The diet of the burrowing owl in open habitats of southern Brazil

Dieta da coruja-buraqueira em ambientes abertos do sul do Brasil

Abstract

Athene cunicularia's diet is composed of vertebrates and invertebrates, whose relative frequencies can change in space or time. We analyse habitat and temporal variation in the weight and the composition of prey in bird pellets. We collected 396 pellets from nine owl couples for six months and in three open habitats: near forest, far from forest, and urban. Mean pellet weight was 1.03 g. August showed pellets 15% heavier and March 22% lighter than average, differing from the other months. Regarding composition of prey, vertebrates occurred more in the pellets during June, July and August, while invertebrates showed higher frequency in summer months in open habitats far from forest. At the lower taxonomic level, we identified the presence of mammals, serpents, amphibians, birds, beetles, ants, spiders, grasshoppers, woodlice, molluscs and cockroaches in the pellets. The diet during winter in open habitats far from forest showed higher presence of mammals, while summer months in open habitats near forest and in urban habitats showed more hymenopterans. The results showed that Athene cunicularia preys on a wide spectrum of prey, but we found some preference for specific prey depending on the season and on the open habitat types.

Keywords: Atlantic Forest, pellets, spatial effect, time effect.

Resumo

A dieta da coruja-buraqueira Athene cunicularia é composta de vertebrados e invertebrados, cujas frequências relativas podem mudar no tempo e/ou espaço. Analisamos variações ambientais e temporais no peso e na composição de presas nas pelotas dessas aves. Coletamos 396 pelotas de nove casais durante seis meses em três áreas abertas no sul do Brasil: próximas de floresta, afastadas de floresta e urbanas. O peso médio das pelotas foi de 1.03 g. Agosto apresentou pelotas 15% mais pesadas, enquanto março teve pelotas 22% menos pesadas, comparadas com a média, ambos se diferenciando dos outros meses. Com relação à composição de presas, vertebrados ocorreram com mais frequência em junho, julho e agosto, enquanto invertebrados nos meses mais quentes em áreas abertas afastadas da floresta. Ao menor nível taxonômico, identificamos mamíferos, serpentes, anfíbios, aves, besouros, formigas, aranhas, gafanhotos, tatuzinhos-de-jardim, moluscos e baratas nas pelotas. A dieta no inverno apresentou maior frequência de mamíferos em áreas abertas afastadas de floresta, enquanto aquela do verão apresentou mais himenópteros em áreas abertas perto de floresta e em áreas urbanas. Os resultados mostram que Athene cunicularia preda em um amplo espectro de presas, mas encontramos algumas preferências para presas específicas, dependendo da estação e do tipo de área aberta.

Palavras-chave: Mata Atlântica, pelotas, efeito espacial, efeito temporal.
Introduction

*Athene cunicularia* (Molina 1782) – the burrowing owl – occurs in areas of short grasses or other sparse vegetation (Coulombe, 1971). It nests and roosts in burrows, which can be self-made or abandoned by other animals. Individuals are small (~ 23 cm) with a rounded head with no tuft, a short tail and long legs (Sick, 2001; Sigrist, 2006). Its activity is mainly diurnal and at dusk, which differentiates it from other owls (Motta-Junior and Alho, 1998).

Similarly to other owls, *A. cunicularia* produces pellets that can be found under perches or near the owl’s nest (Matter, 2010). These are masses of undigested parts of bird’s food and may contain insect bones, exoskeletons, feathers, fur, scales, and skins (Sick, 2001; Bastian et al., 2008; Menezes and Ludwig, 2013). At the end of the day and/or during the night, the owl regurgitates one or two pellets, which may vary depending on the food availability (Motta-Junior and Alho, 2000; Matter, 2010). Regurgitated material may be used to study owl food habits without the need to sacrifice the individuals (Menezes and Meira, 2012).

Small rodents appear as the main group of vertebrates consumed by *A. cunicularia* followed by birds, anurans and reptilians (Motta-Junior and Alho, 2000; Carevic et al., 2013; Cadena-Ortíz et al., 2016). Invertebrates are often abundant and may make up till 90% of owl pellets (Zilio, 2006; Menezes and Ludwig, 2013). Coleoptera, Orthoptera, Hymenoptera, Spider and Scorpionida are the most common orders in the pellets (Motta-Junior and Alho, 2000; Menezes and Ludwig, 2013; Cadena-Ortíz et al., 2016).

As a generalist species *A. cunicularia* can adapt very well to human made environments (Motta-Junior, 2006; Menezes and Meira, 2012). This trait can facilitate its survivor in urban and rural areas where high concentrations of invertebrates are often found (Soares et al., 1992; Perillo et al., 2011). The resource use by *A. cunicularia* may also help in the control of prey in urban environments, maintaining prey populations at equilibrium (Menezes and Meira, 2012; Menezes and Ludwig, 2013). In the present study, we characterize the diet of *A. cunicularia* individuals and compare *A. cunicularia* pellets’ weights and the compositions of food prey during six months in two rural and one urban open habitats of southern Brazil. Our hypothesis is that individuals living in open habitats near fragments of forest have a different composition of food items because there is a mixture of prey from both environments. We also believe that the diet of this species shows higher presence of invertebrates in summer due to the greater availability of this food resource.

Material and methods

Study area

Owl pellets were sampled in the municipalities of Águas de Chapecó (27º04’13” S - 52º59’12” W, altitude = 238 m) and São Carlos (27º04’39” S -53º00’14” W, altitude = 264 m) in southern Brazil (Figure 1). Climate in the region is classified as temperate, without dry season and with hot summer - Cfa Köppen - Geiger classification (Alvares et al., 2014). Annual temperatures range from 13°C to 27°C with an average of 20°C. Annual precipitation ranges from 1,700 mm to 1,900 mm (Pandolfo et al., 2002).

The area belongs to the Atlantic Forest biome and is historically covered by deciduous forest, which was converted during human colonization started in the beginning of 20th century (Renk, 2014). Landscape is composed of remnants of deciduous forest (Klein, 1978) embedded in a mosaic of various man-made patches, notably urban, pasture, and agriculture. Urban habitats are characterized by the presence of one medium (200,000 inhabitants) and other small sized cities. Pasture and agriculture patches were created and are maintained by a strong agroindustry activity initiated at the 1950s. The historical landscape conversion set adequate conditions to the spread of *A. cunicularia*, a species strongly linked to open landscapes.

We selected three open habitats types to analyse the *A. cunicularia* diet, each of them with three replicates. The rural open habitats near forest (Rural 1) are characterized by the presence of a forest fragment in the landscape at least at 50 m of the nests. This open habitat type has been used mainly for cattle breeding. A second type of rural open habitats is characterized by the presence of a forest fragment at least at 250 m far from forest (Rural 2). These habitats have been also used mainly for cattle breeding. The third type is represented by urban open habitats (Urban), being characterized by the presence or not of forest fragments at different distances and used for agriculture, cattle breeding or abandoned grasslands (Figure 1).

Pellet collections

We sampled two pellets of one couple of *A. cunicularia* in the nine open habitats on a weekly basis in June, July, August, and December 2015, and February and March 2016, totalling 396 pellets. Pellets were collected around 3 m from the nests or perches used by the owls. The material was stored in plastic bags, identified, and dehumidified in muffle (38°C) for 48 hours. Individual pellet total mass was measured on a precision scale (Model ARD110, class II, manufactured by OHAUS Corporation) with a precision of 0.01 g. We also weighted the mass of five taxa in the pellets separately: vertebrates, invertebrates, plant (seeds, leaves and fragments),
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mineral (rock fragments), and inorganic residue (plastic, glass, styrofoam, etc.) (Bastian et al., 2008). We further refined the classification of food items based only on the presence of the taxa Mammalia, Serpentes, Amphibia, Aves, non-identified vertebrates, Coleoptera, Hymenoptera, Orthoptera, Oniscidea, Lepidoptera, Mollusca, Blattodea, and non-identified invertebrates.

Vertebrates were identified based on Hildebrand (1995), and invertebrates were identified based on Ribeiro-Costa and Rocha (2002) and on Brusca and Brusca (2007). To avoid bias on items’ classification, we consulted a specialist researcher whenever needed.

Data analyses

The time and open habitat type effects on the three response variables (1) total food weight (univariate), (2) prey taxon weights (quantitative multivariate), and taxon presences (binary multivariate) were analysed by means of one two-way permutational analyses of variance and two two-way permutational multivariate analysis of variance, respectively (Pillar and Orlóci, 1996). ANOVA was based on the resemblance matrix between the times and between the open habitats based on Euclidean distance for prey taxon weights. MANOVAs were based on chord distance for weights of prey in the pellets, and Jaccard for taxa presence (transformed into squared dissimilarities) (Legendre and Legendre, 2012). In permutational analysis of variance the test criterion is the sum of squared dissimilarities between groups of sampling units under time or open habitat factors and the significance of the observed result is tested by means of randomization tests (Pillar and Orlóci, 1996) (1,000 iterations).

We performed two principal coordinate analyses (PCoA) with the compositional data to graphically visualize the patterns of time and open habitat type distribution of pellets based on weights of different prey items and prey taxon presences. We used the centroid of the distribution of the categorical variables scores in the ordination diagram to represent the replicates of the two factors. The response variables were projected on the ordination diagram based on the correlation between each one of them and the two ordination axes, allowing the interpretation of variation in the ordination space based on the higher correlation coefficients (typically ≥ 0.5) (Pillar, 1999).

Results

Invertebrates were the most common items found in the pellets of the burrowing owls showing an average of 81% of relative frequency in the three open habitats and 81.3% in the six months (Tables 2 and 3). Beetles occurred 32.3% in open habitats and 32.5% in the six months. Non-identified invertebrates were the second most common item, followed by the hymenopterans. Vertebrates occurred at an average frequency of 19% in the open habitats.
and 18.7% in the six months. As expected for vertebrates, mammals were the most common taxon, with 15.7% average frequency in the open habitats and 15.7% in the six months (Tables 2 and 3).

The mean weight of the 396 pellets was 1.03 g (± 0.02 standard error). There was a significant time effect on the mean pellet weights (Table 1, Figure 2). August showed the higher pellet weight (1.21 g), whilst March showed the lowest mean weight (0.81 g). We found different patterns of prey compositions based on their weights and on the presence of different taxa. There was a significant interaction between time and open habitat effect on the composition of different prey based on their weights (Table 1, Figure 3). The composition of pellets on the Rural 2 open habitats was described mainly by the biomass of invertebrates during February and March, while composition of winter months showed more vertebrate biomasses in the pellets of Urban open habitats. The composition of pellets based on the presence of taxa was affected by time and open habitat factors, but there was no significant interaction (Table 1, Figures 4 and 5).

Composition of pellets in June showed more mammals and blattodeans, while beetles contributed more to the composition in July. In December, there were more hymenopterans, amphibians, orthopterans, serpents, and oniscideans, while the composition of pellets collected in March and February showed more molluscs, lepidopterans, birds, and non-identified invertebrates. Overall, composition of pellets in warmer months showed the presence of more taxa. Composition of pellets on Rural 2 areas showed only three taxa: blattodeans, coleopterans, and mammals. In that sense, pellets in Rural 1 and Urban open habitats showed the presence of more taxa compared to Rural 2 areas. Mammals and hymenopterans showed higher correlation with the two ordination axes, suggesting that these two items were more important to describe the differences between months and open habitats (Figures 4 and 5).

**Discussion**

Our initial hypotheses were partially confirmed by the results. The composition of prey items in rural open habitats near forest was different from the other habitat types. Overall, *A. cunicularia* diet has a broad prey range, which includes insects, molluscs, amphibians, reptiles, birds, and mammals similarly to other studies in the Neotropical region (Bellocq, 1987, 1988; Martins and Egler, 1990;

| Source of variation          | Sum of squares | P     |
|------------------------------|----------------|-------|
| Total weights                |                |       |
| Time                         | 5.51           | 0.001 |
| Open habitat                 | 0.38           | 0.416 |
| Time × open habitat          | 1.64           | 0.653 |
| Pellet composition based on prey weights |                |       |
| Time                         | 14.28          | 0.001 |
| Open habitat                 | 2.073          | 0.033 |
| Time × open habitat          | 8.174          | 0.001 |
| Pellet composition based on taxon presence |                |       |
| Time                         | 6.30           | 0.001 |
| Significant contrasts        |                |       |
| Jun × Jul                    | 0.87           | 0.029 |
| Jun × Dec                    | 0.78           | 0.040 |
| Jun × Mar                    | 1.92           | 0.002 |
| Jul × Aug                    | 1.57           | 0.003 |
| Jul × Feb                    | 1.08           | 0.007 |
| Aug × Dec                    | 1.13           | 0.015 |
| Aug × Feb                    | 2.02           | 0.001 |
| Aug × Mar                    | 3.21           | 0.001 |
| Dec × Feb                    | 1.38           | 0.005 |
| Feb × Mar                    | 2.04           | 0.001 |
| Open habitat                 | 1.51           | 0.016 |
| Urban × Rural 1              | 1.17           | 0.006 |
| Time × open habitat          | 5.41           | 0.999 |
Table 2. *Athene cunicularia* consumed prey items collected in six months of 2015 and 2016 in southern Brazil. Total and relative biomasses of five classes of prey, and relative frequency of taxon presence.

| Prey categories | Biomass (g) | Relative frequency (%) |
|-----------------|-------------|------------------------|
|                 | Jun | Jul | Aug | Dec | Feb | Mar |
| Vertebrates      | 0.39 | 19.2 | 21.2 | 22.6 | 18.4 | 16.7 | 13.8 |
| Amphibia         | 0   | 0.5 | 0   | 0.5 | 1   | 0   |
| Aves             | 0.5 | 0.9 | 0.4 | 0   | 0   | 0   |
| Mammalia         | 17.6 | 16.2 | 18.8 | 15.6 | 12.3 | 13.2 |
| NI               | 1.1 | 0.5 | 0.9 | 1   | 3   | 0.7 |
| Serpentes        | 0   | 3.15 | 2.6 | 1.4 | 0.5 | 0   |
| Invertebrates    | 0.56 | 80.8 | 78.8 | 77.3 | 81.7 | 83.2 | 86.2 |
| Blattodea        | 0   | 0   | 1.3 | 0.5 | 0   | 1.3 |
| Coleoptera       | 29.7 | 32  | 30.3 | 32.6 | 35.5 | 34.9 |
| Hymenoptera      | 16.5 | 10.4 | 12.8 | 13.3 | 6.9  | 6.6 |
| Lepidoptera      | 0   | 1.4 | 0.9 | 1   | 0   | 0.6 |
| Mollusca         | 0   | 0   | 0   | 0.5 | 2   | 5.3 |
| NI               | 29.7 | 32  | 30.3 | 33  | 35.5 | 35.5 |
| Oniscidea        | 0   | 0   | 0.4 | 0.5 | 1   | 0   |
| Orthoptera       | 5   | 3.2 | 1.3 | 0.5 | 2.5 | 2   |
| Vegetal          | 0.04 |     |     |     |     |     |
| Mineral          | 0.02 |     |     |     |     |     |
| Inorganic        | 0.006 | |     |     |     |     |
| Total prey       | 1.02 | 182 | 222 | 234 | 218 | 203 |
| Number of pellets| 396 | 52  | 72  | 72  | 72  | 52  |
| Richness         | 7   | 10  | 11  | 12  | 10  | 9   |
Table 3. *Athene cunicularia* consumed prey items in three open habitats collected in six months of 2015 and 2016 in southern Brazil. Total and relative biomasses of five classes of prey, and relative frequency of taxon presence of thirteen taxa. Rural 1 = open habitats near forest; Rural 2 = open habitats far from forest; Urban = urban open habitats.

| Prey categories | Biomass (g) | Relative frequency (%) |
|----------------|------------|------------------------|
|                |            | Urban     | Rural 1 | Rural 2 |
| Vertebrates    |            |           |         |         |
| Amphibia       | 19         | 16        | 22      |
| Aves           | 0.2        | 0.3       | 0.5     |
| Mammalia       | 16         | 13        | 18      |
| NI             | 0.7        | 2         | 1       |
| Serpentes      | 0.5        | 1         | 2       |
| Invertebrates  | 70.2       | 81        | 84      | 78      |
| Blattodea      | 0.5        | 0         | 1       |
| Coleoptera     | 32         | 33        | 32      |
| Hymenoptera    | 12         | 14        | 8       |
| Lepidoptera    | 0.2        | 0.7       | 0.7     | 1       |
| Mollusca       | 0.7        | 0.7       | 0.7     | 2       |
| NI             | 33         | 33        | 32      |
| Oniscidea      | 0          | 0.5       | 0.5     | 3       |
| Orthoptera     | 3          | 2         | 3       |
| Vegetal        | 2.78       | 8         | 8       | 8       |
| Mineral        | 1.04       | 2         | 2       | 2       |
| Inorganic      | 0.03       | 0         | 0       | 0       |
| Total prey     | 132.65     | 402       | 398     | 411     |
| Number of pellets | 396    | 132       | 132     | 132     |
| Richness       | 12         | 11        | 12      |

Figure 2. *Athene cunicularia* pellet weight means ± standard errors collected during six months in three open habitats of southern Brazil. Different letters indicate significant differences (P < 0.05).

Figure 3. First and second principal axes of PCoA showing the composition of *A. cunicularia* pellets described by time and open habitat factors based on a chord distance dissimilarity matrix. Correlation coefficients of prey items with the first axis: Vertebrates (Vert) = 0.99; Invertebrates (Invert) = -0.98; Vegetal (Veg) = 0.02; Mineral (Mine) = 0.03; Residues (Resi) = -0.02.
there was a high turnover in prey composition between these two open habitats. More urbanized areas present a smaller variety of prey and greater use of rodents (murids essentially) by the owls. In less urbanized areas, the diet generally has a greater variety of prey and rodents became less important (Silva, 2006). In addition to urbanization, in our study we noticed that areas farther away from forest fragments have lower prey composition. This exchanging in food behaviour allows the maintenance of populations in changing environments by means of fitness maximization (Fisher, 1930; Grafen, 2014). The exchange of prey composition depending on local open habitat characteristics observed in our study may have resulted from niche complementarity, when dissimilarity of foraging behaviour increases fitness (Mason and Bello, 2013).

The turnover in prey composition of *A. cunicularia* allows it to occupy highly disturbed areas (Vieira and Teixiera, 2008; Carevic et al., 2013). However, it should be highlighted that few prey were more important to explain the open habitat and time differences found in our study, confirming the low food-niche breadth found in Argentine grasslands (Cavalli et al., 2014). Nevertheless, the wide spectrum of prey indicates that burrowing owl can adapt to temporal and spatial variation of resources, and can consequently colonize and expand species distribution along the highly heterogeneous human-modified landscape of southern Brazil.

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