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Research Article

Trophic Ecology and Behavioral Pattern of the Vizcachera Owl, *Athene cunicularia* Molina, 1782 (Strigiformes: Strigidae) in an Urban Environment in Southern Santa Fe province, Argentina

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Keywords: Strigiformes; Ecology; Behavior; Santa Fe

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Abstract

This study investigates the trophic ecology and behavioral patterns of *Athene cunicularia* in Funes, Santa Fe, Argentina, during 2023-2024. Observations were made of two individuals throughout the four seasons of the year, recording a total of 16 hours of behavior. The results revealed that the owl showed a varied diet composed of 946 prey items identified in 134 pellets, with arthropods as the main source (91.89%). The pellets presented an average size of 31.98 mm and a weight of 1.31 g. Seven behavioral patterns were identified, with rest being the most frequent, especially in autumn and winter. Variations in diet and behavior appear to reflect adaptations to environmental conditions and resource availability, suggesting that the species is opportunistic and generalist. These findings contribute to the understanding of the ecology of *A. cunicularia* in urban environments, highlighting its role in the local ecological balance.

Introduction

Man has always paid attention to birds of prey (species belonging to the orders Falconiformes and Strigiformes). However, only in recent decades has there been a significant increase in the research and conservation of these birds worldwide, including Argentina [1].

In this context, in our country, birds of prey have been the subject of studies related to the general biology of the species and to different ecological aspects such as population dynamics [2], feeding habits, and hunting techniques [3-6] or distribution patterns and abundance in natural environments [7,8]. However, few studies have focused on their ecology in urban environments [9,10].

Birds of prey are a group particularly sensitive to human activities. Their position as top predators in the trophic webs, their wide areas of action, and their low densities make them sensitive to habitat fragmentation and loss [11]. The main factors affecting raptor populations are the intensification of agriculture, the advance of urbanization, pollution, and human persecution [1].

However, it has been shown that some species have become habituated to living in cities and that for some populations cities can provide high-quality habitats [10]. In addition, the

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presence of birds, insects, and rodents, the main prey of raptors [5,12-13], favors their establishment in urban environments.

In Argentina, the order Strigiformes has the largest number of studies [11]. In this branch of ecology, trophic studies in raptors are commonly conducted for the family Tytonidae, and the barn owl (*Tyto furcata*) stands out for being among the species with the highest number of descriptions of feeding habits [14].

Another species of interest is the barn owl *Athene cunicularia* (Molina, 1782) (Figure 1). Its distribution is very wide, from southern Canada to the southern region of Argentina and Chile [15], although it is absent in Central America and Amazonia. In our country, it is found in almost all its ranges, from the highlands of Jujuy to the south of Santa Cruz and Tierra del Fuego [16].

In central Argentina, *A. cunicularia* is the most frequent owl species in agroecosystems and open grassland areas [17], so its trophic ecology has been studied in detail in these environments [11,18,19], however, in the south of the province of Santa Fe studies on its diet are scarce, being practically nonexistent in urban areas (both for diet and behavioral patterns).

A. cunicularia is a small raptor (154-247g), about 25 cm long. Its back is brown with white spots, the belly is whitish more or less mottled with brown on the flanks, its round head without ear feathers, white eyebrow and throat, and a barred tail. Yellow iris, long whitish legs [20,21].

To the naked eye, there is no sexual dimorphism, i.e. there is no visible difference between the male and female, for example, plumage color or size. They are monogamous, although males have been recorded with two mates [22].

With respect to what is known about their behavior, it can be mentioned that A. cunicularia makes a cave in the ground using their claws to dig, as long as the soil is not very compact. Otherwise, they will use the abandoned caves of other animals, such as viscachas (hence the name) or other animals such as armadillos and maras. This differentiates it from most owls that nest using tree hollows [23].

Figure 1: *Athene cunicularia*. Photograph: S. Pitalivo y M. Scuderi.

Studies in North America have shown their preference to dig tunnels on hillsides or slopes with good visibility and little vegetation cover [24], which gives them more security. The burrow is an important structure in the life of these owls, not only for nesting but also for defense against potential predators, food storage, and shelter [24]. Sometimes it has been observed that they build or take advantage of a second nest or "satellite" den next to the main burrow where they transfer their young. It is not yet known if this behavior is to protect their young or if it has another purpose [25].

In Argentina, their reproduction occurs in the spring-summer period. They are diurnal and crepuscular, although it has been observed that they can hunt throughout the day. It is considered a small predatory species [26]. They feed on invertebrates, such as coleoptera and arachnids; mammals, such as small rodents; and also birds, amphibians, and reptiles. They are generalists since they eat everything, and opportunists because they take advantage of what is abundant at each time of the year [27].

This species stands out for its tolerance to environmental changes produced by human action [28], such as the expansion of cities, increase in crop areas, and expansion of livestock areas, among others.

The ecology of *Athene cunicularia* in urban environments offers a unique approach to conservation biology, as these modified settings challenge its adaptability and behavioral flexibility. The strong human influence in cities-such as green space fragmentation, noise, and artificial lighting-affects population dynamics and reveals ecological responses distinct from those in natural habitats. Furthermore, *A. cunicularia* serves as a bioindicator of urban environmental quality, providing a valuable tool for assessing the impact of human practices on biodiversity. Its role in controlling urban pest populations also highlights its ecological importance, fostering a balance that reduces pesticide use. Finally, the presence of this species near inhabited areas helps connect citizens with local biodiversity, promoting interest in conserving green spaces and underscoring the value of birds in sustaining city ecosystems. These factors make the study of *A. cunicularia* in an urban context an invaluable opportunity to explore conservation strategies applicable to other human-dominated environments.

In this context, and due to the lack of scientific literature that addresses the ecology of this raptor in urban environments in southern Santa Fe, the present research aims to determine the behavioral pattern and trophic ecology of two individuals of *Athene cunicularia* inhabiting an urban area in southern Santa Fe province.

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Materials and methods

Study area

Funes (formerly Villa San José or San José de los Sapos) is a city (since 1991) in southern Santa Fe province, Argentina (Figure 2). Known as the "Garden of the Province", its municipal area is part of Greater Rosario, is mostly within the department of Rosario and has a small portion within the department of San Lorenzo. It has been transformed in the last two decades in the city of greater demographic, commercial, and real estate growth of the Province of Santa Fe. It is 15 km west of Rosario's microcenter, 170 km south of the provincial capital city, 310 km north of Buenos Aires, and 400 km southeast of Córdoba.

The climate is temperate for most of the year. It is classified as a temperate pampean climate with an average annual relative humidity of 76%.

It has 38,274 inhabitants according to [29], which means that more than 15,000 new residents joined the city with respect to the population of 2010. In addition, the number of private homes also grew enormously, from 10,106 according to the previous census to 15,984. This new household register shows an increase of 58%, just below the population increase: about 63% over 2010. An extensive grove of trees and high ground gives this city particular environmental conditions that are highly sought after in the search for new residences.

Before the region was almost entirely dominated by urbanization, agricultural production, and to a lesser extent, livestock production, dense and extensive pastures predominated [20].

Behavioral patterns

To analyze the behavioral patterns of the species, two individuals of *Athene cunicularia* were studied during the four seasons of the year (autumn, winter, spring, and summer) period 2023-2024.

For each season, observations were made during one month, with one day of observation per week, totaling four days/month. In order to contemplate a time range according to the type of research being conducted, three 20-minute observation periods per day were established (dawn - midday - dusk). Thus, the total sampling effort was established at 16 hours of systematized observations.

The observation method used was the instantaneous focal animal method, adapted from Lehner (1996) [30]. Observations were made with the aid of 8 x 40 Celestron binoculars and filming with a Nikon Coolpix P530 camera with 42x optical zoom and 1080p full HD video. The observer maintained a minimum distance of 20m at all times to avoid possible interference with animal behavior [31].

Observed behavior patterns were standardized as proposed by Specht, et al. 2013 adapted from Martins & Egler (1990) [32] and Porto & Piratelli (2005) [33], and the relative frequency of behaviors was calculated according to Berndt (1992) [34], with the modification: percentage of behavior recorded in relation to total observed behaviors. Chi-square tests were used to evaluate whether or not there is independence of factors such as seasons and times of day in the activities of the specimens studied.

Trophic ecology

Many bird species, including raptors, have the ability to regurgitate (effortlessly expel through the mouth) all that they cannot digest from their food. These wastes are eliminated through food pellets called pellets. The pellets are collected around caves or on perches that are lookout sites used by owls, such as light or fence posts [23]. Such pellets contain mammal bones, invertebrate exoskeletons (legs or wings), feathers, etc.

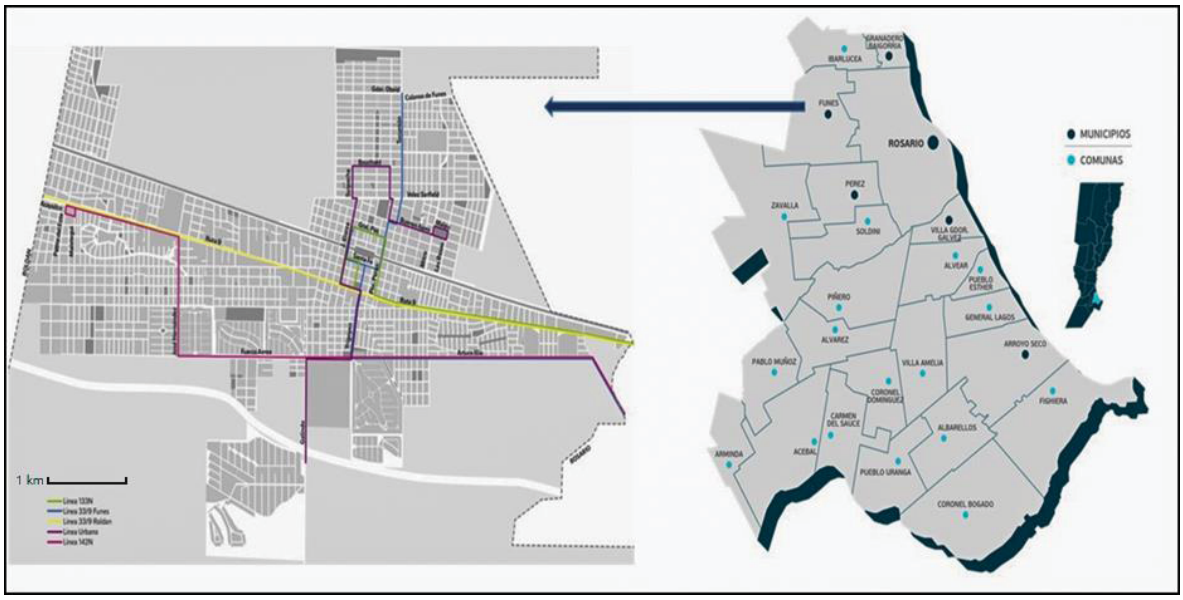

Figure 2: Study area: city of Funes, Santa Fe, Argentina.

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The remains contained in the pellets allow a fairly detailed identification of the predated taxa. This type of analysis offers the possibility of assessing species composition over large geographical areas and obtaining a large number of individuals per sample, at a low cost in terms of time and money [5,35]. At the same time, several authors agree that the relative frequencies of the different prey items counted are representative of their availability [6].

In this sense, the study of the diet of these species is very useful in ecology and ornithology, because through them it is possible to determine the type of feeding and their behavior patterns, but also to know indirectly the fauna of the region [5].

For the aforementioned reasons, during the days established for the observation described above, the pellets found in the caves and nearby perches were collected. Only complete pellets were collected for diet analysis, disregarding those that were disintegrated.

The pellets were placed in previously identified paper bags and then in hermetically sealed polyethylene bags, respecting all biosecurity measures (use of latex gloves and a mask during collection) until the material was dried, which was done in a cabinet or laboratory in an oven at 50°C for 48 hours [36]. Each pellet was weighed on an analytical balance and the length and width were measured with a digital vernier.

The analysis of their contents was performed in the laboratory following conventional techniques proposed by Marti [37].

Prey items were determined to the highest possible taxonomic resolution. Their identification was made by comparison with samples identified in the collection of the Chair of Biology and Ecology of the FCV-UNR, the Provincial Museum of Natural Sciences "Dr. Ángel Gallardo" and specialized literature. In addition, permanent consultations were made to specialists if the case required it.

For each vertebrate prey item, the minimum number of individuals was calculated from the count of homologous elements on the same side (left-right). In invertebrates, the heads and elytra, legs, claws, chelicerae, and exoskeleton remain that allow identification were taken into account. For each taxon, the relative frequency (Ni/Nt where Ni is the minimum number of individuals of prey i and Nt is the total number of prey individuals), the biomass contributed to the diet expressed as a percentage (calculated as ni.wpi.100 /Σ (ni. wpi), where ni is the number of individuals of prey i and wpi is the average weight of prey i; were calculated. Average weights of prey items were taken from literature sources [38] for mammals and insects; [4] for birds; [39] for amphibians and Cabrera, 2015 [40] for reptiles). Trophic niche breadth was calculated from the Levins Index ($B = 1/\Sigma(ni/nt)^2$, where ni/nt is the proportion of each item consumed in the diet) and the standardized trophic niche, calculated using the standardized Levins Index: $Be = \{[1/ \Sigma (ni / N)^2] - 1\} / (n - 1)$, where n is the total number of items consumed [41]. The latter index is more appropriate for analysis because resources may vary between sites or change between sampling times [42] and whose value ranges from 0 (when the population uses a single resource) to 1 (when the population uses the different resources in equal proportions [43]).

Results

Trophic ecology: 946 prey were recorded in 134 pellets of *Athene cunicularia* with an average (± SD) number of prey per pellet of 7.18 ± 1.5. The average length of the pellets was (mean ± SD) 31.98 mm ± 4.9 and the width was 14.13 mm ± 0.30. The average weight was 1.31 g ± 0.03.

The diet was composed of 16 prey items belonging to vertebrates (mammals and amphibians) and arthropods (insects, crustaceans, scorpions, and spiders) (Table 1). The most consumed prey items during the entire study year were arthropods (91.89% ± 6.62), with the Insecta Class contributing the most individuals to the diet (82.16%).

The biomass contribution of arthropods was high during spring (67%) and to a lesser extent in summer (42.04%), where vertebrates reached 57.96% (Graph 1). During autumn and winter, this trend was consolidated showing the highest biomass contribution from this group (vertebrates) with 76.46% and 81.83% respectively, with *Calomys cf. C. laucha - C. musculinus* contributing the highest values (autumn = 67.8%) and winter (55.7%).

Amphibians were present as part of the prey items only in the spring and summer seasons, and in the latter, the species *Rhinella arenarum* contributed the greatest amount of biomass (39.51%).

Values obtained from the standardized Levins index for trophic niche breadth ranged from 0.19 in summer to 0.69 in winter (Table 1), while the average weight of items consumed ranged from 0.1g (Formicidae) to 150g (*Rhinella arenarum*).

Behavioral patterns

With respect to behavioral patterns, after 16 hours of fieldwork, they were totaled for each season (1h 20 min of observation at dawn, 1.20hs. at noon, and 1.20hs. at dusk). From this, seven behavioral categories could be identified: rest, maintenance, inside the nest, and locomotion: in this category two behaviors were identified (walking or flying), non-aggressive social, warning: with two behaviors (alert vocalization and alert vigilance) and excretions (Graph 2).

Rest: Rest is more frequent in autumn in the afternoon (99.19%) and in winter in the morning (97.58%) and midday (95.71%). Spring shows more distributed activity, with 53.27% in the morning and an increase to 92.63% in the afternoon. Summer has high percentages of rest in the morning (96.69%) and a decrease at midday (74.77%) before rising again in the afternoon (87.50%).

Maintenance: In general, it is more common during midday and afternoon, with autumn at midday reaching 16.83%,

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Table 1: Prey items and diet parameters of *Athene cunicularia*.

Individuals prey	Weight	Autumn			Winter			Spring			Summer		
		N	FR	%B	N	FR	%B	N	FR	%B	N	FR	%B
Mammalia													
Rodentia													
Cricetidae													
Calomys cf. C. laucha -C. musculinus	18	36	0,1108	67,8	18	0,1047	55,7	2	0,009	10,61	1	0,0046	4,74
Oligoryzomys flavescens	22	3	0,0092	6,97	4	0,0233	15,13	1	0,004	6,48	-	-	-
Muridae													
Mus musculus	16	1	0,0031	1,69	4	0,0233	11	-	-	-	1	0,0046	4,21
Amphibia		-	-	-	-	-	-	-	-	-			
Leptodactylus sp.	18	-						3	0,013	15,91	2	0,0093	9,48
Rhinella arenarum	150	-	-	-	-	-	-	-	-	-	1	0,0046	39,5
Arachnida													
Araneae	1	2	0,0062	0,21	9	0,0523	1,54	3	0,013	0,88	3	0,0139	0,79
Bothriuridae	8	-	-	-	-	-	-	3	0,013	7,07	1	0,0046	2,1
Malacostraca													
Armadillidium vulgare	0,3	46	0,1415	1,45	28	0,1628	1,44	36	0,155	3,18	24	0,1111	1,89
Insecta													
Blatidae	1,2	18	0,0554	2,28	19	0,1105	3,92	4	0,017	1,41	9	0,0417	2,84
Carabidae	1,3	48	0,1477	6,59	32	0,186	7,15	61	0,262	23,37	38	0,1759	13
Scarabaeidae	1,1	38	0,1169	4,41	18	0,1047	3,4	42	0,18	13,61	12	0,0556	3,47
Mantidae	1,4	-	-	-	-	-	-	-	-	-	2	0,0093	0,73
Formicidae	0,1	105	0,3231	1,1	40	0,2326	0,68	53	0,228	1,56	98	0,4537	2,58
Pentatomidae	0,5	-	-	-	-	-	-	3	0,013	0,44	1	0,0046	0,13
Gryllidae	1,2	-	-	-	-	-	-	2	0,009	0,7	2	0,0093	0,63
Acrididae	2,5	28	0,0862	7,39	-	-	-	20	0,086	14,73	21	0,0972	13,9
Number of pellets		46			34			28			26		
Total number of dams		325			172			233			216		
B		5,46			6,57			5,43			3,79		
B_{est}		0,49			0,69			0,36			0,19		

For each prey item the weight (in g), the number of individuals recorded (N), their relative frequency (RF), and the percentage represented in the diet in terms of biomass (%B) are indicated. Be: Levins index, Beest: standardized Levins index.

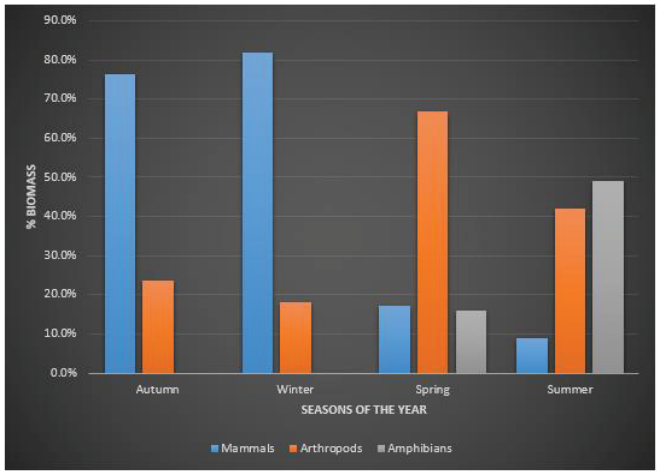
and in winter in the afternoon (12.63%). In spring it reaches the highest value in the morning (13.77%) and in summer it remains constant at 10% during midday and afternoon.

Inside the nest: This behavior is more frequent in autumn in the morning (27.96%) and spring (24.9% in the morning and 22.02% at midday).

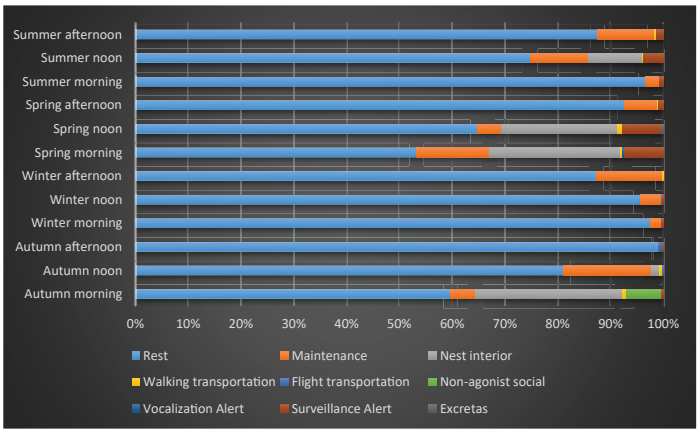
Walking iocomotion: This behavior is infrequent in all seasons, with values less than 1%. Spring seems to have more activity (0.81% at midday), and summer shows very little variation.

Flight iocomotion: Flight is also infrequent, with a slight peak in autumn in the afternoon (0.38%), and is almost non-existent in the other seasons.

Social non-agonist: This behavior only appears in autumn in the morning (6.63%).



Graph 1: Percentage of biomass contributed by prey items according to season.



Graph 2: Percentage of time spent by the owl pair on each activity according to different seasons and different times of the day, morning, noon, and evening.

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Alertness: Alert behavior, both in the form of vocalization and vigilance, appears more clearly in spring (7.31% and 7.46%) and summer, especially in the morning and midday.

Droppings: Mostly observed in autumn and spring, but with a very low percentage (0.44% and 0.27%).

Resting was shown as the dominant behavior followed by maintenance. The time spent by the owl pair on resting showed statistically significant differences between seasons with respect to the time of day ($\chi 2$ = 18, 593 gl = 6; p = 0.005). This pattern was also shown when evaluating the dependence of these two variables with respect to maintenance behavior ($\chi 2$ = 39,814 gl = 6; p = <0.0001). For the rest of the behaviors analyzed, no significant differences were found or the test could not be applied due to the scarcity of records.

Although the highest proportion of activities was recorded in spring, and midday was the time of day with the highest activity (Figures 3a,b), no significant differences could be demonstrated in comparison with other times of day or other seasons of the year (χ^2 = 2.010, gl = 6; p = 0.919).

Discussion

This study supports the description of *Athene cunicularia* as an opportunistic and generalist species, feeding on a wide range of prey such as insects, small mammals, and amphibians [27]. These findings coincide with those reported by several authors in different habitats [19,27,44,45], who have also observed significant seasonal variations in the diet of this owl.

Studies in Argentina and Chile have shown that the proportion of different foods consumed can change markedly depending on the time of year [27,42,46,47]. Based on the data collected, it can be inferred that this species tends to hunt mainly during twilight and night, given that many of its prey, such as mammals (*Calomys cf. C. laucha -C. musculinus*), amphibians (*Rhinella arenarum*), scorpions and coleoptera, are more active during the night. It has also been noted that insect consumption has remained high and constant throughout the year, with a significant increase in spring when this group represents almost 70% of the total biomass of their diet.

During autumn and winter, mammals were more common in the diet, unlike amphibians which were found to be represented in spring and summer (Table 1). These seasonal dynamics are in agreement with those reported by Bellocq & Kravetz [46] and Bellocq [44] for agrarian ecosystems in the Pampas region of Argentina.

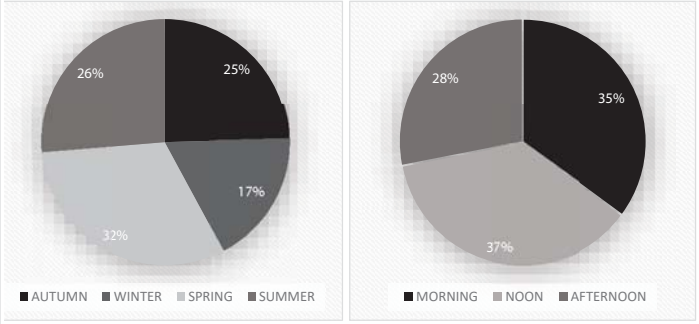

Figure 3a,b: a (left): Percentage of activities by season of the year. Figure 3b (right): Percentage of activities according to time of day.

Regarding the behavioral patterns studied, the results showed that resting was the most observed behavior, with statistically significant seasonal differences. In autumn and winter, *A. cunicularia* showed a high frequency of resting during the observations made in the afternoon (99.19% in autumn) and in the morning (97.58% in winter), which could suggest an adaptive strategy to low temperatures during these seasons [48]. The colder temperatures of these months probably encourage behaviors that promote energy conservation, limiting foraging and exploration activities to specific periods of the day when temperatures are milder. These findings are consistent with previous studies [49,50,51] that document greater inactivity in raptors during periods of low temperatures.

In spring, the more balanced distribution of roosting could be related to the greater availability of resources and more stable weather conditions, allowing *A. cunicularia* to maintain a more varied daily routine. In summer, the resting pattern with a decrease during midday could indicate an adaptation to avoid excessive heat, a common behavior in birds to regulate their body temperature and reduce the risk of heat stress [52].

Maintenance behavior, which included grooming activities (feather preening, body, and leg cleaning) and nest cleaning, was more common at midday, reaching its highest frequency in autumn (16.83%). This may be linked to nest preparation for winter, a period in which adverse conditions require increased efforts to conserve the immediate habitat [48]. Regarding preening, this behavior could be associated with the high relative humidity of the environment and a decrease in temperature during this season, which helps maintain plumage in good condition as thermal insulation [53]. It has been shown that preening effectively reduces parasite loads and serves as an important control measure and line of defense against ectoparasites, which are transferred directly with a high energetic cost to the host bird [54]. A higher number of grooming behavior repertoires could indicate that the birds are stressed, as suggested by Henson [55].

The higher frequency of nest use in autumn and spring suggests that these seasons are key for the preparation and maintenance of the reproductive space. Nest activity in spring could be related to the start of the breeding period when *A. cunicularia* needs to secure a safe environment for its offspring [52]. Furthermore, on several occasions, the observer noted the use of the nest as a refuge against potential threats.

Both walking locomotion and flight were infrequent behaviors across all seasons. However, a slight increase in walking was observed in spring (0.81%), along with a small peak in flight activity in autumn (0.38%). These results may reflect the species' energy efficiency, as it tends to minimize unnecessary physical activity outside foraging or territorial vigilance periods [48]. The use of flight in autumn could be related to searching for new hunting areas or territorial expansion in preparation for winter.

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Non-agonistic social behavior was only recorded in autumn, which may suggest greater social tolerance during this season due to the reduction in reproductive pressures [48]. This behavior is rare in other seasons, likely because of the need to protect territory and offspring. In contrast, alert behavior was more frequent in spring and summer, especially in the morning and midday, coinciding with the breeding season. Active vigilance during this period indicates a need to protect territory and offspring from potential predators or competitors. Similar to what was previously described for locomotion behavior, vigilance with alert calls was observed in response to various risk situations: high-speed vehicles passing by, people walking very close to the nest (less than 1 meter away), unleashed dogs (*Canis familiaris*) exploring nearby, lapwings (*Vanellus chilensis*) vocalizing in alert, and windy days. It is important to note that no behavioral changes were observed in response to vehicles moving at normal speeds and people walking at a reasonable distance.

Defecation was infrequently observed, with the highest percentages occurring in autumn and spring. Although this behavior was less frequent than others, its occurrence in these seasons could be related to nest activity and prolonged use of the surrounding area.

The seasonal patterns observed in the behaviors of *A. cunicularia* reflect a range of behavioral adaptations to changing environmental conditions. The prevalence of resting in autumn and winter, along with intensive nest use and alert behaviors in spring, suggests that *A. cunicularia* adjusts its daily and seasonal activities to maximize energy efficiency and protect its offspring. These observations have important implications for the conservation of the species, as disturbances to their habitat during these critical seasons could significantly impact their survival and reproductive success.

It is important to consider that this study focused on a single observation site, so the patterns described may vary in other populations of *A. cunicularia* depending on local conditions. Furthermore, the frequency of certain behaviors, such as flight locomotion and defecation, was low, possibly due to methodological limitations or observation time. Future research with larger sample sizes and in different habitats could provide a broader perspective on the behavioral ecology of the species.

Conclusion

This study reaffirms that *Athene cunicularia* is an opportunistic and generalist species, adapted to exploit various food resources and adjust its behavior according to seasonality. Variations in its diet and the high frequency of resting in autumn and winter suggest energy conservation strategies in response to unfavorable environmental conditions, while nest maintenance and vigilance activities in spring reinforce its preparation for reproduction.

Although the study was conducted at a single site, which may limit the generalization of the results, these observations highlight the importance of shelters and surroundings for the conservation of *A. cunicularia*. Further research in diverse habitats would provide a better understanding of these adaptations and reinforce the protection of key habitats in different seasons to ensure their survival and reproductive success.

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