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Title: Ecology of Breeding Burrowing Owls in the Columbia Basin,
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The ecology of breeding burrowing owls (Athene cunicularia) was studied in northcentral Oregon during the spring and summer of 1980 and 1981. Pairs began arriving on the study areas as early as the first week of March; however, most arrivals were during April. Egg-laying began the first week of April and continued into the first week of May. Whole family groups left the nesting areas as early as the first week in July while members of other families remained until at least the end of September.

Nest success was 57% for 63 nests in 1980 and 50% for 76 nests in 1981. Desertion was the major reason for nest failure and may have been related to the proximity of other nesting pairs. Badgers (Taxidea taxus) were the major nest predators. Nests which were lined with cow or horse dung were significantly less prone to predation than nests not lined, suggesting dung masks odors of nest occupants.

Diets were determined by pellet analysis. Arthropods comprised 91.6% of the total prey by number; however, they contributed only

22.0% of the total biomass. Vertebrates, mostly small mammals, comprised the balance. Perognathus parvus (Great Basin pocket mouse) was the most important vertebrate prey and Stenopelmatus fuscus (Jerusalem cricket; Gryllacrididae) was the most important arthropod. Coleoptera were preyed upon very heavily, but they were dominated by very small (< 10 mg) beetles and, therefore, contributed little to the total biomass. Burrowing owls preyed on mammals during the spring then shifted to insects during the summer. Burrowing owl diets were influenced by soil type, and owls selected mammals in proportion to their occurrence in the environment.

Burrowing owls selected 3 of 5 habitats for nesting. Hole availability was not the sole stimulus for nest selection. Discriminant function analysis indicated variables responding to horizontal visibility and possibly food availability as important prerequisites for nest selection. Soil texture greatly influenced re-use and longevity of nest burrows.

Ecology of Breeding Burrowing Owls in the Columbia Basin, Oregon

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INTRODUCTION

Burrowing owls (*Athene cunicularis*) rarely excavate their own burrows but utilize those abandoned by semi-fossorial mammals. Butts (1971), Thomsen (1971), Coulombe (1971), and Martin (1973) have illustrated the dependence of burrowing owls on colonial sciurids, particularly *Cynomys* spp. and *Spermophilus* spp., for nest burrows. Since burrows are important to the breeding ecology of both colonial sciurids and burrowing owls, vegetative relationships of these species are presumably quite similiar. Short vegetation is good breeding habitat for burrowing owls (Best 1969, Coulombe 1971, Zarn 1974) and is enhanced by foraging of colonial sciurids. Also, large herbivores such as bison (*Bison bison*) and pronghorn (*Antilocapra americana*) have historically kept vegetation short around some sciurid colonies (Costello 1970).

The Columbia Basin of Oregon and Washington is different ecologically from areas where burrowing owls have been studied previously. For instance, the shrub-steppe region has not been conducive to the establishment of grasses of the C_4 photosynthetic pathway (Mack and Thompson 1982). Although C_4 plants thrive under hot, moderately dry conditions because of an efficient photosynthetic process where transpiration (water loss) is reduced (Kirk 1980:402), the summer drought conditions of the Columbia Basin are apparently great enough to preclude establishment of C_4 grasses. These "warm season" plants are known to be the major components of the diets of bison (Mack and Thompson 1982, Schwartz and Ellis 1981) and *Cynomys* (Fagerstone and Williams 1982) during the summer. Their absence may explain why these herbivores did not inhabit the Columbia Basin during historic times (Mack and Thompson 1982). Other colonial sciurids (*Spermophilus washingtoni*, *S. beldingi* and *S. townsendii*) are endemic to the Columbia Basin; however, they are small (< 350 g) and probably do not provide holes of sufficient size for burrowing owls. As a result, burrowing owls in this region utilize abandoned burrow of badgers (*Taxidea taxus*), a solitary carnivore common to the Columbia Basin.

As badgers are not colonial and do not "crop" the vegetation surrounding their burrow, the association between this predator and burrowing owls is presumably different from associations between burrowing owls and sciurids. The influence of domestic livestock grazing on the presence of burrowing owls in the Basin is also unknown; however, burrowing owls were reported from the western edge of the Basin as early as 1860 (Suckley and Cooper 1860). Nonetheless, burrowing owls in this area nest in shrub communities as well as open, short grass communities (pers. obs.). The behavior of nesting in taller vegetation has not been well documented in the literature and may be an adaptation to commensal relationships with badgers.

The purpose of this work was to describe the ecology of nesting burrowing owls in the shrub-steppe communities of the Columbia Basin. Emphasis is placed upon breeding chronology, nest success, hole-availability, habitat selection and diets. The management implications of the habitat relationships of burrowing owls are also discussed.

STUDY AREA

The 7 study sites investigated were located within the shrub-steppe zones of northern Gilliam, Morrow, and Umatilla counties in northcentral Oregon (Fig. 1). The topography of the area ranges from flat to gently undulating with elevations from 75 m on the loamy-sand soils near the Columbia River to 200 m on the sandy-loam soils. The Arlington Airport site at 125 m elevation has a soil of densily packed silty-loam. The average annual precipitation on the study sites is approximately 22 cm (Ruffner 1978), of which most occurs during the winter and early spring. Summers are characterized as hot and dry with several days of maximum temperatures over 40 C.

Over 100,000 ha of shrub-steppe in northern Morrow and Umatilla counties have been converted to pivot irrigation and dryland farming in the last decade (Muckleston and Highsmith 1978). These croplands were not conducive to nesting by burrowing owls, thus 90% of the total area searched was for nest sites on state or federal government landholdings (see Fig. 1).

The 5,300 ha Umatilla Activity is an U.S. Army installation for storage of military supplies. Bitterbrush (_Purshia tridentata_) and cheatgrass (_Bromus tectorum_) intermixed with golden-aster (_Chryopsis villosa_) were the most abundant plant species. The U.S. Navy Boardman Bombing Range was established as a weapons training facility for use by Navy jet bombers. However, all bombing activity was limited to 2 small target areas leaving over 95% of the 20,300-ha range free of military impact. Both cattle and sheep were grazed on the range

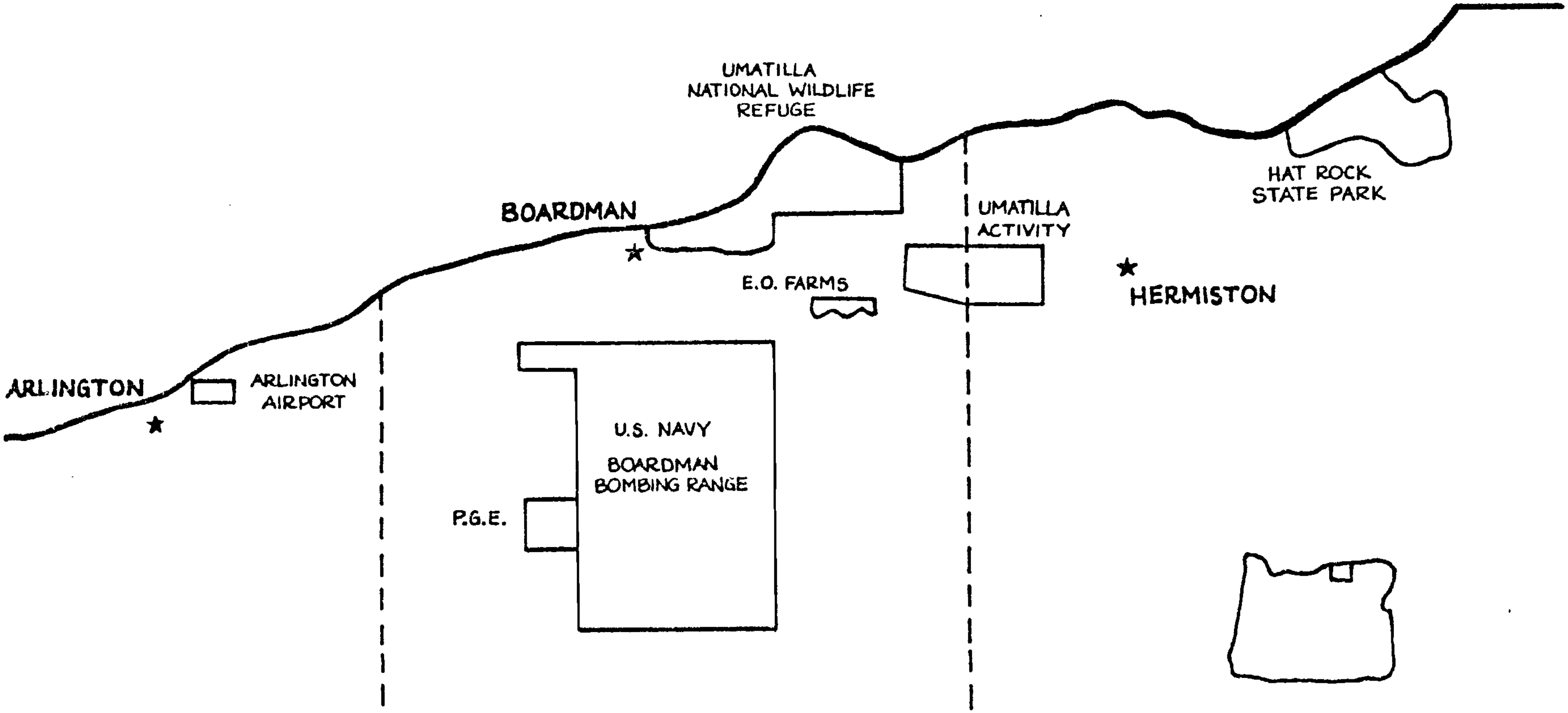

Figure 1. Location of the study sites in the Columbia Basin, Oregon.

during the spring months. Portland General Electric lands (PGE) abutt the west side of the U.S. Navy Boardman Bombing Range and were characterized by a mosiac of big sagebrush (*Artemesia tridentata*), gray rabbitbrush (*Chrysothamnus nauseosus*), cheatgrass, and needle-and-thread grass (*Stipa comata*). A coal-fired power plant and a 567 ha cooling pond are located on the site. Approximately 10 ha of PGE land were used in this study. Hat Rock State Park had moderately sparse stands of bitterbrush with an understory of cheatgrass and filaree (*Erodium cicutarium*) and was characterized by undulating topography. Some patches of the park were set afire by an arsonist in 1980. The study site on Eastern Oregon Farms was of varied width at the northern edge of a large corporate farm. The site consisted of bitterbrush and cheatgrass intermixed with golden-aster and existed as shrub-steppe. The site at Arlington Airport was a parcel of private land adjacent to the east side of the runway and has been subject to intense livestock grazing. Snakeweed (*Gutierrezia sarothrae*) and hairy plaintain (*Plantago patagonica*) dominated the vegetation.

Poulton (1955) described the vegetation of these areas as being either *Artemisia/Stipa* or *Artemesia/Agropyron* plant associations; however, because of prevalent edaphic, zootic (grazing), and fire conditions, the climatic climaxes are seldom realized. Within these plant associations were vegetative groupings henceforth called habitats which are based upon unique physiogomy and species composition.

Snakeweed habitat--This habitat is dominated by snakeweed and hairy plaintain. An exotic, *Snakeweed* is a variant phase of the

Artemesia/Agropyron plant association first arriving on the study site in the 1950's (Poulton 1955). Snakeweed habitats are indicators of heavy grazing pressure by domestic livestock and are most prevalent on the study sites where sheep are continously bedded. The average height is lower in this community than any others described.

Bunchgrass habitat--Two species of bunchgrass dominate this habitat; needle-and-thread grass is prevalent on the sandy soils and is replaced by blue-bunch wheatgrass (*Agropyron spicatum*) on the more loamy soils. Depending upon which grass species dominates, these stands are actually phases or successional stages of either *Artemesia/Stipa* or *Artemesia/Agropyron* plant associations. Dense stands of native bunchgrass occur on only the U.S. Navy Boardman Bombing Range where they have been protected from livestock grazing. Recent relaxation of grazing pressures surrounding these stands has resulted in an increase in abundance of native grasses.

Cheatgrass habitat--The cheatgrass habitat is found on all but 1 of the study sites and has been described as a zootic climax of the bunchgrass phases and a result of heavy grazing pressure (Poulton 1955, Daubenmire 1970). Cheatgrass, an exotic from Europe, is a conspicuous component of all habitats and dominates large areas of the Columbia Basin. Structurally, the cheatgrass habitat is shorter than the bunchgrass habitat, especially on sandy soils where average cheatgrass height may only attain 5-8 cm. Another annual grass, Sandburg's bluegrass (*Poa sandburgii*), and filaree sometimes codominate this habitat.

Bitterbursh habitat--The bitterbrush habitat is an edaphic climax of the *Artemesia/Stipa* plant association (Poulton 1955) and occurs on sandy soils in association with either cheatgrass or a combination of needle-and-thread grass, gray rabbitbrush, and snowy buckwheat (*Eriogonum niveum*). This is the tallest habitat with some shrubs attaining heights of over 2 m. In some areas, bitterbrush has been recently killed by subsurface soil saturation, a result of nearby irrigation.

Rabbitbrush habitat--This habitat is structurally shorter than the bitterbrush habitat because of the dominance of medium-height gray rabbitbrush and short snakeweed. These plants are indicative of grazing and fire pressures on both the *Artemesia/Agropyron* and *Artemesia/Stipa* plant associations. Cheatgrass dominates the interstices between the shrubs.

METHODS

Nesting pairs were located by systematically searching the study areas for conspicuously perched males or small patches of lush cheatgrass characteristic of previously used nest burrows. All areas were searched at least twice to locate late nesting pairs. Once nesting owls were found, the immediate area was repeatedly searched to locate all neighboring pairs. No attempt was made to determine densities throughout the study area because of the clumped but sparse distributions of nest sites.

Food habits of burrowing owl pairs and their young were determined by collection and analysis of regurgitated pellets (castings) around nest sites. Pellets were collected from around perches and burrows at each nest site approximately once monthly in 1980 and every 2 weeks in 1981. Because burrowing owls are known to portion single prey items over more than 1 meal, analysis of single pellets creates biases. Consequently, all pellets collected at a nest site at a particular time were analyzed as a group. Each group was "cleaned" by soaking them overnight in a 2 molar (8%) solution of NaOH, a method which dissolves hair and feathers but leaves chitin and osseus material intact (Degn 1978). After the material was strained and dried, vertebrate and arthropod fragments were separated from the pellet mass, identified to the lowest taxon possible, and the number of individuals per taxon counted. Head capsules and elytra (Coleoptera), jaws (Orthoptera), and lower mandibles (Rodentia) were the main characteristics used in the identification. All data were converted to biomass (dry weight) from Rogers et al. (1976), Gleason and Craig (1979), specimens in the mammal collection at Oregon State University, and specimens collected on the study site.

Five small mammal trapping grids were established in the cheatgrass, bitterbrush, and rabbitbrush habitats on the north-end of the U.S. Navy Bombing Range to estimate species composition of small mammal populations. Three grids were 10 X 10 and 2 were 5 X 10 configurations with 15 m intervals. Trap-nights per grid varied from 400 to 900 with a total of 3,300. Percent composition of rodent species was calculated from the trapping data. These numbers, plus the composition of rodent species in the burrowing owl diet on the north-end of the bombing range during this same time period, were subjected to the natural log of the odds ratio (Fleiss 1973, Jacobs 1974) to determine prey selectivity.

To determine the role of burrow availability in habitat selection by burrowing owls, unoccupied badger burrows were surveyed along 500-m stratified strip-transects in 5 habitats. Depending upon vegetation density, strip widths were 30 or 60 m. Densities of available burrows in habitats used and not used by burrowing owls for nesting were compared.

A nest site was called successful if young were raised to an age at which they flew from the burrow rather than retreated down the hole when approached (approximately 5 weeks of age). An unsuccessful nest site was one which was occupied by the pair to at least the egg-laying stage (approximately 3 weeks). Occurrence of egg shells in pellets (burrowing owls frequently ingest their own egg shell fragments) aided in determining whether or not nesting had occurred in burrows which had been deserted before emergence of young. Observable behavioral activities thought to coincide with egg-laying, incubation, and brooding (see Breeding Chronology) plus the length of known occupancy of a nest site were also used to determine if nesting had been initiated. Concern has been raised by Henny and Blus (1981) that counting of active nesting pairs may be complicated by shifting of burrows while broods are still very young. In this study, the area within 300 m of a deserted nest burrow was intensively searched for a "new" nest burrow to determine if nest shifting may have occurred.

The importance of vegetative structure in nest site selection was determined by comparing vegetation characteristics of nest sites with that of the general habitat. Because a burrow is prerequisite to any nest selection by burrowing owls, unoccupied burrows were used in describing the general habitat. Vegetation comparisons were made within habitats and not among. Fifteen variables were measured at 18 randomly selected "potential" nest sites in each community. The variables measured and three generated variables are described on Table 1.

Statistical Analysis--To determine whether there was a relationship between nest desertion and its proximity to another nest, a median test (Steel and Torrie 1980:543) was performed on distances between nearest-neighbor nests. The test was used to determine whether there were significant differences between nearest-neighbor distances where both nest pairs were successful and those for which one or both of the nests were deserted. Specific inter-nest

Table 1. List and description of variables measured in characterizing the habitat of actual and potential nest sites of burrowing owls in the Columbia Basin.

Variable	Description
Percent bare ground Percent forb Percent grass Percent shrub	Percentage estimate of canopy coverage bare ground, forbs, grasses and shrubs (Daubenmire 1959).
Shrub intercept	Meters of shrubs intercepted along a 50 m transect divided by 100 (Piper 1973).
Shrub volume	Shrub intercept multiplied by the mean height of the intercepted shrubs.
Effective height	Height at which 90% of a white board is obscured by vegetation when viewed from 10 m at a height of 1 m.
Vertical density 0-10 cm Vertical density 10-20 cm Vertical density 20-30 cm Vertical density 30-40 cm Vertical density 40+ cm Vertical density total	Number of touches by plants within 10 cm height intervals along a thin vertical rod (Wiens 1968).
Foliage height diversity Foliage height evenness	Indices computed from vertical density measurements.
Number of perches	Number of perches located at each nest site.
Mean perch distance	Mean distance from burrow to perches at each nest site.
Mean perch height	Mean height of perches at each nest site.

distances were used only once to prevent potential bias that could be created when pairs are reciprocal nearest-neighbors, i.e. some values used twice while others are used only once. Nests lost to predation were not used in the analysis. A 2 X 2 contingency table was used to test for differences in nest success between nests lined with cow dung and those not lined.

Step-wise Discriminant Function Analysis (SPSS; Klecka 1975) was used to test for differences in vegetative characteristics of actual and potential nest sites. The discriminant analysis also determined which variables were significant ($P < 0.05$) in separating actual from potential nest sites. Prior to discriminant analysis, a correlation matrix was generated for all measured variables in each community. High inter-correlation coefficients ($r > 0.700$) resulted in one of the two variables being removed from the analysis.

RESULTS AND DISCUSSION

Breeding Chronology--Breeding behavior of burrowing owls in the Columbia Basin was very similar to burrowing owls studied by Thomsen (1971) in California and Martin (1973) in New Mexico. Burrowing owls were first noticed on the study areas as early as the first week of March; however most first sightings occurred during April (Fig. 2). Pairs usually established a nesting attempt in the first burrow at which they were observed; however, some pairs shifted to nearby burrows or were not seen again after their initial location, a behavior also observed by Thomsen (1971).

Once a nest site was established, pairs participated in courtship and copulation behaviors as observed by Martin (1973). At this time nest material consisting mainly of dried cow manure was brought to many of the nest sites. In areas where cow feces were not available, nests either were not lined or horse manure, pronghorn (*Antilocapra americana*) pellets, bits of black-tailed jackrabbit (*Lepus californicus*) fur, or fragmented prickly-pear cactus (*Opuntia polyacantha*) roots were used. Also during this period the male was conspicuously perched nearby the burrow during periods of inactivity.

The subterranean nesting behavior of this species made it difficult to accurately determine when egg-laying and incubation were initiated. Egg-laying and incubation periods were therefore determined by back-dating from the age of the young. Egg-laying began as early as 1 April and as late as the first week in May. The female was very secretive and the male became more seclusive at this time.

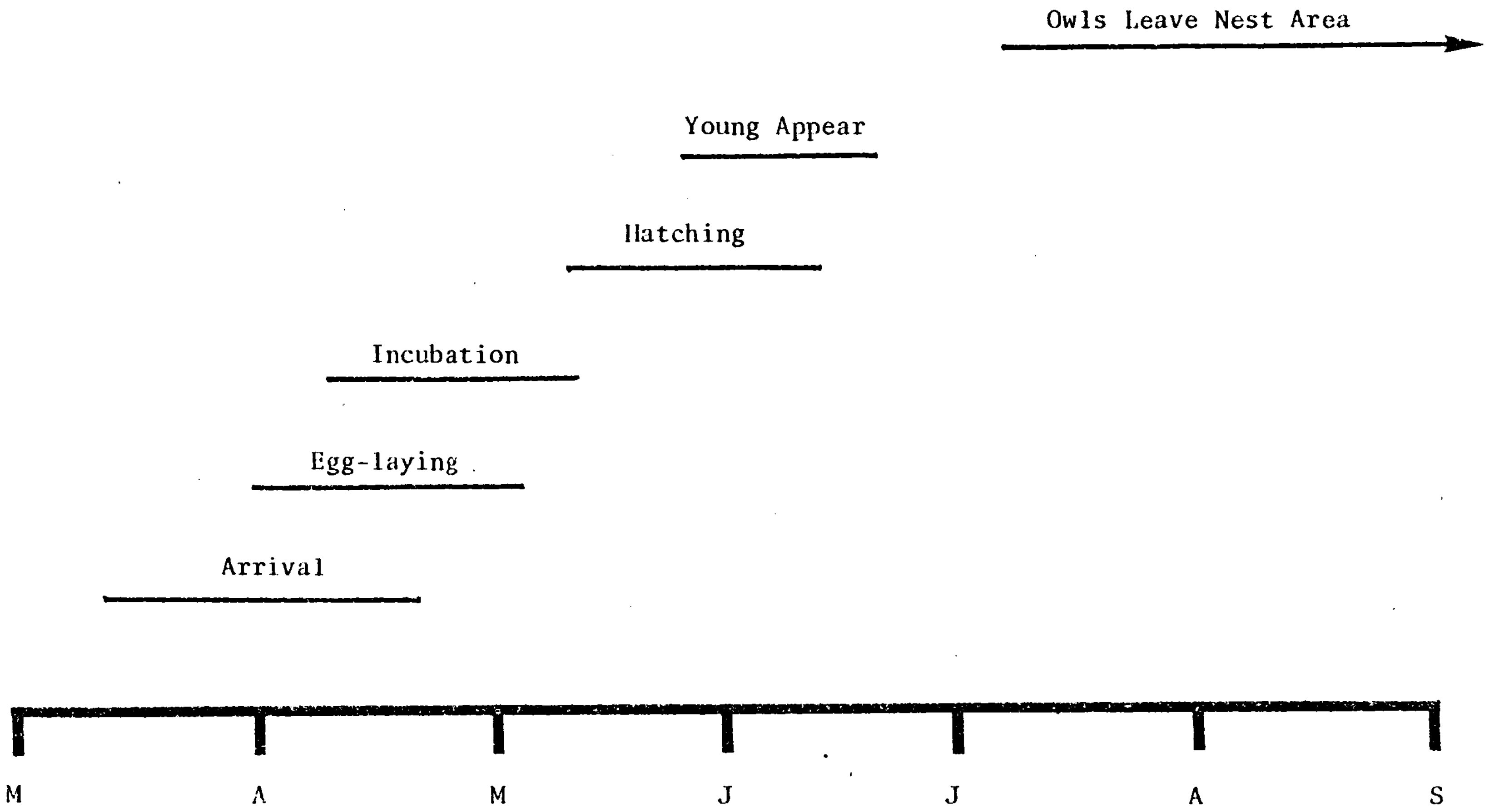

Figure 2. Breeding chronology of burrowing owls in the Columbia Basin, Oregon during 1980 and 1981.

During the egg-laying period, perching by the male was reduced, which may have served to avoid drawing attention to the female while she was burdened by egg production. Once egg-laying was complete, the male became more conspicuous and the incubating female could occasionally be observed leaving the burrow to defecate or take food items left on the midden by the male.

The young hatch asynchronously after a 28-day incubation period (Landry 1979). The brooding female then began to spend more time out of the burrow but generally did not assist the male in foraging activities until the young began emerging. In one case, a brooding female was observed using a cache of rodents provided by the male in an accessory burrow 10 m away. Caching is not uncommon in the burrowing owl (Collins 1976); however, storing food in places other than the burrow entrance or midden was observed only once in the present study.

Young first emerged from the burrow as early as 2 weeks of age but were usually not seen until the third or fourth week of age. The earliest emergence date was 23 May; however, the young were about 3 weeks of age and may have first emerged during the middle of May.

At about 7 to 8 weeks of age the young became more independent of the adults and began utilizing nearby accessory burrows if available. In areas where accessory burrows were few or absent, whole family groups left the study area as early as the first week of July. Where accessory burrows were more abundant, young were found within 100 m of the nest burrow as late as the end of September.

Pairs at the Hat Rock study site were consistently earlier nesters than the pairs at other sites. There was as much as 5 weeks difference between the earliest and the latest nesting pairs and as much as 4 weeks difference in nesting chronology between neighboring pairs.

Nest Success- In 1980, 57% of 63 nests successfully fledged young, and 50% of 76 nests were successful in 1981 (Table 2). Desertion was the major cause of nest failures in both years of the study causing failure in 35 and 30% of the nesting attempts in 1980 and 1981, respectively. Predation occurred at 8% of the 1980 nests and 20% of the 1981 nests. Nest success of owls in the Columbia Basin was much lower than the 79% found for 54 nesting attempts in Oklahoma (Butts 1971). However, Thomsen (1971) reported a nest success of 54% for 24 pairs, which was similar to the present study.

There was a highly significant ($X^2 = 12.7$, $P < 0.0001$) difference in distances between nearest-neighbors for fledged and deserted nests. For every (100%) inter-nest distance under 109 m (11) at least 1 of the 2 associated nests was deserted whereas only 3 of 21 (14%) cases with inter-nest distances greater than 109 m had a desertion of an associated nest (Fig. 3). Many of the desertions occurred at nests known to have young dependent upon adults. No evidence of moving of pre-fledged young from natural, soil-walled burrows by the adults was found; therefore, young were presumed to have perished. In 3 cases extremely lethargic young (thought to be starving) were found at burrows in which adults were not seen on that date or any time after.

Table 2. Success of burrowing owl nest sites in the Columbia Basin, Oregon, during 1980 and 1981.

	1980	1981	Total
Number of nests	63	76	139
Percent fledged	57	50	53
Percent deserted	35	30	32
Percent lost to predation	8	20	15

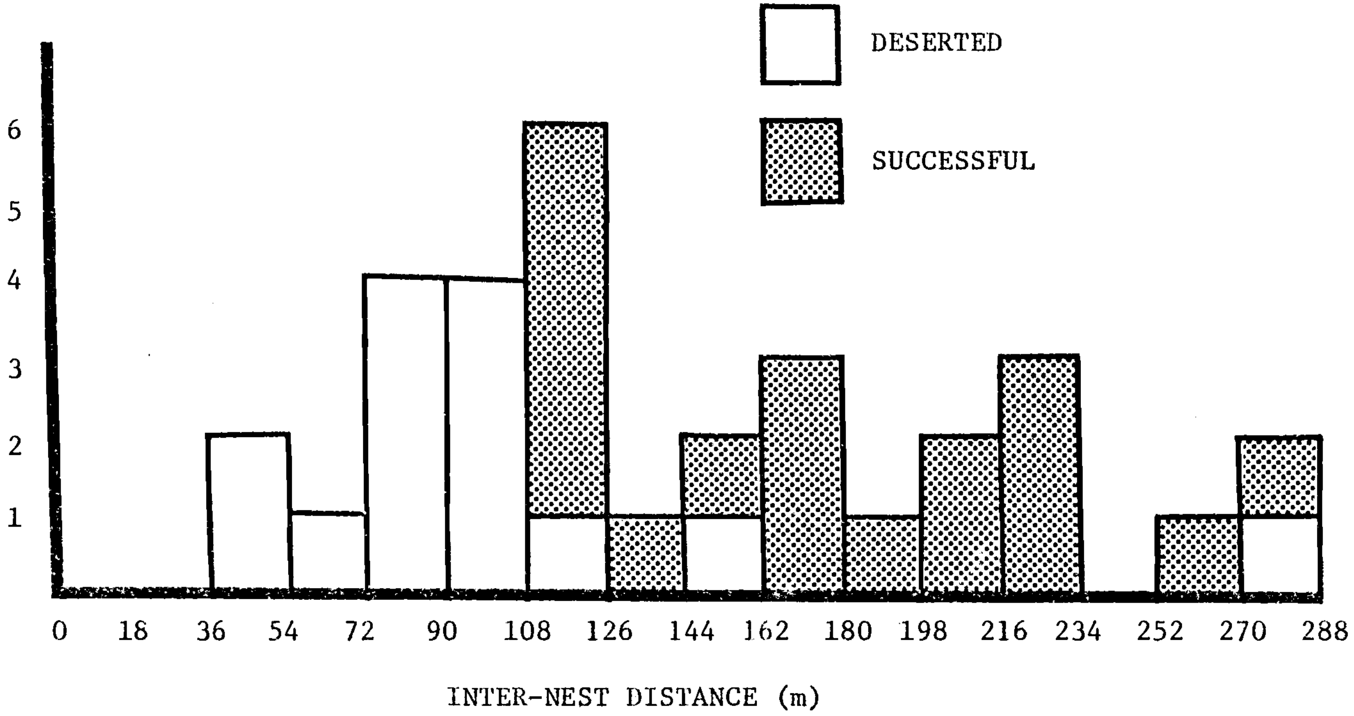

Figure 3. Histogram showing nesting success in relation to distance to nearest-neighbor. "Deserted" values are inter-nest distances where at least 1 of the associated nests was deserted. If both nests fledged young the inter-nest distance was called "successful".

Badgers accounted for 18 of the 20 (90%) nests lost to predation; a coyote (Canis latrans) and a domestic dog (Canis familiaris) took the other 2. As many as 4 nests may have been destroyed by a single badger on the Umatilla Activity. A possible case of a renesting attempt was observed once. The nest site was deserted early in the season and then was re-occupied approximately 2 weeks later. The second nesting attempt persisted until just after the hatching stage (indicated by owl eggshell fragments in their pellets) at which time the nest was destroyed by a badger. Renesting by burrowing owls has been reported by several authors (Bent 1938, Rhoads 1892, Butts 1971, Thomsen 1971).

Martin (1973) speculated that the lining of the nest and the tunnel entrance with cow dung was a mechanism for predator avoidance. Many nest sites in this study were situated in areas where cow and horse dung were not available, thus an opportunity to investigate this hypothesis was present. In 1981, 15 nests of this study were lost to predation. Of these, only 2 (13%) were lined with cow or horse dung, while 23 of 32 (72%) nests from which successfully fledged young were lined with dung. There was a highly significant ($X^2 = 14.1$, $P < 0.0001$) difference in nest success between nests where dung is used and where it is not used. Predator control by way of trapping was conducted at some study sites and not others, therefore, differences in predator density may have influenced the results.

Evidence of possible cannabilism was observed at least 10 times in this study, including 2 occasions where burrowing owl body parts appeared in burrowing owl pellets. Whether the cannabilized juveniles were aggressively killed by their siblings or simply consumed as carrion could not be determined. Cannabilism by burrowing owls has been reported by several authors (Bent 1938, Robinson 1954, and Coulombe 1971) and may serve to maximize reproductive output of the parents (Lack 1966). In another study involving burrowing owls from my study site, the mixing of captured juveniles from 2 separate broods resulted in the killing and cannabilism of the younger brood by the older (R. Rohweder, pers. comm.).

Nest mortality apparently is greatest for Columbia Basin burrowing owl populations when pairs nest closer than 110 m (desertion) and cow or horse dung is not available for nest lining (predation). Burrowing owl populations in Oklahoma (Butts 1971) and California (Thomsen 1971) commonly nested within 110 m, evidently without high incidences of nest desertion. Speculation for why Columbia Basin populations desert their nests so readily is that suitable nest sites are both scarce and clumped in many cases, relegating pairs to choose between nesting in close proximity or not at all. If food sources are less available in the Columbia Basin than in other areas where burrowing owls have been studied, then interspecific competition or interference might be severe enough to force some pairs to abandonment.

Diets--A total of 5559 pellets was analyzed and comprised 32,215 prey individuals representing 30,635 g of biomass. Estimated biomass of taxons ranged from 2 mg to 41.6 g (dry weight). For both years combined, arthropods made up 91.6% of the prey individuals but only 22.0% of the biomass; small vertebrates, mostly mammals, comprised the remaining 8.4% of the number and 78.0% of the biomass (Table 3).

Table 3. Diets of burrowing owls in the Columbia Basin, Oregon, for 1980 and 1981 from 5559 pellets collected around nest sites.

	1980		1981		Total	
Prey Species	% No.	% Biomass	% No.	% Biomass	% No.	% Biomass
Vertebrates						
Perognathus parvus	7.9	31.8	4.1	24.3	5.1	26.8
Peromyscus maniculatus	2.8	12.7	1.2	8.1	1.6	9.6
Thomomys talpoides	0.8	15.2	0.7	20.9	0.7	19.0
Dipodomys ordii	0.4	5.9	0.4	9.2	0.4	8.1
Microtus montanus	0.3	3.5	0.3	4.7	0.3	4.3
Lagomorph[a]	0.3	8.6	0.2	9.8	0.2	9.4
Other vertebrates[b]	0.1	0.8	0.1	0.8	0.1	0.8
subtotal	12.6	78.5	7.0	77.8	8.4	78.0
Arachnids						
Scorpionidae	0.8	0.2	0.4	0.2	0.5	0.2
Solupidae	1.0	0.2	0.3	0.1	0.5	0.1
subtotal	1.8	0.4	0.7	0.3	1.0	0.3
Insects						
Acrididae	26.4	5.3	2.8	0.8	8.7	2.3
Gryllidae	1.1	0.3	0.6	0.2	0.7	0.2
Tettigonidae	17.4	3.9	10.4	3.2	12.2	3.5
Gryllacrididae	15.5	9.3	12.3	10.8	13.1	10.3
Carabidae	3.6	0.3	12.0	1.3	9.9	0.9
Silphidae	5.8	0.7	3.8	0.7	4.3	0.7
Scarabaeidae	3.9	0.4	18.2	2.5	14.6	1.8
Tenebrionidae	10.0	0.7	28.7	2.1	24.0	1.6
Ichneumonidae	0.9	0.1	1.8	0.2	1.6	0.2
Other insects[c]	1.0	0.1	1.5	0.1	1.5	0.2
subtotal	85.6	21.1	92.1	21.9	90.6	21.7
Total numbers and estimated biomass (g dry weight)	8153	10164	24062	20471	32215	30635

[a] Mostly *Sylvilagus nuttallii* but includes a few individuals of *Lepus californicus*.

[b] Includes *Sorex vagrans*, *Onchychomys leucogaster*, *Rattus norvegicus*, *Spermophilus* sp., *Eremophila alpestris*, *Sturnella neglecta*, *Athene cunicularia*, *Scaphiopus intermontanus*, and *Sceloporus* sp.

[c] Includes Cincindelidae, Histeridae, Staphylinidae, Elateridae, Dermestidae, Coccinellidae, Cerambycidae, Chrysomelidae, Curculionidae, unidentified Coleoptera, and Calliphoridae (pupae).

There was little difference in biomass of vertebrate or arthropod prey between 1980 and 1981; however, in terms of numbers, arthropod prey were slightly lower in 1980 (87.4%) than in 1981 (92.8%) and consequently, vertebrates were preyed upon in higher frequencies in 1980. The difference in the amount of arthropod prey numbers was due primarily to a preponderance of very small (< 7 mg) coleptera such as *Diplotaxis subangulata* and *Blapstinus* spp. in the diet in 1981.

Six species of small and medium-sized mammals dominated the vertebrate prey (Table 3), and *Perognathus parvus* (Great Basin pocket mouse) was the most common vertebrate prey in terms of both numbers (5.1%) and biomass (26.8%) of the total owl diet. *Peromyscus maniculatus* (deer mouse) was the second most abundant vertebrate prey item in numbers of individuals (1.6%); however, *Thomomys talpoides* (northern pocket gopher), by virtue of its greater size, contributed twice as much biomass as *Peromyscus* (19.0% compared to 9.6%). All lagomorphs were small juveniles of predominantly *Sylvilagus nuttallii* (Nuttall's cottontail) with an occasional *Lepus californicus* (black-tailed jackrabbit).

Orthopteran species dominated the arthropod biomass. *Stenopelmatus fuscus* (Jerusalem cricket; Gryllacrididae) was the most important insect prey species with a total biomass of 10.3% which was greater than all taxa except *Perognathus* and *Thomomys*. *Stenopelmatus* constituted nearly one-half (44.2% and 49.2%) of the total insect prey by biomass for both years (Table 4).

Melanoplus spp. (Acrididae) were found in epidemic proportions (< $8/m^2$; K. Goeden pers. comm.) in 1980 and were the most common

Table 4. Insect prey of burrowing owls in the Columbia Basin, Oregon for 1980 and 1981 from 5559 pellets collected around nest sites.

1980 Insect Prey Species	% No.	% Biomass
Acrididae		
Melanoplus spp.	30.7	25.1
Tettigonidae		
Apote notabilis	2.8	7.2
Steiraxys spp.	17.5	11.5
Gryllacrididae		
Stenopelmatus fuscus	18.1	44.2
Carabidae		
Amara spp.	2.8	1.0
Other Carabidae	1.4	0.6
Silphidae		
Nicrophorus spp.	6.7	3.3
Other Silphidae	0.1	trace
Scarabaeidae		
Aphodius spp.	1.7	0.2
Onthophagus nuchicornis	1.0	0.2
Bothynus gibbosus	0.5	0.4
Polyphylla decimlineata	0.8	0.8
Other Scarabaeidae	0.5	0.4
Tenebrionidae		
Eleodes spp.	1.4	2.0
Blapstinus spp.	6.4	0.4
Melanaster spp.	1.4	0.1
Other Tenebrionidae	2.3	0.7
Ichneumonidae		
Unidentified Ichneumonidae	1.1	0.4
Other Insects[a]		
Misc. Insects	2.8	1.5
	100.0	100.0
Total numbers and estimated biomass (g dry weight)	7001	2144

1981 Insect Prey Species	% No.	% Biomass
Acrididae		
Melanoplus spp.	3.0	3.7
Tettaigonidae		
Apote notabilis	1.2	4.7
Steiraxys spp.	10.1	9.9
Gryllacrididae		
Stenopelmatus fuscus	13.3	49.2
Carabidae		
Amara spp.	6.3	1.5
Calosoma luxatum	0.7	1.3
Harpalus spp.	3.3	1.8
Dicheirus piceus	2.3	0.8
Other Carabidae	0.4	0.2
Silphidae		
Nicrophorus spp.	4.0	3.0
Silpha spp.	0.2	0.1
Scarabaeidae		
Aphodius spp.	1.3	0.3
Onthophagus nuchicornis	1.3	0.4
Phobetus comatus	0.9	1.5
Bothynus gibbosus	1.0	1.3
Diplotaxis subangulata	13.4	5.2
Cyclocephala longula	1.2	1.2
Polyphylla decimlineata	0.3	0.5
Other Scarabaeidae	0.4	1.4
Tenebrionidae		
Eleodes spp.	2.8	5.9
Eusattus muricatus	1.5	1.0
Blapstinus spp.	26.3	2.6
Oxygonodera hispidula	0.4	trace
Other Tenebrionidae	0.1	0.1
Ichneumonidae		
Unidentified Ichneumonidae	2.0	1.0
Other Insects[b]		
Misc. Insects	2.3	1.4
	100.0	100.0
Total numbers and estimated biomass (g dry weight)	22173	4502

[a] Includes Gryllidae, Histeridae, Elateridae, Meloidae, Chrysomelidae, Curculionidae, and unidentified Coleoptera.

[b] Includes Gryllidae, Cincindelidae, Histeridae, Staphylinidae, Elateridae, Dermestidae, Coccinellidae, Cerambycidae, Chrysomelidae, Curculionidae, unidentified Coleoptera, and Calliphoridae (pupae).

(26.4%) prey item in the owls total diet for that year (Table 3). Melanoplus spp. was second only to Stenopelmatus in biomass importance in 1980 comprising 25.1% of the insect biomass (Table 4). In the summer of 1981 populations of Melanoplus were much lower, and the species was less common in the owls diet. Melanoplus spp. comprised only 2.8% (0.8% biomass) of the total owl diet (Table 3) and constituted only 3.7% of the insect biomass (Table 4) in 1981.

The Tettigonids Steiraxys spp. and Apote notabilis were considerably lower in the owls' diet in 1981. Steiraxys spp. was the third most common insect prey in terms of both numbers and biomass (17.5% and 11.5%, respectively) in 1980. In 1981, they were fourth in numbers (10.1%) and second in biomass (9.9%), a result of more diverse feeding upon smaller prey by the burrowing owls in 1981. The frequency of Apote notabilis in the insect diet dropped from 2.8% (7.2% biomass) to 1.2% (4.7% biomass) from 1980 to 1981.

Approximately one-half (48.5%) of the total prey captured in both years were representatives from the beetle families Carabidae, Scarabaeidae, and Tenebrionidae; however, because these groups were dominated by small beetles weighing less than 10 mg, the 3 orders combined accounted for only 4.3% of the biomass (Table 3). Blapstinus spp. (Tenebrionidae) was the most common taxon of these families for both years comprising 6.4% of the insect individuals in 1980 and 26.3% in 1981. These beetles are the burrowing owls smallest (~2 mg) prey items, and as a result, Blapstinus spp. formed only 0.4% of the insect biomass in 1980 and 2.6% in 1981.

Diplotaxis subangulata (Scarabaeidae) was not recorded in the burrowing owl diet in 1980 but was the most important beetle species in 1981 comprising 5.2% of the insect biomass. Of all other insect taxons, only *Blapstinus* spp. made up a greater frequency of insect numbers than *Diplotaxis subangulata*.

Amara spp. (Carabidae), like *Diplotaxis*, was found in the diet only in 1981. This small beetle constituted 6.3% of the insect numbers and 1.5% of the biomass for that year. The most common beetle prey for 1980 was a Silphid, *Nicrophorus* spp. (sexton beetle). *Nicrophorus* spp. accounted for 6.7% of the insect number that year and 3.3% of the biomass. They comprised 3.0% of the insect biomass in 1981.

Diets of burrowing owls have been studied elsewhere (see Gleason and Craig [1979] for good review) and have shown, as in this study, that these raptors feed extensively on both arthropod and small vertebrate prey, mostly mammals. In fact, the vertebrate/arthropod ratio, for the 2 years of this study (8.4% vertebrate/91.6% arthropod) was identical to Marti's (1974) figures from a 3 year study in Colorado; however composition of prey species were quite different. A much higher percentage of vertebrates was found in the diets of several burrowing owl populations in California (29.3%) and Chile (20.0%) (Jaksic and Marti 1981). Jacksic and Marti (1981) surmised that the greater proportion of vertebrate prey in the California and Chile populations was due to food partitioning as a result of the present of pigmy owls (*Glaucidium* spp.) in the owl assemblage in those areas as compared to the Colorado site. Greater use of vertebrate prey by California and Chile owls might also be due to differences in prey availability and/or small mammal activity periods.

The shift from a more Orthopteran insect diet in 1980 to more emphasis on coleopteran prey in 1981 indicates an opportunistic feeding pattern. The presence of such a wide variety of insect prey in the diet including the occurrence of such ecologically and morphologically diverse prey as Ichneumonids (wasps) and Calliphorid (blow fly) pupae further exemplifies an opportunistic behavior. Opportunistic feeding upon arthropods by burrowing owls has been suggested from Chile (Schlatter et al. 1980) and New Mexico (Best 1969) and by the genus _Athene_ in general (Jaksic and Marti 1981).

A heavy occurrence of _Stenopelmatus_ spp. has been reported from diets of other burrowing owl populations (Maser et al. 1971, Thomsen 1971, Gleason and Craig 1979). Screech owls (_Otus asio_), a similar sized strigiform, feed extensively upon _Stenopelmatus_ as well (Ross 1969). Because _Stenopelmatus_ are nocturnal in behavior, their presence in the diet of burrowing owls would indicate a nocturnal feeding pattern.

Seasonal Variation in Diets--Although the average proportion of arthropod and vertebrate biomass in owl diets was similar for both 1980 and 1981, their seasonal change was greatly different from the 2 years. Vertebrate biomass made up 95% of the owls' diet in the early part of the 1980 breeding season, then steadily dropped to 15% by the end of August (Fig. 4). In 1981 the change from vertebrate to insect prey was more gradual from approximately 90% in the early part of the

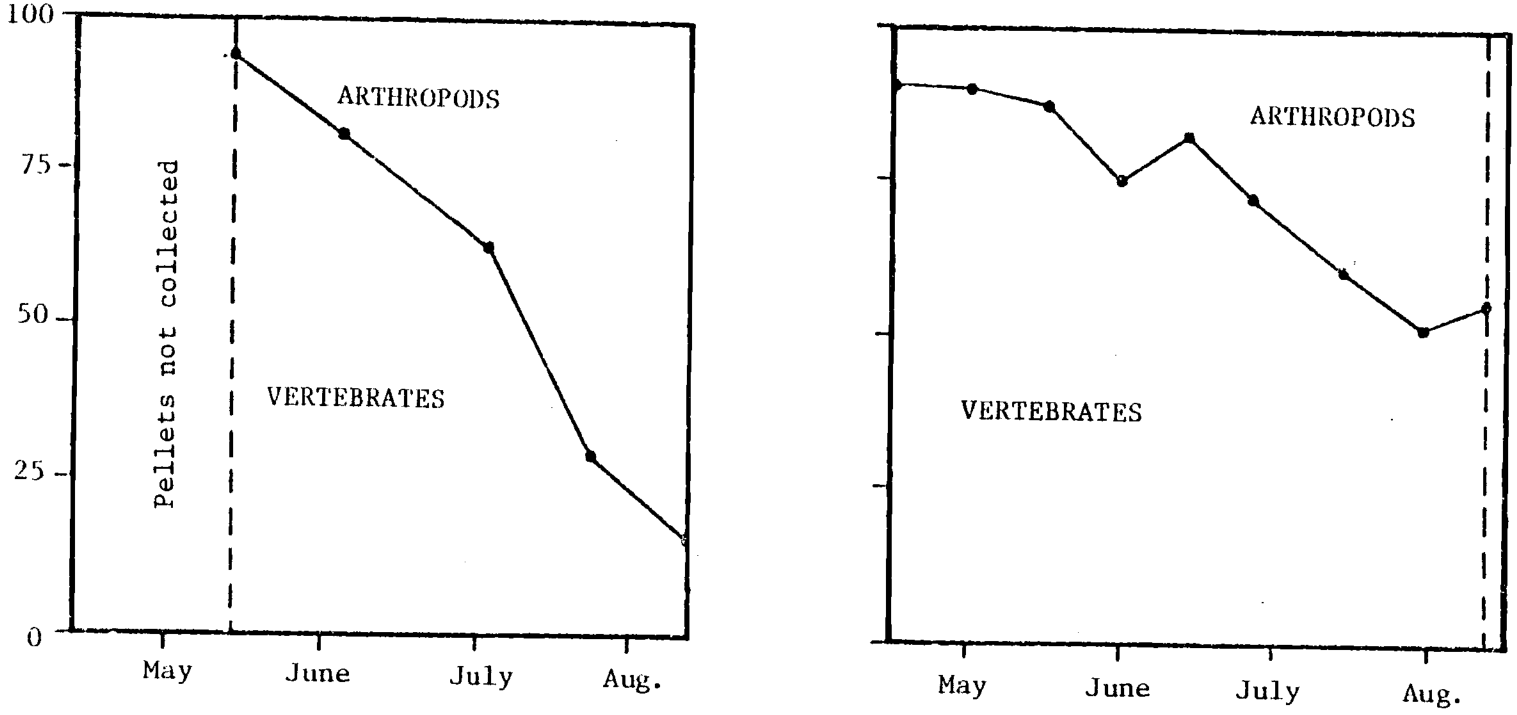

Figure 4. Seasonal variation in the ratio of arthropod and vertebrate biomass in the diet of Columbia Basin burrowing owls for 1980 and 1981.

nesting season to nearly 55% at the end of the nesting period. The greater decline in use of vertebrate prey in the latter part of the 1980 season concides with the appearance of an epidemic population of Orthopteran species. *Melanoplus* spp. numbers were recorded as high as 40 per m^2 on some study sites.

The shift from vertebrate to arthropod prey as the season progresses has been noted elsewhere for burrowing owls (Best 1969, Marti 1974, Gleason 1978) and tawny owls (*Strix aluco*) (Southern 1969). Explanations for this diet shift are an increase in protective vegetation for rodents (Southern 1969), a general decrease in rodent population size (Gleason 1978), or general increase in arthropod numbers (Best 1969) as the season progresses. In the Columbia Basin, peak *Perognathus* populations occur when there is an overlap in the emergence of the years' young and the annual above ground activity of the adults (O'Farrell et al. 1975). This usually occurs during the latter part of the summer (O'Farrell et al. 1975) when rodents are used much less by burrowing owls, thus, the explanation of a general decrease in rodents may not suffice for the Columbia Basin. Also, vertebrate proportions in the diet continue to steadily decline long after the major protective vegetation (cheatgrass) has stabilized suggesting that something other than increased concealment for rodents is dictating the owls feeding behavior. A general increase in arthropod prey during late summer plus a decrease of rodents within feeding territories (due to owl predation) might be a better explanation.

Influence of Soil Type on Use of Mammalian Prey--All of the burrowing owls major vertebrate prey taxa formed a part of the owls diet for both soil types. Perognathus parvus was a much more common component of the diet on the loamy sand soils (66.4%) than on the silty loam soils (26.4%) (Table 5). The lagomorphs also appeared more often in the diets of burrowing owls nesting in the loamy sand soil (2.8% vs 1.3%). The opposite was true for the other 4 major vertebrates. Most notable were Peromyscus maniculatus which were almost twice as great a dietary component from the silty loam site as the loamy sand (31.1% vs 16.6%) and Thomomys talpoides which were captured by the owls at over 5 times greater proportion at the silty loam site (28.8% vs 5.0%). "Other" species were also more commonly taken on the silty loam (0.6% vs 2.3%). Microtus montanus (montane vole) were captured at only a slightly greater proportion on the silty loam soiled area (3.9% vs 4.0%).

In terms of energy consumed, Perognathus constituted the majority (41.1%) of the biomass on the loamy sand. Four other species were fairly equal in biomass representation from the loamy sand soil sites, ranging from 10.7 to 15.5%. At the silty loam soil study site, Thomomys dominated the biomass by comprising 57.1%. Peromyscus followed at 14.0% and Perognathus was 10.5% of the estimated consumed biomass.

Edaphic factors such as soil depth, texture, and strength have been found to affect populations of small mammals (Miller 1964, Best 1973, Kritzman 1974, Feldhammer 1979, Anthony and Fisher 1980). Feldhammer (1979) determined that there was a positive correlation

Table 5. Composition of mammalian prey of burrowing owls nesting in loamy sand and silty loam soils in the Columbia Basin.

	Loamy Sand Soil		Silty Loam Soil	
Prey Species	% No.	% Biomass	% No.	% Biomass
<u>Perognathus parvus</u>	66.4	41.1	26.4	10.5
<u>Peromyscus maniculatus</u>	16.6	11.7	31.1	14.0
<u>Thomomys talpoides</u>	5.0	15.5	28.8	57.1
<u>Dipodomys ordii</u>	4.7	10.7	6.1	8.9
<u>Microtus montanus</u>	3.9	6.2	4.0	4.0
Lagomorphs	2.8	14.5	1.3	4.0
Other	0.6	0.4	2.3	1.5

between population densities of Perognathus parvus and the percentage of sand in the soil. Feldhammer and Kritzman (1974) suggested that sandier soil may aid small heteromyids' digging ability. Feldhammer also discovered a negative correlation between percentage of sand in the soil and Peromyscus maniculatus densities on the more arid sites. He speculated that Peromyscus may have been avoiding the driest areas. Thomomys were captured by owls in the present study at greater proportions on the silty loam soils and were more abundant in these areas. They probably prefer the silty loam soils because they are less friable and therefore easier for burrow maintenance.

Mammalian Prey Preference--Perognathus accounted for 97.2% of the small mammal trap captures (Table 6). Owl pellets collected from the same area during the same time period show that Perognathus comprised 97.4% of the mammalian prey. Tested by the odds ratio ($Z = 3.15$, $P < 0.001$), burrowing owls selected Perognathus in proportion to their occurrence in the environment. Because other small mammal species collectively comprised a small proportion of the diets (2.6%) and in the field (2.8%), as a group they were obviously fed upon in a manner similar to their availability.

Nesting Habitat- Of the habitats searched for burrowing owls, 3 (snakeweed, cheatgrass, and bitterbrush) were used by nesting pairs. Burrowing owls were not found in the bunchgrass and rabbitbrush habitats during the nesting season. Dispersing juveniles occasionally were observed in these habitats after fledging.

Densities of badger holes in habitats used and not used for nesting were surveyed to determine if burrow density influenced

Table 6. Composition of small mammal populations on 5 trapping grids in the Columbia Basin of northcentral Oregon during 1980.

	Grid					
Species	A (n=248)	B (n=22)	C (n=46)	D (n=33)	E (n=80)	Total
Perognathus parvus	92.2%	100.0%	93.5%	94.0%	100.0%	97.2%
Dipodomys ordii	1.2%	---	6.5%	3.0%	---	1.6%
Onychomys leucogaster	1.2%	---	---	3.0%	---	0.9%
Peromyscus maniculatus	0.4%	---	---	---	---	0.3%

habitat use. There were an average of 1.8 (SE = 0.42) potential burrows per ha in the 3 communities used by the owls and 3.1 (SE = 1.26) potential burrows per ha in the 2 communities not used by the owls for nesting. Obviously, burrow availability was not the reason that burrowing owls did not nest in the bunchgrass and rabbitbrush habitats.

Discriminant function analysis of the habitat variables indicated a significant ($P < 0.05$) difference between "potential" and actual nest sites in both the cheatgrass and bitterbrush habitats (Table 7). For the cheatgrass habitat, mean perch height and percent grass discriminated between the 2 groups. Burrowing owls selected nest sites with higher perches (85.9 cm vs 31.6 cm) (or essentially nests sites with perches) and less grass coverage (28% vs 50%) than the "potential" nest sites. The discriminant function correctly reclassified 82% of the sites. Shrub volume was the only variable important in discriminating the 2 groups in the bitterbrush habitat, with the burrowing owls selecting for less shrub volume (9.3 vs 13.5). In the bitterbrush community, 73% of the nest samples were correctly reclassified.

Percent grass cover was negatively correlated with percent bare ground (-0.897) and positively correlated with vertical density at the 0-10 cm (0.700), 10-20 cm (0.708), and total (0.800) height classes (Table 8) for the cheatgrass habitats. No variables were highly correlated with mean perch height for the cheatgrass habitats. Shrub volume was positively correlated with shrub cover (0.881) and effective height (0.827) for bitterbrush habitats. Of these

Table 7. Discriminant function analysis on vegetative characteristics of actual and potential nest sites in cheatgrass and bitterbrush habitats in northcentral Oregon.

Habitat	Percent Correctly Classified	Variables Entered	Actual Nest (n = 18)		Potential Nest (n = 15)	
			x	(SD)	x	(SD)
Cheatgrass	82	Mean perch height	85.9	(43.0)	31.6	(37.8)
		Percent grass	28.3	(13.1)	49.6	(19.4)
Bitterbrush	73	Shrub volume	9.3	(4.7)	13.5	(3.7)

Table 8. Variables that are highly correlated ($r > 0.700$) with variables that significantly separated actual and potential nest sites using discriminant function analysis.

			Actual Nest (n = 18)		Potential Nest (n = 15)		
Discriminant Function Variables	Correlated Variables	Correlation Coefficients	$\bar{x}$	(SD)	$\bar{x}$	(SD)	*P*
Mean perch height	none	---	---	---	---	---	
Percent grass	Percent bare ground	-0.897	54.8	(15.2)	41.3	(15.5)	*
	Vertical density 0-10 cm	0.700	1.50	(0.66)	1.64	(0.57)	*
	Vertical density 10-20 cm	0.708	0.35	(0.28)	0.61	(0.34)	ns
	Vertical density total	0.800	1.95	(0.91)	2.49	(1.07)	ns
Shrub volume	Shrub intercept (cover)	0.881	11.4	(5.30)	19.6	(7.60)	*
	Effective height	0.827	31.1	(8.80)	38.3	(11.9)	ns

* $P < 0.05$, ns = nonsignificant; univariate F-ratio

correlated variables, only percent bare ground, vertical density 0-10 cm, and shrub intercept were significantly different ($P< 0.05$) univariately. Burrowing owls selected nest sites with greater bare ground (54.8% vs 41.3%) and less vertical density 0-10 cm (1.50 vs 1.64) than what was available in the cheatgrass habitat, and less shrub cover (11.4 vs 19.6) in the bitterbrush habitat.

Soil type (or texture) had a significant effect on the longevity of a burrow and hence its availability for re-nesting in the subsequent seasons. Of 85 nests in loamy sand soils, 46% of the burrows were silted in by the next nesting season (Table 9). Of 13 nests in silty loam soils (Arlington Airport), none silted in; however, 15% (2) were caved in by cattle and were unusable. None of the burrows in loamy sand soils was destroyed by cattle to the point of being unusable, probably because the sandier soils were easily dug out. One burrow at the Arlington Airport study site has been consistently re-used by burrowing owls for at least 15 yrs. (J. Green pers. comm.)

Re-use of available burrows for nesting was also different for the 2 soil types. Of burrows used in the previous year, only an average of 52% were actually re-occupied in the loamy sand soils (Table 9). In many cases a nest in a newer burrow could be found within 5 to 50 m from a previously used burrow. All (100%) nest burrows were re-used in the silty loam soils (Arlington Airport). An extensive search in 1981 also disclosed that all available burrows at Arlington Airport were occupied indicating little potential for population expansion. The dependency of burrowing owls on badgers for nest burrows is evident.

Table 9. Percent re-use of nest burrows active in 1980 and 1981 by soil type.

	Soil Type	
	Loamy Sand	Silty Loam
Number of nests	85	13
Percent re-occupied	28	85
Percent inactive	26	0
Percent silted in	46	0
Percent livestock destruction	0	15
Percent available nests re-occupied	52	100

Hole availability has been well documented as a major factor in nest site selection in secondary hole nesters (see Von Haartman 1957, Bruns 1960, Gysel 1961, Beebe 1974). Hole availability was the chief factor limiting population densities of American kestrels (*Falco sparvarius*) (Hammerstrom et al. 1973), and elf owls (*Micrathene whitneyi*) were totally dependent upon woodpeckers for nest sites (Ligon 1968). Nest site selection by wheatears (*Oenanthe oenanthe*) and stock doves (*Columba oenas*) was wholly dependent upon availability of abandoned European rabbit (*Oryctolagus cuniculus*) burrows and not vegetation structure (Lack 1933). Hole availability was not the only factor in nest site selection by burrowing owls in the Columbia Basin. Numerous potential nest burrows existed in the rabbitbrush and bunchgrass habitats, but burrowing owls did not use these habitats for nesting, and owls selected sites that had certain vegetative characteristics in habitats that were used. There was no evidence to support owls excavating their own burrow in this study.

Burrowing owls were selecting nest sites in response to differences in horizontal visibility. The fact that Columbia Basin burrowing owls commonly used some habitats for nesting (snakeweed, cheatgrass, and bitterbrush) and avoided others (rabbitbrush and bunchgrass) may be a result of horizontal visibility of differences. For instance, the snakeweed habitat, with its low vegetation (3-4 cm effective height) and constant grazing pressure, would display characteristics very similar to sciurid colonies in which burrowing owls are commonly known to nest elsewhere. The snakeweed habitat displays the components "openness and short vegetation" deemed essential to good burrowing owl habitat (Best 1969, Coulombe 1971, Zarn 1974) and therefore provide horizontal visibility.

A factor common to all nest sites in both the bitterbrush and cheatgrass habitats was the use of an elevated perch by nesting pairs. The role and use of elevated perches has been studied for other birds (Harrison and Brewer 1979, Collins 1981, Knodel-Montz 1981). Perches can be used for predator and prey detection as well as aid in thermoregulation (Coulombe 1971). If the long, lightly feathered legs of the burrowing owl are used as heat conduits, a function described in other bird species (Kahl 1963, Steen and Steen 1964, Butler 1982), then passive heat loss during mid-day could be achieved only if the owls were not near the high temperatures at the soil surface, i.e., perched up. However, owls in the snakeweed community did not utilize perches. During warm periods, males were found peering from the burrow entrance with their legs in the shaded burrow mouth. Thermoregulation could therefore be achieved because the burrow tunnel would act as a heatsink, and surveillance of their surroundings could be maintained by virtue of the very short vegetation in this habitat. Butts (1971) noted that all (6) of his burrowing owl nests located outside of prairie dog towns were situated in abandoned badger burrows less than 90 m from a potential perch (a fence).

The bitterbrush habitat provided a large number of suitable perches; however, high shrub coverage obstructed vision. The discriminant analysis results showed that burrowing owls selected for less than average shrub volumes which may indicate a trade-off between a maximum number of perches and a minimum number of view obstructing shrubs.

The dominant plants of the bunchgrass and rabbitbrush habitats appeared to be structually unsuitable for owl perches. Burrowing owls that were perched on rabbitbrush (usually because of my presence near its normal perch) were quite unstable. Because the average height of these habitats are great enough to restrict horizontal visibility from ground level, lack of suitable perches probably precludes the owls' use of these habitats.

Nesting pairs selected nest sites with lower than average grass coverage in cheatgrass habitats, probably because prey availability may be greater in these areas. Dense grass or litter may impede movements of Perognathus parvus (Gano and Rickard 1982), Peromyscus maniculatus (Tester and Marshall 1961) and ground-dwelling arthropods (Tester and Marshall 1961, Rickard and Haverfield 1965) and may influence density and/or availability of prey. The grasses may also provide protective cover for the prey making predation difficult for raptors (Southern and Lowe 1968, Wakeley 1978, Bechard 1982). Therefore, burrowing owls may select for low grass cover as it may provide greater prey availability and/or efficiency. Nest sites in other habitats used by burrowing owls also displayed low grass coverage. The soil surface in the snakeweed community was covered with cryptograms and repressed forbs. Grass coverage averaged only 36% and the grass that was present was so low and sparse, that rodents and large beetles could easily traverse over them.

The bitterbrush habitat also had low grass cover for both the actual (31%) and potential (28%) nests. Shrub communities usually have greater amounts of bare ground and sparser grasses than grassland communities. Irregular rain throughfall patterns, allelopathic effects, and associated high small mammal densities in the shrub communities are thought to contribute to the elimination of grassland vegetation within and near the shrubs (Bartholomew 1970, Halligan 1973). Higher populations of small mammals (Rogers and Hedlund 1980, Gano and Rickard 1982) and beetles (Rogers and Fitzner 1980) exist in shrub communities as compared to the grassland communities in the Columbia Basin; therefore, prey abundance probably plays an important role in nest habitat selection for this habitat as well.

MANAGEMENT IMPLICATIONS

Management of burrowing owls may be accomplished by simply maintaining ecological characteristics in areas where populations currently exist. This would be especially important for bitterbrush habitats in parts of the Columbia Basin where this habitat is threatened by agricultural expansion. Bitterbrush habitats conducive to burrowing owls are generally composed of older plants that could not be quickly re-established.

Creation or enhancement of nesting habitat includes several management options. Protection of existing badger populations would ensure future burrow availability, a consideration which would be especially important in areas where burrow longevity is short (sandy soils). Artificial nest boxes have been proven effective as burrowing owl nest burrows (Collins 1980). Boxes should be placed in habitats exhibiting other requisite characteristics (good horizontal visibility and low grass coverage) and should be spaced at least 110 m apart to prevent intra-pair interference. In areas where livestock do not exist, a supply of cow dung may aid the owls in reducing nest predation. Results from this study indicate that nest burrows which owls have lined with cow dung were much less susceptible to predation that those not lined. Cow dung may mask the odors of nest occupants.

Horizontal visibility could be improved by using fire or grazing to reduce vegetation height. Both agents would also be effective in reducing grass coverage, therefore, making prey more available (Southern and Lowe 1968, Wakeley 1978, Bechard 1982). Fire in shrub habitats would provide for good perches by removing foliage. During the course of this study, burrowing owls were observed pioneering into recently burned areas.

Burrowing owls readily use artificial structures for perching (fenceposts, stakes, etc.) making the creation of artificial perches a viable management option, especially in cheatgrass habitats where the average height of the surrounding vegetation is greater than 5 cm. Several perches interspersed throughout the nesting area may be required.

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