

# Fire in Savannas and its Impact on Avifauna: Considerations for a Better Environmental Conservation

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## **Keywords**

Fire ecology  
Biogeography  
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## **Abstract**

Savannas are a pyrophytic biome, a biodiversity hotspot, and have global importance, occupying 20% of the Earth's surface. It is a biome that requires burning to maintain its biodiversity and pyrodiversity. It has suffered from altered fire regimes due to the direct and indirect action of factors such as deforestation, agriculture, cattle ranching, and climate change, resulting in habitat loss, degradation, and fragmentation. This fact can impact the avifauna, changing population dynamics and distribution in the landscape. Thus, through a literature search, this study evaluated the influences of fire on avifauna populations in savannas. It was found that fire impacts avifauna directly or indirectly and acts positively or negatively, according to the niche of the species evaluated and its intrinsic characteristics. The observed effect will depend on the fire detection ability, locomotion capacity, species, habit, functional guild, demographic parameters, resource availability, post-disturbance successional evolution, dispersal ability, and the geographic scale of the area affected by the fire. The main impacts observed for this clade are indirect effects, and its most negatively impacted populations are the ratites and those with poor locomotion ability. Despite the many gaps in knowledge about the impact of fire on the population parameters of avifauna, studies that focus on community dynamics indicate that, in general, there are few changes in richness and abundance indices. Thus, a greater understanding of the consequences of fire on birds is necessary to support better the actions of the Integrated Fire Management Program and its expansion throughout the Brazilian territory in search of quality, dynamic, and integrated environmental management.

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## INTRODUCTION

The savanna is a biome comprising various phytophysiognomies ranging from open fields to forest formations (COUTINHO, 1978). It occurs on four continents (America, Africa, Asia, and Oceania), corresponding to 20% of the Earth's surface (SCHOLES; HALL, 1996; WALTER et al., 2008). It is a pyrophytic biome, which has evolved with natural fires over the past 4 million years (SIMON et al., 2009) and anthropogenic fires for at least 4,000 years (PIVELLO, 2011).

The savannah vegetation suffered pressures that selected tolerant plants adapted to herbivory and fire (COUTINHO, 1979). In these environments, fire is a regulatory and environmental conditioning agent since many plant species depend on its effects on different aspects of their life cycles (WALTER; RIBEIRO, 2010), and it is even necessary for the conservation of the biome (COUTINHO, 1990; MARMORI, 1990).

Some studies show fire as an integral component of the trophic ecology of pyrophytic environments, although this role is usually neglected (BOND; KEELEY, 2005; BOWMAN et al., 2016). In this situation, fire, like herbivores, converts complex organic molecules into simpler organic and mineral products (BOND; KEELEY, 2005). Thus, fire in the landscape is an integral component of food webs, connecting fire regimes, ecological processes and biological diversity in all trophic levels, including humans, generating resilient and functional ecosystems, that is, pyrodiversity (BOWMAN et al., 2016). Despite this, there are few evaluations in this regard, making it difficult to understand its fundamental importance and impact.

Pyrophytic ecosystems naturally present specific fire regimes, that is, characteristics related to the fire pattern presented in time and space, such as type of fuel consumed and fire propagation patterns (surface, soil, or canopy); intensity (temperature); severity (mortality); seasonality; in addition to frequency (BOND; KEELEY, 2005). During the dry season, the outbreaks are usually of anthropogenic origin and spread quickly through the vegetation, reaching large areas and being more intense depending on the greater presence of combustible material and climatic conditions (COLLINSON, 1988). On the other hand, natural fires occur due to lightning in the transition periods between the dry and rainy seasons (RAMOS-NETO; PIVELLO, 2000). On these occasions, as the litter is wet, the fire has difficulty spreading and is therefore short-lived.

It is known that the presence of grasses is a preponderant factor in vegetation in terms of flame propagation (SCHMIDT; ELOY, 2020; SIMPSON et al., 2022). In this context, it is noteworthy that, as savannah forest formations do not have a continuous layer of grasses covering the soil, these phytophysiognomies are rarely affected by large-scale natural fires (HOFFMANN et al., 2009). Accordingly, such plants did not evolve with fire and have high mortality when affected by anthropogenic fires (FRANCO et al., 2014).

In addition to the intrinsic characteristics of each location and phytophysiognomy, climate change has drastically altered the fire regime, resulting in more frequent forest fires that reach larger areas in certain years (SCHMIDT; ELOY, 2020). Due to events such as *El Niño*, the dry seasons have been longer, leading, consequently, to longer fire seasons (ALVARADO et al., 2017; ARCHIBALD et al., 2013), with an average increase of 33 days over the last 35 years (JOLLY et al., 2015). Therefore, it is necessary to implement policies and management actions to help prevent environmental damage, human health, and economic damage caused by fires (JOLLY et al., 2015).

Another relevant factor for changing the fire regime in the savannas was the expansion and development of the agricultural frontier, as well as the environmental consequences of the transformation from the natural landscape to the humanized landscape. In Brazil, the expansion of the agricultural frontier was a factor responsible for the deforestation of the Cerrado vegetation, resulting in the loss of nearly half of the original vegetation (SCHMIDT; ELOY, 2020).

Associated with the issue of deforestation, the expansion of the agricultural frontier was also responsible for the intercontinental introduction of African species, such as the colonial grass *Panicum maximum* Jacq. and signal grass *Urochloa* sp. and *Brachiaria* sp., as these grasses are considered more productive than the natural species (DUTRA E SILVA; BARBOSA, 2020). These species are, on average, taller in stature, have greater leaf area, and have a lower carbon-nitrogen ratio than Australian and South American grasses (JARDINE et al., 2020), collaborating with a greater accumulation of organic matter on the soil and increased combustibility and connectivity, changing natural fire regimes (GORGONE-BARBOSA et al., 2015; MCGRANAHAN et al., 2013; SETTERFIELD et al., 2010; SIMPSON et al., 2022).

Zero-fire policies were implemented globally in savannas, resulting in increased availability of dry litter distributed continuously over the landscape, favoring mega fires (FIDELIS *et al.*, 2018). This process occurs because the suppression of fire leads to the replacement, in the long term, of open fields by forests (STEVENS *et al.*, 2017), which are more prone to fires of great intensity and duration (SCHMIDT; ELOY, 2020). It is important to note that the outbreaks can also reach Gallery and Riparian Forests, fire-sensitive phytophysionomies, causing high mortality of adult trees (FRANCO *et al.*, 2014; SCHMIDT *et al.*, 2018; SCHMIDT; ELOY, 2020; WALTER; RIBEIRO, 2010). Thus, frequent fires favor grasses over woody ones, converting these areas into more open phytophysionomies (MOREIRA, 2000), a fact consistent with the theory of alternative stable states (DUBLIN *et al.* 1990; JACKSON, 2003).

Considering the problem of the zero-fire policies, the Programa de Manejo Integrado do Fogo (Integrated Fire Management Program) was established in federal conservation units and Brazilian indigenous lands. Yet this program encourages pyrodiversity; most of the Cerrado is concentrated in private areas, subject to state coordination (SCHMIDT; ELOY, 2020), which imposes obstacles to its full performance.

There are several studies carried out in savannas that sought to verify the influence of fire on the flora (COUTINHO, 1990; FRANCO *et al.*, 2014; MOREIRA, 2000; SCHMIDT; ELOY, 2020; SCHMIDT *et al.*, 2018; STEVENS *et al.*, 2017; WALTER; RIBEIRO, 2010). However, few have as a goal to verify their effects on the fauna and, when they do, they aim at the effects on the communities as a whole (ANTUNES, 2005; FRIZZO *et al.*, 2011; GANEY *et al.*, 1996; NOVOA *et al.*, 2021; OLIVEIRA, 2013; WATSON, 2012). Furthermore, changes in the fire regime as a result of climate change and the consequences of changes in the landscape by land use make it crucial to assess the specificities of the effects of fire regimes on biodiversity (ALVARADO *et al.*, 2017; ARCHIBALD *et al.*, 2013; JOLLY *et al.*, 2015).

Savannah species had the need to adapt to new scenarios and fire regimes, responding in different ways to changes in the environment (ANTUNES, 2005; BAESSE, 2015; FIDELIS; PIVELLO, 2011; HANSBAUER *et al.*, 2008; MOORMAN *et al.*, 2012). Thus, understanding how population processes are affected by fire in pyrophytic environments is essential for species management in this biome (BROWN *et al.*, 2013), as it assesses factors such as susceptibility of populations to extinction

(NORRIS, 2004), potentially adverse effects of burning (BANKS *et al.*, 2011); and what would be the appropriate fire regime (DRISCOLL *et al.*, 2010).

Birds are dynamic animals, resilient, mobile, and sensitive to environmental conditions, responding quickly to changes (BAESSE, 2015). They are also considered good models for understanding the effects of habitat loss and fragmentation (BOSCOLO; METZGER, 2011) since more than 80% of bird species at risk of extinction are highly impacted by these factors (HILTON-TAYLOR, 2000). Birds have different life habits and reactions to environmental disturbances (ROLSTAD, 1991), and are also used as umbrella species, aiding in the conservation of other species (LAMBECK, 1997).

Therefore, the objective of this article will be to discuss how fire has impacted and influenced bird populations in savannas. This is a very relevant study as it seeks to elucidate how bird species in different functional groups and ecological niches respond to the impact of fire.

## IMPACTS OF FIRE ON BIRDS IN SAVANNAS

Forest fires and land use practices such as clearing vegetation, deforestation, and agriculture result in the loss of habitat for natural species, as well as in fragmentation and degradation of the environment, altering the population dynamics of species and their distribution (FAHRIG; MERRIAM, 1994; PULLIAM; DANIELSON, 1991). In turn, fragmented and isolated populations are more prone to extinction through intrinsic stochastic processes, such as demographic variability or environmental events such as fire (HARRISON; TAYLOR, 1997; WITH; KING, 2001).

Each species' tolerance to changes in the environment varies according to its ability to modify and expand its niche, adjusting to new habitat conditions (ANTUNES, 2005; BAESSE, 2015). The habitat attributes that form the structural complexity of the environment are essential for certain guilds to remain in altered locations (WUNDERLE, 1997). It is also expected that species that exploit the same class of resources similarly respond analogously to the same disturbance (NOVOA *et al.*, 2021). Hence, the effect of fire on birds goes through changes in habitat attributes, as these will determine how birds will respond to new environmental conditions (GANEY *et al.*, 1996),

having direct and indirect effects on these animals.

### *Direct Effects*

As a direct effect of fire, there is a reduction in the population size of birds, either through exposure to extreme heat or smoke (BANKS et al., 2011; BROOKER, 1998; SANDERFOOT et al., 2021). Smoke can also persist in the atmosphere, impacting on a much larger spatial scale than the area burned by deteriorating air quality and degrading visibility (SANDERFOOT et al., 2021).

Birds are considered animals of great locomotion, being able to escape the flames with some ease, although this capacity varies according to the species, habit, habitat in which they live, their functional guild, as well as individual attributes, such as age, morphology, and health. (ROLSTAD, 1991). Their complex respiratory system can be negatively influenced if exposed to smoke, as it suffers carbon monoxide poisoning and thermal and chemical damage, leaving it more susceptible to respiratory diseases (NIMMO et al., 2021).

A population of birds at risk of extinction that had little mobility, such as ratite species, are more likely to be impacted by species mortality (BROWN et al., 2013). Suppose the impact is significant and there is a sharp population reduction. In that case, this population will then suffer the adverse effects of the Allee effect due to the difficulty in finding partners or in cooperative feeding due to the low density (KRAMER et al., 2009).

Despite the various negative impacts, there are direct positive consequences for the birds. A study of the effects of fire on the reproductive success of the burrowing owl *Athene cunicularia* Molina, 1782 in the Brazilian Cerrado, indicated that fire management offers adequate conditions for this species (TUBELIS; DELITTI, 2010). According to the authors, this occurs because this owl uses termite nests for shelter and nesting and to avoid areas with tall grass, as this type of vegetation interferes with its foraging and surveillance against predators.

Durigan et al. (2020), in their study on the net loss of species diversity after prescribed fires in the Brazilian Cerrado, demonstrated that there are no net changes in total abundance and sharp decreases in richness. According to the authors, this may be a reflection of the combination of several factors, such as the use of underground retreats, lack of direct effects of fire, and insectivorous and granivorous habits. These feeding guilds have low mortality, as they benefit from massive flowering and post-fire

seed production, as they attract insects and represent a considerable increase in food resources for birds in these environments (FRIZZO et al., 2011).

### *Side effects*

Fires promote spatial and temporal changes in resources, which fragment the habitat and alter its suitability for the species (BANKS et al., 2011; BROOKER, 1998), increasing the isolation of populations (BOSCOLO; METZGER, 2011; BROWN et al., 2009), forcing them to survive in smaller populations, surrounded by inhospitable matrices and to move more frequently between areas (PORTER, 1999).

The recovery of a population affected by a given disturbance will be influenced by several factors, such as demographic parameters of the survivors (BROOKER, 1998), availability of resources (MURPHY; LEHNHAUSEN, 1998), post-disturbance successional evolution, dispersion ability of the species and the geographic scale of the area affected by the fire and its environmental fragmentation (BROOKER, 1998; WATSON et al., 2012). Severe fires with severe population reduction can cause bottlenecks in population size, leading to losses in genetic diversity, inbreeding, accumulation, and expression of deleterious alleles, as well as the subsequent decrease in population viability (BROWN et al., 2013; CHARLESWORTH; CHARLESWORTH, 1999).

Birds with sedentary habits, ratites, and flying poorly are highly sensitive to environmental disturbances (BROWN et al., 2013). The wren-emu-mallee *Stipiturus mallee* Campbell, 1908, for example, is a species whose attributes likely limit its ability to disperse and recolonize, making it particularly vulnerable to environmental changes (BROWN et al., 2009; HIGGINS et al., 2001). Thus, Brown et al. (2009; 2013) report that the occurrence of large forest fires in Australia (>10,000 ha) and the expansion of deforestation and agriculture caused a genetic bottleneck and decline in the effective population size of this species, motivating the declaration of this bird as endangered according to the IUCN criteria.

Davis et al. (2000) studied the reintroduction of fire in forest areas to restore savannas. They reported that the frequency of observation of birds associated with frequently burned areas was twice that of the species related to areas with low frequency or absence of burning. Still in this study, the authors observed that there was a general trend of decline in insectivorous species, particularly those that feed in the upper

region of the canopy (leaves and airspace), an increase in omnivorous species, particularly those from the ground and lower canopy, as well as the increase of brood parasites. On the other hand, some species that use standing dead trees, such as woodpeckers, were favorably impacted even though they are insectivores.

Another possible impact of fires is favoring the movement of animals across the landscape, attracted by patches of vigorously re-sprouting vegetation, such as birds and mammals (HENRIQUES *et al.*, 2000). Thus, there is an increase in movement and dispersion to more compatible environments in response to drastic changes in the environment and space-time heterogeneity (MOORTER *et al.*, 2013), guided by changes in the availability of resources (CHARNOV *et al.*, 1976), risk of predation (MITCHELL; LIMA, 2002) or intraspecific relationships that drive the evolution of movement (MOORTER *et al.*, 2013).

Extraterritorial movements often require travel through unknown and/or low-quality habitats and the threat of predators and conspecifics (YOUNG; MONFORT, 2009). Several studies suggest that extraterritorial movements can lead to loss of body condition and high costs of survival (RIDLEY *et al.*, 2008; WALTERS *et al.*, 1992), as birds have strong circadian rhythms of activity, sleep, and body temperature, among others. others (HELLER, 1988). In addition, the costs associated with movements can prevent individuals from keeping up with changes in the availability of resources, resulting in trade-offs between the benefits and costs of movements (MOORTER *et al.*, 2013).

In vertebrates, the stress caused by environmental disturbances or threats raises their levels of glucocorticoids, which substantially contributes to the costs of extraterritorial movement (BALM, 1999; YOUNG; MONFORT, 2009). Acute short-term activation of this physiological response aids survival by freeing up resources for responses to agonistic interactions such as fight or flight. Still, over the long term, this mechanism compromises fitness through its many adverse health effects, such as disruption of growth, impairment of reproduction, and decreased immunity (BALM, 1999).

Scales of movement vary between species, between specimens, or within an individual over time, as well as movements are typically categorized into distinct functional groups, ranging from frequent small-scale foraging movements to unusual large-scale migrations or dispersal. (FRYXELL *et al.*, 2008; NATHAN *et al.*, 2008). Some studies indicate that migratory

birds may be more resistant to disturbances than resident birds (IBARRA, 2017; LYNCH; WHIGHAM, 1995). It was even observed that there was a higher density of migratory birds in the most disturbed places, suggesting that burned forests may act as a habitat for these birds (NOVOA *et al.*, 2021).

Some bird species use fragment mosaics as a habitat complement, that is, as alternative areas for obtaining resources (SIQUEIRA *et al.*, 2013; TUBELIS *et al.*, 2004). On the other hand, mosaics can constitute a barrier for other birds (ANTUNES, 2005). The favorable use of these habitat mosaics as supplements is more significant in areas of denser vegetation and among omnivorous, insectivorous, and frugivorous species (OLIVEIRA, 2013; SIQUEIRA *et al.*, 2013), which are attracted by patches of vigorously sprouting vegetation (HENRIQUES *et al.*, 2000) and provide foraging and nesting sites (NOVOA *et al.*, 2021).

Novoa *et al.* (2021) found that granivorous birds benefited from greater access to seeds of colonizing herbaceous plants and guild species that forage shrubby species benefited from reduced tree cover and increased bush volume after fires. On the other hand, the density of users of large trees and vertical profile generalists was higher in lightly and moderately disturbed areas, while understory users are positively associated with a higher density of this arboreal stratum and, therefore, negatively with disturbance by burning (NOVOA *et al.*, 2021).

Birds generally have high mobility and large home ranges, which allow them to perceive fragmented forests in a refined way and cover several of their fragments in their functional home range (ROLSTAD, 1991). Fire, like landscape fragmentation through deforestation, isolates fragments of habitat. This fragmentation may or may not be temporary depending on the type of fire regime and local pyrodiversity and may subdivide bird populations into isolated demos, which would enter into a metapopulation dynamic (ROLSTAD, 1991). According to the author, although metapopulations are poorly documented in birds, it is probably a common feature of populations confined to 'hierarchical' fragmented forests.

## FINAL CONSIDERATIONS

Fire can impact birds directly or indirectly, causing mortality and reduced survival of specimens or modifying local population

dynamics, as well as having a positive or negative impact, depending on the niche of the evaluated species. The observed effect will depend on fire detection capacity, locomotion capacity, species, habit, functional guild, demographic parameters, resource availability, post-disturbance successional evolution, dispersal ability, and the geographical scale of the area affected by the fire.

The main impacts observed for this clade are indirect effects, as they affect the fitness of individuals, the population dynamics of species, and their distribution in the landscape, making them more prone to extinction by intrinsic or extrinsic stochastic processes. Its most negatively impacted populations are ratites and those with low mobility.

There are many knowledge gaps regarding the effects of fire on avifauna population parameters, such as survival, population size, and reproduction. In general, available studies focus on community dynamics, and in pyrophytic environments, there are few changes in richness and abundance indices. Thus, a greater understanding of the consequences of fire on birds is necessary, in search of quality, dynamic, and integrated environmental management.

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## AUTHORS CONTRIBUTION

Bárbara Beatriz da Silva Nunes conceived and developed the presented research.



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