In cooperation with Texas A&M University–Corpus Christi

Winter Ecology of the Western Burrowing Owl *(Athene cunicularia hypugaea)* in Southern Texas 1999–2004

Scientific Investigations Report 2007–5150

U.S. Department of the Interior
U.S. Geological Survey

Cover. The western burrowing owl roosting near a road culvert. Illustration by Russell Hooten, 2005.

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By Marc C. Woodin, Mary K. Skoruppa, and Graham C. Hickman

Prepared in cooperation with Texas A&M University–Corpus Christi

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Forward

Little was known about the winter distribution, abundance and ecology of wintering burrowing owls in Texas before the research in this report was conducted. Band recoveries indicated burrowing owls from all over the Great Plains of the United States winter in Texas but there were no winter records of Canadian birds. In January of 1998, Larry Ditto showed me a picture he had taken of a banded Canadian burrowing owl wintering near Edinburg. The following winter another owl with a transmitter from Canada was located by aerial surveys in south Texas, confirming the population of wintering owls included Canadian "snowbirds." Following up on these findings, in January 1999, I met with ornithologists, researchers, and conservationists in Corpus Christi and was told that burrowing owls were rare in south Texas. That afternoon as fellow biologist Helen Trefry and I drove from Corpus Christi to Kingsville we saw three owls in the Nueces County cotton fields. The winter habitat of burrowing owls, which includes culverts in cotton fields, is not normally explored by bird watchers and biologists. The owls are also entirely nocturnal in the winter and so are often overlooked. The USGS researchers built on these observations to document the habitat and ecology of burrowing owls in Nueces and surrounding counties as reported here. The researchers took their new information and held public information sessions in the area, gathering more locations and providing much needed education to landowners. As a species of tri-national concern this research in Texas has provided important information about a little known component of the life of burrowing owls. Together with research by others in Canada, the United States, and Mexico we now have a more complete understanding of the year round needs of this highly migratory and endangered owl. In addition, the experiments with artificial roosts demonstrate the owls will use them and the conservation of burrowing owls can benefit from human actions. This report represents the first comprehensive review of burrowing owl ecology in the winter and paves the way for future conservation actions in south Texas.

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square centimeter (cm^2)	0.1550	square inch (in^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
	Concentration	
microgram per gram (mg/g)	1.0000×10^{-6}	ounce per ounce (oz/oz)
nanogram per gram (ng/g)	1.0000×10^{-9}	ounce per ounce (oz/oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Winter Ecology of the Western Burrowing Owl *(Athene cunicularia hypugaea)* in Southern Texas, 1999–2004

By Marc C. Woodin, Mary K. Skoruppa, and Graham C. Hickman

Abstract

This study examines the winter ecology of the western burrowing owl (*Athene cunicularia hypugaea*) (fig. 1) in five Texas counties surrounding Corpus Christi, in southern Texas. There is a substantial gap in information on the owl's life cycle during migration and non-breeding winter months; almost all previous research on western burrowing owls has been conducted during the breeding season. The western burrowing owl currently is federally threatened in Mexico, federally endangered in Canada, and in the United States is considered a National Bird of Conservation Concern by the U.S. Fish and Wildlife Service. Topics investigated included status, effectiveness of public outreach, roost sites and use of culverts and artificial burrows, roost site fidelity, diet, contaminant burdens, body mass, and ectoparasites.

Early ornithological reports and a museum egg set revealed that burrowing owls once bred in southern Texas and were common in winter; however, since the 1950's they have been reported in relatively low numbers and only during winter. In this study, public outreach increased western burrowing owl detections by 68 percent. Owls selected winter roost sites with small-diameter openings, including culverts less than or equal to 16 centimeters and artificial burrows of 15 centimeters, probably because the small diameters deterred mammalian predators. Owls showed strong roost site fidelity; 15 banded birds stayed at the same roost sites within a winter, and 8 returned to the same site the following winter. The winter diet was over 90 percent insects, with crickets the primary prey. Analyses of invertebrate prey and regurgitated pellets showed that residues of all but 3 of 28 carbamate and organophosphate pesticides were detected at least once, but all were below known lethal concentrations. Mean body mass of western burrowing owls was 168 grams and was highest in midwinter. Feather lice were detected in low numbers on a few owls, but no fleas or other ectoparasites were found.

Figure 1. Western burrowing owl in southern Texas. Photo by Michael Rawson.

Introduction

The western burrowing owl (*Athene cunicularia hypugaea*) is a small, ground-dwelling, grassland bird that resides in western North America and prefers sparsely vegetated grassland. The small owl is 19–25 centimeters (cm) tall, has a body mass of about 150 grams (g), and a wingspan of approximately 60 cm (Haug and others, 1993). The owl has a short tail, long legs, a round head, and no ear tufts (fig. 2*A*). The burrowing owl name derives from the owl's habit of using animal burrows for summer nesting and winter roosting sites, primarily those of prairie dogs (*Cynomys* spp.) (fig. 2*B*), but also large ground squirrels (*Spermophilus* spp.) and other burrowing animals. Its

Figure 2. The burrowing owl and its habitat. *A*, Burrowing owl. Photo by Matt Rowe. *B*, The entry to an underground burrow.

spotted brown back and light underside with distinct barring camouflage the owl within this environment.

The distribution of the burrowing owl in North and Central America is shown in fig. 3. The western burrowing owl *(A. c. hypugaea)* is one of 22 subspecies of the burrowing owl *(Athene cunicularia)*, a species that is located throughout North, Central, and South America (Integrated Taxonomic Information System, 2006). Other subspecies of *Athene cunicularia* are found in South America, Florida, and the Caribbean (Haug and others, 1993).

Figure 3. Burrowing owl distribution in North and Central America. (Haug and others, 1993).

Burrowing owl populations have declined in the past 50 years, and the historical breeding range has contracted due to loss of habitat, prairie dog eradication, pesticide use, and predation. The western burrowing owl was classified as federally threatened in Mexico in 1994 and as federally endangered in Canada in 1995, and the subspecies was identified in 2002 as a National Bird of Conservation Concern by the U.S. Fish and Wildlife Service (Klute and others, 2003). In addition, populations have been designated legally as endangered, threatened, or as a species of concern in 9 of 19 States of the United States and in all 4 Canadian provinces in which they occur. In 7 of the remaining 10 States, western burrowing owls are considered vulnerable or potentially vulnerable (Klute and others, 2003).

The western burrowing owl also has experienced substantial range contraction. Range shrinkage has been most pronounced at the northern (that is, Canadian prairie provinces) and eastern limits (for example, Minnesota, Iowa) of the historical range, and the subspecies no longer breeds in central or southern Texas (fig. 4). Data from Breeding Bird Surveys[1] (BBS) and Christmas Bird Counts[2] (CBC) in Texas indicate downward trends in numbers of both breeding and wintering burrowing owls, although only the latter were statistically significant (Sauer and others, 1996; McIntyre, 2004; Sauer

[1]Initiated in 1966, the North American Breeding Bird Survey is a cooperative effort between the U.S. Geological Survey and Canadian Wildlife Service to monitor the status and trends of North American bird populations. Thousands of participants report bird sightings on randomly established roadside routes throughout the continent (U.S. Geological Survey, 2006).

[2]Initiated in 1900, the Christmas Bird Count is organized by the National Audubon Society, primarily in North America, but also in Central and South America. The surveys are conducted within a 15 mi (mile) diameter circle in one day in a 2-week period around December 25 (National Audubon Society, 2006).

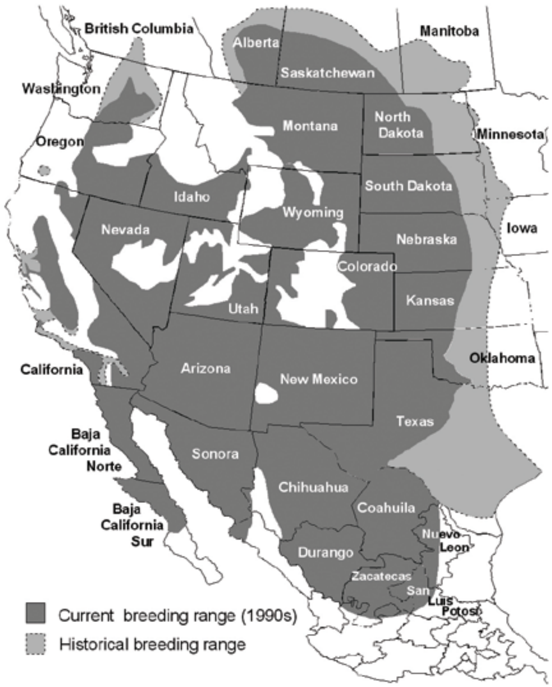

Figure 4. Current and historical breeding range of the western burrowing owl (Wellicome and Holroyd, 2001).

and others, 2005). In 2004, the Commission for Environmental Cooperation (CEC) selected the western burrowing owl as one of only three terrestrial animals for the first transboundary North American Conservation Action Plan (NACAP) (Commission for Environmental Cooperation, 2004).[3]

Important factors identified in the decline of the western burrowing owl are habitat loss resulting from conversion of grasslands to intensive cultivation of row crops (Haug and others, 1993; Sheffield, 1997) and a decline in available burrows due to widespread eradication of prairie dogs and large ground squirrels (Desmond and others, 2000; Murphy and others, 2001). Other factors that may have contributed to increased mortality or to a decline in productivity of western burrowing owls include predation on nests or fledglings (Drost and McCluskey, 1992; Martell and others, 2001), collisions with vehicles (Haug and others, 1993), and application of pesticides (James and Fox, 1987; Fox and others, 1989; Sheffield, 1997).

Most investigations into the causes of the decline of the western burrowing owl and nearly all of the extensive monitoring of population status have focused on breeding birds. For example, virtually all papers devoted to natural history or ecology of burrowing owls in the First (1992) and Second (1998) International Burrowing Owl Symposia (Lincer and Steenhof, 1997; Wellicome and Holroyd, 2001) were concerned with biology or conservation status of breeding populations. In comparison, there is a scarcity of information on western burrowing owls during the winter phase of the annual life cycle, although a handful of exceptions occur (for example, Ross and Smith, 1970; Coulombe, 1971; Butts, 1973).

The gap in knowledge about the winter ecology of burrowing owls has been identified as a research action item by the Canadian Wildlife Service (Holroyd and others, 2001). Historically, the western burrowing owl was located in the Canadian provinces of British Columbia, Alberta, Saskatchewan and Manitoba (fig. 4). First listed as threatened in 1979, the owl was declared endangered in 1995 as landowners reported an annual decline greater than 20 percent (Wellicome and Holroyd, 2001). The endangered status was confirmed in 2000 and 2006 (Government of Canada, 2006). Today, the owl is extirpated from British Columbia and Manitoba in spite of attempts at conservation. The Canadian Wildlife Service has been conducting surveys to determine migration and winter ranges of burrowing owls that breed in Canada.

Although Jones (1999) showed that burrowing owls at Padre Island National Seashore in southern Texas were rare, scattered band returns have demonstrated that migrants from Canada over-winter in Texas, and owls that have been trapped, banded, and had radio transmitters attached in the prairie provinces of Canada have been relocated in southern Texas (Holroyd and Trefry, 2002). The Canadian biologists traveled to Corpus Christi, Texas during the winter of 1998–99 to collaborate with the U.S. Geological Survey (USGS) Texas Gulf Coast Field Research Station and others to begin investigations into the owl's habitat use and winter diet in a small area outside of Corpus Christi (R.G. Batey, U.S. Geological Survey, written commun., 2000). The USGS then expanded the study through its Species at Risk Program, which targeted declining species identified by the U.S. Fish and Wildlife Service and which had specific gaps of information, such as with the winter ecology of the western burrowing owl.

Purpose and Scope

This report examines multiple aspects of the winter ecology of the western burrowing owl. The study was conducted in an area around Corpus Christi, Texas from 1999 to 2004. The owl's fall migration was defined as October 1 to November 14 and spring migration as February 16 to March 31. The period from November 15 to February 15 was considered the stable winter roosting period. The study timeline (table 1) shows the overlapping study objectives, which include:

- Conduct a search of the scientific literature and museum collections to determine the current and historical status of the burrowing owl in southern Texas.

- Evaluate the utility of public and media outreach efforts in the detection of burrowing owls.

[3]The CEC was created through the North American Agreement on Environmental Cooperation, the supplemental environmental agreement to the North American Free Trade Agreement. It encourages Canada, Mexico, and the United States to adopt a continental approach to the conservation of shared marine and terrestrial migratory or transboundary species of common concern (Commission for Environmental Cooperation, 2004) (*www.cec.org*).

Table 1. Study timeline by objectives for the winters of 1999–2004.

	1999–2000	2000–01	2001–02	2002–03	2003–04
Historical status		■	■		
Owl reports		■	■		
Artificial burrows			■	■	
Roost site characteristics			■		
Culvert selection			■		
Fidelity			■	■	■
Diet	■		■	■	■
Contaminants			■		
Body condition/ectoparasites		■	■	■	■

- Characterize roost sites and document the extent of roost site fidelity in winter.
- Examine burrowing owl selection of culverts (road drainage pipe) for burrows and assess burrowing owl use of artificial burrows in winter.
- Examine the winter diet and assess the contaminant burdens exhibited by representative prey items and regurgitated pellets of western burrowing owls.
- Examine body mass and structural size, and survey and identify ectoparasites of wintering burrowing owls.

Study Area

The study area included five counties, Jim Wells, Kleberg, Nueces, Refugio, and San Patricio, in southern Texas totaling 10,383 square kilometers (km^2) (fig. 5). Corpus Christi, a coastal city in Nueces County with a population of 275,000, is located west of two barrier islands, Padre Island and Mustang Island. The other four surrounding counties were included in the outreach and education component of the study through media outlets based in Corpus Christi. The five-county study area is located within a region known as the Texas Coastal Bend and forms part of the coastal prairie region, which extends northeast of Corpus Christi to include half of the southern part of Louisiana. The coastal prairies of Texas and Louisiana are the southernmost tip of the prairie ecosystem in the Great Plains.

The Coastal Bend consists mostly of flat land characterized by mixed prairie grasses, transitional riparian forest, oak savanna, and Tamaulipan thorn-scrub. It is a semi-arid, subtropical region receiving an average of 76.2 cm of rain per year, with the heaviest rainfall usually occurring in the fall. However, precipitation can be extremely erratic, since the region experiences both prolonged droughts and occasional deluges resulting from landfall of tropical storms and hurricanes. The precipitation ranged from a low of 56.1 cm in 2000 to a high of 100.1 cm in 2001 (U.S. Department of Commerce, 2006). The averages of the mean monthly temperatures for each of the years of 1999–2004 ranged from 22 to 23 degrees Celsius (°C), but these annual means for every year exceeded the overall mean. The departure from normal of the mean monthly temperatures ranged from a low of +0.2 °C in 2003 to a maximum of +10.8 °C in 2000, indicating that the area was experiencing a warm cycle during the period of this study. The coldest temperatures occurred in December and January.

Today, urbanization, agriculture, and range improvement have reduced the 3.8 million hectares (ha) of historical coastal prairie environment by 99 percent (U.S. Geological Survey, 2000). In Texas, very little of the original native coastal prairie remains (Smeins and others, 1991). The native coastal prairie remnants have been degraded significantly by fire suppression, which leads to brush invasion (Johnston, 1963), or by the planting of exotic grass species to enhance forage production (Hatch and others, 1999). Most of the native prairie that once swathed the coast has been converted to production (Jahrsdoerfer and Leslie, 1988) of primarily cotton and sorghum in southern Texas, where the majority of farmers practice “clean farming.” Fields are tilled in the fall after the last crop harvest, and little or no stubble remains while the fields lie dormant until spring planting commences in February (fig. 6). In southern Texas, the practice of year-round tilling, along with increased use of pesticides and other chemicals on cotton crops, may result in less biodiversity than in agricultural areas elsewhere. The agricultural land is criss-crossed with oil and gas industry lease roads that are surfaced with a limestone-based material called caliche (fig. 7). Drainage culverts under the roads channel water during intense rains. These culverts, when dry, serve as winter roost sites for the adaptable western burrowing owl.

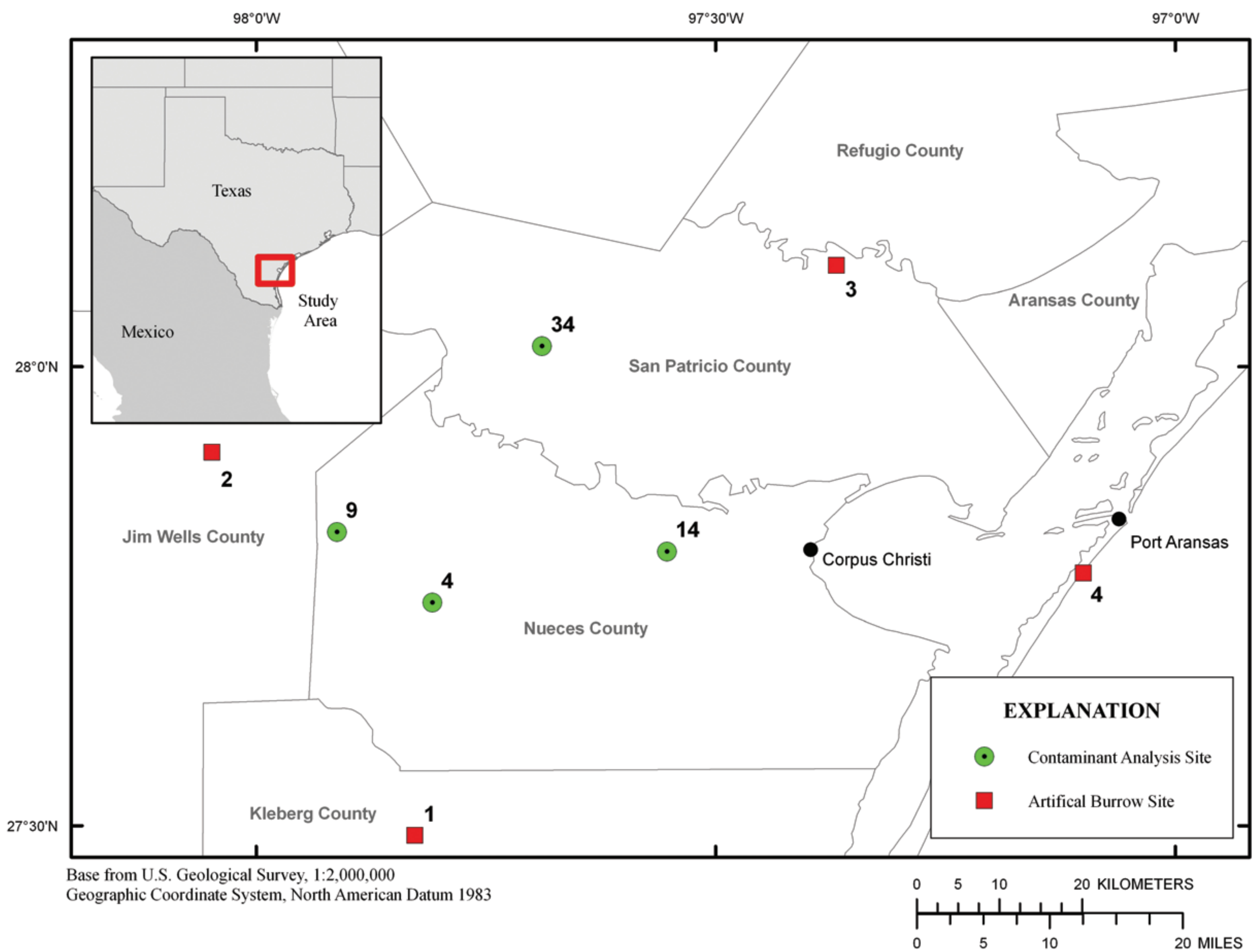

Figure 5. Location of the study area in the Coastal Bend of southern Texas. Artificial burrow sites are in red; sampling sites for prey and pellets for contaminant analyses are in green.

Figure 6. Owls inhabit agricultural areas. Fields are tilled in the fall and little or no stubble remains while the fields lie dormant until spring planting in February.

Figure 7. Oil and gas lease road culverts provide roost sites for the western burrowing owl. Photo by Robert Batey.

Methods

Historical and Current Status

To determine the historical and current status of burrowing owls in southern Texas, published accounts of early ornithological expeditions were reviewed for documented records of burrowing owls (for example, Dresser, 1865–66; Beckham, 1887; Peirce, 1894; Oberholser, 1974). Also, 22 North American museums believed likely to contain specimens of burrowing owls were contacted about records of Texas birds. Additionally, CBC data and the Texas Breeding Bird Atlas were reviewed for sightings of burrowing owls in southern Texas (Sauer and others, 1996; Benson and Arnold, 2001).

Owl Reports

Researchers enlisted help from the public to locate western burrowing owls and their roost sites during the winters of 2000–02. Finding the owls can be a challenge because their cryptic coloring blends into the environment, and the birds often sit nearly motionless all day in the winter. Over 91 percent of Texas is in private ownership (U.S. Department of Agriculture, 2000) and not easily accessible for scientific studies. To acquire help in detecting the owls on private lands and elsewhere, researchers conducted an outreach program (table 2) to explain the conservation needs of the western burrowing owl and to request assistance from ranchers, farmers, birders, and others. Rural landowners were contacted through the local agricultural newsletter and a newspaper with a farm and ranch column. Announcements were aired on a local country music radio program, and information was provided at farm and ranch shows (fig. 8). Other contacts included the local birding club newsletter, the major daily newspaper, and local network television stations.

Specially produced outreach products helped enlist the support of the public, including (1) a USGS fact sheet written in English and Spanish for both technical and nonscientific audiences, (2) a landowner questionnaire mailed to farmers and ranchers and used at farm and ranch shows, and (3) a "wanted poster" placed on bulletin boards in several key gathering places within the study area.

Roost sites were identified either by sighting an owl or by the presence of regurgitated pellets, fecal material, feathers, or the co-occurrence of several of these indicators. With the help of the public, the detection of owl roost sites early in the study facilitated the search in subsequent winters, when the roost sites were located primarily by researchers checking road culverts and other potential roost sites along publicly accessible rural roads.

Table 2. Examples of burrowing owl outreach activities in the Texas Coastal Bend during the winters of 2000–02 (from Jones, 2001).

[Information on burrowing owl conservation in south Texas and a request for burrowing owl information were included in every educational outreach product.]

Date (month/day/year)	Outreach product	Media source
9/20/2000	Burrowing Owls of South Texas fact sheet	Insects and Weeds in Focus (Texas Agricultural Extension Service Newsletter)
10/2000	Burrowing Owls in South Texas fact sheet	The Brown Pelican (Coastal Bend Audubon Society newsletter)
10/25–26/2000	Burrowing Owl Survey	South Texas Farm and Ranch Show, Victoria, Texas (educational booth)
10/26/2000	Burrowing Owls at the South Texas Farm and Ranch Show	KIXS-FM (country music radio station, Victoria, Texas)
12/01/2000	Owl Spotters' Help Sought for a Study	Corpus Christi Caller-Times (major newspaper for the Texas Coastal Bend)
12/05/2000	Burrowing Owls in South Texas fact sheet	KIII-ABC (television news report)
12/11/2000	Canadian Wildlife Service Studies Burrowing Owls in South Texas	KIII-ABC (television news report)
1/08–09/2001	WANTED: Little Winter Texans-Burrowing Owls Need Your Help	Corpus Christi Farm and Ranch Show, Corpus Christi, Texas (educational booth)
1/09/2001	Burrowing Owls at the Corpus Christi Farm and Ranch Show	KIII-ABC (television news report)
4/08/2001	Fertilizer Should be Applied Now	The Victoria Advocate—South Texas Farm and Ranch News (newspaper)
1/16–19/2002	WANTED: Little Winter Texans–Burrowing Owls Need Your Help	Nueces County Junior Livestock Show (educational booth)

Figure 8. All sectors of the public were introduced to the western burrowing owl at farm and ranch shows in southern Texas. Researchers used a questionnaire to generate discussion about the owl and solicit help in locating owls.

Artificial Burrow Experiment

Artificial burrows (n = 72) were installed at four Coastal Bend sites (fig. 5) in the summer and early autumn of 2001 to determine if owls would select artificial burrows as natural burrow substitutes for migration and winter roost sites. Monitoring occurred from October 1 to March 31 for the two sampling periods of 2001–02 and 2002–03. The following artificial burrow sites were selected because they contained grasslands that were mowed, grazed, or naturally sparse:

Site 1—Naval Air Station–Kingsville (Kleberg County).

Site 2—Naval Auxiliary Landing Field–Orange Grove (Jim Wells County).

Site 3—Rob & Bessie Welder Wildlife Foundation (San Patricio County).

Site 4—Port Aransas city limits, Mustang Island (Nueces County).

The artificial burrows were made of perforated and corrugated high-density polyethylene pipe cut into lengths of 2.4 meters (m). Each pipe had two or three openings; the latter had a T-joint midway between the horizontal openings (fig. 9*A*). The opening diameters were 15-, 20-, or 25-cm. At every site, one of each of the six burrow types was buried within three clusters (figs. 9*B,* 10), resulting in a total of 18 burrows per site. The relative positions of each burrow type within different clusters were varied randomly. All burrows were oriented in an east/west direction to protect the owls from northern winds and rains during the passage of winter cold fronts and were covered with soil to maintain them in place. The three clusters at each site were separated by at least 100 m. The six burrows within each cluster were separated by about 5 m, similar to the typical distance between prairie dog burrows within a prairie dog colony (figs. 9*C,* 10).

During 2001–02, artificial burrows at all four sites were visited weekly from October 1 to November 14, biweekly from November 15 to February 15, and then weekly from February 16 to March 31. During 2002–03, Site 1 was not monitored because the surrounding grass was not mowed, making the site unsuitable for burrowing owls. Site 2 was visited about every 1–2 weeks. Sites 3 and 4 were visited every 2–3 weeks.

Owl sightings and presence of regurgitated pellets, feces, and feathers were used to determine which artificial burrows showed use by burrowing owls. During each monitoring visit, each burrow was classified by whether or not it had been used by a burrowing owl.

Roost Site Characteristics

During the winter of 2001–02 (November 15 to February 15), burrowing owl roost sites were located by driving along rural roads and checking road culverts and other potential roost sites. As a result of outreach activities, the public also provided assistance in locating burrowing owl roost sites. The presence of burrowing owls at roost sites was confirmed by sighting an owl or by the presence of indicators such as pellets, fecal material, and/or burrowing owl feathers. Frequently, several of these indicators co-occurred at roost sites. At each confirmed roost site, researchers recorded the following characteristics:

1. Habitat type, including barrier island, agricultural land, grassland, or woodland/brush. Within 200 m of a roost site in agricultural land, the dominant crop type of cotton or grain was also recorded.

2. Percent ground-cover composition of bare ground, grass, forbs, crop stubble, litter, and woody vegetation within a 10-m radius of the roost site.

Figure 9. Artificial burrow installations. *A*, Artificial burrows made of corrugated, polyethylene drainage pipe with two or three openings were installed at four sites. *B*, At Site 4, where native coastal prairie exists, artificial burrows were covered with sand to hold them in place. *C*, The artificial burrows were placed about 5 meters apart in clusters of six.

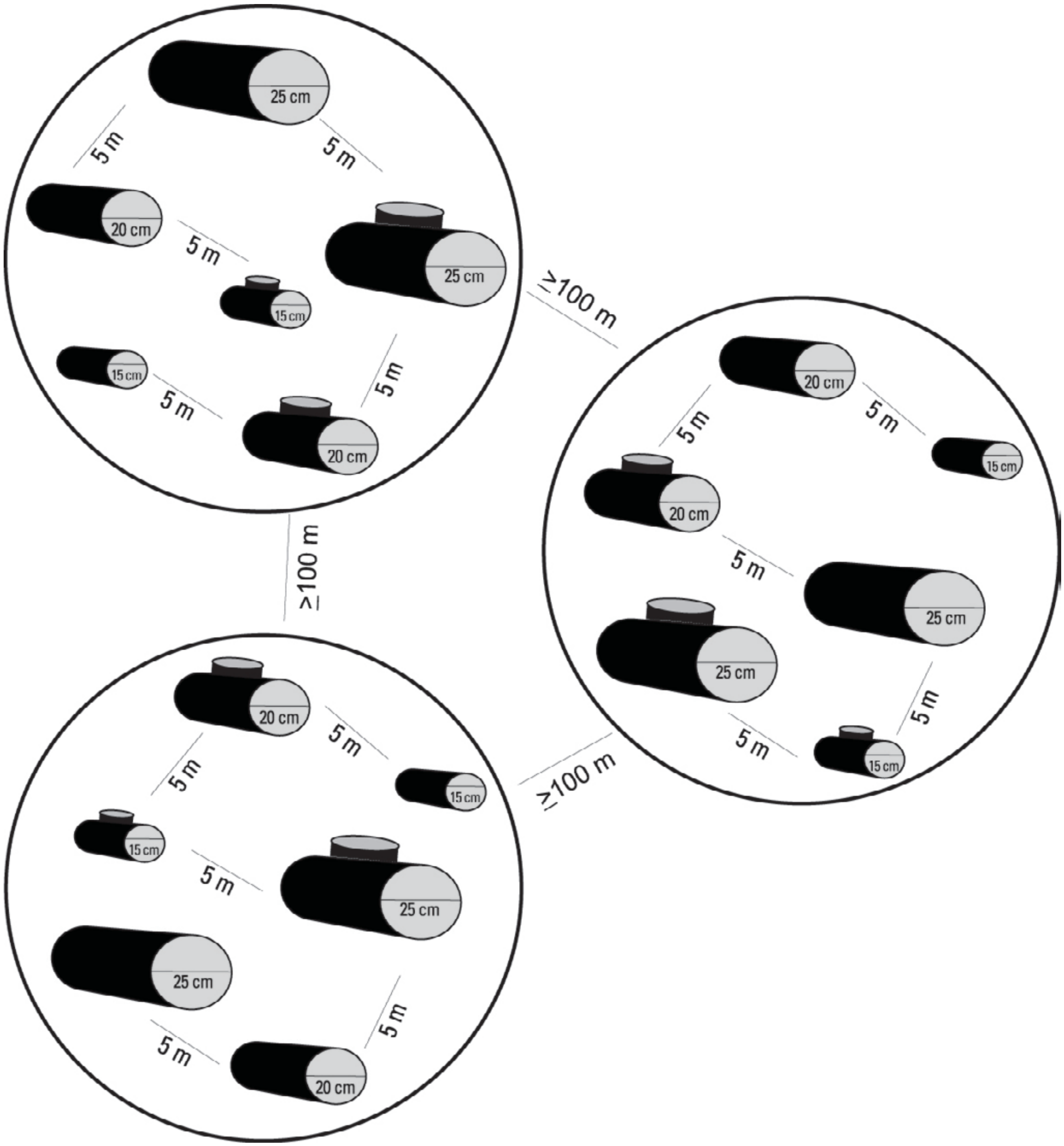

Figure 10. Artificial burrow design strategy for the four sites selected around Corpus Christi.

3. Roost site type, including concrete, galvanized and corrugated steel, or cast iron culverts; natural or artificial burrows; or other.

4. The number and diameter of openings for each burrow. The diameters of the openings were classified as small (≤16 cm), medium (17–24 cm), or large (≥25 cm).

5. Burrow opening orientation (east-west, north-south, northeast-southwest, or northwest-southeast direction).

6. Perch sites, including utility towers, telephone poles, and fence posts within 50 m of each roost site.

Culvert Selection

Because preliminary fieldwork and owl reports in 2000–01 revealed that most burrowing owls wintering in southern Texas roost at roadside culverts, a culvert selection study was initiated. To determine which characteristics of culverts were important to burrowing owls, identical data (see "*Roost Site Characteristics*" methods) for both occupied and unoccupied culverts were collected January 15 to February 15, 2002. Characteristics of culverts occupied by burrowing owls (n = 34) were compared to those that were not occupied (n = 100, 51 in Nueces County and 49 in San Patricio County). To collect unoccupied culvert data, starting points along rural roads in Nueces and San Patricio counties were chosen at random, as was each successive possible choice of direction at road intersections. At the end of the field season, all randomly selected roadside culverts were visited again to confirm that they had remained unoccupied by burrowing owls through the winter. Selection by burrowing owls of culvert characteristics was determined with a series of chi-square tests (Dowdy and Wearden, 1983).

Roost Site Fidelity

Burrowing owls were trapped at roost sites with noose carpets or bow nets. Often, living or dead mice were used as bait in the trap. Trapped owls were banded with leg bands to aid in identification if subsequently re-sighted. A standard aluminum band was placed on the right tarsus and a color-coded (black over green) band was placed on the left tarsus of each owl captured. Known roost sites of banded owls were revisited at approximately 2-week intervals to assess site fidelity within a winter. If marked owls left their roost sites, attempts were made to relocate them by checking other potential roost sites nearby. Roost sites of marked burrowing owls were monitored during the winters of 2001–02 through 2005–06 to determine the extent of site fidelity among years.

Diet

Examination of the western burrowing owl diet began during the winter of 1999–2000 and continued for an additional three winters from 2001–02 to 2003–04. Owls regurgitate pellets that contain indigestible parts of the prey, such as hair and bone. The diet of burrowing owls wintering in southern Texas was determined by collecting regurgitated pellets (pellets) at known roost sites from November 1 to February 28. Occasionally, parts of invertebrate and vertebrate prey (for example, insect remains and bird feathers) were found in the vicinity of roost sites, but these were not included in the results. Pellets were frozen until processing, when they were thawed and broken apart. Prey remains were sorted, identified, and organized by phylogenetic classification. Invertebrate remains were identified by characteristic hard parts. For example, beetles (Class: Insecta; Order: Coleoptera) and ants (Class: Insecta; Order: Hymenoptera) were recognized by the presence of head capsules, whereas mandibles were used to identify crickets and grasshoppers (Class: Insecta; Order: Orthoptera) and moth caterpillars (Class: Insecta; Order: Lepidoptera). Spiders (Class: Arachnida; Order: Araneae) were detected by the presence of mouthparts (chelicerae), scorpions (Class: Arachnida; Order: Scorpiones) by the presence of stingers, and earwigs (Class: Insecta; Order: Dermaptera) by the presence of hard terminal appendages (cerci). Vertebrate remains for mammals (Class: Mammalia) were obvious from the presence of bones and hair, but identification to species and enumeration were reliable only by use of dentition and jaw parts. Birds (Class: Aves) were recognized by the presence of bones and feathers. Prey items were counted by type for each of the four winters and summed over all types. Diets were calculated for each food type as a percentage of the total count of food items from each winter, thereby showing diet variation among winters. The overall diet was produced by summing all food types over the four winters and calculating a percentage of this total for each food type. Percent-of-occurrence data represented the proportions of pellets in which each food type was found.

Contaminants in Prey and Pellets

A survey was conducted of carbamate and organophosphate (OP) pesticide residues in western burrowing owl prey and pellets collected from agricultural fields near roost sites (fig. 5). Representative invertebrate prey were collected near two known roost sites during the winter of 2001–02 and frozen. Five composite samples of invertebrate prey types were submitted subsequently for contaminants analyses. The 5 composite samples of representative prey were wolf spiders (4 individuals), crickets (19 individuals in 2 separate samples), grasshoppers (4 individuals), and earwigs (16 individuals). In addition, 13 pellets were collected from 4 roost sites and frozen. Multiple pellets from the same roost site were broken apart and mixed to yield composite pellet samples, one from each of four roost sites. Nine tissue samples were submitted to the Texas A&M University Geochemical and Environmental Research Group (GERG) for analysis.

U.S. Environmental Protection Agency Standard Operating Procedures (SOPs) were used to analyze for carbamate pesticides (U.S. Environmental Protection Agency, 1996), using an external standard run together with the samples and with dichloromethane and acetone. To obtain carbamate analytes, extracts were purified by back extraction with hexane and acetonitrile, followed by a C-18 solid-phase extraction cartridge cleanup technique. Carbamate pesticides were analyzed using high-performance liquid chromatography with an ultraviolet and fluorescent detector. Samples were extracted and analyzed for OP pesticides following GERG SOPs (Geochemical and Environmental Research Group, 1992). The OP pesticide concentrations were determined using surrogate compounds added to the sample prior to extraction. Homogenized tissue samples were extracted with dichloromethane for analysis of OPs. To obtain OP analytes, extracts were purified with silica gel and alumina chromatography, followed by gel permeation chromatography. The OPs were analyzed using gas chromatography with mass spectrometer.

A procedural blank, a laboratory blank spike (LBS), and a laboratory blank spike duplicate (LBSD) were extracted along with the environmental samples for quality control (QC). A mixture of standard compounds also was analyzed with each batch of samples. Several carbamate and OP pesticide compounds were detected at concentrations less than the minimum detection limit in the procedural blank. Recoveries of spiked compounds from the LBS and LBSD samples were within acceptable QC limits for all analytes (table 3). Recoveries of the spiked surrogate compounds were within acceptable QC ranges. All analytical data met the quality-assurance criteria as specified in the GERG SOPs (Geochemical and Environmental Research Group, 1992).

Body Mass, Structural Size, and Ectoparasites

Burrowing owls were trapped and some recaptured over the five winters of 2000–01 to 2004–05. Trapped owls were removed to the interior of the field vehicle and weighed to the nearest 1 g using a spring scale. Calipers were used to measure culmen length, tarsus length, and tarsus diameter to the nearest 0.1 millimeter (mm). Rulers were used to measure flattened and unflattened wing length (fig. 11), body length (top of head to tip of tail), and tail length to the nearest 1 mm.

After weighing and measuring trapped owls, each bird was examined for ectoparasites by searching areas approximately 2 square centimeters (cm^2) in the crown, upper leg, underwing, and vent regions. Any ectoparasites detected were collected and stored in 70-percent ethanol for later identification with bright-field illumination compound and dissecting microscopes. Photographs were taken using a digital camera mounted to a microscope. The photographs were sent to burrowing owl ectoparasite experts to confirm identification.

Results and Discussion

Historical and Current Status

References to burrowing owl abundance from early collecting expeditions in southern Texas were anecdotal and not quantitative in nature (for example, Beckham, 1887; Peirce, 1894). Responses from 16 museums yielded 77 burrowing owl records from Texas, but most of these were from northern Texas, where the species remains as a relatively common breeder in some locations. Most museum records from southern Texas were from Cameron County ($n = 11$) in the Rio Grande Valley or from Nueces County ($n = 4$). Of special note is an egg set from Kleberg County collected in 1922 (catalog no. 142886, Western Foundation of Vertebrate Zoology, Camarillo, California). In addition to the egg set, three literature sources (Dresser, 1865–66; Peirce, 1894; Oberholser, 1974) indicated that burrowing owls formerly bred in southern Texas.

Western burrowing owls apparently remained relatively common year round in southern Texas through at least the late 19th century. Dresser (1865–66) stated that burrowing owls were “noticed at all seasons in the prairie-country.” Peirce (1894) described “many burrowing owls” occurring in pairs on a collecting trip along the north shore of Corpus Christi Bay in April. His description of owl pairing behavior and the timing of these observations (in April) support the conclusion that these probably were breeding birds. Chapman (1891) observed no burrowing owls in spring near Corpus Christi, but his collecting activities were concentrated in thorn scrub and marshes, habitats that were not suitable for burrowing owls. One confirmed record of a burrowing owl breeding in southern Texas is documented by Oberholser (1974), although the exact location is unclear. Oberholser (1974) maps (p. 454) the location of breeding burrowing owls in Kleberg County, whereas the text (p. 455) identifies Nueces County as the location. This instance may be the egg set mentioned above, collected in Kleberg County in 1922, showing that some breeding persisted in southern Texas until at least the 1920s. In 1951, F.M. Packard (unpub. data) noted that burrowing owls by the mid-20th century probably no longer bred in southern Texas. Probable absence of breeding burrowing owls in southern Texas in the second half of the 20th century has been supported by decades of BBS data (Sauer and others, 2005). Benson and Arnold (2001) also provide no recent records of breeding burrowing owls in southern Texas.

Beckham (1887) considered burrowing owls to be “abundant” near Corpus Christi, Texas, in the winter, and Carroll (1900) also claimed that burrowing owls in Refugio County (north of Corpus Christi) were “very common during the winter months.” However, by the middle of the 20th century, the species also had declined in numbers during winter (F.M. Packard, unpub. data, 1951). CBC data during most of the second half of the 20th century showed no obvious population trend (Sauer and others, 1996), but a significant decline was detected by 2000 (McIntyre, 2004).

Table 3. Concentrations of carbamate and organophosphate pesticides in quality assurance/quality control analytical blank samples and percentage recoveries from analytical spiked samples.

[µg/g, micrograms per gram; ND, not detected; ng/g, nanograms per gram; --, no data]

Carbamate pesticides	Blank sample concentration (µg/g, wet weight)	Laboratory blank spike: Recovery (percent)	Laboratory blank spike: Duplicate recovery (percent)
3-OH-carbofuran	ND	39.34	46.38
Aldicarb (Temik)	[1]0.07	43.21	35.38
Aldicarb sulfone	ND	61.35	43.52
Carbaryl (Servin)	ND	31.46	28.73
Carbofuran (Furadan)	[1]0.06	42.09	31.86
Methiocarb (Mesurol)	ND	29.44	24.68
Methomyl (Lannate)	ND	26.35	20.35
Promecarb	ND	30.26	25.39
Propoxur (Baygon)	[1]0.01	34.06	32.57

Organophosphate pesticides	Blank sample concentration (ng/g, wet weight)	Laboratory blank spike: Recovery (percent)	Laboratory blank spike: Duplicate recovery (percent)
Bolstar sulfone	0.7	--	--
Chlorpyrifos	0.1	96.8	95.7
Coumaphos	ND	103.3	99.9
Demeton-O	ND	--	--
Demeton-S	ND	--	--
Diazinon	ND	92.0	91.3
Dichlorovos	4.7	88.2	74.9
Disulfoton	ND	--	--
Ethoprop	0.2	109.8	104.5
Fenthion	0.2	--	--
Methyl-azinphos	ND	--	--
Methyl parathion	ND	74.9	75.9
Mevinphos	0.6	104.0	103.0
Naled	ND	--	--
Phorate	0.1	--	--
Ronnel	0.1	99.0	98.4
Stiriphos	1.2	92.4	90.4
Tokuthion	0.9	92.4	90.4
Trichloronate	1.2	--	--

[1]Less than minimum detection limit of method.

Figure 11. Wing length was measured as part of the structural size data collected during the western burrowing owl study.

Oberholser (1974) documented confirmed historical records (specimens or eggs) of burrowing owls in southern Texas, most of which were winter records. These winter records were clustered around Corpus Christi (fig. 5) and in the lower Rio Grande Valley. The CBC data suggest that small numbers of burrowing owls winter in southern Texas (Sauer and others, 1996), although searches for burrowing owls equipped with radio transmitters attached in prairie Canada indicated that owl densities in winter in southern Texas may be greater than CBC data demonstrate (Holroyd and Trefry, 2002). The CBC data and landowner reports showed that burrowing owl distribution among counties in southern Texas in winter has changed little in recent decades (Jones, 2001; McIntyre, 2004).

Owl Reports

The response of landowners and the public to the outreach program was positive and supportive. Public outreach activities resulted in a 68-percent increase in burrowing owl reports during the first winter of 2000–01 (Jones, 2001). Though few individuals returned the mailed questionnaire, it proved valuable at public events in generating discussion about owls and sightings (Jones, 2001). The 30 owl sightings by the public included 20 from Nueces County, where all of the major television and newspaper outlets were used for outreach. This indicates that numbers of reported owl sightings in an area are related to the amount of effort exerted to reach the public (Jones, 2001). The western burrowing owl is charismatic because of its unique appearance, behavioral characteristics, and tolerance of humans. As a result, the public's interest in the owl provides a unique opportunity to assist researchers in burrowing owl studies. Public assistance is especially beneficial because owls in southern Texas roost alone across extensive agricultural lands, which makes monitoring difficult. As a matter of fact, wintering owls in southern Texas are underreported by local CBC data (Sauer and others, 1996) and probably elsewhere in their winter range where they occur as solitary individuals distributed widely across extensive agricultural lands. The survey work of the Canadian Wildlife Service has inspired a network of ham and VHF monitoring enthusiasts to search for owls (http://*members.aol.com/joemoell/owl3.html*), demonstrating the high level of interest possible from the public.

Of the 74 confirmed roost sites detected by the public and by researchers, 57 (77 percent) were at road culverts. Three roost sites discovered by the public in Port Aransas on Mustang Island demonstrate the ability of the owls to adapt to urban environments. One of the owls used a residential street storm drain; the residents adopted "Hoot" and erected a sign to protect the owl from disturbances (fig. 12, Jones, 2001).

The roost sites detected with the help of the public during the winter of 2000–01 served as the baseline data for researchers during the winter of 2001–02, when 46 roost sites were confirmed. Probable reasons for the lower number of sites in the second winter include the lack of access to private lands and the wet fall season, when excessive rainfall made some previously occupied sites, especially culverts with standing water, unattractive to the owls.

Figure 12. Western burrowing owls are tolerant of human presence. Here is "Hoot" from Port Aransas, protected by the neighbors, as it stands in front of a city street drain at its winter roost. Photo by Sara Gillmann.

Artificial Burrow Experiment

The 2-year artificial burrow experiment resulted in 58 detections of migrating or wintering western burrowing owls at two sites (fig. 13). Site 2 was used the most with 47 detections over the two sampling periods (fig. 14). This site is more isolated than the others, is elevated, and consists of prairie that was close to owls roosting in agricultural lands. The barrier island environment of Site 4 might have been attractive to owls because the dunes are elevated and contain sparse native vegetation. It is unclear why Site 1 failed to attract any owls in 2001–02, when the grass at this site was kept short by mowing. Monitoring did not occur at Site 1 during 2002–03 because the grasses were not mowed, so the site was not suitable habitat for burrowing owls. Site 3 remained unused even though it was located on a wildlife refuge. The native brush and riparian forests surrounding the burrows at Site 3 may have influenced owl use of the burrows. Additionally, the open fields where the burrows were placed probably were not large enough, given their proximity to the woodland environment. Burrowing owls used all types of artificial burrows, but 39 of 58 detections (67 percent) were at burrows with two openings, and 46 of 58 (79 percent) were at burrows with 15-cm diameter openings (Ortega, 2003).

This study was the first in which artificial burrows were installed and monitored during the winter in southern Texas, though numerous reports are available on the use of artificial burrows during the breeding season in other areas (for example, Collins and Landry, 1977; Trulio, 1995; Botelho and Arrowood, 1998; Smith and Belthoff, 2001a). The results of this study demonstrated that the western burrowing owl will use artificial burrows as winter roost sites (Ortega, 2003). Although burrowing owls wintering in southern Texas used all sizes of artificial burrows, they most frequently chose those with the smallest diameter (15 cm), which was consistent with results obtained for roadside culverts selected by burrowing owls as winter roost sites (Williford, 2003 and also see "*Culvert Selection"* section in this report). Breeding burrowing owls selected small (10 cm) artificial burrows over those with 15-cm diameters (Smith and Belthoff, 2001a). Burrow interiors seldom were used for daily activities in the winter, unlike the interiors of burrows used for nesting. Thus, results from this study support the hypothesis that burrowing owls select small-diameter artificial burrows primarily because they deter large mammalian predators, as opposed to other possible explanations (for example, microclimate characteristics) (Smith and Belthoff, 2001a).

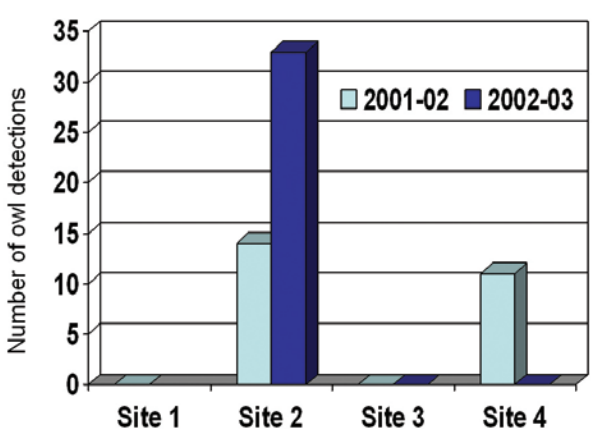

Figure 13. Number of burrowing owl detections at artificial burrow sites during 2001–03.

Figure 14. Two western burrowing owls using artificial burrows at Naval Auxiliary Landing Field–Orange Grove (Site 2).

Roost Site Characteristics

Characteristics of winter roost sites of burrowing owls in southern Texas were similar in many regards to characteristics of nest sites elsewhere, but a distinct difference in roost sites of burrowing owls wintering in southern Texas is that most were roadside culverts (R.G. Batey, U.S. Geological Survey, written commun., 2000; Jones, 2001; Williford, 2003; Williford and others, 2007). Few wintering burrowing owls in this study were detected at natural burrows, because access to grasslands in Texas, which are primarily in private ownership, is limited. In addition, many coastal prairies have been converted to agricultural production (Smeins and others, 1991). In these extensive agricultural areas, large burrowing mammals are not abundant, so natural burrows likewise are relatively uncommon. This could explain why burrowing owls wintering in southern Texas rely extensively on roadside culverts for roost sites. In contrast, breeding burrowing owls frequently use burrows abandoned by their former occupants, often prairie dogs or large ground squirrels (Thomsen, 1971; Martin, 1973; MacCracken and others, 1985; Thompson and Anderson, 1988; Haug and others, 1993; Desmond and Savidge, 1996).

The following characteristics were recorded for the forty-six roost sites that wintering burrowing owls occupied during the winter of 2001–02:

- Habitat type (tables 4, 5)—Forty (87 percent) roost sites were located in agricultural areas, and 37 (80 percent) were located along roads. Only three (6.5 percent) were on a barrier island, three (6.5 percent) were in grasslands, and none were in woodlands or shrubland. The high proportion of roost sites in agricultural areas resulted in part from how the owl search was conducted. Without access to private lands, researchers used public roads to search for owls and to follow up on sightings from the previous year. A few owls in this study were found to use roost sites in highly disturbed areas in housing-tract developments (see also Williford, 2003; Williford and others, 2007). This conforms to known use by burrowing owls of burrows in highly altered or fragmented environments, such as golf courses, cemeteries, airports, and partially developed residential areas (Haug and others, 1993; Millsap and Bear, 2000; Orth and Kennedy, 2001).

Table 4. Burrowing owl roost sites per each habitat type, southern Texas, 2001–02.

Habitat type	Total number of roost sites	Percentage of sites by habitat type
Barrier island	3	6.5
Agricultural land	40	87.0
Woodland/shrubland	0	0
Grassland	3	6.5

Table 5. Burrowing owl roost sites in agricultural land, southern Texas, 2001–02.

Habitat type	Total number of roost sites	Percentage of sites by habitat type
Grain	25	62.5
Cotton	5	12.5
Grain and cotton	1	2.5
Unknown	9	22.5

- Percent ground-cover (fig. 15)—Mean ground cover within a 10-m radius of 30 roost sites was 61 percent bare ground, whereas forbs, grass, and crop stubble all averaged between 11 and 16 percent of total ground cover. Only three roost sites had trees or shrubs within a 10-m radius. These results are comparable to previous studies conducted on breeding owls. Bare ground was also the dominant ground cover in Arizona (Estabrook, 1999). Most roost sites in this study were located in sparse vegetation in agricultural areas, similar to burrow locations in Idaho (Belthoff and King, 2002) and Colorado (Plumpton, 1992). In grasslands, breeding owls used sites that were intensively grazed by cattle or prairie dogs (MacCracken and others, 1985; Haug and others, 1993), approximating the short, sparse vegetation characteristic of shortgrass prairies. Burrowing owls breeding in Oregon (Green and Anthony, 1989) preferred reduced grass cover (and more bare ground) at their nesting burrows.

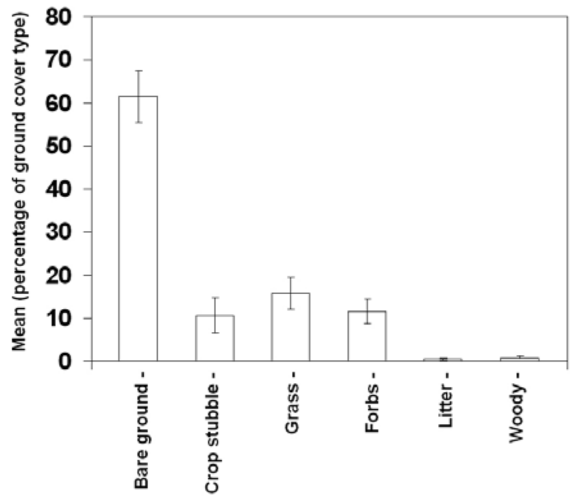

Figure 15. Ground-cover type within a 10-meter radius of burrowing owl roost sites, southern Texas, 2001–02.

- Roost site type (table 6)—Roost site types included 34 (74 percent) culverts, 5 (10.9 percent) natural burrows, 4 (9 percent) artificial burrows, and 3 (6.5 percent) "other" roost sites. The large number of culverts serving as roost sites was similar to results from the previous winter, when 57 of the 74 roost sites (77 percent) were roadside culverts. The small number of natural burrows used probably resulted from limited access to private lands, where most grassland roosts would be located. The "other" category included unusual roost sites, such as a pile of concrete rubble, an eroded area overhung by a concrete foundation slab, and oilfield equipment (fig. 16). Breeding owls also are known to use artificial burrows, and unusual roost sites have been documented regularly in Texas and elsewhere (Coulombe, 1971; Gleason and Johnson, 1985; Rich, 1986; Trulio, 1997; Ortega, 2003; Williford, 2003).

- Openings (table 7)—Of the 46 roost sites, 24 (52 percent) had two openings, 8 (17 percent) had one opening, and 7 (15 percent) had three openings. The maximum number of openings at any roost site was six. The mean diameter of roost site openings was 22 plus or minus ($\pm$) 1.5 cm standard error (*SE)* (range = 8 to 50 cm). Culvert diameters of all size classes were used in similar proportions; use of all size classes of culverts in southern Texas suggested that burrowing owls are opportunistic

Table 6. Roost site types used by wintering burrowing owls, southern Texas, 2001–02.

Roost site type	Number of roost sites	Percentage of roost sites by roost site type
Artificial burrow	4	8.7
Cast iron culvert	4	8.7
Concrete culvert	15	32.6
Steel culvert	15	32.6
Natural burrow	5	10.9
Other	3	6.5

(Williford, 2003; Williford and others, 2007), although the mean diameter for used culverts was relatively small. The mean diameter of burrows used by burrowing owls in southern Texas was similar to dimensions of prairie dog burrows used by burrowing owls wintering in Oklahoma (height, 10–23 cm; width, 10–20 cm) (Butts, 1976) and in Arizona (mean height, 23 cm; mean width, 26 cm) (Estabrook, 1999). Dimensions of nest burrows used by owls in Idaho were similar (height, 8–24 cm; width, 12–28 cm) (Belthoff and King, 2002), as were nest burrow dimensions in Arizona (mean height, 17 cm; mean width, 22 cm) (Estabrook, 1999). However, mean diameter (13 cm) of nest burrows in South Dakota was smaller (MacCracken and others, 1985). Artificial burrows used by burrowing owls for nesting (Smith and Belthoff, 2001a) and as winter roost sites (Ortega, 2003) also were smaller.

Figure 16. Owls sometimes select unusual roost sites such as this pump jack on an oilfield lease.

Table 7. Burrowing owl roost site size classes by diameter of opening, southern Texas, 2001–02.

[≤, less than or equal to; ≥, greater than or equal to; cm, centimeters]

Diameter size class	Number of roost sites	Percentage of total roost sites
Small (≤16 cm)	15	32.6
Medium (17–24 cm)	12	26.1
Large (≥25 cm)	16	34.8
Not determined	3	6.5

- Orientation (table 8)—The most frequent orientation of roost sites was east-west ($n = 17$; 37 percent), whereas the least frequent was north-south ($n = 6$; 13 percent). Roost sites oriented in an east-west direction offer greater protection from the effects of wind during the passage of winter cold fronts.

Table 8. Orientation of burrowing owl roost sites, southern Texas, 2001–02.

Roost site orientation	Number of roost sites	Percentage of total
East-west	17	37.0
North-south	6	13.0
Northeast-southwest	9	19.6
Northwest-southeast	10	21.7
Not determined	4	8.7

- Perch sites (table 9)—Twenty-nine (63 percent) of the 46 roost sites had fence posts and/or telephone poles within a 50-m radius. We assumed that burrowing owls would avoid such roost sites, because large raptors, such as red-tailed hawks (*Buteo jamaicensis*), known predators of burrowing owls (Leupin and Low, 2001), and white-tailed hawks (*B. albicaudatus*) often use these types of perches. However, large buteos might not be the main predators of burrowing owls in southern Texas and actually might deter northern harriers (*Circus cyaneus*) that frequent agricultural areas and are known also to prey on burrowing owls (Leupin and Low, 2001; pers. observ.). Interspecific aggression has been recorded between red-tailed and white-tailed hawks and northern harriers (Johnsgard, 1990). Some studies have shown that burrowing owls seem to prefer short perches, such as fence posts (fig. 17), perhaps to provide a good view of prey or approaching terrestrial predators (Green, 1983). However, only seven roost sites in our study had fence posts nearby.

Table 9. Perch types within 50 meters of known burrowing owl roost sites, southern Texas, 2001–02.

Type of perch	Total number of roost sites	Percentage of roost sites by perch type
Fence posts only	2	4.3
Highlines only	1	2.2
Telephone poles and highlines	22	47.8
Telephone poles, highlines, and fence posts	5	10.9
None	16	34.8

Culvert Selection

Characteristics of culverts occupied by burrowing owls (n = 34) were compared to characteristics of culverts unoccupied by burrowing owls (n = 100) using chi-square tests. Results showed that burrowing owls selected culverts with smaller diameter (≤16 cm) openings (χ^2 = 46.9, d.f. = 2, P <0.0001). Culverts with an east-west orientation were selected over those with other orientations (χ^2 = 9.15, d.f. = 3, P = 0.03). Culvert selection was not related to adjacent crop type (χ^2 = 3.57, d.f. = 2, P = 0.17). Burrowing owls selected roost sites without nearby fence posts (χ^2 = 18.84, d.f. = 1, P <0.0001) or telephone poles (χ^2 = 5.63, d.f. = 1, P = 0.0176).

Burrowing owl selection of culverts (Williford, 2003) and artificial burrows (Smith and Belthoff, 2001a; Ortega, 2003) with smaller diameters probably is a defense mechanism against large mammalian predators (Clayton and Schmutz, 1999). In Arizona, burrowing owls selected burrows that were larger than those available (Estabrook, 1999), but a random sample of burrows (mean height, 12 cm; mean width, 13 cm) must have included many that were too small for owls. Burrowing owl selection of culverts that primarily were oriented in an east-west direction could be related to wind effects created in north-facing culverts during the passage of winter cold fronts (see also Williford, 2003). In contrast, nest burrows of burrowing owls seemingly had no relationship to orientation per se (Coulombe, 1971; Martin, 1973; Rich 1986, Estabrook, 1999; Belthoff and King, 2002). Burrowing owls selected roost sites without nearby fence posts or telephone poles in this study, possibly because these platforms serve as perch sites for large raptors. Estabrook (1999) also showed that winter roost sites were associated with the absence of elevated perches. Other studies, however, have yielded conflicting results (Zarn, 1974; Green and Anthony, 1989), possibly because such elevated structures are useful to burrowing owls as perches from which to observe both potential prey and predators.

Figure 17. Sometimes burrowing owls hunt while perched on fence posts. Photo by Geoff Holroyd.

Roost Site Fidelity

Over the two winters of 2001–03, 14 burrowing owls were banded and monitored. All but one of the 14 owls remained at the same roost site or at a satellite roost site (within 100 m of the original roost site) throughout each of the two winters. The only exception was an owl which moved in February to a new roost site, approximately 1.5 kilometers (km) away from the original, then returned after 14 days. The temporary relocation was probably a result of disturbance caused by frequent monitoring and attempted re-trapping.

A juvenile burrowing owl banded the previous summer in Saskatchewan spent the winter of 2003–04 in southern Texas and returned to the same winter roost site the following winter (2004–05). Of the 15 banded burrowing owls (including the Canadian owl) monitored, 8 (53 percent) returned for a second winter (table 10). Three of the 15 owls (20 percent) returned for a third winter, and 2 owls (13 percent) returned for a fourth winter. One burrowing owl originally banded in 2001–02 returned for a fifth consecutive winter (table 10). Each owl that returned for a subsequent winter returned to the same roost site or a satellite used the year before. The use of one or more satellite roost sites within a short distance (usually ≤100 m) of the main roost site was typical and seems to be an important survival mechanism in the event of disturbance.

The high level of roost site fidelity exhibited by western burrowing owls in southern Texas has not been demonstrated before in winter. Individual burrowing owls return to the same prairie dog colonies and nesting burrows to breed (Martin, 1973; Lutz and Plumpton, 1999) and are known to re-use nesting burrows occupied in previous years (Rich, 1984; Lehman and others, 1998), especially those that produced young successfully. High fidelity for winter roost sites probably has equally significant implications for winter survival as strong fidelity for nesting sites has for productivity (Lutz and Plumpton 1999). Winter roost site fidelity may offer an opportunity

Table 10. Roost site fidelity of banded burrowing owls during winter, southern Texas, 2001–06.

[Letters refer to the leg band codes on banded burrowing owls; Band codes highlighted in yellow indicate wintering burrowing owls that returned to the same roost site in subsequent winters; --, not detected]

2001–02	2002–03	2003–04	2004–05	2005–06	Number of winters
EW	EW	--	--	--	2
EP	--	--	--	--	1
EU	--	--	--	--	1
EC	--	--	--	--	1
DA	DA	--	--	--	2
EE	EE	EE	EE	EE	5
--	EK	--	--	--	1
--	BU	--	--	--	1
--	BV	BV	BV	--	3
--	DB	DB[1]	--	--	2
--	EX	EX[1]	EX[1]	EX	4
--	EV	--	--	--	1
--	EZ	--	--	--	1
--	ED	ED	--	--	2
--	--	UW	UW	--	2

[1]Band code could not be read; ID based on roost location.

for managers to increase wintering owl populations by providing artificial burrows and/or protecting existing burrowing owl roost sites.

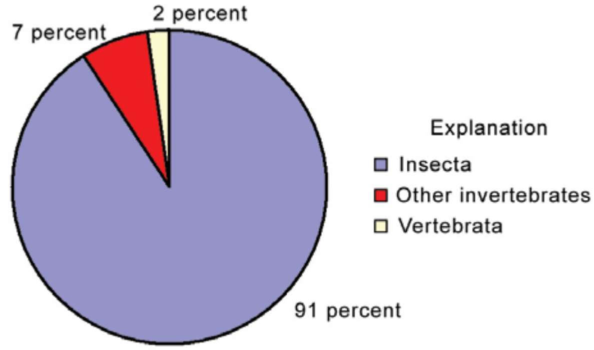

Figure 18. Prey items from burrowing owl pellets collected from southern Texas in winter, 1999–2000 and 2001–04. Crustaceans and spiders are in the "other" category.

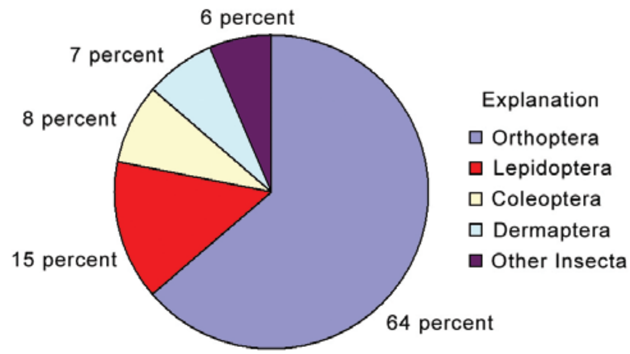

Figure 19. Insect prey items identified by order from burrowing owl pellets (n = 182) collected from southern Texas in winter, 1999–2004.

Diet

Numerically, insects were the dominant prey of burrowing owls, representing about 91 percent of all foods consumed during four winters (fig. 18). Crickets and grasshoppers were the most common type of insect consumed, representing >50 percent of the overall diet for the four winters combined (table 11) and 64 percent of all insects consumed (fig. 19). Orthopterans represented >60 percent of all foods in two winters, 1999–2000 and 2001–02, and >40 percent of all foods in a third winter, 2002–03, although they were only about 12 percent of owl foods in 2003–04. Table 11 shows annual variation in foods and the overall diet of burrowing owls from four winters in southern Texas.

For Orthopterans, frequency of occurrence (table 12) in owl pellets was (1) high (90 percent) for crickets (fig. 20*A*) over all winters, (2) relatively high (>40 percent) for short-horned grasshoppers during 2001–02 and 2002–03, and, (3) peaked sharply for long-horned grasshoppers in 2002–03. Other findings include (tables 11, 12):

- Caterpillars (fig. 20*B*) averaged about 13 percent of the diet, but annual variation was large. Most caterpillars could not be identified taxonomically beyond order; however, those identifiable to family belonged to the Noctuidae (moths). This level of consumption of Noctuidae and other lepidopteran caterpillars, some of which are major crop pests, has not been documented previously.
- Beetles from at least eight families composed about 8 percent of the diet, with no obvious large peaks in consumption during any of the winters, although frequency of occurrence of Carabidae beetles in owl pellets exceeded 50 percent in 2001–02 and 2002–03.
- Earwigs (fig. 20*C*) averaged about 6 percent of all prey. However, in two winters, 2002–03 and 2003–04, they represented about 16 percent of the diet. In one of those winters, 2002–03, the frequency of occurrence of earwigs in pellets was 62 percent, nearly twice that of the nearest value.
- Arachnids averaged about 7 percent of the diet and were relatively consistent among winters (range = 6–10 percent). Almost all Arachnids consumed were spiders (Order: Araneae). Frequency of occurrence of spider remains in owl pellets was relatively high (64 percent) for all winters combined.

Table 11. Prey items from 182 burrowing owl pellets collected during winter from southern Texas, 1999–2004.

[*n*, number of pellets sampled; %, percent; tr, trace amount (less than 0.1 present); --, not detected]

Prey item scientific name (common name)	Winters									
	1999–2000 (*n* = 28)		2001–02 (*n* = 95)		2002–03 (*n* = 47)		2003–04 (*n* = 12)		Total (*n* = 182)	
	Number of items	%[1]	Number of items	%	Number of items	%	Number of items	%	Number of items	%
Invertebrata										
Arachnida										
Araneae										
Lycosidae (wolf spiders)	71	10.1	265	6.0	156	7.0	12	8.0	504	6.8
Other[2]	2	0.3	2	tr	1	tr	--	--	5	tr
Crustacea										
Decapoda										
Ocypodidae (crabs)	--	--	1	tr	--	--	--	--	1	tr
Cambaridae (crayfish)	--	--	--	--	1	tr	--	--	1	tr
Insecta										
Orthoptera										
Gryllidae (crickets)	414	58.9	2,692	61.1	629	28.4	10	6.7	3,745	50.1
Acrididae (short-horned grasshoppers)	23	3.3	205	4.7	77	3.5	4	2.7	309	4.1
Tettigoniidae (long-horned grasshoppers)	11	1.6	44	1.0	211	9.5	4	2.7	270	3.6
Dermaptera										
Labiduridae (earwigs)	27	3.8	73	1.7	349	15.7	25	16.8	474	6.3
Hemiptera (true bugs)										
Lygaeidae (seed bugs)	--	--	--	--	17	0.8	--	--	17	0.2
Other[3]	--	--	2	tr	--	--	--	--	2	tr
Coleoptera (beetles)										
Carabidae (ground)	11	1.6	116	2.6	55	2.5	1	0.7	183	2.5
Elateridae (click)	--	--	7	0.2	6	0.3	1	0.7	14	0.2
Tenebrionidae (darkling)	--	--	72	1.7	3	0.1	--	--	75	1.0
Scarabaeidae (scarab)	2	0.3	49	1.1	4	0.2	--	--	55	0.7
Curculionidae (snout)	2	0.3	81	2.0	22	1.0	3	2.0	108	1.5
Other[4]	17	2.4	55	1.3	63	2.8	2	1.3	137	1.8
Lepidoptera										
Noctuidae (moth caterpillars)	9	1.3	118	2.7	29	1.3	37	24.7	193	2.6
Other[5]	6	0.9	410	9.3	379	17.1	--	--	795	10.6
Hymenoptera										
Formicidae (ants)	55	7.8	170	4.0	148	6.7	19	12.7	392	5.3
Other[6]	23	3.3	2	tr	--	--	--	--	25	0.3
Other Insecta	--	--	4	0.1	1	tr	--	--	5	0.1

Table 11. Prey items from 182 burrowing owl pellets collected during winter from southern Texas, 1999–2004.—Continued

[*n*, number of pellets sampled; %, percent; tr, trace amount (less than 0.1 present); --, not detected]

Prey item scientific name (common name)	Winters: 1999–2000 (*n* = 28) Number of items	%[1]	2001–02 (*n* = 95) Number of items	%	2002–03 (*n* = 47) Number of items	%	2003–04 (*n* = 12) Number of items	%	Total (*n* = 182) Number of items	%
Vertebrata										
Reptilia										
Serpentes (snakes)	--	--	1	tr	--	--	--	--	1	tr
Aves (birds)	3	0.4	5	0.1	8	0.4	1	0.7	17	0.2
Mammalia										
Insectivora										
Soricidae *Cryptotis parva* (least shrew)	4	0.6	1	tr	6	0.3	4	2.7	15	0.2
Rodentia										
Heteromyidae										
Perognathus merriami (Merriam's pocket mouse)	1	0.1	3	0.1	1	tr	--	--	5	0.1
Muridae										
Reithrodontomys fulvescens (fulvous harvest mouse)	1	0.1	4	0.1	25	1.1	1	0.7	31	0.4
Peromyscus maniculatus (deer mouse)	8	1.1	1	tr	2	0.1	5	3.3	16	0.2
Baiomys taylori (northern pygmy mouse)	6	0.9	7	0.2	17	0.8	8	5.4	38	0.5
Sigmodon hispidus (hispid cotton rat)	1	0.1	--	--	1	tr	--	--	2	tr
Mus musculus (house mouse)	--	--	2	tr	4	0.2	7	4.7	13	0.2
Other[7]	1	0.1	3	0.1	2	0.1	5	3.3	11	0.2
Other Vertebrata[8]	5	0.7	10	0.2	2	0.1	--	--	17	0.2
Total	703		4,405		2,219		149		7,476	

[1]Percentage of total prey item for all prey in pellets from each winter.

[2]Includes the orders Acarina (ticks and mites) and Scorpiones (scorpions).

[3]Hemipteran remains that could not be identified to family.

[4]Includes the families Passalidae, Chrysomelidae, and Bruchidae and Coleoptera (beetle) remains that could not be identified to family.

[5]Lepidoptera (caterpillars) remains that could not be identified to family.

[6]Hymenoptera remains that could not be identified to family.

[7]Rodent remains that could not be identified to genus or species.

[8]Includes remains of unidentified mammals and vertebrates.

Table 12. Frequency of occurrence (percent) of prey items in burrowing owl pellets collected during winter from southern Texas, 1999–2004.

[*n*, number of pellets sampled; --, not detected; tr, trace amount (less than 0.1 percent)]

Prey	Frequency of occurrence during winter (percent)				
Scientific name (common names)	1999–2000 (*n* = 28)	2001–02 (*n* = 95)	2002–03 (*n* = 47)	2003–04 (*n* = 12)	Total (*n* = 182)
Invertebrata					
Arachnida					
Acarina (ticks)	3.6	--	--	--	0.5
Scorpiones (scorpions)	3.6	2.1	2.1	--	2.2
Araneae (spiders)	60.7	68.4	68.1	25.0	64.3
Crustacea					
Decapoda	--	1.1	2.1	--	1.1
Ocypodidae (crabs)	--	1.1	--	--	0.5
Cambaridae (crayfish)	--	--	2.1	--	0.5
Insecta					
Orthoptera	89.3	98.9	91.5	66.7	93.4
Gryllidae (crickets)	89.3	98.9	78.7	66.7	90.1
Acrididae (short-horned grasshoppers)	32.1	44.2	42.6	16.7	40.1
Tettigoniidae (long-horned grasshoppers)	10.7	27.4	72.3	16.7	35.7
Dermaptera					
Labiduridae (earwigs)	25.0	32.6	61.7	33.3	39.0
Hemiptera (true bugs)	--	tr	6.4	--	2.2
Lygaeidae (seed bugs)	--	--	6.4	--	1.6
Other[1]	--	1.1	--	--	0.5
Coleoptera (beetles)	42.9	74.7	80.9	50.0	69.8
Carabidae (ground)	14.3	52.6	51.1	8.3	43.4
Elateridae (click)	--	6.3	8.5	8.3	6.0
Tenebrionidae (darkling)	--	17.9	6.4	--	11.0
Scarabaeidae (scarab)	7.1	12.6	4.3	--	8.8
Chrysomelidae (leaf)	--	tr	tr	--	tr
Bruchidae (seed)	--	tr	tr	--	tr
Curculionidae (snout)	3.6	16.8	23.4	16.7	16.5
Other[2]	28.6	16.8	40.4	16.7	24.7
Lepidoptera	28.6	47.4	68.1	58.3	50.5
Noctuidae (moth caterpillars)	21.4	34.7	17.0	58.3	29.7
Other[3]	7.1	36.8	63.8	--	36.8
Hymenoptera	53.6	37.9	51.1	50.0	44.5
Formicidae (ants)	50.0	35.8	51.1	50.0	42.9
Other[4]	3.6	2.1	--	--	1.6
Other Insecta	--	3.2	2.1	--	2.2

Table 12. Frequency of occurrence (percent) of prey items in burrowing owl pellets collected during winter from southern Texas, 1999–2004.—Continued

[*n*, number of pellets sampled; --, not detected; tr, trace amount (less than 0.1 percent)]

Prey	Frequency of occurrence during winter (percent)				
Scientific name (common names)	1999–2000 (*n* = 28)	2001–02 (*n* = 95)	2002–03 (*n* = 47)	2003–04 (*n* = 12)	Total (*n* = 182)
Vertebrata					
Reptilia					
Serpentes (snakes)	--	1.1	--	--	0.5
Aves (birds)	10.7	5.3	17.0	8.3	9.3
Mammalia					
Insectivora					
Cryptotis parva (least shrew)	7.1	1.1	8.5	25.0	5.5
Rodentia	46.4	20.0	59.6	83.3	38.5
Perognathus merriami (Merriam's pocket mouse)	3.6	3.2	2.1	--	2.7
Reithrodontomys fulvescens (fulvous harvest mouse)	3.6	4.2	29.8	8.3	11.0
Peromyscus maniculatus (deer mouse)	17.9	1.1	4.3	33.3	6.6
Baiomys taylori (northern pygmy mouse)	17.9	6.3	29.8	41.7	16.5
Sigmodon hispidus (hispid cotton rat)	3.6	--	2.1	--	1.1
Mus musculus (house mouse)	--	2.1	6.4	41.7	5.5
Other[5]	3.6	3.2	4.3	33.3	5.5
Other Mammalia[6]	10.7	8.4	2.1	--	6.6
Other Vertebrata[7]	7.1	2.1	2.1	--	2.7

[1]Hemiptera remains that could not be identified to family.

[2]Includes the family Passalidae and Coleoptera remains that could not be identified to family.

[3]Lepidoptera remains that could not be identified to family.

[4]Hymenoptera remains that could not be identified to family.

[5]Rodent remains that could not be identified to genus or species.

[6]Includes remains of unidentified mammals that could not be identified beyond class.

[7]Includes vertebrate remains that could not be identified to class or beyond.

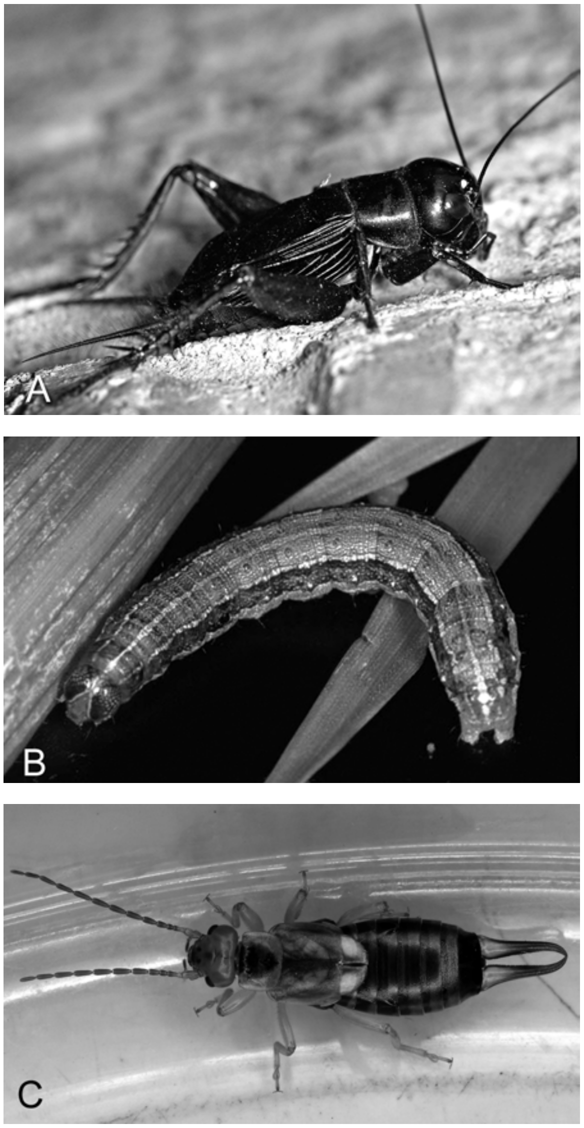

Figure 20. Insect prey. *A*, Crickets were the single most common prey in the western burrowing owl diet. *B*, Crop pests, such as this fall armyworm larva and other caterpillars, made up about 13 percent of the total number of items in the burrowing owl diet over four winters. Photo by Frank B. Peairs, Colorado State University. *C*, Earwigs varied significantly in importance in the burrowing owl diet over four winters in southern Texas.

Small mammals were the most important component of vertebrate prey of burrowing owls in winter (table 12). However, vertebrates represented only about 2 percent of all prey items consumed by burrowing owls (fig. 18). The most common vertebrate prey species were northern pygmy mice (*Baiomys taylori*) and fulvous harvest mice (*Reithrodontomys fulvescens*). Annual variation among winters was significant (table 11). Frequency-of-occurrence data (table 12) showed that small mammal remains occurred in about 40 percent of all owl pellets collected during this study.

As with all other aspects of the western burrowing owl's winter ecology, information on diet for comparison is limited; however, one recent investigation exists for the diet of burrowing owls wintering in Guanajuato, Mexico (Valdez Gómez, 2003). In that study, burrowing owls consumed mostly (78 percent) invertebrates. Importance of invertebrates (in percentage of total prey numbers) showed a gradual decline from October to March. Orthoptera was the single most important insect order in the diet of burrowing owls wintering in Mexico (Valdez Gómez, 2003), which agreed with data presented in this report for burrowing owls wintering in southern Texas. Small mammals were the second most important prey group for burrowing owls wintering in Mexico (Valdez Gómez, 2003), representing about 21 percent of all prey items consumed. This is similar to southern Texas data (20 percent) for the winter of 2003–04; however, the southern Texas data may be misleading, because only 12 pellets were collected that winter, all late in the season (when invertebrate populations would have been lower). Small mammals were consumed more by owls wintering in Mexico than by those wintering in southern Texas (this study), where they were only 2 percent of prey items consumed during all winters. The most common small mammals in the winter diet of burrowing owls in Mexico were deer mice (*Peromyscus maniculatus*) and Baird pocket mice (*Perognathus flavus*), whereas in this study, the two small mammal species consumed most frequently were pygmy mice and fulvous harvest mice.

In Argentina, South America, the winter diet of another subspecies of burrowing owl was about 80 percent invertebrates and 20 percent rodents (Bellocq, 1997) by numbers of prey, but prey biomass reversed the order of importance; rodents were about 90 percent of the biomass. It is common for small invertebrates to be emphasized in studies in which owl diets are expressed as percentage enumeration of prey items, and it is equally as common for less numerous, but larger, prey (such as rodents) to assume greater importance when owl diets are expressed as percentage biomass of prey items (for example, Marti, 1974). It is possible that use of percentage biomass of prey items in determining burrowing owl diet could yield biased results because large prey sometimes are not ingested entirely, and vertebrate prey consumed sometimes may be completely unrepresented in pellets (Grant, 1965; Southern, 1969; Marti, 1987).

The few published accounts of winter foods of burrowing owls in the United States are mostly qualitative or dated. Coulombe (1971) reported that earwigs were the major food item in the winter diet of burrowing owls in southern California, and important foods (as a percentage of occurrence and a percentage of volume) of owls wintering along the central coast of California were orthopterans, beetles, and small mammals, primarily California voles (*Microtus californicus*) (Thomsen 1971). Nonbreeding (including postbreeding resident, migrant, and wintering) burrowing owls in southern California were almost entirely insectivorous, consuming mostly orthopterans, earwigs, and beetles (York and others, 2002). Arthropods (primarily beetles and orthopterans) were about 78 percent of all prey items of wintering western burrowing owls in Oklahoma, whereas mammals represented nearly 22 percent of prey (Butts, 1973). Small vertebrates were found in about 85 percent of pellets from owls wintering in Oklahoma (Butts, 1973), and Tyler (1983) reported that the most important prey in winter (as a percentage of occurrence in pellets) in Oklahoma were orthopterans, beetles, and small mammals (primarily *Perognathus* spp., *Peromyscus* spp., and *Reithrodontomys* spp.).

The substantial body of literature that exists on the diet of breeding burrowing owls (Millsap and others, 1997) shows that diet results presented in this study are similar to those of many populations of breeding burrowing owls (for example, Marti, 1974; Gleason and Johnson, 1985; Thompson and Anderson, 1988; Green and others, 1993; Rodríguez-Estrella, 1997; Restani and others, 2001). Heavy consumption of certain insect foods in some winters during this study (for example, Gryllidae, Labiduridae, Lepidoptera) suggested that burrowing owls responded opportunistically to annual variation in insect abundances. The importance of invertebrate prey in the diet of burrowing owls in southern Texas may reflect greater abundance of these prey items in agricultural systems (Moulton, 2003) than in grasslands. Evidence also indicates that abundances of some small mammal species were greater in farmlands than in grasslands in Saskatchewan (Poulin, 2003), Idaho (Rich, 1986), and Oklahoma (Butts, 1973).

In Saskatchewan, deer mice were more abundant in farmlands and ditches, whereas meadow voles (*Microtus pennsylvanicus*) were more abundant in ditches, than was either species in native grasslands (Poulin, 2003). Large numbers of breeding burrowing owls were associated with elevated numbers of small mammals and ground-dwelling arthropods in Oklahoma (Butts, 1973), and reproductive success of burrowing owls has been shown to correspond with increased abundance and capture rates of small mammals (Poulin, 2003). If elevated populations of small mammals and invertebrate prey similarly occur in farmlands and ditches of southern Texas, this could explain the apparent presence of more burrowing owls in farmlands than in grasslands in winter.

Contaminants in Prey and Pellets

Concentrations of carbamate and organophosphate (OP) pesticides were low compared to lethal doses in both the invertebrate and regurgitated pellet samples collected for this study. However, all but three OP pesticides (Trichloronate, Stiriphos, and Tokuthion) of the twenty-eight pesticides analyzed were detected in samples (table 13). Both carbamates and OPs were detected more frequently in owl pellets than in the prey that were examined. There were no discernible trends in concentrations of carbamate and OP pesticides.

Restrictions on the use of synthetic organochlorine pesticides, because of their persistence, bioconcentration in food chains, and toxicity, have led to increased use of carbamate and OP pesticides. Smith (1987) estimated that over 89 million acre-treatments of carbamate and OP pesticides were applied annually to farmlands, rangelands, and forests of the United States. Carbamate and OP pesticides pose risks to wildlife through the interaction of several variables, including the toxicity of the compound, persistence of the parent compound in the environment, magnitude and frequency of application over time, the presence of toxic metabolites, and the degree of bioaccumulation in food chains (Smith, 1987). These factors interact with feeding habits and behavioral ecology to produce lethal, sublethal, or no-effect responses in exposed individuals. Although carbamate and OP pesticides generally are perceived as less environmentally hazardous than their predecessor organochlorine pesticides, bird kills and indirect effects on avian species have been documented as a result of carbamate and OP pesticide use (Smith, 1987; Cox, 1991; Haug and others, 1993; Fluetsch and Sparling, 1994).

Concentrations of carbamate and OP pesticides in representative prey and pellets were considerably less than known lethal doses for other species of birds (Smith, 1987). Concentrations of the carbamate carbofuran in the prey and pellet samples analyzed were considerably less than levels implicated in mortality and reduced reproductive success of burrowing owls (James and Fox, 1987; Fox and others, 1989) when this insecticide was sprayed directly over nest burrows. Some evidence suggests that pesticide interactions will lead to greater deleterious effects on populations of burrowing owls (James and Fox, 1987), so the rich mixture of chemicals (including organochlorines, herbicides, and defoliants) to which burrowing owls in southern Texas are exposed is a concern. Sublethal effects of these pesticides on burrowing owls are unknown, as are the synergistic effects of various chemicals showing up in different food sources.

Body Mass, Structural Size, and Ectoparasites

The mean of 31 body mass measurements from 25 western burrowing owls (some of the banded owls were captured more than once) was 167.9 g (standard deviation = 18.3). Some owls were trapped before or after the winter period (that is, before or after the period of November 15 to February 15), however, only masses from banded owls known to have over-wintered were used in the analysis. No significant difference ($F = 0.15$; d.f. = 1,29; $P = 0.70$) in body mass existed between owls wintering at roost sites in grasslands and in agricultural areas. Likewise, no significant difference ($F = 0.17$; d.f. = 1,29; $P = 0.68$) in body mass was detected between owls trapped in early winter (October 15 to December 31) and those trapped in late winter (January 1 to March 15). However, a quadratic effect over the course of the winter was significant ($F = 4.31$; d.f. = 2,28; $P = 0.02$) for variation in body mass, with higher body masses occurring during midwinter (fig. 21).

The mean body mass of western burrowing owls is reported often as approximately 150 g (for example, Imler, 1937; Earhart and Johnson, 1970; Sibley, 2000; Klute and others, 2003). Oberholser (1974) reported that the mean mass

Table 13. Carbamate and organophosphate pesticide concentrations in prey and regurgitated pellet samples of wintering burrowing owls in southern Texas, 2001–02.

[µg/g, micrograms per gram; ND, not detected; ng/g, nanograms per gram]

	Sample type, sampling site (fig. 5), and concentration								
	Spiders Site 14	Crickets Site 4	Grass-hoppers Site 4	Earwigs Site 14	Crickets Site 14	Pellets Site 9a	Pellets Site 9b	Pellets Site 14	Pellets Site 34
Carbamate pesticides (µg/g, wet weight)									
3-OH-carbofuran	ND	ND	ND	ND	2.36	ND	ND	ND	ND
Aldicarb (Temik)	ND	ND	ND	ND	ND	5.74	[1]0.37	[1]0.23	[1]0.84
Aldicarb sulfone	ND	ND	ND	ND	ND	ND	ND	[1]0.12	ND
Carbaryl (Servin)	ND	ND	ND	ND	[1]0.72	ND	[1]0.77	[1]0.16	2.08
Carbofuran (Furadan)	ND	ND	ND	ND	3.64	1.06	[1]0.40	ND	[1]0.51
Methiocarb (Mesurol)	ND	ND	ND	ND	4.74	ND	[1]0.71	[1]0.76	ND
Methomyl (Lannate)	ND	ND	ND	ND	2.34	ND	ND	[1]0.02	ND
Promecarb	ND	ND	ND	ND	ND	ND	ND	[1]0.64	ND
Propoxur (Baygon)	ND	ND	ND	ND	[1]0.56	1.06	[1]0.40	[1]0.51	[1]0.51
Organophosphate pesticides (ng/g, wet weight)									
Bolstar sulfone	ND	ND	96.9	ND	ND	55.7	ND	101.1	164.1
Chlorpyrifos	ND	ND	ND	ND	ND	139.6	ND	ND	ND
Coumaphos	ND	ND	ND	78.6		27.6	ND	ND	ND
Demeton-O	238.2	340.1	ND	ND	ND	69.3	ND	60.0	56.5
Demeton-S	3.9	ND	5.2	ND	ND	ND	4.5	3.1	4.5
Diazinon	5.1	6.4	3.0	6.8	ND	5.5	5.4	2.9	6.7
Dichlorovos	6.4	8.0	1.5	3.2	33.5	16.0	1.7	1.2	8.0
Disulfoton	2.4	ND	0.5	ND	ND	2.0	1.6	3.1	6.1
Ethoprop	ND	8.3	12.7	2.4	ND	18.2	2.5	5.1	1.4
Fenthion	ND	ND	ND	ND	ND	ND	5.1	13.0	10.5
Methyl-azinphos	21.6	102.0	48.2	184.1	ND	66.5	30.4	35.6	33.2
Methyl parathion	69.8	64.1	59.5	12.0	ND	115.9	20.3	71.0	41.8
Mevinphos	4.0	5.1	1.6	21.1	ND	3.7	0.4	0.8	0.6
Naled	12.9	ND	ND	ND	ND	24.0	ND	ND	ND
Phorate	13.9	30.3	7.0	3.1	ND	10.7	14.3	19.2	22.0
Ronnel	10.9	1.9	1.4	6.0	18.4	1.5	2.2	0.5	1.2
Stiriphos	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tokuthion	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloronate	ND	ND	ND	ND	ND	ND	ND	ND	ND

[1]Less than minimum detection limit of analytical method.

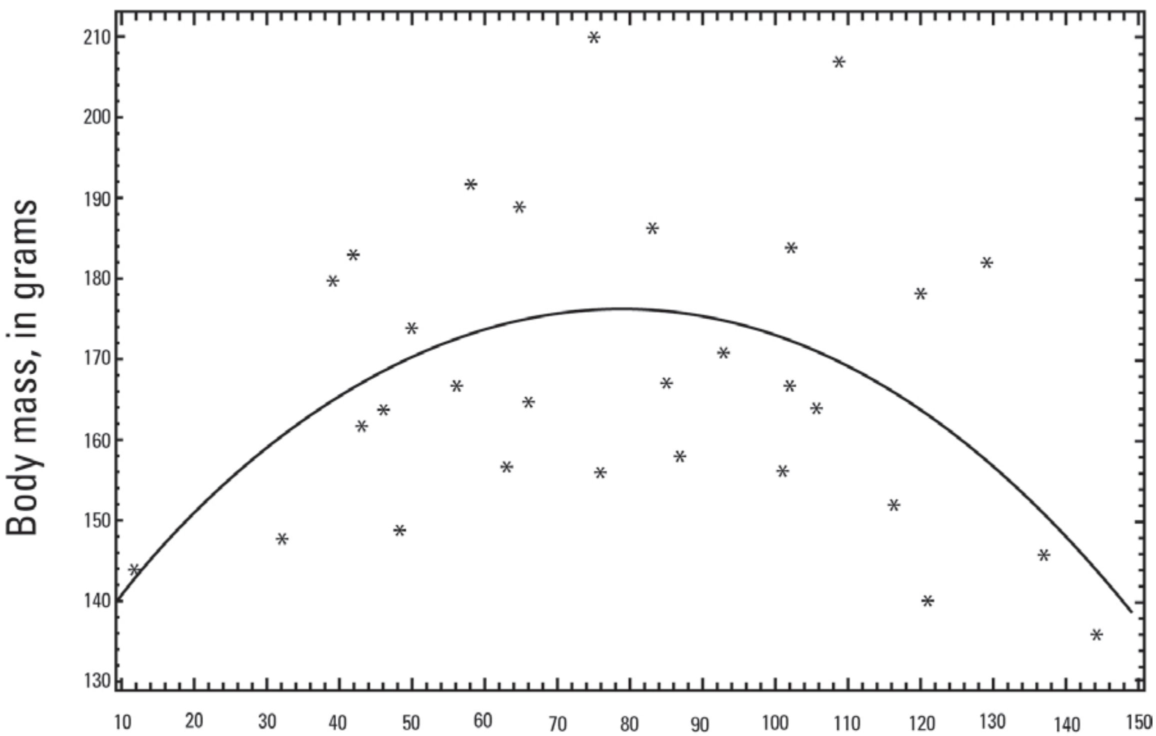

Figure 21. Body masses of burrowing owls wintering in southern Texas, 2000–05. “Winter date” is the continuous range of dates where 1 = October 15.

for Texas birds was about 175 g. Relatively little, however, has been published on variation in body masses of burrowing owls (but see Earhart and Johnson, 1970). Consequently, few data are readily available with which to compare different populations of burrowing owls or to assess changes in body mass over time.

Mean body mass (167.9 g) of burrowing owls wintering in southern Texas (this study) and in the Texas Panhandle (165.0 g; n = 15) (Teaschner, 2005) exceeded the mean body mass (149.6 g; n = 81) of burrowing owls wintering in Mexico (G.L. Holroyd, unpub. data, 2005). However, burrowing owls wintering in California were heavier (186.0 g) (Coulombe, 1970). Burrowing owls wintering in Texas were heavier than those breeding in Colorado, California, Texas, and Alberta, but mean body masses of owls wintering in Texas and breeding in Saskatchewan appeared to be similar (Plumpton, 1992; Plumpton and Lutz, 1994; Teaschner, 2005). These data suggest that burrowing owls in northern portions of their breeding and wintering ranges may exhibit the greatest mean body masses, although data from different populations during different years must always be interpreted cautiously.

Coulombe (1970) reported variation in body mass of burrowing owls between summer and winter within the same population of California owls. The California owls underwent a 27 percent weight gain from 147 g in summer to 186 g in winter. Variation in body mass of burrowing owls in winter is documented for the first time in the present study. The curvilinear relation between body mass and days of winter implies that burrowing owls arrived on the winter range in lean condition, and then began adding fat until reaching a midwinter maximum body mass, after which they began losing mass. By late winter, mean body mass was approximately equal to that of early arrivals in the fall. This pattern runs counter to that exhibited by some birds, which accumulate fat and become heavier as they prepare for migration and/or breeding (for example, McLandress and Raveling, 1981; Nicoletti and others, 2005). It could indicate that colder temperatures in December and January depress insect activity and availability, causing burrowing owls, which consume large numbers of insects, to lose body mass during the remainder of the winter.

Data on temporal changes in body mass of owls and other raptors during winter are rarely available. However, Henny and Van Camp (1979) found that Eastern screech-owls (*Otus asio*) in Ohio weighed less in late winter (January to February) than in early winter (October to December) and considered the early winter peak to be a result of increased fat reserves, an aid to winter survival. Smallwood (1987) reported that three consecutive days of cold weather (<0 ^{o}C) in Florida, which depressed insect activity and availability, caused wintering American kestrels (*Falco sparverius*) to lose body mass, although the loss was significant only for males. Northern hawk owls (*Surnia ulula*) captured in Minnesota in February averaged heavier weights than those captured in December (Nicoletti and others, 2005). Although conducted over only one winter, the Minnesota study provides strong evidence that hawk owls are able to fare well in winter. These contrasting examples of winter body mass changes may imply that small raptors (such as burrowing owls, American kestrels, and Eastern screech-owls) are affected more by reduced food resources in winter than are larger raptors. Dunning (1985) observed that wide ranges in body weight values occur more often in small owls than in large owls.

A summary of body size measures is shown in table 14. Although reports of variation in measures of structural size of burrowing owls exist, several reasons cause direct comparisons of southern Texas results with these other datasets to be problematic. Earhart and Johnson (1970) reported unflattened wing length for museum specimens (67 males, 36 females), but this was a pooled sample from multiple collecting locations. Plumpton and Lutz (1994) summarized measures of central rectrix length, unflattened wing length, and tarsometatarsus length for male and female western burrowing owls breeding in Colorado. Measures of unflattened wing length and tail length were provided by K.M. Clayton and others (unpub. data, 2006) for male and female burrowing owls in Florida, California, Colorado, Alberta, and Saskatchewan, but, once again, these were all breeding birds. Teaschner (2005) reported a large database of measures of tarsus width, tarsus depth, and wing chord for male and female western burrowing owls from the Texas Panhandle, but all except 15 were for breeding birds.

Table 14. Means and standard errors of measures of structural size of burrowing owls in southern Texas, 2000–05.

[mm, millimeters; n, sample size]

Variable	Mean (mm)	*n*	Standard error
Wing flattened	177.4	25	1.1
Wing unflattened	173.9	25	1.1
Tarsus length	55.7	15	1.6
Tarsus diameter	4.8	15	0.1
Tail length	84.7	17	1.1
Culmen length	14.0	14	0.3
Body length	210.4	16	1.8

The summary statistics reported in table 14 are for wintering birds, thus, because of differential feather wear for breeding and wintering birds, it is not possible to compare the data from this study with most of the existing data for structural size of burrowing owls. In addition, results presented herein are for birds of undetermined sex and age, which also makes comparisons of the data for winter birds with existing data for breeding birds difficult to interpret. Because of these concerns, the authors chose not to make direct comparisons of measures of structural size of burrowing owls.

Of the 25 burrowing owls captured, 15 were examined for ectoparasites. Only four were found to be lightly infected with lice, and none had fleas, ticks, mites, or wingless diptera. The lice included two of the three genera of chewing feather lice (formerly Order: Mallophaga) (Integrated Taxonomic Information System, 2004) known to parasitize owls (Clayton, 1990). A total of eight ectoparasites representing two species of feather lice were found. Four *Colpocephalum pectinatum* (Order: Phthiraptera, Suborder: Amblycera, Family: Menoponidae) were collected from three owls. Four *Strigiphilus speotyti* (Order: Phthiraptera, Suborder: Ischnocera, Family: Philopteridae) were found on three owls. Both species were found on two burrowing owls, and the maximum number of lice found per bird was three. One owl was captured twice (each of the two winters) and had the same number (one) and species (*S. speotyti)* of louse found upon each capture.

Based on Smith's (1999) classification, all of the owls in southern Texas had an infestation level of "low" ($\leq$5 individual parasites). Other reports of ectoparasites and burrowing owls are limited (see also Skoruppa and others, 2006). Smith and Belthoff (2001b) collected a total of 8 *S. speotyti* lice and 143 fleas from 11 adults and 4 broods of burrowing owls in Idaho, and Thomsen (1971) stated that some of the burrowing owls in California carried "a few" *C. pectinatum* lice. In contrast, more than 40 lice were found on a single burrowing owl in southwestern Idaho (Smith, 1999), and about 55 lice were collected from a single owl in California (Stoner, 1932).

Nesting burrowing owls may be more susceptible to ectoparasite infestations than wintering burrowing owls. Underground burrows provide favorable environmental conditions for parasites (Kennerly, 1964), and burrowing owl use of burrows excavated within colonies of prairie dogs and ground squirrels facilitates transfer of fleas among rodents and birds (Philips and Dindal, 1977). Burrowing owl nests harbor at least 39 arthropod species, a minimum of 15 of which are fleas (Philips and Dindal, 1977). Of six published studies on burrowing owl parasites, lice were reported in at least four, and fleas were reported in five of the six studies (Hubbard, 1968; Thomsen, 1971; Philips and Dindal, 1977; Baird and Saunders, 1992; Smith and Belthoff, 2001b). Only burrowing owls in Oklahoma were found to be free of fleas (Tyler and Buscher, 1975).

The absence of fleas on captured burrowing owls may be attributable to the fact that 13 of the 15 owls captured (87 percent) were roosting at road culverts. Because mammals in the area are not known to use road culverts regularly as burrow sites, the culverts probably did not harbor large flea populations. Moreover, unlike nesting burrowing owls, wintering burrowing owls do not roost inside their burrows. Most burrowing owls in southern Texas roost at the entrances to their burrows and enter the interiors only for protection from inclement weather or to avoid avian predators.

Wide dispersal on the winter range also may limit greatly the incidence of ectoparasite transfer between burrowing owls, as winter roost sites in southern Texas are scattered throughout open areas. It is not uncommon to drive more than 1 km to observe two burrowing owls. In contrast, breeding burrowing owls frequently form aggregations because of their close association with burrows in colonies of prairie dogs and ground squirrels (Butts, 1973; Desmond and others, 1995; Desmond and Savidge, 1996). This semicolonial social organization and association with colonies of burrowing mammals during the breeding season is much more conducive to flea infestations.

Although sample size is small, the low numbers of lice and the lack of fleas in this study of burrowing owls wintering in southern Texas indicate that the winter habits (that is, use of widely dispersed road culverts instead of natural mammal burrows) may be advantageous in avoiding ectoparasites, especially fleas (Skoruppa and others, 2006).

Summary and Conclusions

The western burrowing owl is a small, ground-dwelling, grassland bird of western North America that traditionally uses abandoned burrows of prairie dogs, ground squirrels, and other burrowing animals as summer nesting and winter roost sites. In the latter half of the 20th century, owl populations began to show evidence of decline, and the historical breeding range contracted, especially at the northern limits in the prairie provinces of Canada and at the eastern limits of the Great Plains in the United States. The western burrowing owl was classified as federally threatened in Mexico in 1994, federally endangered in Canada in 1995, and as a National Bird of Conservation Concern by the U.S. Fish and Wildlife Service in 2002. The Commission for Environmental Cooperation of the North American Free Trade Agreement selected the western burrowing owl as one of only three terrestrial animals for the first transboundary North American Conservation Action Plan. There is a substantial gap in information about the winter phase of the western burrowing owl's annual life cycle.

The USGS designed a study through its Species at Risk Program to help close the knowledge gap about the western burrowing owl's winter ecology and to provide the scientific information needed by resource managers to conserve and protect the species. The USGS collaborated with the Canadian Wildlife Service and Texas A&M University–Corpus Christi to study the winter ecology of the western burrowing owl from 1999–2004 in a five-county area in southern Texas. Three literature sources and one museum record of an egg set (collected in the 1920s) indicated that burrowing owls formerly bred in southern Texas. Sometime in the first half of the 20th century, however, records for breeding burrowing owls in southern Texas ceased to exist, but they continue to migrate there for the winter.

Two years of searching for owls and roost sites during 2000–01 and 2001–02 resulted in 74 sightings the first winter and 46 the second. The larger number was due to an extensive outreach effort that resulted in 30 owl sightings by the public, a 68 percent increase directly attributable to public outreach.

Installation of artificial burrows (n = 72) at four grassland sites was the first experiment of its kind to be conducted exclusively for wintering burrowing owls. The artificial burrows were constructed from two- or three-opening drainage pipe; the openings had diameters of 15, 20, or 25 cm. The owls were detected 58 times at two of the four sites; 46 of these detections (79 percent) were at pipes with 15-cm diameter openings, and 39 (67 percent) were at pipes with two openings. This study showed that owls prefer burrows with small (15-cm diameter) openings.

Characteristics of burrowing owl winter roost sites were documented. Fifty-seven of 74 roost sites (77 percent) were located at road culverts the first winter, and 34 of 46 (74 percent) were at road culverts the second winter. The roost sites were located primarily in agricultural lands, and bare ground comprised 61 percent of ground-cover composition within a 10-m radius of roost sites. In the second winter, 34 occupied culverts were compared to 100 unoccupied culverts to determine characteristics used by the owls to select culverts. The owls preferred culverts with ≤16 cm diameter openings, east-west orientations, and absence of nearby perch sites.

Fifteen banded burrowing owls were monitored for roost site fidelity. All remained at the same roost site throughout the winter, except for one that was disturbed but returned 2 weeks later. Eight (53 percent) returned to the same roost site for a second winter, three (20 percent) returned for a third winter, and two (13 percent) returned for a fourth winter.

For the diet component of the study, regurgitated pellets (n = 182) from 4 winters were examined. Insects were 91 percent of all prey items, including crickets and grasshoppers (58 percent), caterpillars (13 percent), and beetles (8 percent). Vertebrates in the diet were 2 percent of prey items; most of these were small mammals, especially northern pygmy mice and fulvous harvest mice.

This study was the first to quantify pesticides in the owl's winter diet. Prey items and pellets were analyzed for 9 carbamate and 19 organophosphate pesticides. All but three compounds were detected at least once, though concentrations of all pesticides in all samples were less than known lethal doses for birds. Some evidence suggests that pesticide interactions will lead to greater deleterious effects on burrowing owl populations (James and Fox, 1987). Another concern is that some of the prey items consumed by the western burrowing owl are agricultural pests, which are specifically targeted with carbamate and organophosphate pesticides, so application of these chemicals to control crop pests could affect burrowing owls. Sublethal effects of these pesticides on the western burrowing owl are unknown. Additional studies on sources of the pesticides and sublethal and synergistic effects could prove valuable in understanding if pesticide contamination is contributing to the decline of the species.

Body mass measurements (n = 31) resulted in a mean of 167.9 g with no significant difference between owls trapped in early winter (October 15 to December 31) and those trapped in late winter (January 1 to March 15). However, body mass varied nonlinearly over the course of the winter, with maximum body masses occurring during midwinter. This demonstrates that the owls probably had adequate quantities of prey when they arrived at winter roost sites, but the prey availability declined toward the end of winter. Additional research on over-winter changes in body mass during the course of several winters could provide additional information for wildlife management. Integration of long-term research on variation in body mass, population dynamics of prey, weather fluctuations, and winter survival could be used to determine if burrowing owls and other small, primarily insectivorous raptor species may face "ecological crunches" in winter that affect winter mortality and reproductive success in subsequent breeding seasons. This research could include work to improve capture techniques during winter, when owls are not trapped as reliably as they are during the breeding season.

This study also provides baseline data on the owls' body size, including wing length (flattened and unflattened), culmen length, tarsus length, tarsus diameter, body length (top of head to tip of tail), and tail length. The owls were also examined for ectoparasites. Four of the 15 burrowing owls (27 percent) had feather lice (*Colpocephalum pectinatum* and/or *Strigiphilus speotyti*). However, of the four owls with lice, the maximum number found per bird was three. No fleas or other ectoparasites were found on wintering burrowing owls. This probably indicates that man-made culverts, unlike nesting burrows, do not harbor large flea populations.

Results of this study provide scientific information on the winter ecology of the western burrowing owl in southern Texas. The western burrowing owl selects road culverts in agricultural fields as substitutes for mammal burrows and also will use areas populated by humans. This adaptability is apparent in the owl's willingness to inhabit artificial burrows made from drainage pipe, if the surrounding environment is mowed or grazed grassland. The owl prefers two-hole burrows with small ($\leq$16 cm) diameters, probably as protection against avian and mammalian predators. It also seems to prefer burrows with openings facing east-west for protection from the adverse winter weather.

The study provides information for resource managers to use in conserving and protecting the species. The willingness of the public to participate in owl conservation could be expanded upon by encouraging the installation of artificial burrows on private lands. Because the western burrowing owl exhibits strong fidelity for winter roost sites, managers (and private property owners who want to "adopt-an-owl") may increase survival of this species by placing artificial burrows in protected areas with high-quality habitat. Good target areas for artificial burrow installation would be grazed or mowed grasslands and farmlands with remaining tracts of grass that currently have, or had in the recent past, winter populations of western burrowing owls. Future research direction could include investigations of wintering burrowing owl body mass changes in relation to fluctuations in prey availability within grassland and agricultural habitats in winter. Research on the effects of low-level exposure to agricultural pesticides is also important to consider.

References

Baird, C.R., and Saunders, R.C., 1992, An annotated checklist of the fleas of Idaho (*Siphonaptera*): Idaho Agricultural Experiment Station and University of Idaho College of Agriculture Research Bulletin, no. 148, 34 p.

Beckham, C.W., 1887, Observations on the birds of southwestern Texas: Proceedings of the U.S. National Museum, v. 10, p. 633–696.

Bellocq, M.I., 1997, Ecology of the burrowing owl in agrosystems of central Argentina, *in* Lincer, J.L., and Steenhof, K., eds., 1997, The burrowing owl, its biology and management—including the proceedings of the first international burrowing owl symposium, Seattle, Wash., 1992: Raptor Research Foundation, Raptor Research Report No. 9, p. 52–57.

Belthoff, J.R., and King, R.A., 2002, Nest-site characteristics of burrowing owls (*Athene cunicularia*) in the Snake River Birds of Prey National Conservation Area, Idaho, and applications of artificial burrow installation: Western North American Naturalist, v. 62, p.112–119.

Benson, K.L.P., and Arnold, K.A., 2001, The Texas breeding bird atlas: Texas A&M University System, College Station and Corpus Christi, Tex., accessed January 24, 2007, at URL *http://txtbba.tamu.edu*.

Botelho, E.S., and Arrowood, P.C., 1998, The effect of burrow site use in the reproductive success of a partially migratory population of western burrowing owls (*Speotyto cunicularia hypugaea*): Journal of Raptor Research, v. 32, p. 233–240.

Butts, K.O., 1973, Life history and habitat requirements of burrowing owls in western Oklahoma: Stillwater, Okla., Oklahoma State University, Masters of Science thesis, 188 p.

Butts, K.O., 1976, Burrowing owls wintering in the Oklahoma panhandle: The Auk, v. 93, p. 510–516.

Carroll, J.J., 1900, Notes on the birds of Refugio County, Texas: The Auk, v. 17, p. 337–348.

Chapman, F.M., 1891, On the birds observed near Corpus Christi, Texas, during parts of March and April, 1891: Bulletin of the American Museum of Natural History, v. 3, p. 315–328.

Clayton, D.H., 1990, Host specificity of *Strigiphilus* owl lice (*Ischnocera: Philopteridae*), with the description of new species and host associations: Journal of Medical Entomology, v. 27, p. 257–265.

Clayton, K.M., and Schmutz, J.K., 1999, Is the decline of burrowing owls *Speotyto cunicularia* in prairie Canada linked to changes in Great Plains ecosystems?: Bird Conservation International, v. 9, p. 163–185.

Collins, C.T., and Landry, R.E., 1977, Artificial nest burrows for burrowing owls: North American Bird Bander, v. 2, p. 151–154.

Commission for Environmental Cooperation, 2004, North American Conservation Action Plan: Montreal (Quebec), Canada, ISBN 2-923358-24-4, accessed August 28, 2006, at URL *http://www.cec.org/*.

Coulombe, H.N., 1970, Physiological and physical aspects of temperature regulation in the burrowing owl (*Speotyto cunicularia*): Comparative Biochemistry and Physiology, v. 35, p. 307–337.

Coulombe, H.N. 1971, Behavior and population ecology of the burrowing owl (*Speotyto cunicularia*) in the Imperial Valley of California: Condor, v. 73, p. 162–176.

Cox, C., 1991, Pesticides and birds—from DDT to today's poisons: Journal of Pesticide Reform, v. 11, p. 2–6.

Desmond, M.J., and Savidge, J.A., 1996, Factors influencing burrowing owl (*Speotyto cunicularia*) nest densities and numbers in western Nebraska: American Midland Naturalist, v. 136, p. 143–148.

Desmond, M.J., Savidge, J.A, and Eskridge, K.M., 2000, Correlations between burrowing owl and black-tailed prairie dog declines—a 7-year analysis: Journal of Wildlife Management, v. 64, p. 1,067–1,075.

Desmond, M.J., Savidge, J.A., and Seibert, T.F, 1995, Spatial patterns of burrowing owl (*Speotyto cunicularia*) nests within black-tailed prairie dog (*Cynomys ludovicianus*) towns: Canadian Journal of Zoology, v. 73, p. 1,375–1,379.

Dowdy, S., and Wearden, S., 1983, Statistics for research: New York, John Wiley & Sons, Inc., 554 p.

Dresser, H.E., 1865-1866, Notes on the birds of southern Texas: Ibis, v. 1, p. 312–330 and 466–495; v. 2, p. 23–46.

Drost, C.A., and McCluskey, R.C., 1992, Extirpation of alternative prey during a small rodent crash: Oecologia, v. 92, p. 301–304.

Dunning, J.B., Jr., 1985, Owl weights in the literature—a review: Raptor Research, v. 19, p. 113–121.

Earhart, C.M., and Johnson, N.K., 1970, Size dimorphism and food habits of North American owls: Condor, v. 72, p. 251–264.

Estabrook, T.S., 1999, Burrow selection by burrowing owls in an urban environment: Tucson, Ariz., University of Arizona, Master of Science thesis, 60 p.

Fluetsch, K.M., and Sparling, D.W., 1994, Avian nesting and diversity in conventionally and organically managed apple orchards: Environmental Toxicology and Chemistry, v. 13, p. 1,651–1,659.

Fox, G.A., Mineau, P., Collins, B., and James, P.C., 1989, The impact of the insecticide carbofuran (Furadan 480F) on the burrowing owl in Canada: Canadian Wildlife Service Technical Report, no. 72, 21 p.

Geochemical and Environmental Research Group, 1992, Analysis of organophosphorus compounds by capillary gas chromatography: Standard Operating Procedure, no. 9217, 20 p.

Gleason, R.S., and Johnson, D.R., 1985, Factors influencing nesting success of burrowing owls in southeastern Idaho: Great Basin Naturalist, v. 45, p. 81–84.

Government of Canada, 2006, Species at risk—Committee on the Status of Endangered Wildlife in Canada (COSEWIC), accessed July 23, 2006, at URL *http://www.sararegistry.gc.ca/species/default_e.cfm*.

Grant, R.A., 1965, The burrowing owl in Minnesota: The Loon. v. 37, p. 2–17.

Green, G.A., 1983, Ecology of breeding burrowing owls in the Columbia Basin, Oregon: Corvallis, Oreg., Oregon State University, Master of Science thesis, 51 p.

Green, G.A., and Anthony, R.G., 1989, Nesting success and habitat relationships of burrowing owls in the Columbia Basin, Oregon: Condor, v. 91, p. 347–354.

Green, G.A., Fitzner, R.E., Anthony, R.G., and Rogers, L.E., 1993, Comparative diets of burrowing owls in Oregon and Washington: Northwest Science, v. 67, p. 88–93.

Hatch, S.L., Schuster, J.L., and Drawe, D.L., 1999, Grasses of the Texas gulf prairies and marshes: College Station, Tex., A&M University Press, 355 p.

Haug, E.A., Millsap, B.A., and Martell, M.S., 1993, Burrowing owl (*Speotyto cunicularia*) *in* Poole, A., and Gill, F., eds., The Birds of North America, no. 61, The Academy of Natural Sciences, Philadelphia: Washington, D.C., The American Ornithologists' Union, 20 p.

Henny, C.J., and Van Camp, L.F., 1979, Annual weight cycle in wild screech owls: The Auk, v. 96, p. 795–796.

Holroyd, G.L., Rodríguez-Estrella, R., and Sheffield, S.R., 2001, Conservation of the burrowing owl in western North America—issues, challenges, and recommendations: Journal of Raptor Research, v. 35, p. 399–407.

Holroyd, G. L., and Trefry, H., 2002, Conservation and protection of wintering habitat of burrowing owls (*Athene cunicularia*) in Texas and Mexico: Edmonton, Canada, Beaverhill Bird Observatory and Canadian Wildlife Service, Final Rep., submitted to National Fish and Wildlife Foundation, 27 p.

Hubbard, C.A., 1968, Fleas of western North America—their relation to the public health: New York, Hafner Publishing Company, 533 p.

Imler, R.H., 1937, Weights of some birds of prey of western Kansas: Bird-banding, v. 8, p. 166–169.

Integrated Taxonomic Information System, 2004, accessed February 19, 2005, at URL *http://www.itis.usda.gov/access.html*.

Integrated Taxonomic Information System, 2006, accessed July 24, 2006, at URL *http://www.itis.usda.gov*.

Jahrsdoerfer, S.E., and Leslie, D.M., Jr., 1988, Tamaulipan brushland of the lower Rio Grande Valley of south Texas—description, human impacts, and management options: U.S. Fish and Wildlife Service Biological Report No. 88(36), 63 p.

James, P.C., and Fox, G.A., 1987, Effects of some insecticides on productivity of burrowing owls: Blue Jay, v. 45, p. 65–71.

Johnsgard, P.A., 1990, Hawks, eagles, and falcons of North America: Washington, D.C., Smithsonian Institution Press, 403 p.

Johnston, M.C., 1963, Past and present grasslands of southern Texas and northeastern Mexico: Ecology, v. 44, p. 456–466.

Jones, C.B., 1999, Wintering burrowing owl (*Athene cunicularia*) abundance and burrow availability on northern Padre Island National Seashore: Final report submitted to U.S. Geological Survey and Texas A&M University–Corpus Christi, 17 p.

Jones, C.B., 2001, Using public outreach methods to document the occurrence of burrowing owls (*Athene cunicularia*) in the Coastal Bend of south Texas: Final report submitted to U.S. Geological Survey and Texas A&M University–Corpus Christi, 18 p.

Kennerly, T.E., Jr., 1964, Microenvironmental conditions of the pocket gopher burrow: Texas Journal of Science, v. 16, p. 395–441.

Klute, D.S., Ayers, L.W., Green, M.T., Howe, W.H., Jones, S.L., Shaffer, J.A., Sheffield, S.R., and Zimmerman, T.S., 2003, Status assessment and conservation plan for the western burrowing owl in the United States: U.S. Fish and Wildlife Service Biological Technical Publication FWS/BTP–R6001–2003, 108 p.

Lehman, R.N., Carpenter, L.B., Steenhof, K., and Kochert, M.N., 1998, Assessing relative abundance and reproductive success of shrubsteppe raptors: Journal of Field Ornithology, v. 69, p. 244–256.

Leupin, E.E., and Low, D.J., 2001, Burrowing owl reintroduction efforts in the Thompson-Nicola region of British Columbia: Journal of Raptor Research, v. 35, p. 392–398.

Lincer, J.L., and Steenhof, K., eds., 1997, The burrowing owl, its biology and management—including the proceedings of the first international burrowing owl symposium, Seattle, Wash., 1992: Raptor Research Foundation, Raptor Research Report No. 9, 177 p.

Lutz, R.S., and Plumpton, D.L, 1999, Philopatry and nest site reuse by burrowing owls—implications for productivity: Journal of Raptor Research, v. 33, p. 149–153.

MacCracken, J.G., Uresk, D.W., and Hansen, R.M., 1985, Burrowing owl foods in Conata Basin, South Dakota: Great Basin Naturalist, v. 45, p. 287–290.

McIntyre, N.E., 2004, Historical and current status of breeding and wintering western burrowing owls (*Athene cunicularia hypugaea*) in Texas: Journal of Raptor Research, v. 38, p. 91–95.

McLandress, R.M., and Raveling, D.G., 1981, Changes in diet and body composition of Canada geese before spring migration: The Auk, v. 98, p. 65–79.

Martell, M.S., Schladweiler, J., and Cuthbert, F., 2001, Status and attempted reintroduction of burrowing owls in Minnesota, USA: Journal of Raptor Research, v. 35, p. 331–336.

Marti, C.D., 1974, Feeding ecology of four sympatric owls: Condor, v. 76, p. 45–61.

Marti, C.D., 1987, Raptor food habit studies, *in* Raptor Management Techniques Manual: Washington, D.C., Giron Pendleton, B.A., Millsap, B.A., Cline, K.W., and Bird, D.W., eds., National Wildlife Federation Scientific and Technical Series, no. 10, p. 67–80.

Martin, D.J., 1973, Selected aspects of burrowing owl ecology and behavior in central New Mexico: Condor, v. 75, p. 446–456.

Millsap, B.A., and Bear, C., 2000, Density and reproduction of burrowing owls along an urban development gradient: Journal of Wildlife Management, v. 64, p. 33–41.

Millsap, B.A., Bellocq, M.I., and Mullenix, M., 1997, Overview of literature on the burrowing owl, *in* Lincer, J.L., and Steenhof, K., eds., 1997, The burrowing owl, its biology and management—including the proceedings of the first international burrowing owl symposium, Seattle, Wash., 1992: Raptor Research Foundation, Raptor Research Report No. 9, p. 6–10.

Moulton, C.E., 2003, Ecology of burrowing owls in southwestern Idaho—association with agriculture, food habits, and territorial behavior: Boise, Idaho, Boise State University, Master of Science thesis, 113 p.

Murphy, R. K., Hasselblad, D.W., Grondahl, C.D., Sidle, J.G., Martin, R.E., and Freed, D.W., 2001, Status of the burrowing owl in North Dakota: Journal of Raptor Research, v. 35, p. 322–330.

National Audubon Society, 2006, Christmas Bird Count accessed July 19, 2006, at URL *www.audubon.org/bird/cbc/index.html*.

Nicoletti, F.J., Brady, R., and Alexander, D., 2005, The 2004-2005 influx of northern owls, part III–northern hawk owl banding: The Loon, v. 77, p. 209–219.

Oberholser, H.C., 1974, The bird life of Texas: Austin, Tex. and London, England, University of Texas Press, v. 1, 530 p.

Ortega, J.L., 2003, Artificial burrow use by burrowing owls (*Athene cunicularia*) and other vertebrates during winter in south Texas: Corpus Christi, Tex., Texas A&M University, Master of Science thesis, 42 p.

Orth, P.B., and Kennedy, P.L., 2001, Do land-use patterns influence nest-site selection by burrowing owls (*Athene cunicularia hypugaea*) in northeastern Colorado?: Canadian Journal of Zoology, v. 79, p. 1,038–1,045.

Peirce, A.C., 1894, A man from Corpus Christi, or the adventures of two bird hunters and a dog in Texan bogs: New York, Forest and Stream Publishing Company, 257 p.

Philips, J.R., and Dindal, D.L., 1977, Raptor nests as a habitat for invertebrates—a review: Raptor Research, v. 11, p. 87–96.

Plumpton, D.L., 1992, Aspects of nest site selection and habitat use by burrowing owls at the Rocky Mountain Arsenal, Colorado: Lubbock, Tex., Texas Tech University, Master of Science thesis, 72 p.

Plumpton, D.L., and Lutz, R.S., 1994, Sexual size dimorphism, mate choice, and productivity of burrowing owls: The Auk, v. 111, p. 724–727.

Poulin, R.G., 2003, Relationships between burrowing owls (*Athene cunicularia*), small mammals, and agriculture: Saskatchewan, Canada, University of Regina, Ph.D. dissertation, 145 p.

Restani, M., Rau, L.R., and Flath, D.L., 2001, Nesting ecology of burrowing owls occupying black-tailed prairie dog towns in southeastern Montana: Journal of Raptor Research, v. 35, p. 296–303.

Rich, T., 1984, Monitoring burrowing owl populations—implications of burrow re-use: Wildlife Society Bulletin, v. 12, p. 178–180.

Rich, T., 1986, Habitat and nest-site selection by burrowing owls in the sagebrush steppe of Idaho: Journal of Wildlife Management, v. 50, p. 548–555.

Rodríguez-Estrella, R., 1997, Nesting sites and feeding habits of the burrowing owl in the Biosphere Reserve of Mapimi, Mexico, *in* Lincer, J.L., and Steenhof, K., eds., 1997, The burrowing owl, its biology and management—including the proceedings of the first international burrowing owl symposium, Seattle, Wash., 1992: Raptor Research Foundation, Raptor Research Report No. 9, p. 99–106.

Ross, P.V., and Smith, D.J., 1970, Notes on the ecology of the burrowing owl (*Speotyto cunicularia*) in the Texas High Plains: Texas Journal of Science, v. 21, p. 479–480.

Sauer, J.R., Hines, J.E., and Fallon, J., 2005, The North American breeding bird survey, results and analysis 1966-2004: U.S. Geological Survey, Version 2005.2, accessed March 5, 2005, at URL *http://www.mbr-pwrc.usgs.gov/bbs/bbs.html*.

Sauer, J.R., Schwartz, S., and Hoover, B., 1996, The Christmas bird count home page: U.S. Geological Survey, Version 95.1, accessed March 5, 2005, at URL *http://www.mbr-pwrc.usgs.gov/bbs/cbc.html*.

Sheffield, S.R., 1997, Owls as biomonitors of environmental health hazards, *in* Biology and conservation of owls of the North Hemisphere: U.S. Forest Service General Technical Report NC–190, p. 383–398

Sibley, D.A., 2000, The Sibley guide to birds: New York, Alfred A. Knopf, Inc., 544 p.

Skoruppa, M.K., Pearce, B., Woodin, M.C., and Hickman, G.C., 2006, Ectoparasites of burrowing owls (*Athene cunicularia hypugaea*) wintering in southern Texas: Texas Journal of Science, v. 58, p. 73–78.

Smallwood, J.A., 1987, Sexual segregation by habitat in American kestrels wintering in southcentral Florida—vegetative structure and responses to differential prey availability: Condor, v. 89, p. 842–849.

Smeins, F.E., Diamond, D.D., and Hanselka, C.W., 1991, Coastal prairie, *in* R. T. Coupland, ed., Natural grasslands—introduction and Western Hemisphere, ecosystems of the world 8A: Amsterdam, The Netherlands, Elsevier, p. 269–290.

Smith, B.W., 1999, Nest-site selection, ectoparasites, and mitigation techniques—studies of burrowing owls and artificial burrow systems in southwestern Idaho: Boise, Idaho, Boise State University, Master of Science thesis, 108 p.

Smith, B.W., and Belthoff, J.R., 2001a, Effects of nest dimensions on use of artificial burrow systems by burrowing owls: Journal of Wildlife Management, v. 65, p. 318–326.

Smith, B.W., and Belthoff, J.R., 2001b, Identification of ectoparasites on burrowing owls in southwestern Idaho: Journal of Raptor Research, v. 35, p. 159–161.

Smith, G.J., 1987, Pesticide use and toxicology in relation to wildlife–organophosphorus and carbamate compounds: Washington, D.C., U.S. Fish and Wildlife Service Research Publication no. 170, 171 p.

Southern, H.N., 1969, Prey taken by tawny owls during the breeding season: Ibis, v. 111, p. 293–299.

Stoner, E.A., 1932, The approximate louse population of a burrowing owl: Condor, v. 34, p. 230–231.

Teaschner, A., 2005, Burrowing owl nest site use and productivity on prairie dog colonies in the southern high plains of Texas: Lubbock, Tex., Texas Tech University, Master of Science thesis, 61 p.

Thompson, C.D., and Anderson, S.H., 1988, Foraging behavior and food habits of burrowing owls in Wyoming: The Prairie Naturalist, v. 20, p. 23–28.

Thomsen, L., 1971, Behavior and ecology of burrowing owls on the Oakland municipal airport: Condor, v. 73, p. 177–192.

Trulio, L.A., 1995, Passive relocation—a method to preserve burrowing owls on disturbed sites: Journal of Field Ornithology, v. 66, p. 99–106.

Trulio, L.A., 1997, Burrowing owl demography and habitat use at two urban sites in Santa Clara County, California, *in* Lincer, J.L., and Steenhof, K., eds., 1997, The burrowing owl, its biology and management—including the proceedings of the first international burrowing owl symposium, Seattle, Wash., 1992: Raptor Research Foundation, Raptor Research Report No. 9, p. 84–89.

Tyler, J.D., 1983, Notes on burrowing owl food habits in Oklahoma: Southwestern Naturalist, v. 28, p. 100–102.

Tyler, J.D., and Buscher, H.N., 1975, Parasites of vertebrates inhabiting prairie dog towns in Oklahoma—I. Ectoparasites: Proceedings of Oklahoma Academy of Science, v. 55, p. 166–168.

U.S. Department of Agriculture, 2000, Summary report—1997 national resources inventory (revised December 2000): Washington D.C., Natural Resources Conservation Service, and Ames, Iowa, Statistical Laboratory, Iowa State University, 89 p.

U.S. Department of Commerce, 2006, Corpus Christi Climate Archive: Silver Spring, Md., National Weather Forecast Office, National Oceanic and Atmospheric Administration, accessed July 15, 2006, at URL *http://www.srh.noaa.gov/crp/climate/crpf-6.html*.

U.S. Environmental Protection Agency, 1996, Solvent extractable nonvolatile compounds by high performance liquid chromatography/thermaspray/mass spectrometry (HPLC/TX/MS) or ultraviolet (UV) detection: Standard Operating Procedure, Method No. 8321A, 49 p.

U.S. Geological Survey, 2000, Coastal Prairie: Lafayette, La., U.S. Geological Survey Fact Sheet 019–00, 2 p., accessed July 23, 2006, at URL *http://www.nwrc.usgs.gov*.

U.S. Geological Survey, 2006, North American breeding bird survey: U.S. Geological Survey, accessed July 19, 2006, at URL *http://www.mbr-pwrc.usgs.gov/gov/bbs*.

Valdez Gómez, C.H.E., 2003, Dieta del tecolote llanero occidental (*Athene cunicularia hypugaea*) (Bonaparte, 1825), durante su estancia invernal en El Bajío Mexicano: Jalisco, Mexico, University of Guadalajara, Licensed Biological Thesis, 41 p.

Wellicome, T.I., and Holroyd, G.L., 2001, The Second International Burrowing Owl Symposium—background and context: Journal of Raptor Research, v. 35, p. 269–273.

Williford, D.L., 2003, Habitat and roost site selection by burrowing owls (*Athene cunicularia*) wintering in the Coastal Bend of Texas: Final report submitted to U.S. Geological Survey and Texas A&M University–Corpus Christi, 35 p.

Williford, D.L., Woodin, M.C., Skoruppa, M.K., and Hickman, G.C., 2007, Characteristics of roost sites used by burrowing owls (*Athene cunicularia*) wintering in southern Texas: Southwestern Naturalist, v. 52, p. 60–66.

York, M.M., Rosenberg, D.K., and Sturm, K.K., 2002, Diet and food-niche breadth of burrowing owls (*Athene cunicularia*) in the Imperial Valley, California: Western North American Naturalist, v. 62, p. 280–287.

Zarn, M., 1974, Burrowing owl—habitat management series for unique or endangered species: Denver, Colo., Bureau of Land Management Report No. 11, 25 p.

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