EFFICACY OF HABITAT RECLAMATION FOR ENDANGERED SPECIES AT THE ELK HILLS OIL FIELD, CALIFORNIA

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ABSTRACT: Ecological and economical efficacy of endangered species habitat reclamation at the Elk Hills Oil Field (formerly Naval Petroleum Reserve No. 1) was evaluated. Revegetation success and level of site re-disturbance were evaluated 5 years post-treatment and 10 years post-treatment on 996 disturbed sites reclaimed between 1985 and 1989. Also, in 1994, vegetation cover and site usage by predators and prey of the endangered San Joaquin kit fox (*Vulpes macrotis mutica*) were recorded for a sample of these sites. Revegetation was considered successful when a site's vegetation cover at the end of the growing season was ≥70% of the average cover observed on reference sites or adjacent undisturbed areas. After 5 years 47.2% of sites met this criterion. After 10 years 74.4% of a sample of sites still being monitored met this criterion. Annual grasses comprised most vegetative cover during the first 2 years. Shrubs comprised most vegetative cover after 4 years. After 5 years, 70.3% of the reclaimed sites were still intact and 29.7% had been partly or wholly re-disturbed. Lagomorphs (Lepus californicus and Sylvilagus audubonii) appeared to use most sites almost immediately after reclamation. Site use by rodents (*Dipodomys* spp., *Onychomys torridus*, *Perognathus inornatus inornatus*, and *Peromyscus maniculatus*) stabilized by the second year and burrows or feces were observed at ≥90% of sites. Use of reclaimed sites by coyotes (*Canis latrans*) and kit foxes appeared to slightly increase 3 or 4 years following treatment. Because vegetative composition and structure on reclaimed sites >3 years old appeared to favor coyotes and bobcats (*Felis rufus*), the main predators of kit foxes, and on-site mitigation costs were more than 5 times higher than the estimated off-site mitigation costs, reclamation of disturbed endangered species habitat at Naval Petroleum Reserve No. 1 was not considered to be efficacious.

Key Words: habitat reclamation, endangered species, San Joaquin kit fox, revegetation, vegetation cover, Elk Hills

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INTRODUCTION

Reclamation of disturbed lands should be evaluated in relation to resource managers' objectives. Common yardsticks that managers use to evaluate the efficacy of reclamation programs include cost-effectiveness, vegetation recovery rates, soil stability, vegetation composition, and vegetation structure at reclaimed sites. Sometimes other criteria may be important to consider such as recolonization by particular wildlife species (Patten 1997) such as federal listed threatened and endangered species.

This paper describes the results of our post hoc evaluation of the U.S. Department of Energy's (DOE) habitat reclamation program at Elk Hills. The program consisted of reclaiming disturbed endangered species habitat areas over a 9-year period, and then monitoring the success of these reclamation activities. The objectives of DOE's program were (1) to reduce erosion, and (2) to restore the carrying capacity of habitat for endangered species and their prey (O'Farrell and Mitchell 1985). In 1987, annual monitoring was initiated to evaluate revegetation success (Anderson 1987). Revegetation was considered successful when a site's vegetation cover at the end of the growing season was (70% of that observed on reference sites or on adjacent undisturbed areas (EG&G Energy Measurements Inc. 1995; D. C. Anderson and B. L. Cypher, unpublished data). Although information on plant species composition, erosion, wildlife utilization, and post-treatment disturbance were gathered during monitoring, vegetation cover and utilization of treated sites by kit fox and their prey were the key variables used to determine whether objectives were being met. Reclamation of disturbed sites at Elk Hills ended in 1993, but reclaimed sites continued to be monitored to evaluate the program's success.

After the reclamation program ended, we conducted an evaluation of its success. The objectives of our study were to: (1) determine revegetation success rates; (2) document the level of re-disturbance on reclaimed sites after 5 and 10 years; (3) evaluate the ecological and economical efficacy of habitat reclamation at Elk Hills for endangered species; and (4) suggest practical modifications or alternatives that will meet current management objectives and adequately mitigate impacts to endangered species habitat. Herein, we present the results of this study.

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STUDY AREA

The Elk Hills Oil Field (Elk Hills; formerly known as Naval Petroleum Reserve No. 1 or NPR-1) is an extensive oil and gas production area formerly administered by the DOE. Revegetation test trials were conducted at Elk Hills during the 1970s with little success. However, results of trials conducted in the early 1980s yielded more positive results (O'Farrell and Mitchell 1985). In 1985, a reclamation program was operationalized at Elk Hills to mitigate impacts to threatened and endangered species habitat resulting from oil and gas field development (Anderson 1987). Elk Hills is located in the southern San Joaquin Valley, Kern County, California. The 19,134-ha study area is jointly owned by Occidental of Elk Hills, Inc. and Chevron Production Company. Elk Hills includes intact natural habitat interspersed among lands developed for oil and gas production. Elevations range from 92 to 458 m. Topography ranges from nearly flat valley floors to the steep slopes of the Elk Hills geological formation. Soils are primarily Torriorthents in the hills and sandy loam Orthids at lower elevations. The climate is Mediterranean: summers are hot and dry; winters are cool and moist. The 30-year average annual precipitation is 160 mm, most of which occurs as winter rain (National Climatic Data Center 1996). Herbaceous plants primarily grow between 1 January and 15 April. Vegetation is characterized as Lower Sonoran Grassland (Twisselmann 1967). Dominant herbaceous species include red brome (*Bromus madritensis*), mousetail fescue (*Vulpia myuros*), Mediterranean grass (*Schismus* spp.), and red-stem filaree (*Erodium cicutarium*). Shrubs which tend to be abundant in later seral communities include desert saltbush (*Atriplex polycarpa*), spiny saltbush (*A. spinifera*), and cheesebush (*Hymenoclea salsola*). Federal listed species at Elk Hills include the San Joaquin kit fox, blunt-nosed leopard lizard (*Gambelia sila*), giant kangaroo rat (*Dipodomys ingens*), Tipton kangaroo rat (*D. nitratoides nitratoides*), and an annual wildflower called Hoover's wooly-star (*Eriastrum hooveri*). The California listed San Joaquin antelope squirrel (*Ammospermophilus nelsoni*) is also present. Of these species, research and management activities have historically emphasized the kit fox. Elk Hills comprises a significant portion of the remaining habitat occupied by the endangered San Joaquin kit fox (Williams et al. 1997).

METHODS

Reclamation of Disturbed Sites

A total of 1,180 disturbed sites (364 ha) were reclaimed by EG&G Energy Measurements, Inc. subcontractors between 1985 and 1993. Disturbance types included abandoned well pads, sumps (shallow, earthen pits), borrow areas, roads, pipelines, and cut and fill slopes. Sites averaged 0.2 ha (range = 0.01 to 8.0 ha).

Preliminary results for sites reclaimed in 1985 and 1986 and two research test plots were described by Anderson (1987). Reclamation methods were subsequently modified based on Andersons' conclusions. Because ecological research was not the focus of the program, treatments were not prescribed according to a set research design which would allow statistical comparison among variables (therefore, we are unable to present such comparisons in this paper). Instead, treatments were purposely flexible and adaptive to allow for the wide range of disturbance types and field conditions encountered. Revegetation treatments and seed mixes varied among sites and years depending on slope, aspect, soil pH and depth, presence of asphalt or concrete or contaminated soil, potential natural vegetation community, and seed availability (Hamman Wolfe 1986, Anderson 1987).

The following general description summarizes 1985 to 1993 reclamation treatments. With few exceptions, recontouring was not employed. Heavily compacted locations such as old roads and well pads were usually ripped and disked. Most sites that could be safely accessed by equipment were disked. Unsafe slopes and old 2-track roads that were appropriate for interseeding were not disked. Phosphorus and nitrogen fertilizer was commonly added in amounts ranging from 17.8 to 71.3 kg P or N ha^{-1}. From 1 to 10 different seed mixes were used each year depending on the current resource manager, budget, and seed availability. For example, Table 1 lists species and seeding rates for the 1985 Seed Mix "A", 1 of 10 seed mixes used that year. Seed mixes contained varying proportions of endemic, naturalized, and exotic shrub, grass, and forb species. Because shrubs were thought to be necessary to the survival of rodents and lagomorphs upon which kit fox preyed, and shrubs were believed to compete poorly with naturalized annual grasses in the study area (Anderson 1987), mixes were generally weighted towards shrub species, especially in later years. Seed mixes were applied at rates ranging from 5.5 to 36.9 kg ha^{-1} via drill seeding, hydroseeding, or broadcast seeding. Straw mulch and/or wood fiber mulch was applied at rates ranging from 1,782 to 3,564 kg ha^{-1} and/or 178 to 267 kg ha^{-1}, respectively. Straw was crimped into place on sites that were accessible to vehicles. On steeper slopes, a tactifying spray or photo degradable plastic netting was employed to secure mulch to the soil surface. Following reclamation activities, sites were marked with redwood stakes for future identification. In 1990 and thereafter, signs and cable or earthen barriers were installed at the entrances of many reclaimed linear disturbances (e.g., roads and pipeline right-of-ways) to help alleviate a chronic problem of vehicular re-disturbance.

Field Sampling

We monitored reclaimed sites and reference sites each year between April and June; however, until 1990, no data were collected with which to compare cover on reclaimed and non-reclaimed sites. In 1990, we established 11 undisturbed reference sites that appeared to be representative of intact habitat on the north and south slopes of the Elk Hills. We established 5 additional sites the following year, for a total of 16 reference sites. Half were located on south-facing slopes and half on north-facing slopes. We measured vegetation cover (as defined by Bonham [1989:96]) at reference sites using a 10X cover scope (ESCO Associates, Inc., Boulder, CO, 303-447-2999) mounted on a tripod. The cover scope was positioned about 1.5 m above the ground surface. For 1990 to 1993 comparisons, we sampled 10 cover points at 5 or 10-m intervals along a 50 or 100-m transect for a total of 100 points at each reference site. However, for 1994 and later comparisons, in lieu of cover at permanent reference sites, we measured cover at undisturbed areas that were similar to and adjacent to the reclaimed sites. The decision to modify our methods was made because we concluded that the similarity between reclaimed site cover and adjacent undisturbed site cover was a better index of revegetation success than using cover averages from distant, widely separated reference sites.

Unaided visual estimates of cover were calibrated in the following manner. We visually estimated vegetation cover along a transect without the aid of optical devices. Next, we compared our visual estimates to cover values previously generated by another observer for the same transect using a cover scope. Our future estimations were then adjusted higher or lower based on our proximity to the cover scope estimates. This method of calibration was used sequentially each year along 10 transects, although only 6 transects were sampled in 1997.

To evaluate revegetation success, we visually estimated vegetation cover on all sites still being monitored 5 years after reclamation and on one-third of those sites still being monitored 10 years after reclamation. Impacts to treated sites caused by vehicular traffic, blading, new facilities, oil spills, and water erosion were also noted at this time. In 1994, on a random sample of 347 sites treated between 1985 and 1993 and stratified by disturbance type, we recorded visual estimates of cover and site utilization by wildlife including predators and prey of the endangered San Joaquin kit fox.

Table 1. Plant species and seeding rates (kg pure live seed [PLS] ha-1) for Seed Mix "A," Elk Hills reclamation program, 1985.

SPECIES		HYDROSEED RATE	DRILL RATE
Shrubs			
Atriplex polycarpa	desert saltbush	5.7	3.8
Eriogonum fasciculatum	California buckwheat	1.1	0.8
Krascheninnikovia lanata	winterfat	9.4	6.3
Isomeris arborea	bladderpod	3.0	2.0
Chrysothamnus nauseosus	rubber rabbitbrush	0.4	0.3
Grasses			
Bromus madritensis	red brome	0.8	0.6
Festuca idahoensis	Idaho fescue	4.9	3.3
Vulpia myuros	mousetail fescue	1.1	0.6
Sporobolus airoides	alkali sacaton	3.4	2.2
Achnatherum hymenoides	Indian ricegrass	3.4	2.2
Forbs			
Achillea millefolium	western yarrow	T[a]	T
Collinsia heterophylla	Chinese houses	T	T
Eschscholzia caespitosa	Tufted poppy	T	T
Lasthenia californica	California goldfields	T	T

[a] Trace amount (<0.1 kg PLS ha-1).
(adapted from Hamman Wolfe 1986)

Data Analysis

We performed statistical analyses using SAS/STAT™ 6.0 (SAS Institute Inc. 1989) and MSUSTAT (Research & Development Institute Inc. 1995) software. *T*-tests were performed to detect differences in mean vegetation cover and adjacent undisturbed or reference site cover between sites situated on north and south-facing slopes. Vegetation cover estimates were transformed using an arcsin conversion. We performed general linear model analysis to determine effects of first-year, last-year, and cumulative precipitation on vegetation cover and revegetation success. When significant differences were found, post hoc comparisons of main effects were conducted using Tukey's studentized range test. Regression analysis was conducted to determine the relationship between unaided and cover scope-generated estimates of cover. Contingency table analysis was performed between years on success count data to determine effects of reclamation year on revegetation success. In our analyses, statistical significance was assumed at $P \leq (0.05$.

RESULTS AND DISCUSSION

Mean vegetation cover on reclaimed sites located on north-facing slopes was significantly higher than on south-facing slopes after 5 years ($P = 0.032$). This was consistent with observations by field personnel that north-facing slopes at Elk Hills appear to be more heavily vegetated. However, after 10 years, cover on north-facing and south-facing reclaimed sites was not significantly different and there were no differences in cover between reclaimed sites and adjacent undisturbed or reference sites after either 5 or 10 years. This was probably due to high variation in cover among sites, a low sample size for north slope sites, and other factors.

General linear model analysis revealed significant differences in vegetation cover among years for sites sampled 5 years after reclamation. Post hoc pairwise comparisons of transformed data showed that mean vegetation cover differed ($P \leq (0.05$) between all combinations of years except 1985 and 1989. These differences were probably attributable to the variation observed in annual precipitation at NPR-1 and resulting differences in aboveground plant growth. General linear model analysis for 10-year-old sites also indicated significant differences in vegetation cover among years, although no pairwise comparisons were significant.

When evaluating the effects of first-year, last-year, and cumulative precipitation on mean vegetation cover and revegetation success through multiple regression analysis, no relationships were found to be statistically significant. However, it appeared that the older a reclaimed site, the less effect first-year and last-year precipitation had on vegetation cover. Vegetation cover on sites which were only 5 years old was more strongly related to precipitation contributing to current year's plant growth (last-year precipitation) than cumulative precipitation.

The relationship between observers' unaided estimates of cover with cover scope-generated cover estimates was reasonably high ($r^2 = 0.75$, df = 90, $P < 0.001$). On average, observers were able to subjectively estimate vegetation cover along transects to within about 10% of the values obtained using cover scopes.

The cover scope method was an objective, rapid way to measure vegetation and other types of cover in the grassland and short-stature shrubland habitats of Elk Hills. However, using cover scopes required loading and unloading of equipment and, at our option, the establishment of transects; thus, the cover scope method required more time to implement than the unaided visual estimation method. Therefore, for budgetary reasons, we chose to use subjective, visual estimates of cover that were calibrated using cover scopes. The reasonably high r^2 and low P values resulting from the regressions indicated that, with proper training and calibration, this could be an effective sampling strategy for resource managers with minimal funding or managers not requiring the high level of accuracy achieved using cover scopes.

After 5 years, 47.2% of the reclaimed sites were considered successfully revegetated because vegetation cover was estimated to be ≥70% of the cover on reference or adjacent undisturbed sites (Table 2). The remaining 52.8% of the sites failed to meet this criterion primarily due to poor reestablishment of vegetation. After 5 years, of the 996 sites studied, 29.7% were either partly (18.6%) or entirely (11.1%) re-disturbed by vehicles, new development, oil spills, or human-induced water erosion. After 10 years, 74.4% of a sample of the reclaimed sites still being monitored met the revegetation success criterion; however, this sample did not include sites that had been completely re-disturbed or that required a second reseeding 5 years prior or that required asphalt removal and subsequent retreatment. If all of these sites were included, then the actual revegetation success rate after 10 years dropped to 58.8%, which was unacceptably low in our opinion.

Of sites sampled in 1994, those less than 3 years old appeared to be dominated by annual grasses (Table 3). Shrubs appeared to be the dominant lifeform on sites more than 3 years old. Shrub cover was lowest on 1 and 2-year-old sites and appeared to increase over time at the expense of grass and forb species to reach 67.1% on 9-year-old sites. Forbs comprised 15.5% of plant cover after 1 year, but then decreased to only 2 to 4% on the older sites. As expected, litter in the form of mulch applied during treatment was observed at high levels on 1 and 2-year-old sites. After 2 years, litter cover decreased to less than half the initial amounts. As treatment mulch decomposed, bareground increased slightly and reached relatively steady levels on sites 2 to 9 years old.

These ecological successional data are consistent with previous field observations made in the southern San Joaquin Valley (O'Farrell and Mitchell 1985; D. C. Anderson and B. L. Cypher, unpublished data). After mineral soils are exposed by earthmoving activities, shrubs and annual grasses and forbs begin colonizing the sites. Shrub seedling survival is often initially high on these sites in contrast to other disturbances like grazing or burning which generally do not expose mineral soil. As shrubs mature, they tend to out-compete grasses and forbs for soil moisture and nutrients, and eventually become the dominant cover (O'Farrell and Mitchell 1985). In the absence of grazing or fire, shrubs often appear to dominate late seral plant communities growing on disturbed mineral soils of non-recontoured sites.

Lagomorphs appeared to use most sites almost immediately after reclamation (Table 4). By the second year, lagomorph use stabilized and feces were observed at ≥90% of sites. A similar pattern of use was observed

Table 2. Revegetation success[a] and re-disturbance rates of 996 disturbed sites 5 years and 10 years after reclamation at Elk Hills.

SITE STATUS	PROPORTION (%) OF SITES					MEAN
5 years post-treatment						
Reclamation year	1985	1986	1987	1988	1989	
n [N]	143	267	182	354	50	[996]
Successful[1]	50.3	29.2	42.9	62.4	42.0	47.2
Intact	35.0	20.6	37.9	56.5	40.0	39.6
Partly re-disturbed	15.3	8.6	5.0	5.9	2.0	7.6
Unsuccessful	49.7	70.8	57.1	37.6	58.0	52.8
Intact, low cover	14.7	25.8	40.7	26.0	14.0	26.2
Intact, reseeded/asphalt removed	0.0	7.1	1.1	2.5	24.0	4.5
Partly re-disturbed, low cover	12.6	18.4	10.4	5.4	10.0	11.0
Completely re-disturbed	22.4	19.5	4.9	3.7	10.0	11.1
10 years post-treatment[b]						
Reclamation year	1985	1986	1987	1988	1989	
n [N]	50	69	61	-	-	[180]
Successful	70.0	82.6	68.9	-	-	74.4
Intact	64.0	78.3	57.4	-	-	67.2
Partly re-disturbed	6.0	4.3	11.4	-	-	7.2
Unsuccessful	30.0	17.4	31.1	-	-	25.6
Intact, low cover	26.0	8.7	18.0	-	-	16.7
Partly re-disturbed, low cover	4.0	4.3	8.2	-	-	5.6
Completely re-disturbed	0.0	4.3	4.9	-	-	3.3

[a] Revegetation was considered successful when vegetation cover was (70% of that observed on reference sites or adjacent undisturbed sites.

[b] 10-year estimates do not include sites eliminated by disturbance prior to, or revegetated a second time due to the findings of, the 5-year monitoring effort.

for rodents, although at slightly reduced levels. Use of reclaimed sites by coyotes and kit foxes appeared to slightly increase 3 or 4 years after reclamation. Vegetative composition and structure (i.e., dense shrubs) on reclaimed sites more than 3 years old appeared to favor coyotes and bobcats, which are the primary predators of kit fox at Elk Hills (Warrick and Cypher 1998). Although reclaimed sites appeared to attract kit fox prey species (Table 4), kit fox are thought to favor open habitats for denning and resting (Grinnell et al. 1937, Morrell 1972) because they may be better able to detect predators in these areas (Zoellick et al. 1989, Warrick and Cypher 1998). Vegetation growing on reclaimed sites after 9 years was dominated by shrubs, primarily desert saltbush. Based on observations at Elk Hills, the San Joaquin kit fox, giant kangaroo rat, blunt-nosed leopard lizard, Tipton kangaroo rat, and Hoover's wooly-star appear to be more abundant in areas with relatively low shrub cover. In their unpublished report, Anderson and Cypher suggested that reclamation techniques previously used at Elk Hills may not effectively benefit endangered species due to the resulting increase in shrub cover, and we agree, based on the results of our analyses.

In their study, with a smaller sample size than we had, Anderson and Cypher evaluated revegetation rates on a sample of the same sites included in this study. They also compared reclaimed sites to non-reclaimed disturbed sites. Probably due to the annual habit and high seed production of herbaceous plants in the study area, they found that the time required for vegetation located on flat and moderately sloping disturbed sites to attain (70% of the cover on adjacent undisturbed areas was about 5 years on non-reclaimed sites and 8 years on reclaimed sites. They concluded that, if the goal was to establish vegetation cover at the lowest possible cost, then simple site (seedbed) preparation or topsoil spreading might be considered.

Treatment costs averaged \$1,026 ha^{-1} for materials and \$3,828 ha-1 for contractor fees between 1985 and 1993 (EG&G Energy Measurements Inc. 1995). Ten years of site monitoring was estimated to have cost \$2,100 ha^{-1}. Taking into account the 58.8% estimated revegetation success rate, DOE's revegetation program at Elk Hills is estimated to have cost \$11,827 per successfully revegetated hectare.

In the southern San Joaquin Valley and other areas,

Table 3. Average cover estimates for 347 disturbed sites reclaimed at Elk Hills between 1985 to 1993 and sampled in 1994.

COVER CATEGORY	MEAN COVER (%) AND SD (IN PARENTHESES)								
Reclamation year	1985	1986	1987	1988	1989	1990	1991	1992	1993
n	46	37	39	45	33	36	47	40	24
Vegetation	35.4	29.1	31.2	32.2	33.9	35.6	28.6	21.6	6.9
	(2.36)	(2.54)	(2.73)	(2.06)	(1.95)	(2.82)	(2.01)	(2.42)	(1.85)
Forbs	2.0	4.1	4.1	2.0	12.0	6.2	2.7	9.7	15.5
	(0.82)	(2.27)	(2.24)	(0.59)	(4.28)	(3.10)	(0.95)	(2.36)	(5.87)
Shrubs	67.1	60.8	63.3	62.6	51.6	63.7	50.4	28.8	28.3
	(3.47)	(4.36)	(4.97)	(3.94)	(5.23)	(4.89)	(4.53)	(3.71)	(6.45)
Grasses	30.9	35.2	32.6	35.3	36.2	30.2	46.9	61.5	56.1
	(3.19)	(4.03)	(4.64)	(3.76)	(4.79)	(4.25)	(4.27)	(4.20)	(7.82)
Litter	15.9	16.5	15.2	15.4	21.9	17.8	20.9	32.6	56.3
	(0.93)	(1.19)	(1.21)	(0.98)	(1.40)	(1.32)	(1.39)	(1.87)	(3.87)
Bareground, rock, cryptogamic crust	48.7	54.4	53.6	53.4	44.2	46.6	50.5	45.8	36.8
	(n.a)[a]	(n.a.)	(n.a.)	(n.a.)	(n.a.)	(n.a.)	(n.a.)	(n.a.)	(n.a.)

[a] Not available.
(adapted from EG&G Energy Measurements Inc. 1995b)

mitigation for damaging or destroying endangered species habitat is routinely accomplished in the form of "compensation" by providing the funds to purchase and manage off-site areas of habitat in perpetuity for the benefit of the species of concern. This form of mitigation may provide an alternative to more expensive and less reliable mitigation practices such as habitat reclamation. Presently, surface rights for intact endangered species habitat in the Elk Hills-Lokern area cost about \$815 to 1,090 ha^{-1} (B. Pace, Center for Natural Lands Management, Fallbrook, California, pers. commun.). An additional \$1,112 ha^{-1} would be necessary for stewardship and perpetual management of intact natural habitat parcels larger than 100 ac (247 ha) for the benefit of endangered species, yielding a total estimated cost of \$1,927 to 2,202 ha^{-1}.

One way to compare the habitat reclamation alternative with the off-site compensation alternative is to calculate the net areas of habitat reclaimed and permanently set aside for endangered species. For the \$4.3 million spent to reclaim 364 ha (899 ac) of disturbed habitat, instead, DOE could have allocated these funds towards the purchase, fencing, and perpetual management of $\geq$1,953 ha (4,825 ac) of intact, off-site endangered species habitat. This represents a 5-fold difference. Although natural resource managers generally prefer the habitat reclamation alternative over the off-site compensation alternative to avoid having a net loss of habitat, the results of our evaluation illustrate that reclamation is not always successful and not necessarily the best alternative.

MANAGEMENT IMPLICATIONS

The 58.8% revegetation success rate achieved for 10-year old sites in this study was lower than anticipated. Treatment and monitoring costs were high and many sites did not meet success criteria due to re-disturbance or poor reestablishment of vegetation. The estimated actual cost of the Elk Hills reclamation program was \$11,827 for each successfully revegetated hectare, whereas off-site mitigation through compensation currently costs \$1,927 to 2,202 ha^{-1}. Reclamation treatments effectively converted disturbed bare-soil habitat into shrubland habitat in an area more typically characterized by open grassland habitat with scattered shrubs. Although prey species of the endangered San Joaquin

Table 4. Proportion of sites exhibiting evidence of wildlife use in 1994 for 347 sites reclaimed at Elk Hills between 1985 and 1993.

EVIDENCE TYPE	PERCENT (%) OF SITES WITH EVIDENCE								
Reclamation year	1985	1986	1987	1988	1989	1990	1991	1992	1993
n	46	37	39	45	33	36	47	40	24
Herbivory	67	70	64	64	70	67	66	65	38
Feces									
Rodents	91	89	85	96	88	100	87	90	67
Lagomorphs	93	100	95	98	97	94	98	100	88
Kit fox	0	3	3	0	0	0	0	0	0
Coyote	20	5	21	18	18	14	19	5	8
Dens or burrows									
Small mammals	98	92	85	93	85	81	91	68	46
Kit fox	0	3	0	2	0	3	0	0	0
Direct observation									
Lagomorphs	11	5	8	4	9	8	11	18	0
Ground squirrels	2	0	0	0	3	0	0	5	0
Birds	2	0	0	9	3	0	0	3	0

(adapted from EG&G Energy Measurements Inc. 1995b) kit fox did use reclaimed sites, the sites appeared more suitable for kit fox predators than the kit fox themselves. The reclaimed sites also appeared less suitable for other endangered species at Elk Hills (e.g., blunt-nosed leopard lizard, giant kangaroo rat, Tipton kangaroo rat, and Hoover's wooly-star). Therefore, reclamation of endangered species habitat at Elk Hills using these methods did not appear to be ecologically or economically efficacious. Unless reclamation and monitoring costs are reduced, sites are protected from re-disturbance, and favorable habitat is created for kit fox and co-occurring endangered species, further reclamation should not be carried out at Elk Hills except to alleviate erosion at problem areas. Instead, we recommend that either (1) intact off-site habitat be purchased and managed as natural wildlife habitat in perpetuity, or that (2) a combination of recontouring, surface scarification, and subsequent natural revegetation be implemented on a trial basis at Elk Hills to test its effectiveness as a habitat restoration and mitigation tool.

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