Fire management and the nesting of *Athene cunicularia* (Aves, Strigidae) in grasslands in central Cerrado, Brazil

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***Abstract**:* Fire management is a common practice in several reserves in the Cerrado, but its influences on bird reproduction remain unknown. In addition, the nesting biology of the Burrowing Owl (*Athene cunicularia*) has been studied in numerous environments, but not in tropical grasslands managed by fire. This study examined the effects of fire management on the nesting biology of *A. cunicularia* in Emas National Park, State of Goias, central Brazilian Cerrado. We compared the number of breeding pairs and their burrows in October and November 2009 at 15 study sites in grasslands managed by fire (firebreaks) and unmanaged grasslands adjacent to and distant from firebreaks. We visited active burrows two-four times and described the burrow entrances and sentinel sites and counted and observed adults and young. A total of 19 burrows were found at firebreaks. One and two burrows were found in grasslands adjacent to and distant from firebreaks, respectively. For all burrows found, one to three young reached the adult size, being able to fly and/or run in early November. The 22 burrows found were in the ground, associated or not with termite and ant nests. Most (86.4%) burrows had only one entrance. Only three burrows had two or three entrances. Structures used as sentinel perches by adults were mounds in front of the burrow entrances, termite nests, shrubs and trees. Most of these sentinel sites were shorter than 2 m high and located less than 10 m from the burrow entrance. At Emas National Park, firebreaks appear to provide more attractive conditions to the nesting of *A. cunicularia* than unmanaged grasslands, likely because of the short herbaceous stratum due to frequent burning of firebreaks. This study suggests that fire management provides suitable conditions for the successful reproduction of *A. cunicularia* in firebreaks at Emas National Park.
***Keywords:** firebreak, landscape, burrowing owl, reproduction, savanna.*

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***Resumo**:* O manejo de fogo é uma prática comum em várias reservas do Cerrado, mas suas influências sobre a reprodução de aves não é conhecida. Adicionalmente, a nidificação da coruja-buraqueira (*Athene cunicularia*) foi estudada em numerosos ambientes, mas não em campos tropicais manejados por fogo. O presente estudo teve como objetivo examinar efeitos do manejo de fogo sobre a nidificação de *A. cunicularia* no Parque Nacional das Emas, Estado de Goiás, Cerrado central brasileiro. Comparamos o número de casais reprodutivos e suas tocas em outubro e novembro de 2009 em 15 locais de estudo, que incluíram trechos de campo sujo manejados por fogo (aceiros) e trechos não manejados, próximos e distantes de aceiros. Visitamos tocas ativas duas a quatro vezes, descrevemos as entradas das tocas e os locais de sentinela, assim como contamos e observamos os adultos e os filhotes. Um total de 19 tocas foi encontrado em aceiros. Uma e duas tocas foram encontradas em campos próximos e distantes de aceiros, respectivamente. Para todas as tocas encontradas, um a três filhotes atingiram o tamanho adulto, sendo aptos para voar ou correr no início de novembro. Todas as 22 tocas foram feitas no solo, associadas ou não a cupinzeiros ou formigueiros. A maioria (86.4%) das tocas tinha somente uma entrada. Três tocas tinham duas ou três entradas. As estruturas usadas como locais de sentinela por adultos foram montes de terra feitos à frente das entradas das tocas, cupinzeiros, arbustos e árvores. A maioria desses locais de sentinela tinha menos de 2 m de altura e localizavam-se a menos de 10 m de distância das entradas das tocas. No Parque Nacional das Emas, aceiros parecem propiciar condições mais atrativas à nidificação de *A. cunicularia* do que campos não manejados, provavelmente devido à reduzida altura do estrato herbáceo decorrente de freqüentes queimadas feitas nos aceiros. Este estudo sugere que o manejo de fogo possibilita que *Athene cunicularia* se reproduza com sucesso em aceiros no Parque Nacional das Emas.
***Palavras-chave:** aceiro, paisagem, coruja-buraqueira, reprodução, savana.*

Introduction

Athene cunicularia (Molina, 1782) is a small owl species widely distributed through the American hemisphere (Del Hoyo et al. 1999, König & Weick 2008). It occurs in most of non-Amazonian South America, in Caribbean islands, in Western North America, and Florida (Haug et al. 1993, Stotz et al. 1996, Erize et al. 2006). Some populations are in decline in North America (Holroyd et al. 2001). It inhabits a diverse range of open habitats marked by short vegetation or bare ground, such as native grasslands, pastures, deserts, sand dunes, urban parks and golf courses (Sick 1997, König et al. 1999, Erize et al. 2006, König & Weick 2008, Sigrist 2009). Arthropods and small vertebrates are their major food items (Soares et al. 1992, Teixeira & Melo 2000, Motta-Junior & Bueno 2004, Vieira & Teixeira 2008). Breeding pairs usually nest in burrows excavated by themselves or mammalian vertebrates (Haug et al. 1993, Del Hoyo et al. 1999, König & Weick 2008).

In Brazil, where 22 species of the family Strigidae occur, *A. cunicularia* is one of the most studied species (CBRO 2009, Motta-Junior et al. in press). Despite having been the focus of numerous investigations, aspects of its reproduction remain relatively poorly known (Motta-Junior et al. in press). Its reproductive behavior was studied in detail only in a Cerrado patch in northeastern Brazil (Lima 1997). Additionally, major publications on Brazilian birds briefly reported its reproduction in burrows in the ground and in termite nests that can be excavated by themselves, armadillos or woodpeckers (Antas & Cavalcanti 1988, Sick 1997, Sigrist 2009).

In the Cerrado ecoregion of central Brazil, *A. cunicularia* can be found inside and outside the reserve system (Antas & Cavalcanti 1988, Tubelis & Cavalcanti 2000, Braz & Cavalcanti 2001). Within reserves, the owl is often found in grasslands with numerous shrubs and scattered trees (Negret 1983, Braga 2006, Braga & Motta-Junior 2009) and in firebreaks such in Emas National Park (unpublished data).

Firebreaks in Cerrado's reserves are usually burned early in the dry season to create bands of vegetation marked by low biomass in attempt to stop fire spreading (Coutinho 1994, Pivello 2006, França et al. 2007). Although the impact of fire on plants is well known, knowledge of the impacts on many groups of the native fauna is lacking (Miranda et al. 2002, 2004, 2009). Exceptions at Emas National Park were two investigations of fire management and the feeding ecology of macaws that are attracted to grassland and woodland firebreaks during the fruiting season of *Anacardium humile* (Tubelis 2009a, b). No studies have investigated influences of fire management on bird reproduction in the Cerrado.

This study investigated effects of fire management on the breeding biology of *A. cunicularia* at Emas National Park, central Cerrado, Brazil. The numbers of breeding pairs and young, and their burrows, were compared between native grasslands managed as firebreaks and unmanaged by fire. Burrow characteristics, the number and dimensions of their entrances, and structures of the habitat used as sentinel perches by adults also were examined. Results are discussed in terms of the nesting biology of *A. cunicularia* in the Western hemisphere, and of fire management in Cerrado's reserves.

Material and Methods

1. Study area

This study was conducted at Emas National Park, a 132,000 ha conservation unit located in southwestern Goias State, central Brazil (Figure 1). This park harbors numerous physiognomies commonly found in central Cerrado's landscapes (Eiten 1972, Scariot et al. 2005). Grasslands are the major habitat type, covering most of flat uplands

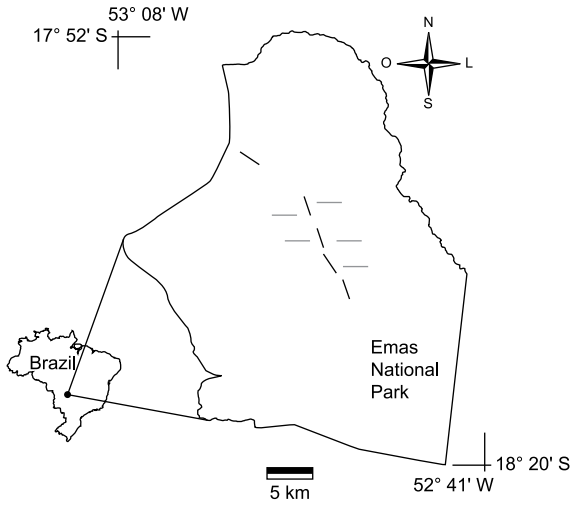

Figure 1. Study sites that were surveyed for nesting *Athene cunicularia* in Emas National Park, central Brazil, in October and November 2009. Gray traces indicate grasslands distant from firebreaks, while black traces indicate pairs of sites of firebreaks and adjacent grasslands.

(França et al. 2007). Grasslands with few shrubs and no trees are called *campo limpo*, while those with numerous shrubs and scattered trees are called *campo sujo* (Eiten 1972, Oliveira-Filho & Ratter 2002). Less dominant vegetation in the park are savanna woodlands, riparian forests, wet fields and *veredas* (Ramos-Neto & Pivello 2000, França et al. 2007).

Elevation ranges between 720 and 900 m above sea level (Ramos-Neto & Pivello 2000). The regional climate is marked by two well-defined periods: wet and dry seasons (Assad 1994). Annual rainfall ranges between 1,200 and 2,000 mm and falls between October and April. The dry season occurs between May and September. Temperatures usually range between 0 °C in July and 40 °C in January-February (Assad 1994).

Fires at Emas National Park can be natural or human-induced (França et al. 2007). Natural fires usually occur early in the rainy period as result of lightning and often burn small areas. On other hand, human-induced fires originate in surrounding farmland, most often occur during the dry season and can spread through extensive portions of the landscape (Ramos-Neto & Pivello 2000). Fire management by park managers is basically restricted to maintenance of firebreaks (*aceiros*) - strips of grassland or woodland vegetation that are usually burned in June (early dry season), every 1-2 years in an attempt to restrict fire spreading during the dry season (Ramos-Neto & Pivello 2000, França et al. 2007). Firebreaks are located between two unpaved roads and usually are 25-100 m in width.

2. Study sites

A total of 15 study sites, 2.5 km long and 25-50 m wide, were selected at Emas National Park (Figure 1). Shrubby grassland sites (*campo sujo*, Eiten 1993) were grouped into three treatments, with five replicates each: 1) grassland strips managed by fire (here called "firebreaks"), 2) grassland areas not managed by fire and adjacent to firebreaks (here called "adjacent grasslands"), and 3) grassland areas not managed by fire and located 500-3000 m from firebreaks (here called "distant grasslands"). Firebreaks and adjacent grasslands were separated only by an unpaved road measuring 6-7 m in width. They were along the major road of the park (Figure 1).

All study sites were dominated by *capim flecha* grass (*Tristachya leiostachya* Ness). This grass was 80-220 cm high in grasslands not managed by fire, and much shorter (5-15 cm high) in firebreaks (Figure 2). The density of shrubs was lower in firebreaks than in grasslands. These differences in vegetation occur because park managers burn firebreaks every 1-2 years, while unmanaged grasslands are usually burned every 4-10 years by natural or accidental fire (França et al. 2007). The study sites of a given treatment were > 500 m from each other and > 100 m from other vegetation physiognomies, such as *veredas* and woodlands.

To ensure the sampling of equal areas of different treatments, sections of firebreaks with uniform width were selected and the same width sampled in the adjacent and distant grasslands. The mean width of firebreaks measured at 5-7 points were: 25, 30, 40, 40 and 45 m. Thus, the five replicates of each treatment had areas of 6.2, 7.5, 10.0, 10.0 and 11.2 ha.

3. Burrow finding

The firebreaks and grasslands were searched for adult *A. cunicularia*. Initially we drove a vehicle slowly along roads between firebreaks and adjacent grasslands during daytime (07:00 AM - 06:00 PM on 05 October 2009). After surveying a firebreak and a 30 minutes interval, the adjacent grassland was surveyed in opposite direction. The detection of owls and their nest sites from the vehicle was possible because: 1) adults often perched adjacent to or near the burrow entrance during the breeding season, 2) termite nests often used as sentinel sites by breeding adults were often partially covered with white feces, 3) firebreaks and areas searched in adjacent grasslands were narrow enough to allow detection of owls and termite nests from the vehicle.

When owls or termite nests with white feces were detected, the presence of an active *A. cunicularia* burrow was confirmed by DPT by some of the following facts: 1) one or two adults close to a burrow entrance, 2) restless behavior such as several alarm calls and short flight 10-40 m from their perch in response to the approach of the observer, 3) the presence of young at the entrance of the burrow, 4) footprints on the mound in front of the burrow entrance. Burrows with these characteristics were called "active burrows". On other hand, burrows with entrances partially obstructed by vegetation, with no mounds and footprints around its opening, and not used by adults or young were considered as "inactive burrows".

During these surveys, the tall and fully developed *capim flecha* grasses could lead to lower detection of breeding adults and their burrows in unmanaged vegetation. Thus, the five sites of adjacent grassland were walked 15-20 m from the adjacent road between 6 and 8 November 2009. At this time, young were more developed and could be easily seen. To verify the nesting of *A. cunicularia* in a more natural situation, distant grassland sites 500-3000 m from firebreaks were also searched on foot during these three days. Each adjacent and distant grassland site was walked once.

4. Observations and habitat measures

Each nest site at firebreaks was visited three times (once per day) between 5 and 7 October. Burrows found in grasslands and firebreaks were visited once between 6 and 8 November 2009. During each visit, adult and young owls were counted and habitat components were measured. In November, adults and more developed young could be distinguished due to their distinct plumages (König & Weick 2008, Sigrist 2009).

All burrow entrances were photographed and their height and width were measured. Habitat structures (shrubs, trees, mounds, and termite nests) where adults were perched at the observer's arrival were considered sentinel sites. Plants and termite nests had their heights and distances to the cavity entrance measured. In cases of burrows with more than one entrance, that closer to where the adult landed was considered the active entrance. These observations and measurements were done during each visit to each nest site. Mounds were not measured. Sentinel perches were not measured in unmanaged grasslands due to the low number of active burrows found.

5. Analyses

Chi-square test was used to compare the numbers of burrows found in different treatments. Pearson correlation was used to examine the relation between the height of perches and their distance to the burrow entrance. The mean heights of plants and termite nests identified as sentinel perches were compared with the Kruskal-Wallis test. All analyses were performed using BioEstat 2.0 (Ayres et al. 2000). Significance was set at $P < 0.05$.

Results

1. Number of burrows

Twenty-two pairs of *A. cunicularia* were found in the 15 study sites. A significantly higher number of active burrows was detected at firebreaks (19, 86%) than in adjacent grasslands ($N = 1$; $\chi^2 = 16.20$; g.l. = 1; $P < 0.001$) and in distant grasslands ($N = 2$; $\chi^2 = 13.76$; g.l. = 1; $P < 0.001$). Driving on consecutive days along firebreaks and adjacent grassland sites did not lead to the finding of any additional pairs in October.

2. Burrow characteristics

The active burrows were grouped into three major categories, according to their association with nests of social insects. At firebreaks, 12 (63%) burrows were < 100 cm from the base of termite nests that showed substantial variation in size (Figure 3a, b). Burrows were excavated under the termite nests. Three burrows (16%) were within large mounds of soft soil covered by sparse or no vegetation associated with abandoned ant nests in firebreaks (Figure 3c). Four (21%) burrows found in firebreaks were not closely associated with ant or termite nests, which were > 6 m from the entrance. The only burrow found in adjacent grasslands was associated with an

Figure 2. A boundary with two study sites separated by an unpaved road at Emas National Park, central Brazilian Cerrado, in October 2009. *Capim flecha* grasses are higher than termite nests and shrubs in the adjacent grassland but shorter than them at the firebreak (vegetation on the left of the road).

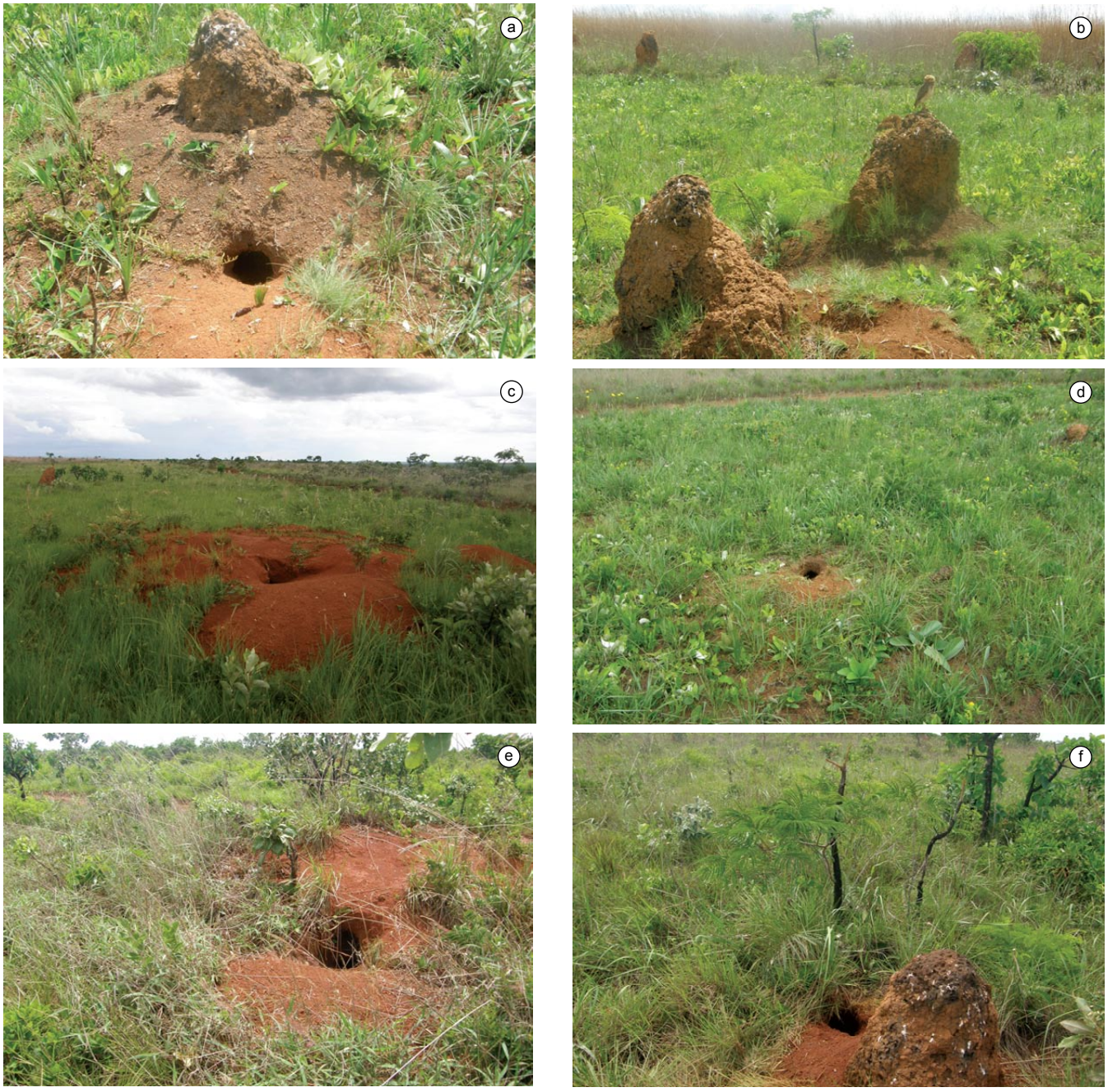

Figure 3. Types of *Athene cunicularia* burrows found in firebreaks (a, b, c, d) and grasslands not managed by fire (e, f) at Emas National Park, central Brazilian Cerrado, in October and November 2009. a) a burrow associated with a small termite nest; b) a burrow associated with a large termite nest; c) a burrow associated with an abandoned ant nest; d) a burrow not associated with ant and termite nests; e) a burrow in a grassland adjacent to a firebreak; f) a burrow in a grassland distant from firebreaks.

abandoned ant nest (Figure 3e). The two burrows detected in distant grasslands were associated with termite nests (Figure 3f).

The openings of six burrows found at firebreaks had a nearly elliptical shape, being wider than higher (Figure 4a). Entrances of other burrows detected in firebreaks and those in grasslands not managed by fire were nearly round (Figure 4b). All burrows had a mound in front of its opening, the result of the burrow excavation. At most (82%) of the 22 burrows, the immediate proximity of the entrances was free of vegetation (Figure 4a, b). Grasses were quite close to the entrance of two burrows (Figure 4c), and a short palm was on the side of two burrow entrances (Figure 4d).

The three burrows excavated in unmanaged grasslands had only one entrance, as occurred with 16 (84%) burrows found in firebreaks. One of the burrows excavated at firebreaks had two entrances while two had three entrances (Figure 4e). All three burrows with more than one entrance were associated with abandoned ant nests at firebreaks. The use of these additional entrances by the owl family was apparent when young ran inside them, by footprints on their mounds, and by vigilant adults.

At eight (42%) nest sites in firebreaks, one inactive burrow was found 5-15 m from the active burrow. Entrances of these inactive burrows were quite similar in size and shape to the entrances of the 22 burrows but

Figure 4. Entrances of *Athene cunicularia* burrows in firebreaks at Emas National Park, central Brazilian Cerrado, in October and November 2009. a) a wide entrance; b) a nearly round entrance surrounded mainly by bare ground; c) an entrance surrounded by short grasses; d) an entrance with a short palm; e) a burrow with three active entrances; f) the entrance of a burrow considered as inactive.

they had no mounds nearby. The entrances were partially obstructed by parts of plants, such as leaves and roots (Figure 4f).

3. Adult and young owls

During each visit to nest sites, one or two adults were seen in association with each burrow. Two adults were seen in 84 and 86% of the visits in October and November, respectively. Consecutive visits led us to know that two adults were present at every burrow. However, young were seen in only 37% of the visits in October. Young were cryptic, as they tended to quickly run inside the burrow during this period. Also, some could have not emerged in October. On other hand, young were seen in 91% of the visits in November, when they were in less of a hurry to run inside the burrow in response to the observer's approach, and some could fly. Each breeding pair nesting in adjacent and distant grasslands had two young. At firebreaks, breeding pairs had an average of 2.1 young per burrow: two pairs had one young, 13 had two young, and four had three young.

4. Sentinel perches

Breeding adults used the earth mound in front of the burrow entrance, termite nests, and plants as sentinel perches at firebreaks (Figure 5). Four to six perches were used at each nest site in firebreaks.

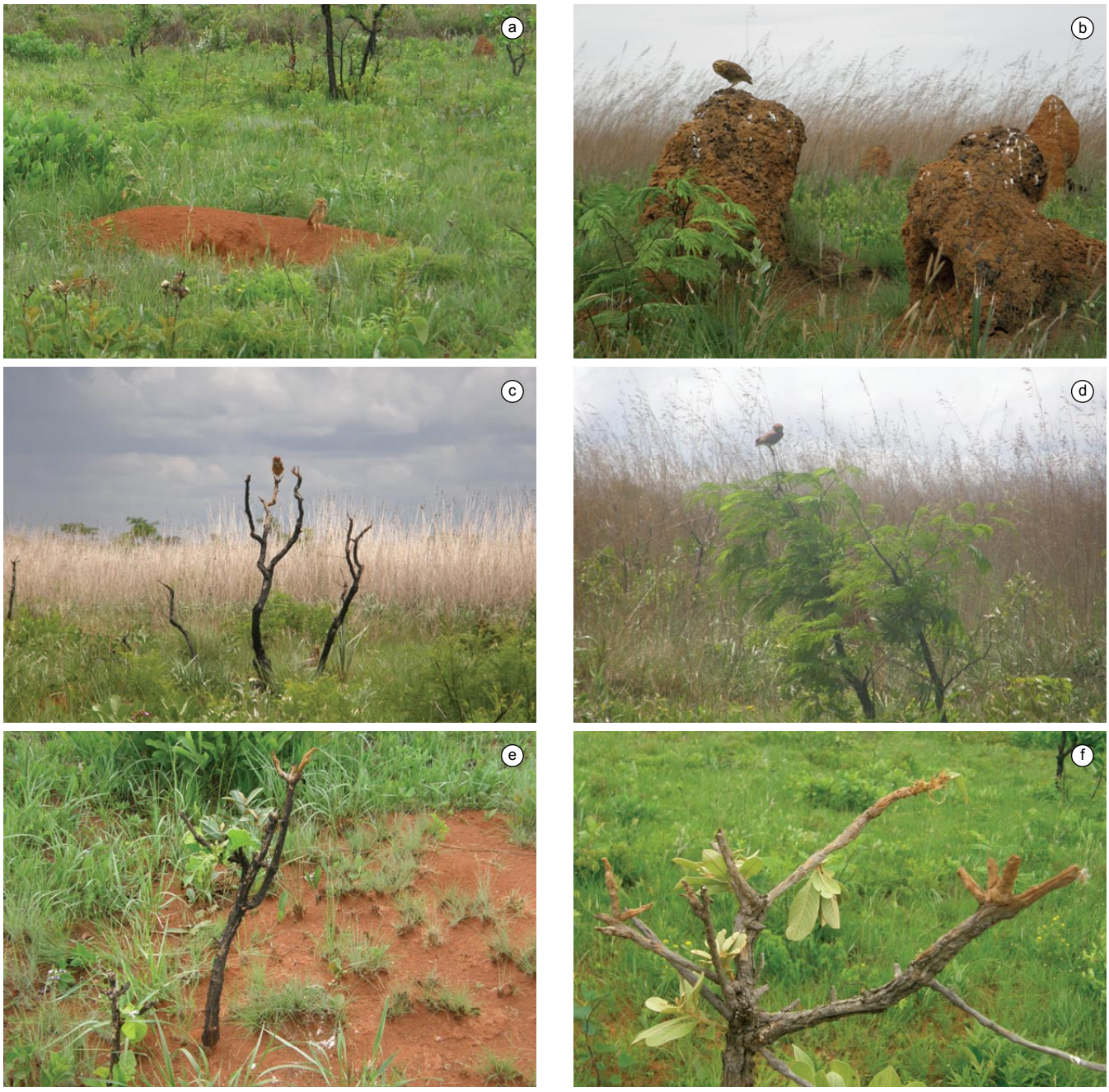

Figure 5. Elements of firebreaks used as sentinel sites by *Athene cunicularia* breeding pairs at Emas National Park, central Brazilian Cerrado, in October and November 2009. a) a mound resulted of the burrow excavation; b) termite nests; c) a dry and small tree without leaves; d) a shrub with numerous leaves; e) a small shrub with white feces under it; f) a shrub with dirt parts often used by adults.

An adult was on the mound in 98% of the visits to the nest sites. Termite nests and plants were used as sentinel sites in 52 and 54% of the visits, respectively, in firebreaks. Usually, during a visit, one owl was on the mound and the other perched on a plant or a termite nest.

In all habitats, mounds were usually clean with no pellets, food remains or nest materials. The mounds were usually less than 20 cm above the surrounding ground. Thus, they were typically higher than the grass at firebreaks (Figure 5a), but shorter in the unmanaged sites (Figures 3e, f). At firebreaks, termite nests where adults perched were usually covered by white feces (Figures 3b and 5b), probably the result of long periods on these structures. The height of termite nests ranged between 38 and 150 cm (mean = 71.9 cm; s.d. = 25.1 cm; n = 61), and they were 10-1400 cm from the burrow openings (mean = 451 cm, s.d. = 720 cm; n = 61). The correlation between the height of termite nests and the distance to the burrow openings was weak and not significant at firebreaks ($r = 0.17$; g.l. = 59; $P = 0.195$; n = 61).

In firebreaks, plants used by adult owls as sentinel perches varied from small shrubs to small trees (Figure 5) between 42 and 250 cm in height (mean = 138.5 cm; s.d. = 52.7 cm; n = 67) with or without leaves. Owls usually perched on braches located above the leaves (Figure 5d). The parts of plants where owls were perched were

covered by soil (Figures 4b and 5e, f). The ground under plants used as perches was often covered by numerous white feces (Figure 5e). Plants used as perches were 30 to 1400 cm from the burrow openings (mean = 481 cm, s.d. = 352 cm; n = 61). The correlation between the height of plants and the distance to the burrow openings was weak and significant (r = 0.29; g.l. = 65; P = 0.016; n = 67). Plants used as sentinel perches were significantly higher than termite nests (H = 48.635, g.l. = 1, P < 0.001). Distances of plants and termite nests to the burrows were not significantly different (H = 0.642, g.l. = 1, P = 0.42). In unmanaged grasslands, owls also perched on mounds, termite nests and plants.

Discussion

1. Number of burrows

Our study is the first to estimate densities of *A. cunicularia* breeding pairs in the Cerrado and other South American tropical regions. The density of breeding pairs (19/44.9 ha or one pair/2.4 ha) detected in firebreaks is within the range found in North American landscapes (Haug et al. 1993, Restani et al. 2001, König & Weick 2008). For example, one pair/110 ha was found in Montana (Restani et al. 2001), while one pair/0.2 ha was detected in Oklahoma (Butts 1971). Neighboring active burrows about 100 m from each other, as occurred at firebreaks, also have been found in the United States (Green & Anthony 1989, Desmond & Savidge 1996). On other hand, the densities of breeding pairs found in distant and adjacent grasslands (one pair /22.5 ha and one pair/44.9 ha, respectively) are considerably lower than densities commonly recorded elsewhere.

The occurrence of more active burrows in managed than in unmanaged grasslands is the result of frequent burning by park managers - the maintenance of a short herbaceous stratum at firebreaks. These owls avoid areas with tall grass (Del Hoyo et al. 1999, König & Weick 2008), and appear to not be adapted to dense tall *capim flecha* grasslands at Emas National Park. Fully developed *capim flecha* grasses can substantially affect the movements and visibility of owls. Since foraging by *A. cunicularia* often involves short flights and running to capture prey on the ground (Thomsen 1971, Martins & Egler 1990), dense tall *capim flecha* would interfere with foraging. Tall *capim flecha* grasses would negatively influence owl vigilance against predators. On other hand, *A. cunicularia* can fly, walk, run and view over long distances in firebreaks with short grasses (pers. observ.).

The three nest sites found in unmanaged grasslands were in areas also dominated by *capim flecha* grass. However, the grasses reproductive and tall parts were scattered or patchily distributed which would allow owls to fly, run and see easily from the nest sites. Actually, the density of *capim flecha* reproductive parts varied considerably through the extension of the grassland matrix at Emas National Park. Probably, *A. cunicularia* can not reproduce in areas where tall *capim flecha* occurs at high densities (see grasslands behind firebreaks in Figures 5b and 5c), unless they are close to firebreaks, potential places for feeding. Unmanaged grasslands were described as the primary habitat of *A. cunicularia* in the Cerrado (Braga 2006, Braga & Motta Junior 2009). At Emas National Park, only grasslands burned within the previous 2-3 years might provide adequate conditions for *A. cunicularia* nesting because reproductive parts of *capim flecha* grass are absent, short or sparse in these areas.

The lower numbers of active burrows in unmanaged grasslands than in firebreaks might be the result, in part, of lower visibility by the observer. However, we considered that the slow passes, the careful searches, and the narrow width of the study sites favored the finding of all breeding pairs during surveys on foot. Furthermore, the conspicuous behavior (alarm calls and flights) of adult owls and termite nests partially covered with white feces contributed to make counts accurate, especially considering the short width of search area (15-20 m). Thus, we believe that the dramatic difference between the numbers of active burrows in grasslands vs. in firebreaks was the result of nest-site selection by breeding pairs. Since few burrows were detected in unmanaged grasslands, further studies are necessary to better investigate differences between the *A. cunicularia* nesting in grasslands adjacent to and distant from firebreaks.

2. Burrow characteristics

The three burrow types might involve different ecological factors and forces of selection. Burrows with openings at the base of termite nests provided opportunities for owl vigilance adjacent to the opening in an elevated position. Further, termite nests usually have a cavity underground that might be used by owls as a nest chamber. On other hand, burrows made in abandoned ant nests have elevated openings, likely permitting good horizontal visibility for adults. Also, the soil of these huge ant nests is softer than that of grasslands (pers. observ.), likely making burrow excavation easier at these sites. The vigilance from burrows not closely associated with termite and ant nests can be done by perching on the mounds, and on nearby plants and termite nests. As burrows used by owls can be excavated by armadillos (Antas & Cavalcanti 1988, Sigrist 2009), the position of burrows might be the result of opportunist behavior by owls.

Burrow openings were usually surrounded by short and sparse grasses, as has been often recorded in North America (Rich 1986, Botelho & Arrowood 1998, Belthoff & King 2002, König & Weick 2008). The advantage is good horizontal visibility by adults.

At the nest sites, we did not find numerous pellets, dung or other decorations around the burrow openings as reported in some studies (Thomsen 1971, Sigrist 2009). While pellets might have been spread out by the heavy rains that occurred at night during the period of observations, the lack of other decorations is very different that at *A. cunicularia* nests in North America (Thomsen 1971, Haug et al. 1997). Burrows with more than one entrance were recorded only at abandoned ant nests. Since this soil is soft, additional entrances and tunnels might be relatively easy to be built. They would help to avoid the imprisonment of young in cases of tunnel collapse, or escape from predators.

3. Adult and young owls

Each active burrow was associated with a pair of adults as has been widely recorded in studies of *A. cunicularia* (Del Hoyo et al. 1999, König & Weick 2008). The detection of only one adult during each visit at a given nest site might result of two situations. The other adult could be foraging beyond the burrow surroundings or protecting eggs and young inside the burrow. The presence of breeding pairs distant about 100 m also has been detected in colonies of nesting *A. cunicularia* in North America (König & Weick 2008).

The production of 1-3 young per pair recorded in our study is smaller than those commonly observed in the United States and Canada where eight or more young can be produced with means often between 2.5 and 6 young per burrow (Haug et al. 1993, Plumpton & Lutz 1993, Botelho & Arrowood 1998, Restani et al. 2001, Belthoff & King 2002, König & Weick 2008). In Brazil, Antas & Cavalcanti (1988) reported the laying of up to four eggs in central Cerrado. As we have not examined burrow interiors, we do not know the numbers of eggs produced by each breeding pair. So, detailed estimates of breeding success (e.g., Mayfield 1975, Marini et al. 2009) can not be done with our results. As the mean number of young produced at firebreaks sites was similar to those numbers produced in unmanaged

grasslands, *A. cunicularia* can successfully reproduce in firebreaks at Emas National Park.

4. Sentinel perches

In Brazil, several studies have reported that *A. cunicularia* breeding adults use perches located around to the nest burrow for vigilance (e.g., Antas & Cavalcanti 1988, Sick 1997, Lima 2007). They reported that termite nests, fences, buildings, poles and telephonic lines can be used by breeding owls.

Our study showed that breeding adults most often use the mound in front of the burrow opening as sentinel site. These mounds are shorter than other habitat elements used as sentinel perches. However, due to their close proximity to the burrow entrance, mounds might favor efficient detection of predators trying to get inside the burrow. Termite nests and plants were used as sentinel perches in similar frequencies. Despite this, they might represent slightly different ecological conditions. Termite nests are durable and immobile perches. On other hand, plants can provide better horizontal visibility, especially trees and shrubs that were higher than termite nests. Some plants have the disadvantage of being temporary, due to frequent burning of firebreaks or natural death followed by fall and decomposition.

Usually, when the two adults were recorded, one was on the mound and the other perched on a termite nest or a plant. This behavior likely favors vigilance of the burrow entrance and surroundings. We do not know if perches help thermoregulation of adults, as suggested to occur in California (Coulombe 1971).

5. Fire management in Cerrado's reserves

Our study is the first to bring information on influences of fire management on bird reproduction in the Cerrado. Effects of fire management on *A. cunicularia* appeared to be positive at Emas National Park because firebreaks harbored higher densities of breeding pairs than unmanaged grasslands. The burning of firebreaks by June/July permitted owl breeding activities in the austral spring.

Firebreaks are recent landscape elements that should be viewed as important areas for *A. cunicularia* at Emas National Park. The grassland matrix of this reserve has been dominated by the tall *capim flecha* grass during the last decades (Ramos-Neto & Pinheiro-Machado 1996, França et al. 2007). Thus, the herbaceous layer of native grasslands had become taller than previously. To some extent, firebreaks mitigated the negative effects of *capim flecha* on *A. cunicularia* by maintaining grassland areas with short grasses in this park. Recently, unmanaged grasslands with short grasses occur only patchily, as result of natural and accidental fire. As *capim flecha* grasses fully develop after about two years, these grassland patches with short herbaceous layer are temporary at Emas National Park. Maintenance of the current management practices in some grassland firebreaks will provide suitable habitat for breeding *A. cunicularia* in some areas of Emas National Park.

In the Cerrado, frequent burning leads to the thinning of the woody layer in savanna woodlands, such as *campo cerrado* and cerrado sensu stricto (Miranda et al. 2002, 2004). Thus, management with fire of these physiognomies has created vegetation similar to that of shrubby grasslands with a short grass layer at Emas National Park. This habitat was suitable for *A. cunicularia* reproduction, as shown by the fortuitous finding of four nests with developed young in November 2009 at firebreaks crossing these woodlands.

Differences between the numbers of *A. cunicularia* burrows in managed and unmanaged grasslands might have been less dramatic in Cerrado's reserves where *capim flecha* grass is not dominant. Thus, decisions on fire management in the Cerrado should take into account characteristics of the reserves. As influences of fire on bird reproduction can be species specific, studies on a wide range of taxa are necessary to adequately guide fire management focusing conservation of bird diversity in Cerrado's reserves.

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