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Spatial and temporal variations in the feeding ecology of ferruginous pygmy-owls (*Glaucidium brasilianum*) in semiarid forests of central Argentina

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A B S T R A C T

Forested landscapes vary greatly in habitat structure and complexity due to natural and anthropogenic disturbances that may alter forest attributes. Habitat structure along with temporal factors may directly affect interactions between species, particularly those between predators and their prey. Our study assesses the effects of habitat structure in prey intake of a small avian predator, the ferruginous pygmy-owl (*Glaucidium brasilianum*) in semiarid forests of caldén (*Prosopis caldenia*) in central Argentina. Overall, the main prey of owls was small mammals, followed in importance by birds, insects and reptiles. The mean abundance of mammals in the diet was affected by season and year, while the abundance of birds in the diet was greater during spring-summer than during autumn-winter. As for insect prey, abundance of birds in the diet was also greater in open than in closed forests. Habitat type seems to plays an important role in the use of food resources by the ferruginous pygmy-owl in caldén forests. Due to the recurrence, spatial extent and remarkable effects of natural disturbances on habitat structure in these environments, our results suggest that habitat type and structure should be taken into account in diet studies of forest specialist avian predators in these habitats.

1. Introduction

Forested habitats are among the most variable habitats in terms of structure and complexity. Despite the appearance of a homogeneous landscape, small variations in soil (moisture, temperature and nutrient availability) and microclimate features (air humidity and temperature, light exposure) may result in a patchy distribution of forest types that differ in plant species composition and vertical structure (Kumar et al., 2011; Raynor, 1971; Tateno and Takeda, 2003). Human-induced and natural disturbances also play an important role in shaping habitat heterogeneity and structure in these environments. Disturbances can increase habitat complexity by reducing both canopy cover and competition for light and by enhancing sprouting of trees and brushes that in some cases may result in more densely covered forest types (Sarasola et al., 2005; Weishampel et al., 2007).

Habitat structure and spatial heterogeneity in forested habitats are also important environmental determinants of the distribution of animal species. In the particular case of predators and their prey, habitat complexity may affect the way in which they interact, determining the structure of ecological communities (August, 1983; Holt, 1984; Murdoch and Oaten, 1975). For specialized predators, for example, habitat complexity can influence the spatial distribution of the preferred prey; this may, in turn, determine a numerical response of predators (Solomon, 1949) through changes in their densities. By contrast, predators feeding on a wide spectrum of prey species can cope with changes in prey abundance by shifting the diet to prey upon alternative species (i.e. functional response; *sensu* Solomon, 1949).

Here we examined the feeding ecology of a small avian predator, the ferruginous pygmy-owl (*Glaucidium brasilianum*), in semiarid forests of caldén (*Prosopis caldenia*) in central Argentina in relation to variation in time and habitat type. This small owl (ca. 88°g) ranges from southern Texas and south Arizona through central and South America to Bolivia and Argentina (König and Weick, 2008; Proudfoot and Johnson, 2000). This cavity-nesting, diurnally active owl inhabits a variety of landscapes, from tropical and

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subtropical dry forest to semiarid, open-forest in the southern limits of its range (Holt et al., 1999; König and Weick, 2008; Proudfoot and Johnson, 2000). Several studies on its diet and foraging ecology indicate that ferruginous pygmy-owl is a generalist predator that preys on a wide spectrum of prey including mammals, birds, reptiles, amphibians, and invertebrates, although rodents and birds appear to be their main prey (Carrera et al., 2008; De la Peña and Salvador, 2010; Di Giacomo, 2005; Holt et al., 1999; Motta-Junior, 2007; Proudfoot and Johnson, 2000). This variability in its food habits may allow the ferruginous pygmy-owl to adapt to local changes in prey availability and abundance.

Ferruginous pygmy-owl may occur in high densities in semiarid forest of central Argentina and this occurrence pattern seems to be independent of vertical plant structure and habitat features at micro and macro scales (Campioni et al., 2013). However, habitat structure could have effects on field resources availability or on the way they are exploited by owls. Multi-scale resource selection studies have shown that resource availability affects owls' habitat selection and reproductive performance in desert environments (Flesch and Steidl, 2010). There is, however, little information on the ecology of forest-specialist owls for much of southern South America (Trejo et al., 2006) including semiarid forest of the Espinal region. While the food habits of the ferruginous pygmy-owl have been described locally for some habitat types across its range, no studies have yet analyzed the effects of spatial and temporal variability on the feeding ecology of this owl in a particular habitat. Our aims were hence to analyze ferruginous pygmy owl feeding ecology in semiarid caldén forest of the Espinal region. We hypothesize that, along with seasonality, habitat structure has important effects on prey type intake and on the occurrence of different prey types in the diet of this small, forest-specialist avian predator.

2. Materials and methods

2.1. Study area

The study was conducted in the Parque Luro Reserve (36° 55′ S, 64° 16'W), La Pampa province, central Argentina. The reserve (7604 ha) was declared as protected area in middle 1970's (Amieva, 1993) and it consists of a continuous xerophytic forests of caldén (*P. caldenia*), the characteristic landscape of the Espinal biome in this region of Argentina (Cabrera, 1994). However, forest areas in the reserve differ structurally due to soil features as well as the effects of past human (roads and forest clearing for tourist activities) and natural (wildfires) disturbances (Sarasola et al., 2005). However, such antrophogenic perturbations are not longer occurring and forest clearing or cutting, as well as cattle rising activities, have been banned from the area since it was established as a protected area by the Government of La Pampa province.

Broad, open areas of natural grassland are also common in some parts of the reserve, particularly in the tourist area of the reserve (400 ha). Nevertheless, our study was restricted to the non-tourist zone which is entirely dominated by a continuous of caldén forests without grassland areas. These semiarid forests are characterized by hot summers and cold winters with low humidity and low annual rainfall, typically concentrated in spring and summer (350 and 450 mm yr−1; Fernández and Busso, 1999). Habitats surrounding the reserve consist of agricultural areas planted with crops and perennial and annual pastures.

2.2. Sample collection and analysis

Pellets and prey remains were collected during 2001–2003 in twelve of the 50 nest-boxes set through the reserve as part of a long-term study on the breeding ecology of American kestrels (*Falco sparverius*) (Liébana et al., 2009; Sarasola et al., 2003). These nest boxes were usually occupied by pygmy-owls during the breeding seasons but also during winter when owls occupied nest boxes presumably for roosting. Year-round nest box occupancy allowed us to assign pellets and prey remains to geographic area, habitat type, and time of year. Because the ferruginous pygmy-owl is considered to be monogamous and territorial (Proudfoot and Johnson, 2000), the use of nest boxes by pygmy owls also allowed us to allocate diet samples to each site and to a discrete number of owls both throughout the study area and at each of the sampling sites. Mean distance between nest boxes used by owls was 5480 m ($n = 12$; minimum distance = 1215 m; maximum distance = 11,543 m). All the nest boxes from which we obtained pellet samples were set inside the forest and at a distance ranging between 50 and 80 m from the nearest road.

Pellets were hydrated and broken apart by hand and remains of prey items were separated for identification. Smalls mammals were identified to species on the basis of skulls, dentition, hairs and claws using keys (Chehebar and Martin, 1989; Pearson, 1995) and reference collections located at the Universidad Nacional de La Pampa (UNLPam). Insects were identified to family level by mandibles, heads, elytras, and other parts using reference collections also located at the UNLPam. To estimate the minimum number of individual prey items in each sample, we counted skulls of mammals and birds; we used whole heads, feet, elytras and mandibles for insects. When only hairs, bones, or feathers were found, these were counted as one individual and classified as unidentified.

For each sample of pellets and prey remains belonging to the same nest-box, we calculated the standardized food niche breadth (Bsta) following Colwell and Futuyma (1971). For the index calculation, vertebrate prey were categorized as species, genus, or order (in the case of unidentified birds), and invertebrate prey were categorized to family (Marti et al., 1993). We also calculated the geometric mean mass of vertebrate prey (MWVP) consumed in a diet sample by multiplying the log-transformed mean mass of each prey type by the number of that prey in the sample, summing these products, dividing by the total number of prey, and back-transforming this value. This procedure partially compensated for the skewed distribution of prey sizes and the potential to over- or under-estimate mean prey mass (Marti et al., 1993).

We calculated total prey biomass in the diet by multiplying the mean mass of each prey type by the number of that prey recorded. To compute prey biomass, we obtained the mean body mass of small mammal species and arthropods from Sarasola et al. (2003, 2007). Santillán (unpubl. data) provided data for the body mass of birds and amphibians, respectively. Unidentified prey items were not considered in the prey biomass calculation.

2.3. Habitat classification

We classified the habitat type surrounding each nest box where samples were collected (radius 200 m from the nest box). Classifications followed habitat categorizations for the reserve made by Gonzalez-Roglich et al. (2012) and vegetal physiognomic units identified in this habitat by Sarasola et al. (2005). We categorized forest types around sampling sites as open or closed forest. Differences between these two forest types are due mainly to foliage coverage at the ground (<0.5 m high) and shrub layer (0.75–3 m). The plant structure and physiognomy of the open forests resembles the typical physiognomy of caldén forest, with well developed ground (<0.5 m), subcanopy (3.25–6 m) and canopy (>6 m) strata but with an almost absent shrub layer. The closed forest, on the contrary, has similar vertical structural features as open forest with a less developed ground strata (grasses) and the inclusion of a well developed, dense and conspicuous shrub stratum that can reach in