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THE EFFECT OF BURROW SITE USE ON THE REPRODUCTIVE SUCCESS OF A PARTIALLY MIGRATORY POPULATION OF WESTERN BURROWING OWLS (*SPEOTYTO CUNICULARIA HYPUGAEA*)

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ABSTRACT.—We compared the number of nestlings produced by pairs of Burrowing Owls (*Speotyto cunicularia hypugaea*) using burrows in different types of nest sites, use of different types of burrows by resident and migrant males, and burrow type use by returning migrant males and females and the productivity of individuals that switched burrows. The number of nestlings and fledglings produced by pairs nesting in artificial burrows was also compared to the productivity of pairs in natural burrows. We determined that pairs in undisturbed areas used burrows located in or at the base of cliff walls more often than any other burrow type, while pairs in disturbed areas used burrows on flat ground more often. Both resident and migrant males used burrows in or at the base of cliff walls more often in undisturbed areas but, in disturbed areas, they used burrows in flat ground more often. Most males and females that switched burrows from one year to the next produced more nestlings in burrows they left than in new burrows. Pairs which nested in artificial burrows produced significantly more nestlings than those that used natural burrows, but pairs in natural burrows produced significantly more fledglings. Our results suggest the importance of determining burrow sites favored by nesting owls prior to initiation of conservation plans which require protection of areas containing nest holes or installation of artificial burrows.

KEY WORDS: *Burrowing Owl;* Speotyto cunicularia hypugaea; *nest type use; artificial burrows; conservation.*

El efecto de los sitios de madriguera en el éxito reproductivo de una población parcialmente migratoria de *Speotyto cunicularia hypugaca*

RESUMEN.—Comparamos el número de pichones producidos por pares de *Speotyto cunicularia hypugaea* que utilizaron madrigueras en distintos tipos de sitios de anidación, el uso de distintos tipos de madrigueras por machos residentes y migratorios, el uso de distintos tipos de madrigueras por machos y hembras que retornaron al mismo lugar y la productividad de los individuos que cambiaron madrigueras. El número de pichones producidos por pares que anidaron en las madrigueras artificiales fue comparado con la productividad de los pares que anidaron en las madrigueras artificiales. Determinamos que los pares en áreas no perturbadas utilizaron madrigueras localizadas en la base de paredes en precipicios en mas ocasiones que otro tipo de madrigueras, mientras que los pares en áreas perturbadas utilizaron madrigueras en el suelo con mas frecuencia. Los machos residentes y migratorios utilizaron madrigueras en la base o en los precipicios con mayor frecuencia en las áreas no perturbadas, pero en las áreas perturbadas utilizaron el suelo con mayor frecuencia. Los machos y hembras que cambiaron madrigueras de un año a otro, produjeron mas pichones en la madriguera que dejaron que en la nueva. Los pares que anidaron en madrigueras artificiales produjeron significativamente mas pichones. Nuestros resultados resaltan la importancia de la determinación de sitios de madrigueras para anidación de buhos antes de la iniciación de planes de conservación, los cuales pueden requerir de la protección de áreas que contengan cavidades de nidos o la instalación de madrigueras artificiales.

[Traducción de César Márquez]

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The western Burrowing Owl (*Speotyto cunicularia hypugaea,* from here on referred to as the Burrowing Owl) nests in underground burrows usually dug by other animals (Coulombe 1971, Thomsen 1971, Haug et al. 1993). Its requirement for underground nests may leave it with few choices, depending on the biology of animals that excavate burrows in a particular location (e.g., colonial vs. dispersed fossorial mammals). Conversely, in regions with diverse physiography (e.g., cavities in the cliff faces of dry creeks or rivers), Burrowing Owls may encounter a variety of possible nest site possibilities. Understanding the relationship between the use of different burrow site types and reproductive success in burrowing owls is important in light of recent conservation plans for the species throughout much of its range (Haug et al. 1993).

This study was conducted on a population of Burrowing Owls which nested on the campus of New Mexico State University (NMSU). Partial migration occurs in this population with all females and fledglings migrating from the study area each year. The majority of males, however, reside on the study area throughout the year (resident) but a few migrate (migrants). Resident and migrant males use nesting burrows (either retaining the previously-used one or switching to a new one) and defend the area surrounding their burrows prior to the arrival of females each year. Females begin to arrive in the area in February and immediately choose a mate.

Variation in burrow use by this population led us to consider what factors might affect the productivity of pairs which nested in different types of burrows. Burrow sites with no or low grass cover and high elevation should offer the most protection from predators, thus, males should more commonly use burrows in cliff walls. Compared to flat ground, burrows at the base of cliffs should offer more protection from predators, so they should be used more often than those on flat ground but less than those in cliffs. An abundance of lights in our study area attracted insects, bats and nighthawks (*Chordeiles* spp.), all of which the owls ate. In some lighted areas, the only type of burrow available was on flat ground; in these cases the increased prey availability should have offset increased predation risk. Thus, based on food availability, pairs in disturbed areas should be more successful than those in natural, nonlighted areas. Pairs with a resident male should produce more nestlings due to the increased experience of males in these areas and their opportunity throughout the winter to assess different burrows. We also felt that the use of artificial burrows should enhance reproductive success since they are not susceptible to collapse, are protected from flooding, and are impossible for larger predators to dig out and enter.

In order to test these predictions, we evaluated the reproductive success of Burrowing Owls that used burrows of different types. We also compared the types of burrows used by resident males with that of migrants. To determine the effect of switching nest burrows from one year to the next, we compared the number of nestlings produced by individuals at their current and previous burrow sites. We also compared the number of nestlings produced by pairs which used natural versus artificial burrows. Our results will help to determine if the types of burrows used by Burrowing Owls should be considered as part of future conservation plans, especially plans which involve installation of artificial burrows in areas without natural burrows.

STUDY AREA AND METHODS

Our study area on the NMSU campus encompassed a triangle of approximately 364 ha. The campus included irrigated pastures at its lowest elevation (~3900 m) and Chihuahuan Desert vegetation of approximately 121 ha at its highest elevation (~4100 m). Campus buildings occupied the central part of the triangle. The abundance of rock squirrels (*Spermophilus variegatus*) throughout the campus resulted in a large number of available burrows. Sometimes the squirrels dug shallow burrows which the owls enlarged. Spotted ground squirrels (*Spermophilus spilosoma*) dug smaller burrows which may have been enlarged by the owls. In natural areas, rock squirrels, cottontail rabbits (*Sylvilagus spp.*) and jackrabbits (*Lepus spp.*) also dug burrows. The rabbit population was large in the natural areas. Naturally-occurring crevices, abundant throughout the campus, were also used or enlarged by the owls. Since there were hundreds of shallow and deep burrows present at any one time, the owls had an abundant supply of burrow opportunities.

A total of 59 pairs nested in natural burrows located in two natural and two disturbed areas on the campus of NMSU. No pair was used more than once in this study. We did, however, include different pairs which used the same burrow in different years and we have repeated data for some pairs which switched burrows from year to year. We define a "natural" burrow as any existing cavity either above or below ground that had not been modified by us. We do not mean to suggest that a "natural" burrow was located in a natural (i.e., undisturbed) setting, although some of the burrows used in this study did fall into this category.

We used two natural areas in our study. The first consisted of an abandoned landfill (4.1 ha) inoperative for at least 10 yr prior to this study. Its initial contents had been covered with soil and its base was overgrown with native vegetation. The second area consisted of an earthen dam at one end of a flood control basin (8 ha, Botelho and Arrowood 1996). Both natural areas were located in the remote southeast part of campus and rarely visited by people. They were actually large depressions surrounded by cliffs up to 10 m high. Burrows were located in several different sites including flat ground, above ground and 3–10 m up in the sides or at the base of cliff walls. Vegetation consisted of typical arid Chihuahuan Desert vegetation, dominated by Creosote Bush (*Larra tridentata*) and Mesquite (*Prosopsis spp.*).

Disturbed areas consisted of the university quadrangle (quad) and football stadium (stadium). Owls nested among closely-spaced buildings separated by walkways, lawns, parking lots and other buildings on the quad and at the top of small hills and at the base of cement walls behind each endzone in the stadium (Botelho and Arrowood 1996). Pairs typically used burrows under cement walkways or curbs, especially those in the vicinity of street lights or other types of artificial lighting. Soil was rich loamy topsoil; more durable burrows occurred in this soil type because it was less susceptible to collapse during rainstorms. Vegetation consisted of irrigated cultivated grass on well-manicured lawns with some trees and shrubs (Botelho and Arrowood 1996). In addition, burrows were located at the base of light posts in a large parking lot and in large pipes above ground.

Some burrows in cliff walls in natural areas were located high off the ground, but within human reach from the top of the cliff. Burrows in cliff walls had very little space at their entrances for nestlings to congregate during feedings. As a consequence, nestlings sometimes fell from the front of their burrows and either found shelter in a burrow close to the ground or fell victim to predation. In disturbed areas, burrows in cliff walls were similar to those in natural areas. Burrows in cliff walls in disturbed areas were only available behind each endzone inside the stadium. Owls which used these burrows perched on the tops of bleachers and on fences.

Burrows at the base of cliff walls in natural areas were dug at ground level into the sides of cliff walls. Because of their location at ground level, these burrows had more space at their entrances for nestlings to congregate during feedings and there was no danger of nestlings falling from their burrows. Because of their close proximity to both the ground and a cliff wall, these burrows could be blocked when loose dirt from the cliff poured over their entrances during heavy rains. Burrows were located beneath stone walls behind each endzone in the stadium and at the base of buildings in the quad in disturbed areas. Unlike burrows at the base of cliff walls in natural areas, in disturbed areas some burrows were dug under concrete sidewalks and abutments. Owls which used burrows at the base of cliff walls used buildings or cement walls as perches.

Burrows in flat ground in natural areas were dug directly into the desert floor and were surrounded by sparse vegetation. These burrows had few elevated perch sites and were resistant to erosion but lacked a cliff face which may have increased vulnerability to predation because predators could approach the burrow from all directions. Burrows in flat ground, however, had ample space at their entrances for nestlings to congregate during feedings without the danger of nestlings falling from the burrow. Burrows in flat ground in disturbed areas were located on lawns (often at the base of chain link fences), or under curbs. Owls regularly used man-made perch sites (e.g., fences, walls, and buildings) when nesting in these burrows.

All above ground nesting attempts occurred in disturbed areas. These nest sites consisted of large metal pipes located on flat ground. In one case a pair nested in a drainpipe located in the side of a building.

We constructed 24 artificial burrows. Eight of 24 natural burrows were situated in such a way that we could replace them with artificial burrows. The remaining 16 burrows were left in place and artificial burrows were installed in the vicinity of and adjacent to them. We replaced natural burrows with artificial burrows in winter when breeding was not in progress. Natural burrows were excavated in the evening after we placed a one-way door (this door allowed owls to leave the burrow but not reenter) over the burrow entrance for at least 48 h to ensure that no owls were present inside the burrow during excavation. We oriented the chambers and tunnels of our artificial burrows as close as possible to that of original burrows.

Artificial burrows were completely self contained and consisted of a nesting chamber (a 19 l covered plastic bucket) located at the end of a tunnel made of two 2 5 m × 10 cm PVC pipes (with 2 cm holes drilled every 6 cm for drainage) connected by a right angle PVC connector. A single 10 cm hole was cut into the side of the plastic bucket about two cm from the bottom to allow insertion of the PVC tunnel pipe. A 10 cm hole also was cut into the cover of the bucket; we could insert a hand through this hole to gain access to the nest for weighing and measuring nestlings without removing the entire bucket lid. The cover hole was capped with a PVC lid We drilled three to four holes (each 2 cm in diameter) in the bottom of the plastic bucket for drainage. During installation we placed dirt in the bottom of the bucket and inside the tunnel pipes. To avoid human disturbance, the entire burrow (including covers) was buried. Artificial burrows were not buried under mounds as in Trullio (1995) and Collins and Landry (1977) because some of our early, more obvious artificial burrows were stolen (probably for the PVC pipe) before any owls had begun to use them.

All of the owl pairs used in this study and any young they produced were trapped using either a cage and one-way door trap (Banuelos 1993, PVC tube trap (Botelho and Arrowood 1995), or captured by hand in the artificial nest cavity. Captured owls were banded with USGS aluminum bands and a unique combination of colored plastic bands. We insured that all nestlings were captured by repeated observation and trapping at each burrow until all nestlings were marked on three consecutive observation periods. Because we did not excavate natural burrows, we cannot rule out that some nestlings may have gone undetected. We feel, however, that undetected nestlings, if they did occur, were rare.

Because our data is nonnormal, we used nonparamet-

Table 1. Types of burrows used by nesting Burrowing Owls and the numbers of nestlings they produced in undisturbed and disturbed areas.

	UNDISTURBED AREAS			DISTURBED AREAS		
BURROW TYPE	NO. PAIRS (%)	NO. NESTLINGS (%)	NESTLINGS/PAIR ($\bar{x}$ ± 1 SE)	NO. PAIRS (%)	NO. NESTLINGS (%)	NESTLINGS/PAIR ($\bar{x}$ ± 1 SE)
Vertical cliff	15 (47)	25 (45)	1.7 ± 1.8	4 (15)	0 (0)	0
Base of cliff	11 (34)	14 (25)	1.3 ± 1.7	7 (26)	25 (38)	3.6 ± 2.1
Flat ground	6 (19)	17 (30)	2.8 ± 4.1	12 (44)	41 (62)	3.4 ± 1.8
Above ground	0 (0)	0 (0)	0	4 (15)	0 (0)	0
Total	32	87		27	66	

ric statistics. Our alpha level for significance is 0.05. Means are reported with standard errors ($\bar{x}$ ± 1 SE).

RESULTS

In undisturbed areas, pairs used burrows in cliff walls more often than burrows on flat ground but the difference was not significant ($\chi^2 = 3.80$, df = 2, $0.10 > P > 0.02$; Table 1). In disturbed areas, pairs used burrows in flat ground more than burrows in cliff walls and above ground but, here also, the difference was not significant ($\chi^2 = 6.33$, df = 3, $0.10 > P > 0.05$). Burrows in flat ground in disturbed areas were very common and potential sites in cliff walls were less common than in natural areas because they only occurred in the stadium and banks of the irrigation canal. However, there were numerous burrows in the stadium and along the canal that were dug by squirrels. Burrows in cliff walls in disturbed areas that appeared suitable for nesting were not used. Sites at the base of cliffs were common under the concrete edges of buildings and walls. Even though burrows in culverts and pipes appeared to be common throughout disturbed areas, only four pairs utilized them. These nesting attempts failed.

In undisturbed areas, pairs that used burrows in flat ground produced significantly more nestlings than pairs in the other types of burrows (Kruskal-Wallis test, F = 13.52, df = 2, $P < 0.005$; Table 1). In disturbed areas, pairs that nested in burrows in cliff wall and above ground sites produced no nestlings. Pairs which used burrows at the base of cliff walls and in flat ground produced significantly more nestlings than their counterparts in natural areas (F = 11.40, df = 3, $P < 0.005$; Table 1).

In undisturbed areas, the distribution of breeding resident males was more equal among available burrow types than was the distribution of breeding migrant males (Table 2). Migrant males exclusively used burrows in cliff walls although the highest percentage of resident males also used burrows in cliff walls. The lowest percentage of males in natural areas used burrows in flat ground. In contrast to undisturbed areas, very few migrant and resident males used burrows in cliff walls in disturbed areas. Instead, they mostly used burrows in flat ground with resident males using burrows at the base of cliff walls more often than migrants.

Among migrants that bred in 1993 and returned to breed in 1994 ($N = 15$), 60% changed burrow site types with 67% of males and 50% of females using burrows in different site types in 1994 (Table 3). Among those migrants that bred in 1994 and returned to breed in 1995 ($N = 12$), 58% changed burrow site types. Males that returned in 1995 overwhelmingly used burrows of the same site type (75%), the reverse of what happened in 1994. Seventy-one percent of females, however, used burrows in sites different from those used in 1994. Use of same ($N = 11$) and different ($N = 16$) burrow types over both years by males and females did not differ significantly ($\chi^2 = 0.926$, df = 1, $P > 0.05$).

Table 2. Types of burrow sites used by resident and migrant male Burrowing Owls in undisturbed and disturbed areas.

	UNDISTURBED AREAS		DISTURBED AREAS	
BURROW LOCATION	NO. RESIDENT MALES (%)	NO. MIGRANT MALES (%)	NO. RESIDENT MALES (%)	NO. MIGRANT MALES (%)
Vertical cliff	11 (52)	5 (100)	0 (0)	1 (10)
Base of cliff	8 (38)	0 (0)	6 (43)	1 (10)
Flat ground	2 (10)	0 (0)	7 (50)	7 (70)
Above ground	0 (0)	0 (0)	1 (7)	1 (10)

Table 3. Burrow switching by migrant male and female Burrowing Owls between 1993–94 and 1994–95.

	1993–1994			1994–1995		
BURROW TYPE	MALES	FEMALES	TOTAL	MALES	FEMALES	TOTAL
From base of cliff to base of cliff	1	0	1	0	0	0
to cliff wall	2	1	3	0	1	1
to flat ground	0	0	0	0	0	0
to artificial burrow	0	0	0	0	0	0
From cliff wall to cliff wall	1	1	2	1	0	1
to base of cliff	1	1	2	0	1	1
to flat ground	1	0	1	0	1	1
to artificial burrow	0	1	1	0	0	0
From flat ground to flat ground	1	1	2	2	2	4
to base of cliff	1	0	1	0	0	0
to cliff wall	1	0	1	0	1	1
to artificial burrow	0	0	0	0	0	0
From artificial burrow to artificial burrow	0	1	1	0	0	0
to flat ground	0	0	0	1	2	3
to base of cliff	0	0	0	0	0	0
to cliff wall	0	0	0	0	0	0
Total nestings	9	6	15	4	7	12
Total number switches between years	6	3	9	1	5	7

Among those individuals that used burrows on different sites the following year, two (one male and one female) moved from a burrow in or at the base of a cliff wall to a burrow in flat ground (Table 3). Of the remainder, 18% moved from burrows in cliff walls to burrows at the base of cliffs. Only 11% of the owls that moved from burrows in flat ground to those in or at the base of cliff walls moved to a different site type.

The number of nestlings produced by pairs that bred in our study area in one year and returned to breed again the following year did not differ significantly regardless of burrow type used (Wilcoxon Signed Ranks Test, T = −13, P = 0.343, N = 6 for males and T = 10, P = 0.0635, N = 4 for females). On average, females that switched burrow types from one year to the next, produced more nestlings in the burrows they left rather than in their new burrows (Table 4). Males switching burrows from one year to the next produced equal numbers of nestlings in the two sites.

Eight pairs which nested in artificial burrows produced an average of 8.3 ± 3.5 eggs per pair (Table 5). The number of nestlings ranged from 0–8 ($\bar{x}$ = 3.5 ± 2.9). Clutches in all but two artificial burrows partially hatched; the two clutches which failed to hatch were abandoned prior to hatching because the mates died. Of the 28 nestlings produced in artificial burrows, only 12 or 43% fledged. In all but one burrow where all nestlings hatched synchronously, one nestling hatched much later (2–4 d) than the rest and always died. These smaller nestlings usually disappeared from the burrow overnight either through predation or cannibalism. One female was videotaped feeding her youngest nestling to the surviving young. Older nestlings which failed to fledge also disappeared quickly from burrows without a trace. Owls in artificial burrows produced an average of 3.5 ± 2.9 nestlings (N = 8 nests) which is significantly higher than production in natural burrows (2.2 ± 1.9 nestlings, N = 59 nests; Mann-Whitney U test, Z = −2.07, N = 67, $P < 0.02$). When pairs abandoning their burrows prior to hatching were removed from the analysis, owls which used artificial burrows still produced significantly more nestlings ($\bar{x}$ = 3.3 ± 1.3 nestlings for natural and $\bar{x}$ = 4.7 ± 2.3 nestlings for artificial burrows, Z = −1.68, N = 44, $P < 0.05$). However, when we compared the number of fledglings produced by the two types of burrows, the number produced by pairs in natural burrows was significantly greater for natural than for artificial burrows ($\bar{x}$ = 1.9 ± 1.9 nestlings for natural and $\bar{x}$ = 1.5 ± 1.5 nestlings for artificial burrows, Z = −2.81, N = 67, $P < 0.003$). The average number of fledglings produced by pairs in

Table 4. Number of nestlings produced by migrant Burrowing Owls that returned to the same and different burrow types between 1993–94 and 1994–95.

	Males			Females		
	Current Year	Previous Year	Total	Current Year	Previous Year	Total
From base of cliff to base of cliff	0	4	4	0	0	0
to vertical cliff	1	6	7	6	7	13
to flat ground	0	0	0	0	0	0
to artificial burrow	0	0	0	0	0	0
From vertical cliff to vertical cliff	1	0	1	0	0	0
to base of cliff	2	1	3	0	4	4
to flat surface	0	0	0	3	8	11
to artificial burrow	0	0	0	3	3	6
From flat surface to flat surface	3	3	6	6	6	12
to base of cliff	3	3	6	0	0	0
to vertical cliff	3	2	5	3	3	6
to artificial burrow	0	0	0	0	0	0
From artificial to artificial burrow	0	0	0	3	3	6
to flat ground	6	7	13	9	10	19
to base of cliff	0	0	0	0	0	0
to cliff wall	0	0	0	0	0	0
Average for migrants returning to same type of burrow	1.0 ± 1.4	1.8 ± 2.1		2.3 ± 2.9	2.3 ± 2.9	
Average for migrants returning to different type of burrow	1.3 ± 1.9	1.6 ± 2.5		2.0 ± 3.0	2.9 ± 3.6	

Table 5. Hatching and fledging success of eight pairs of Burrowing Owls nesting in artificial burrows form 1993–95. Fledglings are defined as young that were observed flying in their natal territories.

Pair Clutch Size	No. Eggs Hatching (%)	No. Fledglings (%)	
1	6	0 (0)	0 (0)[a]
2	7	0 (0)	0 (0)[a]
3	7	3 (43)	2 (67)
4	7	3 (27)	2 (67)
5	8	7 (64)	4 (57)
6	9	3 (33)	0 (0)
7	11	4 (36)	3 (75)
8	11	8 (73)	1 (13)
Total	66	28	12
Mean	8.3	3.5	1.5
SE	1.9	2.9	1.5
Total[b]	53	28	12
Mean[b]	8.8	4.6	2.0
SE[b]	1.8	2.3	1.4

[a] Nest abandoned.

[b] Abandoned burrows have been omitted.

natural burrows where adults did not abandon was 2.9 ± 1.5, significantly higher than that produced by pairs in artificial burrows (2.0 ± 1.4 fledglings, $Z = -2.97$, $N = 43$, $P < 0.002$).

Discussion

Our prediction that males would use burrows located in sites with high elevation and low grass cover in cliffs more often due to decreased predation was supported for resident and migrant males in natural areas but not disturbed areas. Only one male in a disturbed area used a burrow in a cliff wall despite the apparent availability of cliff sites. One possible reason for not using burrows in cliffs may have been that they were located in the territories of other males not using cliff burrows. Another reason may have been the possible high mortality of fledglings when they fell from their burrows although this seemed unlikely because pairs using burrows in cliff walls were as productive as pairs that used burrows at the base of cliffs in natural areas.

Burrows in cliff walls appeared to be safer from predators because of their height and approach by predators was possible in only one direction. MacCracken et al. (1985) and Green and Anthony (1989) have shown that Burrowing Owls use burrows located in sites on mounds of dirt with low grass cover, but our study shows for the first time that Burrowing Owls can also use sites associated with cliffs. The presence of depressions surrounded by steep cliffs coupled with the tendency of rock squirrels and rabbits to colonize these areas and dig holes in and at the bases of the cliff walls can provide an unusual type of nest site for Burrowing Owls. The only other case we know of where Burrowing Owls have been shown to use burrows in or at the bases of cliffs is in Albuquerque, New Mexico, 155 km north of our study site (Kendall pers. comm.).

Our prediction that pairs should use burrows at the bases of cliffs more often than on flat ground was supported for undisturbed areas but not disturbed areas. Also, pairs that nested at the bases of cliffs in undisturbed areas produced fewer nestlings on average than pairs which nested either in cliff walls or in flat ground. In disturbed areas, however, pairs that nested in the bases of cliffs produced more nestlings than all other burrow types. Larger broods in disturbed areas may have been due to increased prey availability attributed to artificial lighting, especially in the stadium. Also, the larger amount of space at the entrances to burrows in the bases of cliffs better accommodated larger broods and restricted the approach routes of predators. Decreased risk of nestling predation in disturbed areas may have contributed to this trend but we have no data on the effect of predation on the reproductive success of this population.

Most studies of Burrowing Owls have found them occupying burrows in relatively flat ground although some elevation near the burrow is important. Burrowing Owls in Oregon (Green and Anthony 1989), in South Dakota (MacCracken et al. 1985), and in Colorado (Plumpton and Lutz 1993) preferred burrows on high ground with low mean shrub volume or low grass cover, possibly to gain an elevated unobstructed view. Females in this study monitored their surroundings from an elevated site with a clear view and gave alarm calls to which the nestlings responded by running into the burrow. For flightless nestlings to respond quickly, females must produce alarm calls well in advance of a predator's approach making a clear view of the area surrounding the burrow important. In undisturbed areas, pairs using burrows in flat ground were most productive; in disturbed areas such pairs produced only slightly fewer nestlings than pairs at the bases of cliffs.

The lower overall productivity of pairs in undisturbed areas may have been due in part to predation. A pair of Barn Owls (*Tyto alba*) used a burrow located in a cliff wall in the landfill only 2–3 m away from an occupied Burrowing Owl nest and within easy striking distance of up to 13 other nests. Burrowing Owls actively mobbed the Barn Owls as they left their burrow but we are unaware of any predation by the Barn Owls on Burrowing Owls. Also, lack of an available food supply close to their burrows may have lowered productivity, especially among those pairs which nested in areas without the benefit of insects attracted by artificial lighting. Violent storms, which passed through the study area in late summer, may have also resulted in the deaths of small nestlings caught outside their burrows.

Most females and males which returned to a different burrow type from one year to the next produced fewer nestlings in their second breeding attempt than in their first. Decreased reproductive success in new burrows may explain why owls switched burrows infrequently and never accepted artificial burrows installed in the vicinity of their nesting burrow.

An average hatching and fledging success of 42% and 18%, respectively, by pairs which nested in artificial burrows was lower than that found in other studies where artificial burrows have been used (Landry 1979, Olenick 1987). Pairs that nested in artificial burrows produced significantly more nestlings than pairs that used natural burrows even if pairs that failed to hatch any eggs were included in the analysis. In fact, pairs which nested in artificial burrows produced almost one nestling more on average than their counterparts in natural burrows. The opposite was true for fledglings. Pairs that nested in natural burrows produced significantly more fledglings than pairs that used artificial burrows regardless of whether pairs failing to hatch any eggs were included in the analysis. After removing pairs that failed to hatch any eggs, pairs nesting in natural burrows produced almost one more fledgling on average than pairs which used artificial burrows. These results were unexpected because we thought the antipredator advantages of artificial burrows would enhance fledgling production. Nestlings in artificial burrows were captured inside the nest chamber and weighed three to four times per week during the nestling period to determine growth rates for another study. Artificial burrows, however, were not disturbed once clutches were complete and incubation began. Thus, one reason for the observed trend in nestling and fledgling production by pairs in natural and artificial burrows could have been human disturbance during the nestling period and the lack of it during the incubation period.

We suggest that conservation plans for Burrowing Owls involving the use of artificial burrows in areas without natural nesting burrows should consider the characteristics of burrow sites previously used by the owls for nesting. Because some of the owls that switched burrows from year to year suffered decreased nesting success, there may be selection against year to year movement among burrows. Given their nest site fidelity (Haug et al. 1993), disturbance of nest sites could have a devastating impact on Burrowing Owl populations, even if artificial burrows are installed nearby.

This study demonstrates the importance of installing artificial burrows in sites most favored by nesting pairs. Owls in this study nesting in undisturbed areas used burrows located in and at the bases of cliff walls where artificial burrows could not be installed. On average, pairs in artificial burrows produced significantly more nestlings than pairs in natural burrows, indicating that artificial burrows did not contribute to decreased nestling productivity. Furthermore, human disturbance may have played a role in lower fledgling production by pairs in artificial burrows.

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