620	0.1492
Dipodomys merriami	0	1	0.0	0.1		
Neotoma lepida	55	60	7.4	8.0	−0.424	0.6845
Peromyscus eremicus	41	24	5.8	3.4	1.800	0.1155
Peromyscus maniculatus	36	20	4.5	2.8	1.530	0.1705
Spermophilus beecheyi	0	1	0.0	0.1		
Total:	177	143	23.5	19.3		

* Mean number of captures refers to the mean in each of the two habitat types on any given night. Paired *t* tests are between mean number of captures per trapping night in restored and natural desert scrub (df = 7 for all tests). Positive *t* values slope into the restoration area, whereas negative values slope into the natural area.

Table 3. Measures of diversity and evenness between rodents in restored and natural desert scrub.*

Measure	Restored	Natural
Hill's Index (N_2)	4.47	3.78
Shannon's Index ($\ln N_1$)	1.55	1.51
Richness (N_0)	5.0	7.0
Pielou's J ($\ln N_1/\ln N_0$)	0.96	0.78

*See Hill 1973. Hutcheson's (1970) t test for comparing Shannon's indices across areas showed no significant difference ($t = 0.618$, $p > 0.5$, df = 200).

cies than does the less rocky natural area. The patterns shown by the two *Peromyscus* species are more difficult to explain, although there is evidence that *P. maniculatus* readily colonizes disturbed sites (Verts 1957; Wetzel 1958; Kirkland 1976; Hansen & Warnock 1978).

Harvester ant numbers (both *Messor* spp. and *Pogonomyrmex* spp.), though not measured, appeared to be substantially higher in natural areas. Furthermore, far more Sherman live traps were marauded by ants in the natural area than in the restored areas. Competition with ants can greatly alter community structure and overall numbers of rodents (Brown et al. 1979*a*, 1979*b*). At Tahquitz Creek, competition with ants may be more limiting to rodent numbers in natural vegetation than in restored areas.

Areas with restored vegetation at Tahquitz Creek support a community of small rodents comparable to the community occupying undeveloped desert scrub surrounding the project area. These findings are consistent with the work of Andersen (1994), who found that a rodent community in a rehabilitated desert riparian area acted as a source habitat for most of the species sampled, indicating that a rodent community had successfully established itself in restored desert scrub on his study site. As noted above, the more varied microhabitat, the proximity to water in roughly half the restoration area, and the reduced competition with harvester ants probably combined to yield higher rodent diversity in the restored desert scrub.

Table 4. Trapping results from restored desert scrub and natural desert scrub with only juveniles considered.*

Species	Restored	Natural
Chaetodipus fallax	1	4
Chaetodipus spinatus	2	0
Neotoma lepida	3	8
Peromyscus eremicus	8	5
Peromyscus maniculatus	10	4
Total	24	21

*The presence of a large number of juveniles in the restored area likely indicates that those species are established in that area.

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