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Author(s): Shaneen R. H. Beebe, Aaron B. Switalski, Heather L. Bateman and Kiril D. Hristovski

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Burrowing Owl (*Athene cunicularia*) Habitat Associations in Agriculture Fields and along Canal Trails in Phoenix, Arizona

Shaneen R. H. Beebe, Aaron B. Switalski, Heather L. Bateman, Department of Human and Environmental Systems, Arizona State University-Polytechnic, 7231 E Sonoran Arroyo Mall, MC 1780, Mesa, Arizona 85212; and
Kiril D. Hristovski, Department of Engineering and Computing Systems, Arizona State University-Polytechnic, 7231 E Sonoran Arroya Mall, MC 2180, Mesa, Arizona 85212

Abstract

Burrowing Owls (*Athene cunicularia*) have experienced significant population declines over the last 100 years in parts of the United States and Canada. This decline may be associated with increasing urbanization and land-cover change; however, owls can occupy urbanized environments. To determine habitat selection in the southeast valley of Phoenix, Arizona, we conducted visual surveys for owls during summer 2011 and measured microhabitat and landscape characteristics in 23 agricultural fields (fields) and along 15 canal right-of-ways (trails). We estimated occupancy rate and detectability using Program MARK. We identified microhabitat selection to relate owl occurrence to landscape variables. Occupancy rate was 32% in both fields and trails and owls had greater detectability along trails. Burrowing Owl occurrence was similar in fields with varying agricultural stages (from undisturbed to harvested) and moisture conditions. Owl occupancy was positively associated with soil type and canal water presence, and occupancy decreased when developed landscape cover (e.g., roads and buildings) increased. These findings suggest that Burrowing Owls are able to live in urbanized environments below 40% developed land cover provided that water and suitable soils are available.

Introduction

Burrowing Owl (*Athene cunicularia*) populations have declined throughout the United States and parts of Canada. Numerous studies have indicated that human urbanization has led to owl decline through habitat degradation and the destruction of prey animals' habitats (Millsap and Bear 2000, Jones and Bock 2002, Chipman et al. 2008). However, Burrowing Owls are able to live near humans and subsist in some urban environments (Holmes 1998, Chipman et al. 2008, Berardelli et al. 2010). For example, owls have been known to use streetlights for foraging in urban areas (Chipman et al. 2008). Owls have also capitalized on human-made irrigation systems (canals) found along agricultural fields (Catlin et al. 2005).

Owl behaviors, survival, reproduction, diet, and occurrence have all been studied in the western portion of the United States. Despite being considered a short-grass prairie species (Jones and Bock 2002), they commonly show affinity for agricultural areas (Moulton et al. 2005, Conway et al. 2006, Catlin et al. 2006). When owls in urban and agricultural environments in Washington were compared, Conway et al. (2006) concluded that nest density was greater and nest success was highest in agricultural regions. In southern Idaho, Burrowing Owls had higher nest density in irrigated agricultural fields even though they resided in both agricultural and non-agricultural locations (Moulton et al. 2006). In Idaho, Larson (2009) related owl occurrence in agricultural fields to characteristics of soil type. Because owls will use and modify animal burrows (Coulombe 1971), substrate is important in owl habitat selection.

Identifying important habitat characteristics of Burrowing Owls living in agricultural areas surrounded by urbanization has not been widely studied. As open lands occupied by Burrowing Owls become developed, understanding characteristics that support owl populations can better guide conservation efforts to support this species. The southeast valley of Phoenix represents a system to address questions on urban Burrowing Owls (Fig. 1) because the area features numerous agricultural islands surrounded by urban developments. In addition, Arizona was the second fastest growing state between 2000 and 2010 (U.S. Census Bureau 2011) with rapid urban development and land conversion.

Our goals were to determine (1) Burrowing Owl detectability and occupancy rate, (2) landscape and microhabitat characteristics of locations occupied by owls, and (3) types of features (e.g., perch types) used by owls in agricultural fields and along canal trail right-of-ways in the southeast valley of Phoenix, Arizona. By identifying key landscape and microhabitat features, natural resource managers can make informed conservation decisions if development occurs in known urban owl locations. Our study may also help understand the scale and magnitude of landscape-level effects of Burrowing Owls in urban areas across the southwest United States.

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***Figure 1.** Burrowing Owl (*Athene cunicularia*) in the southeast valley of Phoenix, Arizona, 6 November 2012. Photo by Andy E. Bridges.*

METHODS

Study Area and Measurements

Field Sites

We conducted our study in the cities of Chandler, Gilbert, Mesa, and Queen Creek, Arizona. These cities are located within the boundaries of the Sonoran Desert and feature hot summers with temperatures often surpassing 43 °C and mild winters with temperatures generally not falling below -1 °C. Phoenix is classified as a semi-arid or arid region because it receives very little precipitation and humidity levels remain low throughout the year. Phoenix is composed of residential, commercial, and agricultural land.

Our study focused on comparing owl observations in agricultural fields (fields) and along canal and wash trails (trails). Many of the canals owned by the Salt River Project (SRP) and other washes feature pedestrian right-of-way trails bordered by residential or industrial land use. Canals present at both trails and field perimeters are concrete-lined, with soil along the upper margin and rim, where pockets of erosion and other holes were observed. No canals from surveyed trails or fields intersected.

Data Collection

Owl Surveys

We identified 175 fields within our focal cities that were >1 ha in size and identified 26 trails >500 m in length (and without being bisected by a road). Due to logistical constraints, we randomly selected a subset of fields and trails for inclusion in the study for a total of 23 fields and 15 trails (n=38). A single observer conducted visual surveys for owls from 1 June 2011 to 17 July 2011 between 0500 and 1000. We visited each site from one to three times throughout the survey period. We surveyed fields by walking along the perimeter (four sides of each field) and used binoculars to view field interiors. The interior of a field was surveyed at each crop row, or when crops were absent, approximately every 6 to 12 m. We surveyed trails by walking the length of the trail from a starting point (i.e., major road) to an ending point (i.e., subsequent major road) and back to the starting point. We used binoculars to observe the trail length and paused approximately every 6 to 12 m to view the trail in all directions. We recorded owl detections and counts at each site. We calculated site area by multiplying the length of the field or trail by its width. Since most trails were surrounded by residential or industrial land uses, trail width included the trail and surrounding undeveloped land on either side of the trail.

Microhabitat Characteristics

Because soil type affects burrow construction, we characterized soil type in fields and trails by using the U.S. Department of Agriculture, Natural Resources Conservation Service Web Soil Survey (NRCS 2011) software. We selected the area of each field and trail to identify soils present. Where more than one soil type was present, we used the soil present in the highest percentage within the selected area for analyses.

During each survey visit to fields, we recorded field stage, such as undisturbed (not visibly used for agriculture), cultivated (newly tilled soil prepared for crops), vegetated (crops growing), or harvested (crops removed and dry vegetation remained); and moisture conditions (i.e., dry or moist/flooded). Field ground cover was categorized as soil only, soil with sparse trees, crop (i.e., corn and hay), and weeds (i.e., annual or perennial non-woody vegetation). We recorded canal presence along one or more edges of a field's perimeter and presence of water. During the first visit (and double-checked on the second visit) to each site, we tallied the number of holes or animal burrows. Holes were defined as owl burrows, potential or suspected burrows, and small mammal burrows. We also recorded presence of water in canals along the width of trails.

We recorded natural history and human-made characteristics of areas occupied by owls. When an owl was detected, we recorded perch type categorized as ground, in vegetation, or on a human-made structure. So as not to flush owls, we determined heights using ocular estimation in categories and we used a range finder to measure distances. We estimated perch height (i.e., <0.1 m, 0.1-1.0 m, and

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>1.0 m), distance to canal water (i.e., <3 m, 3-100 m, and >100 m), distance to nearest hole (within a 50-m radius around owl), distance to perimeter (fields only), and distance to center of right-of-way (trails only).

Landscape Characteristics

To determine how Burrowing Owl occurrence was related to landscape characteristics surrounding fields and trails within an urban setting, we acquired NAIP imagery (i.e., USDA National Agriculture Imagery Program, from 2011, 3-band, 1-m) from the Central Arizona–Phoenix Long-Term Ecological Research program (CAP LTER). The CAP LTER imagery included seven classes of land-cover layers (i.e., road, soil, tree, grass, building, water, and swimming pool) with a 30-m cell size. In a Geographical Information System (GIS; ARC Map 10.0, ESRI), we buffered trail lengths and field perimeters by 300 m to delineate the area of interest around each study site. We overlaid the buffered extents over the CAP LTER data to determine the percent of developed and open land. We combined road, building, and swimming pool cover types to define developed land. We combined grass, tree, water, and soil cover types to define open land.

Statistical Analysis

Because owls can be found singly or in family groups (and thus not independent) we focused only on owl sightings (presence, absence) per survey for analyses. We estimated detectability (e.g., probability that an owl was present and seen by observer) and occupancy rate (e.g., probability that an owl occupied a survey site) using Program MARK (White and Burnham 1999). We derived estimates from surveys from three occasions and two groups (e.g., fields and trails). Since Program MARK can handle missing values, we included blanks for the few sites which had fewer than three surveys (i.e., 3 fields were surveyed once, 2 fields were surveyed twice, and 18 fields and all 15 trails were surveyed three times).

To determine if owls were selecting specific soil types, field stages, and field conditions, we compared the proportion of sites with owls present or absent using a chi-square analysis. To determine if owls were selecting different types of perches in fields compared to trails, we used a chi-square analysis to compare proportions of perch type and perch heights. If chi-square analyses were significant at the 0.10 level (due to our small sample sizes), we performed a z-test of proportions on each increment pair to determine which pair(s) had significant differences. To determine which habitat characteristics were good predictors of owl occurrence, we used a backward elimination logistic regression (Hosmer and Lemeshow 2000) on uncorrelated habitat variables. Habitat variables in the model included: percent developed, water presence, percent soil cover, percent tree cover, percent water cover, and soil type which we derived from the GIS (i.e., cover types), NRCS results (i.e., soil type) and from field surveys (i.e., water detected in canals).

Results

Abundance and Occupancy Rate

We detected owls in 7 of 23 fields and along 4 of 15 trails. Where sighted, the number of owls observed per survey ranged from 1 to 30 owls in fields and from 1 to 7 owls along trails. Owl occurrences were similar between agricultural fields and trails (Mann-Whitney Rank Sum test, U=166.0, P=0.823). Including a detectability measure in estimation (± standard error, Program MARK), Burrowing Owls occupied 32.1% (±8.4) of both agricultural fields and trails and owls were more detectable along trails (91.6% ±8.1) compared to fields (52.2% ±15.8).

Habitat Use

We identified a relationship between owl occupancy and Gilman Loam soil type (Table 1). Gilman Loam was the most prevalent soil type in the study area and 82% of the occupied sites had this soil type. Among the agriculture fields, Burrowing Owl occurrence was similar across field stage (i.e., undisturbed, cultivated, vegetated, or harvested), field type (i.e., ground cover of soil, crops, weeds, or soil with sparse trees), and field condition (i.e., dry or moist/flooded; Table 1).

Owls differed in microhabitat selection in fields compared to trails. We observed owls using structures and vegetation as perches, but more than 50% perched on the ground in both fields and along trails (Table 2). Although soil at ground-level was the most common perch type used by owls in fields and trails, owls in fields rarely used perches above 1 m (Table 2). Owls were sighted closer to canal water along trails compared to owls sighted in fields and only owls in fields were sighted greater than 100 m from canal water (Table 2). We did not detect owls in fields with standing water.

Since owls were found at similar occupancies we combined sightings from fields and trails to evaluate landscape-level habitat selection. Occupied sites had a lower proportion of developed land area (i.e., covered by buildings and roads) compared to unoccupied sites (Table 3). Land cover surrounding developed land and sites without owl sightings ranged from 4-61% developed land. Owl occupancy sites with owl sightings ranged from 0-37% was

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Table 1. *Chi-square analysis and z-test of proportions of microhabitat variables measured in agriculture fields and canal trails surveyed for the presence of Burrowing Owls during 2011 in the southeast valley of Phoenix, Arizona. Soils were recorded from the USDA Natural Resources Conservation Service Web Soil Survey (2011) in fields and trails. Stage and condition were measured in agriculture fields only. Pairwise differences indicated by *.*

Variable	χ^2 (df)	Significant (P)	Classes	Surveys with owls present	Surveys with owls absent	z-test
Soil type	6.391 (3)	0.094		n=11	n=21	
			Contine Clay Loam	0%	19.1%	0.985
			Gilman Fine Sandy Loam	9.1%	9.5%	-0.599
			Gilman Loam	81.8%	38.1%	1.981*
			Mohall Loam	9.1%	33.3%	1.074
Field stage	1.517 (3)	0.678		n=7	n=24	NS
			Undisturbed	0%	8.3%	
			Cultivated	14.3%	12.5%	
			Vegetated	57.1%	29.2%	
			Harvested	28.6%	50.0%	
Field type	5.995 (3)	0.112		n=7	n=18	NS
			Soil	14.3%	33.3%	
			Crops (corn, hay)	42.9%	55.6%	
			Weeds	14.3%	11.1%	
			Soil, trees	28.6%	0%	
Field condition	0.094 (1)	0.759		n=9	n=20	NS
			Dry	66.7%	80.0%	
			Moist	33.3%	20.0%	

best predicted by three variables – larger areas (size of site), low percent developed land, and low percent tree cover (Logistic Regression, n=36, $P<0.001$, Nagelkerke $R^2=0.603$, and model classification accuracy=78.9% correctly predicted owls occurrence).

DISCUSSION

In our study, we found that Burrowing Owls occupied agricultural fields and trails within a metropolitan area at similar rates and owl occupancy was related to surrounding land use. Similar to Millsap and Bear (2000) we observed a negative relationship with percent developed urban cover. Some authors suggest that human activities have caused the degradation of owl habitat (Jones and Bock 2002, Chipman et al. 2008). Some studies have documented declining owl numbers, lower reproductive success (Millsap and Bear 2000), and greater nest failure in urban areas compared to grasslands (Berardelli et al. 2010). In our study, owl occupancy in the southeast area of Phoenix, Arizona was negatively associated with high levels of urbanization. For example, we did not detect owls where developed land cover exceeded 40%.

Moulton et al. (2006) found that owl nesting density in Idaho was greater in irrigated agricultural fields than in non-irrigated non-agricultural locations

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Table 2. *Chi-square analysis and z-test of proportions of microhabitat variables measured in agriculture fields and canal trails surveyed for the presence of Burrowing Owls during 2011 in the southeast valley of Phoenix, Arizona. Number represents owl sightings during the survey. Pairwise differences indicated by *.*

Variable	χ^2 (df)	Significant (P)	Classes	Owls in fields (n=33)	Owls along trails (n=35)	z-test
Perch type	7.271 (2)	0.026	Ground	81.8%	51.4%	2.391*
			Structure	12.1%	25.7%	1.117
			Vegetation	6.1%	22.9%	1.611
Perch height	14.425 (2)	<0.001	<0.1 m	60.6%	48.6%	0.749
			0.1-1.0 m	30.3%	5.7%	2.342*
			>1.1 m	9.1%	45.7%	3.091*
Distance to canal water	28.230 (2)	<0.001	<3.0 m	30.3%	62.9%	2.445*
			3.0-100 m	12.1%	37.1%	2.101*
			>100 m	57.6%	0%	5.018*

Table 3. *Mean (±SE) percentage of land cover types in agriculture fields and canal trails surveyed for the presence of Burrowing Owls in the southeast valley of Phoenix, Arizona. Imagery from the USDA National Agriculture Imagery Program was classifed into seven cover layers (of 30-m cell sizes) by the Central Arizona–Phoenix Long-Term Ecological Research program. We combined buildings, roads, and pools to represent "developed" land and combined grass, tree, water, and soil to represent "open" land.*

	Agriculture fields		Canal trails	
Owl occupancy	Present (n=7)	Absent (n=16)	Present (n=4)	Absent (n=11)
Developed				
Building	3.0 (1.4)	7.0 (2.0)	5.1 (3.0)	9.0 (2.0)
Road	10.0 (2.3)	20.0 (3.1)	18.0 (3.0)	26.2 (3.0)
Swimming pool	0.1 (0.1)	0.02 (0.02)	0.1 (0.1)	0.03 (0.02)
Open				
Grass	55.0 (14.0)	38.4 (8.0)	25.0 (13.4)	16.4 (4.4)
Tree	0.3 (0.1)	3.1 (1.4)	1.0 (0.4)	4.0 (1.0)
Water	--	0.1 (0.1)	--	0.1 (0.03)
Soil	32.3 (13.1)	32.0 (5.2)	52.0 (14.0)	45.0 (5.1)
Area (ha)	79.3 (7.6)		79.7 (6.4)	

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cultivated, vegetated, or harvested) or field moisture conditions (i.e., dry or moist/flood irrigated); however, we did find a positive relationship between owl occupancy and presence of water in canals. Owl proximity to water likely reflects their using insects or other food that are generated because of the presence of water and not from direct consumption. Within agriculture fields, owl sightings were mostly in areas containing bare ground with sparse trees. When owls were observed, we found that owls perched on the ground in both fields and trails. Although we did not measure perch availability, our experience from surveying indicates that there were more perch options along trails than in fields; however, we suggest future research for verification of perch usage.

Our study found a relationship between owl occupancy and Gilman Loam soil, which is characterized by coarse-to-fine loamy sand that is well drained and moderately permeable (NRCS 2011). Other authors have also found that owl occupancy was related to soil type and Larson (2009) identified that Burrowing Owl nests in Washington were found in loamy sand soils more than sandy loam soils or silty loam. In contrast to our study, however, Larson (2009) did not find that Burrowing Owls selected loamy sand soils more than any other soil type, based upon availability. Larson (2009) speculates that burrow abundance in loamy sand soils may be because it is more conducive for small mammals to create burrows. Because we observed both erosion pockets and burrows along canals in fields and trails, we suspect that the abundance of Gilman Loam and loam soils in Phoenix may attract burrowing rodents and may be more susceptible to erosion. Burrowing Owls use burrows created by small mammals, such as rock squirrels (*Spermophilus variegatus*) and black-tailed prairie dogs (*Cynomys ludovicianus*) in New Mexico (Berardelli et al. 2010) and prairie dogs in Colorado (Tipton et al. 2008). However, those species are rare in our study area, but other mammals such as round-tailed ground squirrels (*Xerospermophilus tereticaudus*) and Botta's pocket gophers (*Thomomys bottae*) are common and known to create burrows used by owls (Thomsen 1971, Martin 1973).

Even though our study was limited to a single summer season in Phoenix, this is among the first studies to document owl habitat associations in urban areas in the southwestern United States (although see Grandmaison and Urreiztieta 2006). It is possible that owls were overlooked at some sites; however, by using Program MARK we were able to account for detectability differences between site types to estimate an occupancy rate of 32.1%, which was slightly above our naïve estimate of 28.9% (MacKenzie et al. 2002). Additionally, we conducted our study during appropriate times when owls are present and available for detection in the Southwest. Our study provides information that Burrowing Owls within the greater Phoenix metropolitan area are found in regions with suitable soils and with moderate development. As Phoenix continues to expand and convert agriculture fields into residential and other urban developed land, Burrowing Owls could likely lose suitable habitat.

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