Winter diet of Burrowing Owls in the Llano La Soledad, Galeana, Nuevo Leon, Mexico.

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Abstract

We determined dietary niche breadth of Burrowing (*Athene cunicularia* Molina, 1782) in Llano La Soledad, Galeana, Nuevo Leon in northern Mexico, considering prey type, frequency of occurrence, and biomass. We compared data from three winter seasons (2002-2003, 2003-2004, 2004-2005) by analyzing 358 pellets and identifying 821 prey items. Vertebrates accounted for 87% of consumed biomass of which 74% represented mammals. Most of the mammal biomass consumed was comprised of Cricetid rodents (58%). Ninety percent of prey items were invertebrates, most of which were insects (84%); beetles were the most common insects found in pellets (55%). Niche breadth based on frequency of occurrence and biomass confirmed the burrowing owl as a generalist species with mean values per year ranging between 0.68 and 0.82. There was a significant association between both relative biomass of rodent species and invertebrate families with wintering season. This association was driven mainly by changes in composition and frequency of these types of prey during the second season, which was likely caused by high annual rainfall. The second season also showed a significantly narrower niche (0.68 vs. 0.82) and the smallest overlap (<47% *vs.* 88%) among the three winters.

Key words: biomass, burrowing owl, grassland, niche breadth, winter diet.

INTRODUCTION

The Burrowing Owl (*Athene cunicularia* Molina, 1782; Fig.1); has shown a significant negative population trend in the United States for almost 50 years (-0.91%/yr.; 1966-2015; *Sauer et al*., 2017). In Canada, this decline is especially steep (-6.42%/yr.; 1966-2015; *Sauer et al*., 2017), where it is listed as an endangered species (Committee on the Status of Endangered Wildlife in Canada [*COSEWIC*] 2006). The Burrowing Owl is considered a National Bird of Conservation Concern (U.S. Fish and Wildlife Service [*USFWS]* 2008), whereas in Mexico it is protected under the "Special Protection" category (Secretaria de Medio Ambiente y Recursos Naturales [*SEMARNAT*] 2010). The current population status of the Burrowing Owl is a result of multiple threats such as habitat fragmentation, decreased prey availability, increased predation, inclement weather, vehicles strikes, environmental contaminants, and the loss of burrows (*Environment Canada*, *2012*). Food availability, in particular, is one of the most important natural limiting factors in populations during the winter (*Newton, 1998; McDonald et al., 2004*).

Most winter diet studies of the Burrowing Owl have been conducted in Texas, Nevada, and California, as well as in other countries in both North and South America. In most studies, Burrowing Owl diet consists mainly of invertebrates, small mammals, and reptiles *(Plumpton & Lutz, 1993*). Invertebrates are consumed most frequently (*Poulin, 2003*), but mammals account for most of the biomass (*Andrade et al., 2004; Littles et al., 2007; Nabte et al., 2008; De Tomasso et al., 2009; Andrade et al., 2010; Carevic et al., 2013*). However, frequency of occurrence (frequency data are numerical in nature. What you refer to here are percent occurrence values, which is the way to go) of insect orders is highly variable, both temporally and spatially. Beetle (Coleoptera) and cricket (Gryllidae) consumption ranged from 20% to 80% (Unclear as to the meaning of your percentage values. i.e., Percent occurrence in pellets??). On the other hand, mammal species, which include North American Deer-Mice (*Peromyscus maniculatus*), Silky Pocket Mice (*Perognathus flavus*) and Merriam's Kangaroo Rats (*Dipodomys merriami*), are reported to be as high as 98% (once again, 98% of what?) (*Ross & Smith, 1970; Coulombe, 1971; Butts, 1976; Tyler, 1983; Barrows, 1989; Mills, 2016*). Data from British Columbia, Canada, indicate that 56% of their diet is insects, such as earwigs and beetles (*Morgan, 1993*). The only winter diet from Mexico comes from central Mexico in the state of Guanajuato, where 78% of prey items were invertebrates (*Valdez-Gómez, 2003*). Biomass data were more evenly distributed among Orthoptera (26.8%), Lepidoptera (20.6%) and rodents (20.9%; *Valdez-Gómez et al., 2009*). Breeding season diet has also been analyzed in the states of Durango and Nuevo León, where insects were the most abundant prey items (67-84%); mammals represented 50% of the biomass (*Rodríguez-Estrella, 1997, Ruiz-Aymá, 2019*).

Variation in diet has been associated with prey availability, suggesting that small mammals are selected over invertebrates when their densities are sufficiently high (*Silva et al., 1995*). A change in prey composition has also been associated with rainfall, with more grasshoppers and some rodents (e.g., *Perognathus sp.*, *Onychomys leucogaster)* consumed during dry years and birds during wet years (*Conrey, 2010*).

Information on the winter diet of Burrowing Owls in Mexico is limited, and temporal variation has not been examined. Thus, our objective was to determine the diet composition and dietary niche breadth of Burrowing Owls during three winter seasons (2002-2003, 2003-2004, 2004-2005) in northern Mexico, (Llano La Soledad, in the southern Chihuahuan Desert). Our hypotheses are (1) that in years with high rainfall, diet composition will be different than in drier years, and (2) that differences in rainfall will also affect dietary niche breadth.

STUDY AREA AND METHODS

Site Description

Llano la Soledad is a plain habitat located in northeastern Mexico, state of Nuevo Leon, municipality of Galeana, within the Grassland Priority Conservation Area "El Tokio" (CEC & TNC 2005, Pool & Panjabi 2011). This area is a part of the Chihuahuan Desert ecoregion (25° 9' 8.87" N, 101° 6' 8.00" W and 24° 18' 54.12"N, 100° 23' 41.48" W; Fig. 2). It is a State Natural Protected Area (*Diario Oficial de la Federación, 2002*) internationally known for its importance for shorebird conservation (*WHSRN, 2004*). It is also part of an important bird area "Pradera de Tokio" (AICA-NE-36; *Del Coro & Márquez, 2000*) that harbors vulnerable bird species both endemic and migratory, such as the Golden Eagle (*Aquila chrysaetos)*, Long-billed Curlew (*Numenius americanus)*, Mountain Plover (*Charadrius montanus)* and Worthen's Sparrow (*Spizella wortheni)* (*Macias et al., 2011*). The Llano La Soledad also contains the largest colony of the Mexican Prairie Dog (*Cynomys mexicanus)* (*Treviño & Grant, 1998*), and therefore represents the most extensive and continuous habitat in terms of burrow and food availability for Burrowing Owls in northeastern Mexico. The area is dominated by open grasslands with 80% bare ground and 20% plant cover consisting of 3% of grass and 17% forbs and shrubs. The most common species are Spear Globemallow (*Sphaeralcea hastulata*), Four Wing Saltbush (*Atriplex canescens*), Three Awn (*Aristida ssp*.), Burrograss (*Scleropogon brevifolius*), Creeping Muhly (*Muhlenbergia repens*), Sand Muhly (*M. arenicola*), and Grama (*Bouteloua karwinskii*) (*Cruz-Nieto, 2006*). The semi-arid climate features temperatures ranging from 6 to 25 °C with an annual average of 16 °C (*CONAGUA, 2019*). Average annual precipitation is 427mm (*INEGI, 2005*). Annual rainfall for the years 2002-2004 were obtained from the closest (~6 km) meteorological station in La Carbonera (19032; *CONAGUA, 2019*).

Pellet Collection and Analyses

Pellets were collected at the entrances of burrows, from the first week of October through the first week of March over three winter seasons: 2002-2003, 2003-2004, and 2004-2005. We Collected pellets from burrows every third day. We analyzed and quantified the remains of each pellet according to the methods of *Errington*, (*1930; 1932*) and *Marti,* (*1987*). We identified mammals according to *Anderson*, (*1972*) and *Roest*, (*1991*), herpetofauna following *Smith & Taylor*, (*1950)* and *Smith & Smith,* (*1993*), birds following *Howell & Webb*, (*2004*) and *Dunn*, (*2006*), and invertebrates according to *Borror et al.*, (*1989*). All vertebrate prey items that could not be identified to the species level were included in the unidentified category. We estimated biomass multiplying weight for the frequency of occurrence of each type of prey, assuming there was one individual per pellet. For mammals we used the median of the weight for each species to avoid overestimation (*Holt & Childs,* 1991). Medians were obtained from data given for Mexico by *Ceballos & Oliva,* (*2005*). For reptiles, we used specimens from the Herpetology Laboratory collection at the Universidad Autonoma de Nuevo Leon/Facultad de Ciencias Biologicas; for insects, data reported by *Olalla* (*2014*); and for spider, median weights were obtained from live specimens of the Arachnology collection at the Facultad de Ciencias Biologicas/Universidad Autonoma de Nuevo Leon.

Statistical Analyses

We estimated niche breadth and their 95% confidence intervals for each field season using Smith's measure (1982), and their overlap using Horn's index (1966) with Ecological Methodology 7.2 (*Krebs, 2011*) software. We considered niche breadth estimates with non-overlapping 95% confidence intervals as statistically different.

To test for an association ($\alpha = 0.05$) of prey frequency and biomass among taxonomic levels and years we used X^2 contingency tests (*Zar, 1998*). We also calculated and interpreted Cramér's phi coefficient (ϕ_c) as a measure of the effect size of the association (Cohen 1988). These analyses were conducted using PAST 3.14 (*Hammer et al., 2001*).

RESULTS

We analyzed 358 pellets, and found 821 prey items from 26 taxa. We recorded 7 Orders and 17 families of invertebrates, 6 Genera of small mammals, 2 Genera of reptiles, and 1 avian Genus. Vertebrates represented 10% and invertebrates 90% of total prey items consumed during the three winter seasons, whereas these proportions were the opposite for biomass, with vertebrates comprising 84% and invertebrates 16% of biomass consumed. Rodents comprised 7% of all prey items eaten, but 82% of the biomass, particularly Cricetid rodents. Insects, primarily from the Orders Coleoptera (55%) and Orthoptera (27%) represented 84% of consumed items but contributed only to 12% of the biomass (Fig. 3; Tables 1, 2).

Niche breadth measures were wide, indicating a generalist species, with consistent overall estimates for both frequency of occurrence (FT= 0.77; 95%CI=0.74-0.80) and biomass (FT=0.74; 95%CI=0.70-0.77). However, the niche breadth based on biomass was significantly smaller for the winter of 2003-04 (Table 3, Fig. 4). This also coincided with above average (395 mm; 1956-2014) annual precipitation of 505 mm during 2003, compared with drier years: 288 mm (2002) and 304 mm (2004).

There was a highly significant and small correlation between yearly parameters and prey items of invertebrate classes (X^2=23.13, df=2, p<0.0001**,** ϕ_c =0.18) and orders (X^2=47.14, df=8, p<0.0001, ϕ_c =0.18), and moderate with families (X^2=215.2, df=32, p<0.0001, ϕ_c =0.38). There were weak to strong associations between biomass and year at every taxonomic level (Table 4). Year associations with vertebrate taxonomic levels were primarily caused by a greater consumption of mammal (rodents) biomass, particularly, Spotted Ground Squirrel (*Xerospermophilus spilosoma*) and Mexican Woodrats (*Neotoma mexicana*). During the second (wet) year, Merriam´s Kangaroo Rat (*Dipodomys merriami*) consumption decreased during the same period (Table 2). Changes in prey composition and relative biomass during the second season were also evident from niche overlap indices, which show the smallest values when compared to the first and third seasons

(0.45 and 0.47), and greater frequency of occurrence, ranging from 0.78 to 0.87 (Table 5). Birds on the contrary, were very stable among years with a relative biomass between 11 and 13% (Table 2).

DISCUSSION

Our findings provide additional evidence that the burrowing owl is a generalist and opportunistic predator. Invertebrates (mainly arthropods) were the most common and abundant food items, corroborating previous studies that have shown that overwintering Burrowing Owls feed mainly on arthropods and small mammals (*Ross & Smith, 1970; Coulombe, 1971; Butts, 1976; Tyler, 1983; York et al., 200; Valdez- Gómez, 2003; Littles et al., 2007; Hall et al., 2009*).

Invertebrates represented 90% of prey items consumed, which is similar to results from other studies (*Littles et al., 2007; Caveric et al., 2013; Cavalli et al., 2014*) as they report values ranging from 93% to 98%, but higher than the 78% reported by *Valdez- Gómez* for Mexico (*2003*).

Insects represented 84% of the items in the diet, which was very similar among the seasons, varying between 83 and 87%, which is greater than the 63% reported in México (*Valdez- Gómez, 2003*) and less than the 91% reported in southern Texas (*Littles et al., 2007*).

Beetles were the most-frequently consumed insects overall with 55%, and a maximum variation of 10% between years. Beetle consumption during the winter months is not common in North America, having only been observed during the breeding season (39%-54%; e.g. *Haug, 1985; Green et al., 1993; Floate et al., 2008*) and more prevailing in South America (e.g. *Andrade et al., 2010; Cavalli et al., 2013*). In most North American studies, crickets (Gryllidae) were the most frequently ingested insects (*York et al., 2002; Valdez- Gómez, 2003; Littles et al., 2007; Hall et al., 2009*). Carabid beetles were the most frequently consumed (25%) in our study, while other authors report Gryllidae (crickets; *Valdez- Gómez, 2003; Littles et al., 2007*). *Jonas et al.,* (*2002*) observed a positive correlation between native vegetation and beetles, whose consumption by Burrowing Owls in our study was likely related to the high proportion of native vegetation in Llano La Soledad. Beetles have an affinity for native vegetation (*Crisp et al., 1998; Jonas et al., 2002; Littles et al., 2007*), whereas crickets are common in disturbed areas (*Smith, 1940; Jonas et al., 2002*) in North America, especially in grazed and overgrazed pastures, abandoned pastures (*Jonas et al., 2002*), abandoned crop fields, lawns, old fields, and other grassy areas (*Cade & Otte, 2000; Moulton et al., 2005*), as well as in tilled and plowed fields (*Carmona, 1998*); however, these types of fields were not common in our study area, and the closest were located approximately 10 km away.

Conversely, in South America, although beetles have been found to be highly consumed and preferred by the burrowing owl, their relative abundance was higher in agricultural areas than in vegetated sand-dunes (*Cavalli et al., 2013*). These authors suggested that beetles may also have been common in owls' diet because they require little effort to capture, particularly when they are abundant near burrows. *Littles et al.,* (*2007*) reported that beetles were the second most consumed item (32%) of all prey items on a barrier island, where vast expanses of the native vegetation occur in comparison to agricultural and grassland, in grasslands, fire suppression has allowed brush species such as Honey Mesquite (*Prosopis glandulosa*) to invade the remaining native pastures and most remaining grasslands are dominated by exotic grass species that were introduced for cattle.

The second-most frequently consumed prey items in our study were grasshoppers (22%), while *Valdez- Gómez, 2003* reported to this same group (15%) and *Littles et al., 2007*, mentioned Lepidoptera (13%). Our data showed variation in relative frequency of consumption among arthropod groups, with the greatest frequency of occurrence of spiders during the first season

(<10%); and a decrease in the presence of Scarabeidae and an increase of Tenebrionidae and Gryllidae occurrence in the third year (Table 1).

In addition, the Burrowing Owls' consumption at Llano de la Soledad showed more variation, which is an indicator of a natural habitat and typical of an opportunistic predator that feeds on what is available (*Jaksic & Martí, 1981; Jaksic, 1988; Green et al., 1993; Haug et al., 1993; Littles, 2007*).

Vertebrates represented 10% of the remaining prey items consumed by the Burrowing Owls, which was less than the 21% recorded in Guanajuato, Mexico (*Valdez- Gómez, 2003*), and greater than the 2% recorded in southern Texas (*Littles et al., 2007*). However, rodents were consistent as the most frequently vertebrate with 74%, in comparison with 70% reported by *Littles et al.*, (*2007*) and 86% by *Valdez- Gómez* (*2003*).

We found that the Silky Pocket mice was the most common rodent prey (19%), followed by the Western Harvest Mouse (15%), the Deer Mice and Merriam's Kangaroo Rats (14% each). In contrast, the most commonly found rodents in Guanajuato were deer (39%) and Silky Pocket Mice (35%; *Valdez- Gómez, 2003*); while in Texas the most common were Northern Pigmy (23%) and Fulvous Harvest Mice (19%; *Littles et al., 2007*). All of these rodent species are distributed in U. S. and Mexico, mostly within arid areas of both countries, and their variation as the most consumed prey per region is consistent with the capacity of the Burrowing Owl to use what is likely most available on each region.

Even though vertebrates only represent 10% of total prey items, they accounted for 87% of the total biomass consumed, which is similar to other authors' findings (*Littles et al., 2007; Nabte et al., 2008; Carevic et al., 2013*). Mammals biomass was of 74% varied between 62 and 82% between years, which is higher than what has been reported for Texas (52%) (*Littles et al., 2007*) and Mexico (25%; *Valdéz-Gómez et al., 2009*), but within the 25 to 95% reported in Argentina and Chile (*Andrade et al., 2004; Nabte et al., 2008; De Tomasso et al., 2009; Andrade et al., 2010; Carevic et al., 2013*). Cricetid rodents composed 58% of the biomass, which falls within the range of 37 to 95% found in other studies (*Littles et al., 2007; Nabte et al., 2008; Andrade et al., 2010*).

As previously stated, within vertebrates, changes in rodent species biomass during the second season drove the main differences in niche breadth and prey composition among years. These differences coincide with a high annual rainfall that may have resulted in irruptive population events (*Greenville et al., 2012*), or caused changes in rodent species' population densities, which would affect their availability and their selection as prey by the Burrowing Owl (*Silva et al., 1995*). Although this was not measured, temporal variation in populations of all prey taxa in our study have been associated with rainfall, more strongly for the species we found changed the most, such as Merriam's Kangaroo Rat, Silky Pocket Mice, Spotted Ground Squirrel and Western Harvest Mouse (*Whitford, 1976; Brown & Zeng, 1989; Brown & Ernest, 2002*).

Temporal studies that include prey availability in disturbed and undisturbed areas of the southern Chihuahuan Desert would clarify the dynamics of prey use and preference for this vulnerable owl species. Examining the effects of the variation in vertebrate biomass consumption on survival of Burrowing Owls during wet and dry years would also be informative, especially considering climate change scenarios. Another relevant aspect of the temporal framework for diet studies is their relationship with pesticides and indirect exposure to contaminated prey, which is likely, although with limited evidence at the moment (*Haug & Oliphant, 1987; James et al., 1990*).

Finally, it is also important to highlight that Llano La Soledad grasslands are key to maintaining healthy populations of the Burrowing Owl and other species (e.g.,???). The conservation and management of this population depends on the depth of our knowledge of the Natural History of this species, including the key components is its foraging ecology.

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