HABITAT AND NEST-SITE SELECTION BY BURROWING OWLS IN THE SAGEBRUSH STEPPE OF IDAHO

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Abstract: The local topography and vegetation around 80 occupied burrowing owl (*Athene cunicularia*) nest sites in the sagebrush steppe of southcentral Idaho were quantified. Several additional topographical variables within a 1-km radius and habitat variables within a 693-m radius of these sites were then compared with data for an equal number of randomly chosen sites. Owls used burrows provided by badgers (*Taxidea taxus*) in open soil and by yellow-bellied marmots (*Marmota flaviventris*) in small lava outcrops; the latter were chosen significantly more often ($P < 0.005$) than expected on the basis of availability. Cover within a 50-m radius of 80 occupied burrows was mainly bare earth, cheatgrass brome (*Bromus tectorum*), rock, and annual forbs. In comparison to randomly chosen sites, occupied sites had a greater cover of cheatgrass brome, had a greater habitat diversity, were lower in elevation, and were more frequently located on southerly aspects. Farmland occurred on 30 occupied sites and 33 randomly chosen sites but averaged significantly less ($P < 0.05$) acreage on occupied sites. Big sagebrush (*Artemisia tridentata*) occurred on 48 occupied sites and 32 randomly chosen sites and also averaged significantly less ($P < 0.05$) acreage on occupied sites. Surface water was present on 14 (18%) occupied sites but on only 2 (3%) randomly chosen sites. Burrow security and prey availability, especially the proximity to populations of montane voles (*Microtus montanus*) on farmland, may explain some of the habitat selection observed.

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Recent population declines of the burrowing owl (Zarn 1974, Collins 1979) have been attributed to control of burrowing mammals (Butts 1973) and loss of habitat to cultivation (Howie 1980). Because of the population status of the species, land management and wildlife agencies have placed an emphasis on managing burrowing owl habitat in Idaho to maintain or increase the population. However, no detailed studies of nest-site and habitat selection have been made in the shrubsteppe of Idaho. Determination of habitat requirements is needed in order to aid decisions involving land use and habitat manipulation.

This study was designed to quantify the habitat and nest-site preferences of burrowing owls in southcentral Idaho. One objective was to determine if the habitat occupied by owls differed from that available to them. I also analyzed diet to determine if it was significantly correlated with habitat selection. I reasoned that because prey density and availability vary greatly among the available habitats, this might be a major proximate factor influencing nest-site and habitat selection.

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STUDY AREA

The study area, located on the Snake River Plain in southcentral Idaho (Fig. 1), had flat to rolling topography and elevations between 900 and 1,500 m. Part of the study area had partially vegetated lava flows and lava outcrops. Annual precipitation averages 25 cm with most falling between December and June. Mean annual temperature was 9 C with a monthly mean of 23 C in July and −4 C in January.

The native vegetation was mainly big sagebrush, threetip sagebrush (*A. tripartita*), Douglas rabbitbrush (*Chrysothamnus viscidiflorus*), rubber rabbitbrush (*C. nauseosus*), Thurber needlegrass (*Stipa thurberiana*), bluebunch wheatgrass (*Agropyron spicatum*), western wheatgrass (*A. smithii*), Sandberg bluegrass (*Poa sandbergii*), bottlebrush squirreltail (*Sitanion hystrix*), and basin wildrye (*Elymus cinereus*).

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However, because large areas have been converted to irrigated farmland (Fig. 1), water was available in many places where it did not occur historically. Recurrent wildfires have allowed much of the remainder of the area to be dominated by cheatgrass brome, an exotic annual. Most of the range habitat is grazed by sheep or cattle.

METHODS

To determine if the habitat occupied by owls differed from that available to them I compared topographic and vegetative features of occupied nest sites with those from randomly chosen sites. This approach to understanding nest-site and habitat selection has been used successfully on a variety of avian species (e.g., Burger and Shisler 1978, MacKenzie and Sealy 1981, Titus and Mosher 1981, Redmond et al. 1982, Clark et al. 1983). In particular, I applied stepwise discriminant function analysis (DFA) to identify important variables that differ between occupied and randomly chosen sites. I tested the results of DFA with independent data from a 2nd set of 47 occupied sites.

Between 1 March and 1 August 1981, I spent 2–3 days/week in the field searching for nest sites and taking measurements on sites. Eighty occupied sites located during this period were used in this analysis. Other nest sites were located between 1976 and 1981 and in 1983. None of these sites were used in the present analysis. However, their locations also are shown in Figure 1, and the distribution of these occupied sites was used to define the breeding range of burrowing owls in the study area for selection of randomly located sites.

Between 1 May and 1 August 1982, I spent 1–2 days/week in the field and located 47 occupied sites that were either not occupied or not detected in 1981. Only elevation and data from aerial photographs as described below were recorded for these sites.

A site was considered occupied if young were observed or ≥1 owl, fresh castings, and a debris ring were present. Where alternate burrows occurred, the nesting burrow was identified by a larger debris ring.

The following infomation was obtained for the 80 occupied burrows located in 1981: presence of rock outcrops within a 1-km radius, type of burrow, compass orientation of burrow opening, slope and aspect of the ground within a 50-m radius, height of outcrop (if present) above the burrow, maximum right-angled dimensions of the outcrop, estimated percent ground cover within 50 m of the burrow, and number of alternate burrows.

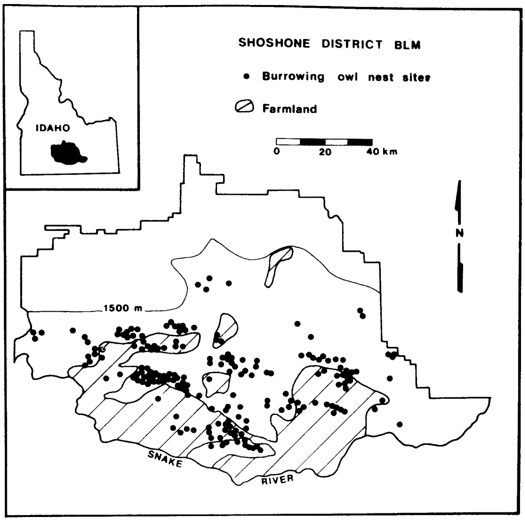

Fig. 1. Location of the study area, farmland, and all burrowing owl nest sites located between 1976 and 1983 in the study area in southcentral Idaho.

I used random numbers to select a township, range, section, and point within the section for each of the 80 randomly located sites. A selected site was acceptable unless it fell on a road, water surface, or farmland or was ≤100 m from an occupied human dwelling or livestock facility. In the 7 cases where unacceptable sites were selected, new numbers were used to establish acceptable sites. Each occupied and randomly chosen site was plotted on a 7.5 minute topographic map and the following information obtained: elevation of site, maximum and minimum elevation within 1 km, relief (maximum–minimum), slope, and slope aspect of the land within a 1-km radius. Measurement of the last 2 values was facilitated by the gentle topography of the region.

Finally, the same sites were plotted on aerial photographs (1:24,000) to determine cover of 5 different habitat types: cheatgrass brome, sagebrush (>10% canopy coverage), farmland, water, and lava. I recorded the area in each habitat type within 6 concentric zones centered on the site. Beginning with the innermost, the areas of these zones were: 12.6-ha each for Zones 1A, 1B, and 1C and 37.7-ha each for Zones 2, 3, and 4 for a total of 150.7 ha/site. The radius of Zone 1A was 200 m, and the outer radius of

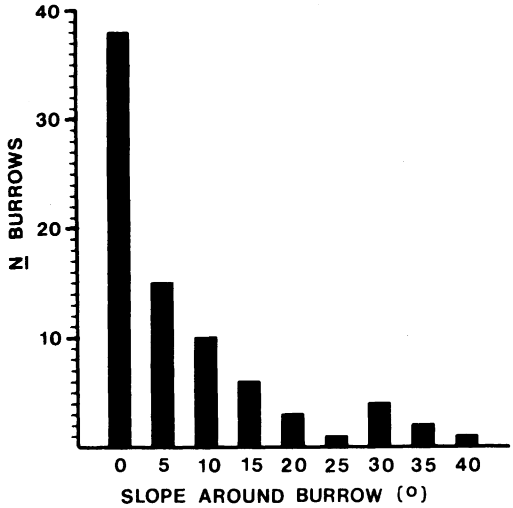

Fig. 2. Location of 80 occupied burrowing owl burrows on different slopes in southcentral Idaho in 1981.

Table 1. Mean percent of most common types of cover within 50 m of 80 occupied burrowing owl nest sites in southcentral Idaho in 1981. *N* = number of sites with a given cover type.

Cover type	*N*	%	SD
Cheatgrass brome	77	59	5
Bare ground	56	19	4
Rock	47	7	2
Sagebrush	35	7	3
Common tumblemustard (*Sisymbrium altissimum*)	30	9	4
Rabbitbrush	28	4	2
Crested wheatgrass (*Agropyron cristatum*)	21	13	4
Bur buttercup (*Ranunculus testiculatus*)	19	21	4
Basin wildrye	16	2	1
Thistle (*Cirsium* spp.)	11	1	0
Perfoliate pepperweed (*Lepidium perfoliatum*)	11	20	4

Zone 4 was 693 m. An index of habitat diversity (*H*) (Shannon 1948) was calculated with the total area in each habitat type for each site. Distance to water was the final variable measured from the photographs.

I collected regurgitated pellets between 15 and 31 July from 52 of the nest sites located in 1981. A random sample of 10 pellets from each site was analyzed for all identifiable prey. A subset of these data, which consisted of more commonly occurring prey items, then was correlated with the area in each of the habitat types.

Univariate statistical analysis followed Zar (1974:41–43, 243–245, 313–320), whereas analysis of variance (ANOVA) and DFA were performed with programs in the BMDP series (Dixon 1981:347–358, 519–537). In the latter analysis vegetative variables were entered as the area within each zone covered by cheatgrass brome, farmland, sagebrush, and water. The cover of lava was omitted to avoid a singularity (Smith 1981). In the text all values following means are standard deviations. Data screening revealed that distributions of several variables were positively skewed. These variables were log-transformed before analysis and are so noted in the text and tables.

RESULTS

Burrowing owls arrived on the study area in early April, but nest-site conspicuousness peaked in July when most young were fledging yet remained close to the burrow. Since 1976, young have been observed near natal burrows as early as 10 June and as late as 17 September. Between the summers of 1976 and 1983, 242 occupied burrows were located (Fig. 1).

Burrow Characteristics

Outcrop and Mound Sites.—I classified occupied burrows located in rock outcrops as outcrop sites and those in mounds of soil as mound sites. Outcrop sites often were abandoned burrows of yellow-bellied marmots, but several consisted of natural rock cavities. Badgers excavated most mound sites. In 1981, 28 outcrop sites and 52 mound sites were located. Alternate burrows were present at 3 of 28 (11%) outcrop sites and at 19 of 52 (37%) mound sites.

The number of outcrops available within 1 km of each occupied site was ranked as high, medium, or low. Within each rank the number of outcrop and mound sites, respectively, were: high, 17 and 12; medium, 10 and 30; and low, 1 and 10, respectively. The type of nest site was not independent of the availability of outcrops ($\chi^2 = 12.1$, $P < 0.005$); i.e., burrowing owls used outcrop sites more than expected on the basis of availability. They also preferred smaller outcrops. Mean dimensions of the 28 occupied outcrops were: width 10 ± 8 m and length 16 ± 13 m (excluding 4 outcrops that were >50 m long). Many larger outcrops were available, some extending for several kilometers.

Burrow Orientation, Slope Aspect, and Slope.—Mean angles and angular dispersion in-

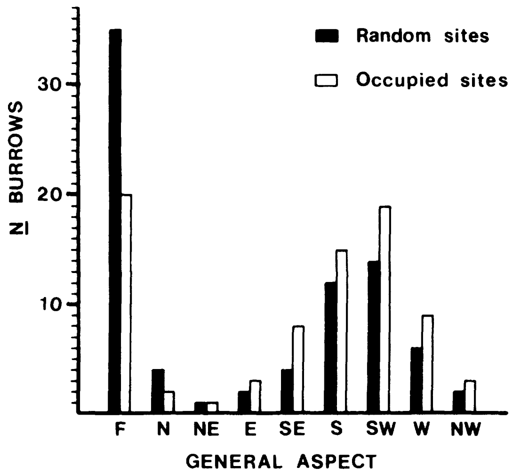

Fig. 3. Number of occupied burrowing owl burrows and randomly selected sites placed on various slope aspects in southcentral Idaho in 1981. Letters denote the cardinal directions and F = flat.

dicated random orientation of burrows on the 80 occupied sites. However, there was a correlation between orientation and local slope aspect of the 42 burrows placed on slopes ($r = 0.89$, $P < 0.001$); i.e., most burrows were simply dug into the slope.

The owls apparently preferred flat sites because 79% of the burrows were located on slopes of ≤10° (Fig. 2). Burrows were not randomly placed with respect to slope ($\chi^2 = 65.9$, $P < 0.001$), with an excess of sites on flat terrain. At outcrop sites openness was reflected in the minimal height (42 ± 24 cm) of the rock face under which the burrows were located.

Local Vegetation.—Cover within 50 m of the 80 occupied burrows (Table 1) was mainly cheatgrass brome with substantial portions of bare ground. Both sagebrush and rabbitbrush were found frequently but composed only a small portion of the cover. The 4 genera that indicate highly disturbed sites—*Sisymbrium*, *Ranunculus*, *Cirsium*, and *Lepidium*—were encountered often but did not dominate the sites.

Occupied vs. Randomly Chosen Sites

General Topography and Slope Aspect.—Owls selected sites averaging 47 m lower than what was available (Table 2). Occupied sites also averaged 319 m nearer water although the difference was not significant. The slope aspects within 1 km of occupied and randomly chosen sites (Fig. 3) were different ($\chi^2 = 17.46$, $P < 0.05$). More occupied sites than expected were located on all aspects except flat, north, and northeast. The variance in all variables for randomly chosen sites was slightly greater than for occupied sites (Table 2). Thus, owls selected from a narrower range of topographic features than was available.

Vegetation.—I first examined how vegetative cover changed as the estimate of home range was increased. For 3 habitat types (excluding water and lava that had small sample sizes) the area of cover did not differ over all zones for either randomly chosen or occupied sites (1-way ANOVA, all $P > 0.20$). In other words, expanding the area around the randomly chosen or occupied site did not significantly alter the probability of encountering a given habitat type.

Second, the mean area of each habitat type differed between occupied and randomly chosen sites for some zones. The cover of cheatgrass brome was greater on occupied sites for Zones 1A ($t = 3.75$, $P < 0.001$), 1B ($t = 2.13$, $P < 0.05$), and 1C ($t = 2.50$, $P < 0.02$) but was not different for the other zones (all $P > 0.10$). For farmland cover on occupied sites was less only in Zone 1A ($t = 2.86$, $P < 0.05$). The other zones revealed no differences (all $P > 0.20$). Sage-

Table 2. Topographic variables for 80 occupied burrowing owl nest sites and 80 randomly chosen sites in southcentral Idaho in 1981. The significance of the difference between means for each type of site is shown.

Variable	Occupied $\bar{x}$	Occupied SD	Random $\bar{x}$	Random SD	P
Elevation (m)	1,256	77	1,303	113	<0.005
Max.	1,276	84	1,322	125	<0.01
Min.	1,240	79	1,288	105	<0.002
Relief[a]	36	24	34	34	>0.50
Slope (%)	3.8	3.5	4.2	4.3	>0.50
Distance to water (m)[a]	872	1,005	1,191	1,377	>0.05

[a] Logarithmic transformation used before t-test.

Table 3. Cover of 5 different habitat types for 80 occupied burrowing owl nest sites and 80 randomly chosen sites in southcentral Idaho in 1981. The significance of the difference between means for each type is shown.

Habitat	Nest site[a]			Randomly chosen site			P
	N	$\bar{x}$ (ha)	SD	N	$\bar{x}$ (ha)	SD	
Cheatgrass brome	80	86.5	53.9	64	86.1	59.5	>0.50
Farmland	30	77.1	42.5	33	107.7	42.3	<0.05
Sagebrush	48	58.1	37.0	32	76.7	56.5	<0.05
Lava[b]	0			6	93.2	43.0	
Water	14	3.9	3.2	2	3.5	0.6	

[a] $\bar{x}$ and SD are for only those sites with the given habitat type.
[b] Nest sites in rock outcrops did not have measurable cover of the lava habitat type. Thus, $N = 6$, not 28.

brush cover was not different between observed and randomly chosen sites over all zones (all $P > 0.10$).

Comparison of site habitat totals reveals that among those sites having some cheatgrass brome the mean area covered did not differ between randomly chosen and occupied sites (Table 3). About the same number of occupied and randomly chosen sites had some farmland, but the latter averaged >30 ha more. Sagebrush cover averaged significantly greater on randomly chosen sites yet there were 16 more occupied sites with some sagebrush.

DFA.—The amount of cheatgrass brome in Zone 1A was the best discriminating variable (Table 4), with occupied sites having more than randomly chosen sites. Habitat diversity was next best, with occupied sites ($H = 0.21 \pm 0.17$) being more diverse than randomly chosen sites ($H = 0.12 \pm 0.13$) ($t = 3.63$, $P < 0.001$). Elevation was lower, distance to water less, and the amount of cheatgrass brome in Zone 1B was greater for occupied sites (Table 2). The classification functions (Table 5) succeeded in classifying 77.5% of the sites correctly.

To test the robustness of these classification functions I entered the data from the 47 occupied sites discovered in 1982. These data did not enter into formulation of the functions but simply were classified by them. These sites were not successfully classified (1982 sites in Table 5), with nearly 60% classified as randomly chosen sites.

I then combined the original 80 occupied sites with the 47 sites found in 1982 to improve the discriminant functions. The new analysis (Table 6) shows the 1st 3 variables entered to be the same as before (Table 4). However, distance to water lost its discriminating value. The percentage of occupied sites correctly placed (78.7%, Table 7) was almost exactly the same as before (78.8%, Table 5). But the percentage of randomly chosen sites properly identified declined (62.5 vs. 76.3%, Table 5).

Occupied sites were more tightly clustered than randomly chosen sites along the discriminant axis (Fig. 4). This supports the data on topography (Table 2) and slope aspect (Fig. 3) showing that burrowing owls selected from a narrower range of values than was available.

Habitat and Diet

The area in cheatgrass brome was positively correlated with occurrence of the Great Basin

Table 4. Stepwise discriminant analysis of 80 occupied burrowing owl nest sites and 80 randomly chosen sites in southcentral Idaho in 1981.

Step	Variable entered[a]	F to enter	U-statistic	df
1	C1A	14.96	0.91	1 & 158
2	H	22.77	0.8	2 & 157
3	EL	6.57	0.77	3 & 156
4	LOGW	9.03	0.72	4 & 155

[a] C1A = area in cheatgrass brome in Zone 1A, H = habitat diversity, EL = elevation of site, and LOGW = distance to water, log-transformed.

Table 5. Classification matrix resulting from stepwise discriminant analysis of 80 occupied burrowing owl nest sites and 80 randomly chosen sites in southcentral Idaho in 1981 and 1982. The 47 sites discovered in 1982 did not enter into formulation of the classification functions but were classified by them.

Group	% correct	N cases classified into group	
		Random	Occupied
1981			
Random	76.3	61	19
Occupied	78.8	17	63
Total	77.5	78	82
1982	40.4	28	19

Table 6. Stepwise discriminant analysis of 127 occupied burrowing owl nest sites and 80 randomly chosen sites in southcentral Idaho in 1981 and 1982.

Step	Variable entered[a]	*F* to enter	*U*-statistic	df
1	C1A	20.97	0.91	1 & 205
2	*H*	29.22	0.8	2 & 204
3	EL	6.11	0.77	3 & 203
4	C1B	4.44	0.75	4 & 202

[a] C1A = area in cheatgrass brome in Zone 1A, *H* = habitat diversity, EL = elevation of site, and CIB = area in cheatgrass brome in Zone 1B.

Table 7. Classification matrix resulting from stepwise discriminant analysis of 127 occupied burrowing owl nest sites and 80 randomly chosen sites in southcentral Idaho in 1981 and 1982.

Group	% correct	*N* cases classified into group	
		Random	Occupied
Random	62.5	50	30
Occupied	78.7	27	100
Total	72.5	77	130

pocket mouse (*Perognathus parvus*) and burying beetles (*Nicrophorus* spp., Table 8). The correlation between Great Basin pocket mice and cheatgrass brome was the highest in Table 8, suggesting that this prey species was either relatively common or easily captured. The burying beetles, although small, commonly were found in pellets and, because of their behavior, may be exploited in large numbers.

The only species having a significant positive correlation with area in farmland was the montane vole (Table 8). This vole was the largest prey regularly taken, and its remains were the most commonly encountered items in pellets.

Only Jerusalem crickets (*Stenopelmatus* spp.) had a significant positive correlation with the amount of sagebrush habitat. It is the largest invertebrate consumed, is easy to capture, and its remains also are commonly found in pellets (Green 1983).

Habitat diversity was positively correlated with voles and Jerusalem crickets. Thus, both the largest vertebrate and invertebrate prey increased in the diet of owls in more diverse habitats. Prey diversity was positively correlated with cover of cheatgrass brome and negatively correlated with area in farmland (Table 8). There also was a negative correlation between habitat diversity and prey diversity.

DISCUSSION

Burrowing owls preferred small rock outcrops for nest sites (also see Rich [1984]), perhaps affording protection against badger and canid predation in the burrow. Other types of nest sites where at least part of the burrow was rigid have been reported (Coulombe 1971, Wedgewood 1976, Collins and Landry 1977, Henny and Blus 1981). Badgers not only provide burrows for owls in many areas (Scott 1940, Maser et al. 1971, Butts 1973, Wedgewood 1976, Howie 1980) but also regularly check burrows within their territories (Messick and Hornocker 1981) and dig out nests (Coulombe 1971, Gleason 1978, Green 1983). Because domestic dogs damage burrows in some areas (Thomsen 1971, Green 1983), coyotes (*Canis latrans*) also might be expected to excavate burrows.

Burrow orientation was found to be governed mainly by the local aspect. Others also have failed to find any significant orientation preference (Coulombe 1971, Butts 1973, Martin 1973).

Burrowing owls may be one of only a few avian species that benefit from substantially disturbed habitat in the sagebrush steppe. Cover within 50 m of the burrow in this study indicated sites had been disturbed by fire and grazing. But sites were not dominated by plants indicative of the highest degree of disturbance possible for this region. The character of the habitat was similar to that reported for many other areas (Grant 1965, Thomsen 1971, Butts 1973, Martin 1973, Wedgewood 1976, Howie 1980, Stevenson et al. 1980).

Burrowing owls selected from a narrower range of topographical variables than was available although significant selection emerged only for elevation and slope aspect. Outcrop sites, especially, were available on the higher parts of buttes in the study area but, to my knowledge, have never been used. Wedgewood (1976) similarly found that sites in "hill country" were located on flat land between hills.

Although only 30 occupied sites from 1981 contained farmland, most of the recent known sites have been associated with cultivated lands (Fig. 1). On the Birds of Prey Natural Area in southwestern Idaho 41 of 53 nest sites had farmland within a 693-m radius (M. Q. Moritsch, pers. commun.). Although this was a higher percentage of sites than found in the

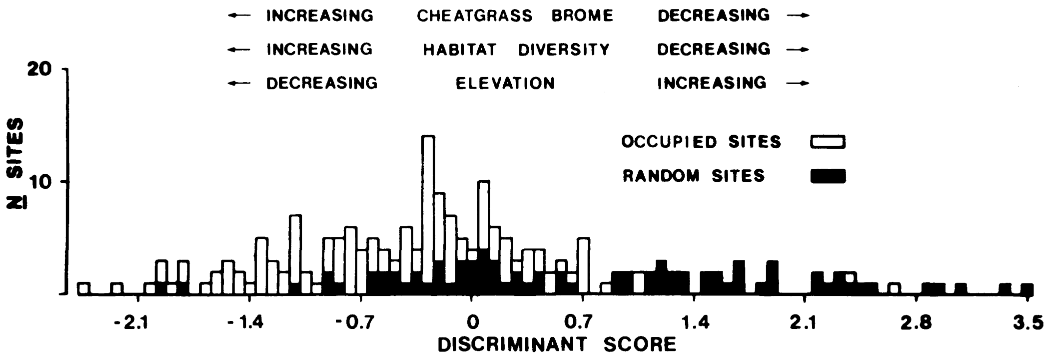

Fig. 4. Discriminant scores of 127 occupied burrowing owl nest sites and 80 randomly chosen sites in southcentral Idaho in 1981 and 1982.

present study (Table 3), the mean area in farmland (77.9 ± 45.3 ha) was almost identical ($t = 0.08$, $P > 0.50$). Owls nesting near irrigated cropland in another part of southern Idaho preyed more heavily on montane voles and produced significantly more young/brood than those nesting away from that habitat (Gleason 1978). Diet analysis revealed a positive correlation between the amount of land under cultivation and the number of voles in pellets.

Butts (1973) found denser owl populations in areas adjacent to cereal crops and significantly greater densities of rodents. Although cultivated fields may support a large prey biomass, dense vegetation may make prey unavailable (Bechard 1982). In the present study area, hay is a common crop that is cut 2–3 times during the summer. Variation in cutting dates yields a mosaic of fields in different stages of growth. Therefore, rodent populations in these fields were available throughout the owls' breeding season.

Sagebrush was a potentially important habitat type on occupied sites in the present study. In another part of southern Idaho, 30 of 36 occupied burrows were located within 100 m of sagebrush (T. H. and E. H. Craig, pers. commun.). Continuous, dense sagebrush stands (10–35% canopy coverage) were not occupied by burrowing owls in my study area even though thousands of hectares of this habitat were available. In fact, invasion of shrubby species may have contributed to population declines in some areas (Best 1969, Howie 1980).

MANAGEMENT IMPLICATIONS

The ecological relationship between burrowing owls and farming deserves more detailed study. In particular, it is necessary to determine whether burrowing owls nest near farmland because of the habitat or if they historically nested there because of some other factor; e.g., soil quality. If the 1st case is true, the owl populations are higher now than historically in southern Idaho. If the 2nd case is true, populations are lower because much of the historically suitable area is now converted to farmland.

The similarity of the proportion of farmland

Table 8. Spearman rank correlation coefficients between habitat variables and selected prey species in the pellets of burrowing owls from 52 occupied nest sites in southcentral Idaho in mid-July 1981. The weight of prey species also is given.

	Hectares in			
Prey species	Cheatgrass brome	Farmland	Sagebrush	Habitat diversity
Montane vole (38 g)	−0.32*	0.39**	−0.03	0.34*
Deer mouse (*Peromyscus maniculatus*) (17 g)	0.12	−0.28*	0.16	−0.14
Great Basin pocket mouse (15 g)	0.64***	−0.38**	−0.41**	−0.61***
Jerusalem cricket (2 g)	−0.44***	0.16	0.38**	0.42**
Burying beetles (0.8 g)	0.45***	−0.32*	−0.24	−0.51***
Grasshoppers (0.3 g)	0.11	0.01	−0.15	−0.05
Prey diversity	0.34*	−0.28*	−0.13	−0.28*

* $P < 0.05$, ** $P < 0.005$, and *** $P < 0.001$.

within a 693-m radius in this study and in the Birds of Prey Natural Area suggests that many pairs of owls select a specific proportion of cultivated land. If owls prefer to hunt this habitat because of vole populations and thereby increase their reproductive success, this offers an opportunity for increasing owl populations. Extensive ecotone between rangeland and farmland within the burrowing owl's range may be made more suitable once other habitat requirements are met. For example, artificial nest structures may be best placed near hay fields. Martin (1973) believed that this owl was "behaviorally plastic" and may be one of the raptors least affected by man-made environmental changes. It is possible that burrowing owls may be benefited by some of these changes.

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