



The availability of Blue-fronted Amazon nesting cavities is at risk in west-central Brazil

La disponibilidad de cavidades de anidación del Loro de frente azul (*Amazona aestiva*) está en riesgo en el centro-oeste de Brasil

Gláucia H. F. Seixas¹  and Guilherme M. Mourão² 

ABSTRACT. Tree cavities are a critical resource for nesting by the Blue-fronted Amazon (*Amazona aestiva*), one of the most poached birds in South America. Poachers often damage cavities to access nestlings, destroying them or decreasing their quality for nesting in the following years. Given the importance of cavity availability for the Blue-fronted Amazon and other cavity nesters, we investigated cavity loss rates and their drivers. From 2016 to 2024, we surveyed, marked, and monitored nesting cavities across ~5000 km² of west-central Brazil—an area where native forests were largely replaced by pasturelands by the 1990s and by industrial agriculture from the 2000s onward. We found that 95.1% (1724) of the nests occurred in individuals of a single palm species (*Acrocomia aculeata*), which we considered alive if still standing up and structurally intact. We applied Kaplan–Meier survival analysis and Cox proportional hazards modeling to assess the effects of vegetation cover and poaching frequency on cavity longevity. Over the study period, 74.9% of the cavities (1292) were disturbed by poachers one to five times. Median cavity lifespan was six to seven years, but survival declined with increased poaching and greater habitat modification—from wetlands to pastures to industrial agriculture. These combined pressures threaten the persistence of the Blue-fronted Amazon and other cavity nesters in west-central Brazil and likely across the Brazilian savanna.

RESUMEN. Las cavidades de árboles son un recurso crucial para la anidación del Loro de frente azul (*Amazona aestiva*), una de las aves más cazadas furtivamente en América del Sur. Los cazadores furtivos a menudo dañan las cavidades para acceder a los polluelos, destruyéndolas o disminuyendo su calidad para la anidación en los años siguientes. Dada la importancia de la disponibilidad de cavidades para el Loro de frente azul y otros anidadores de cavidades, investigamos las tasas de pérdida de cavidades y sus causas. De 2016 a 2024, censamos, marcamos y monitoreamos cavidades de anidación en ~5000 km² del centro-oeste de Brasil —un área donde los bosques nativos fueron reemplazados principalmente por pastizales en la década de 1990 y por agricultura industrial a partir de la década de 2000—. Descubrimos que el 95.1% (1724) de los nidos se encontraban en individuos de una sola especie de palma (*Acrocomia aculeata*), que consideramos vivas si aún estaban en pie y estructuralmente intactas. Aplicamos el análisis de supervivencia de Kaplan–Meier y el modelo de riesgos proporcionales de Cox para evaluar los efectos de la cobertura vegetal y la frecuencia de la caza furtiva en la longevidad de las cavidades. Durante el período de estudio, el 74.9% de las cavidades (1292) fueron alteradas por cazadores furtivos de una a cinco veces. La vida útil media de las cavidades fue de seis a siete años, pero la supervivencia disminuyó con el aumento de la caza furtiva y una mayor modificación del hábitat, desde humedales hasta pastizales y agricultura industrial. Estas presiones combinadas amenazan la persistencia del Loro de frente azul y otros anidadores de cavidades en el centro-oeste de Brasil y probablemente en toda la sabana brasileña.

Key Words: *Amazona aestiva*; cavity nesters; palm cavity survival; parrot; tree hollow

INTRODUCTION

Eighteen percent of the world's avifauna uses tree cavities for nesting, including 93% of the 374 psittacid species (van der Hoek et al. 2017). Approximately one-third of psittacid species are threatened by habitat degradation, which leads to a decrease in the availability of tree cavities for nesting (Olah et al. 2016, Berkunsky et al. 2017). Additionally, psittacids are among the most trafficked birds worldwide, and the Blue-fronted Amazon (*Amazona aestiva*), a cavity-nesting species, is one of the main targets of poachers in South America (Berkunsky et al. 2017) and in the state of Mato Grosso do Sul (MS) in Brazil (Seixas and Mourão 2000).

The Blue-fronted Amazon is a relatively widespread species, occurring across much of Brazil's interior (excluding the Amazon

region), eastern Bolivia, northern Argentina, and southern Paraguay (Seixas and Mourão 2002). Despite its wide distribution, it has been classified as Near Threatened by the Brazilian authority (Ministério do Meio Ambiente [MMA]) since 2014 and by the International Union for Conservation of Nature and Natural Resources (IUCN) since 2019. The ongoing destruction of nesting habitats, coupled with the removal of eggs and chicks from natural nests, could contribute to declines in Blue-fronted Amazon populations (Beissinger and Bucher 1992, Seixas and Mourão 2022).

This parrot is a non-excavator species that nests in pre-existing tree cavities, which are typically formed through tree decay or by other excavator species (van der Hoek et al. 2017; G. H. F. Seixas, personal observation). Tree cavities may be a limiting resource for

¹Fundação Neotrópica do Brasil, ²Embrapa Pantanal

non-excavator species (Newton 1994, Aitken and Martin 2008), particularly in the more diverse bird communities of tropical regions (van der Hoek et al. 2017).

Most of the existing habitats in the Mato Grosso do Sul state, where our study area is located, were converted from forested areas to pastures and, to a lesser extent, agricultural land during the 1960s (de Freitas and Teixeira 2022). However, when forests were cleared, palm trees are often left standing in newly formed pastures, possibly because they occupy little space and provide food resources (leaves and fruits) for cattle. The most common palm species in that area is macaúba (*Acrocomia aculeata*). Dead macaúba palms are prone to forming cavities, as the interior of the palm's stem decays faster than its outer edge. In west-central Brazil, these cavities are among the most commonly used by nesting Blue-fronted Amazons (Seixas and Mourão 2002), and serve as shelter and/or nests for various other animal species (this study). Nest cavities are frequently reused (Seixas and Mourão 2002), and Blue-fronted Amazon pairs generally exhibit fidelity to their chosen nest cavity, returning to it every year as long as it remains suitable (Berkunsky and Reboreda 2009). Since the 2000s, much of the land in west-central Brazil that was once used for pastures has been converted to agricultural use (MapBiomias 2024). During this conversion, macaúba palms were often partially or completely removed, reducing the availability of tree cavities to cavity nesters.

Poaching to supply the pet trade and tree clearance are among the main threats to their populations (Berkunsky et al. 2017, Seixas and Mourão 2022). The capture of nestlings often involves cruelty (Clarke and de By 2013), and it has been estimated that approximately three out of four parrots taken from the wild die as a result of improper handling, even before being taken to market (Cantu et al. 2007).

Poachers typically violate nest cavities by enlarging the entrance of the cavity or creating new openings to assess the nestlings or eggs, and they can do so repeatedly over the years. This process can degrade the quality of the cavities, making them unsuitable for use by the parrots in subsequent years (G. H. F. Seixas, personal observation). Additionally, disturbances to the palm cavity by poachers can result in the palms collapsing.

Given the importance of macaúba cavities for the Blue-fronted Amazon and many other animal species, we are interested in studying their persistence in the area. Edworthy et al. (2012) proposed the use of demographic concepts such as survival and longevity to investigate cavity loss rates in cavity-nesting bird populations. Cavities were considered “surviving” if they remained suitable for nesting by the target bird species, even if the trees were already dead. We applied this approach to study: (1) whether the vegetation cover and the poaching activities affected the “survival” probability of palm cavities used by the Blue-fronted Amazon in an area of west-central Brazil, (2) to forecast how poaching and habitat type might affect palm cavity survival over a five-year period, and (3) to evaluate the land cover trends in the study area. We hypothesized that the degree of human interference in the habitat and the frequency of disturbances caused by poachers negatively affect the survival of palm cavities, and that there is a tendency of expansion of industrial agriculture in the region.

METHODS

Study area

From 2016 to 2024, we searched for and marked tree cavities available to Blue-fronted Amazons nesting within a 5071 km² area in Mato Grosso do Sul (MS), west-central Brazil (Fig. 1). This region included portions of the Atlantic Forest and Cerrado ecoregions. The climate is humid, characterized by mild winters (mean daily temperatures ranging from 15 to 19 °C) and warm summers (mean daily temperatures ranging from 23 to 26 °C). The average annual rainfall is approximately 1400 mm (Pott et al. 2014).

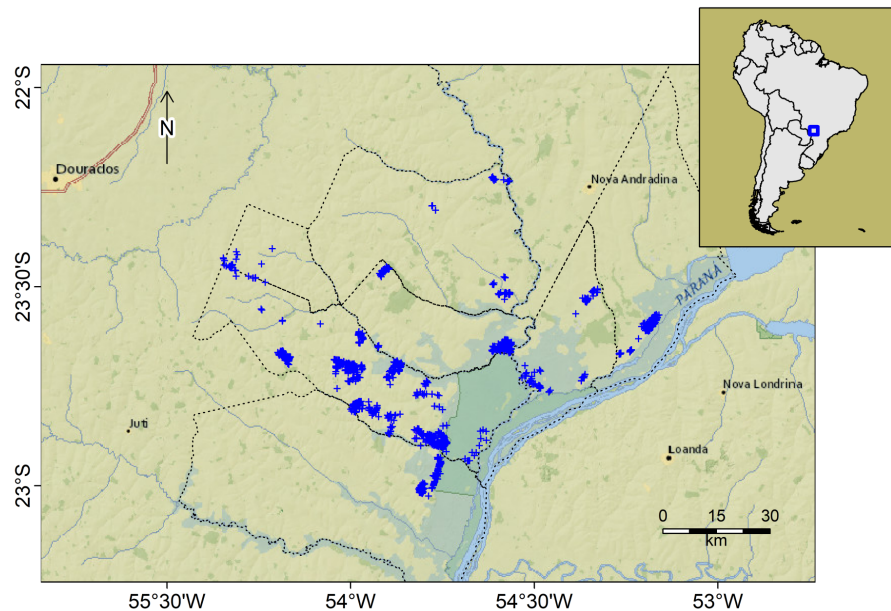
The four dominant vegetation types were forests, wetlands, pastures, and agricultural lands. Most remaining forested areas include protected riparian forests and other legally protected zones under Brazilian law. The wetlands are predominantly herbaceous and subject to seasonal flooding from fluvial or lacustrine influences. In some areas, these wetlands are associated with wet arboreal savanna or palm groves. Pastures were created by clearing forested land and sowing non-native forage grasses; however, landowners often allowed sparse trees to remain, especially macaúba palm. Since the 2000s, agriculture has become increasingly important to the regional economy. Large areas that were once forest, pasture, or wetlands have been converted to sugarcane, soybeans, corn, cassava, and other crops (MapBiomias 2024).

Cavity location and monitoring

Between July and December of each year from 2016 to 2024, we searched for, geolocated, marked, and monitored a total of 1724 palm cavities and 88 tree cavities available for Blue-fronted Amazon nesting within the study area. We considered a cavity available if the tree's diameter at chest height exceeded 17 cm and the cavity was deeper than 20 cm, or if there were signs of parrots use (such as their presence nearby or peck marks) or evidence of poacher disturbance. However, not all available cavities were suitable for nesting every year, as some may have been occupied by other species that the parrots could not displace, such as wasps (*Pepsis* spp.), termites (Isoptera), or Toco Toucans (*Ramphastos toco*).

Every marked palm cavity was monitored in subsequent years, totaling 4585 monitoring events. We calculated the minimum convex polygon (MPC) each year to estimate the area covered by the marked palm cavities as a proxy of sampling effort. Using the coordinates of cavities marked from 2016 to 2023, we extracted vegetation cover data from GeoTiff mosaics provided annually by the MapBiomias project for all of Brazil (MapBiomias 2024), with a resolution of 30 m. Details of the MapBiomias methodology are available in Souza et al. (2020). We converted the mosaics into raster format to extract vegetation cover information using functions from the “terra” package (Hijmans 2024) within the R environment (R Core Team 2024). However, at the time of our analyses, the MapBiomias mosaics for 2024 were not yet available, so we relied on field observations to determine the vegetation cover for cavities found in 2024. Each year, cavities were inspected during the breeding season to assess whether the palm remained standing, whether the cavity was in use by the parrots or other species, and whether it had been disturbed by poachers. If the cavity palm had fallen, we attempted to determine

Fig. 1. Map of the study area, which includes seven municipalities in Mato Grosso do Sul in west-central Brazil. Dotted lines indicate municipal boundaries (Batayporã, Glória de Dourados, Ivinhema, Jateí, Naviraí, Novo Horizonte do Sul, Taquarussu), and blue crosses indicate the locations of marked palm cavities from July 2016 to December 2024.



the immediate cause, categorizing it as one of the following: pasture-related, agriculture-related, burning-related, poacher-related, or natural. Pasture-related causes involved suppression of the cavity tree due to pasture establishment or maintenance of pastures intended for cattle breeding. Agriculture-related causes were linked to clearing of trees for crop cultivation. Burning-related causes occurred when fires destroyed the cavity. Poacher-related causes included disturbances that led to a tree fall during poaching attempts. Natural causes referred to falls due to weather or natural decay.

Data analysis

Although we found nests of Blue-fronted Amazons in 13 tree species plus three palm species (Appendix 1), the vast majority of suitable cavities (1724, or 95.1%) occurred in dead individuals of a single palm species, macaúba. None of the other species accounted for more than 1.5% of the marked cavities. Therefore, we restricted our analyses to cavities found in macaúba palms. Although these palms were dead, we refer to them as surviving if they remained standing and could support a parrot nest.

We used the Kaplan–Meier survival method to model survival curves of palm cavities available for Blue-fronted Amazons nesting, estimating their median lifespans and other survival parameters (Edworthy et al. 2012). Our approach differs from that of Berkunsky et al. (2016) who applied the Kaplan–Meier method to nest survival rather than cavity survival. Because cavities were not always discovered in their first year of use, the calculated lifespan represents minimum estimates. We then applied a Cox proportional hazards regression model, using the formulation proposed by Andersen and Gill (1982) to evaluate the effects of vegetation cover and poacher disturbance frequency of palm cavity survival. This model allowed us to predict cavity survival

under varying conditions of habitat and poaching pressure. All survival analyses were conducted by using the “survival” package in R (Therneau and Grambsch 2000, Therneau 2024).

Our study area covered a large portion of seven municipalities in MS, west-central Brazil. To understand long-term landscape dynamics, we merged land cover change data for these municipalities provided by MapBiomas (2024) to assess trends from 1985 to 2023, a period longer than our field study (2016–2024).

RESULTS

The annual area surveyed for searching and marking new macaúba palm cavities ranged from 221 km² to 4765 km², totaling a surface of 5071 km² during the study.

A total of 1724 cavities were marked and monitored from 2016 to 2024, resulting in 4585 monitoring events. In 2360 instances, the cavities were suitable for nesting by Blue-fronted Amazon, and in 1248 of these (52.9%), the cavities were effectively occupied by the parrots. On average, 145 cavities were used by nesting parrots per year (Table 1). Among the marked palm cavities, 73.5% were located in pastures, 20.7% in agricultural lands, and 4.9% in wetlands. Fifteen palm cavities (0.9%) were found in forest-wetland ecotones; for analysis purposes, these were grouped with wetlands records. In addition to Blue-fronted Amazons, palm cavities were occupied by 14 bird species, two mammals, and three social insects (Appendix 2).

Over the nine-year study period, 1356 palm cavities were lost. Of these, 52.0% fell because of natural causes, 25.3% were removed for agricultural development, 11.1% were removed during pasture establishment or maintenance, 11.1% fell because of direct poacher actions, and only three were lost to fire.

Table 1. Area covered per year for macaúba palm (*Acrocomia aculeata*) cavities searches, cumulative number of marked cavities, number of cavities suitable for parrots in each year, number of fallen cavities, number of cavities effectively occupied by parrots and the percentage of occupation relative to suitable cavities for that year. [†] Estimated as a 100% minimum convex polygon (MCP) encompassing the locations of marked palm cavities for each year. [‡] Total study area estimated as a 100% MCP including all marked palm cavities. [§] Interquartile range.

Year	Area [†] (km ²)	Marked	Suitable	Fallen	Occupied (%)
2016	221	79	63	2	39 (61.9)
2017	579	204	128	30	67 (50.3)
2018	628	266	113	43	57 (50.4)
2019	2046	447	243	54	142 (58.4)
2020	3970	1067	441	229	168 (38.1)
2021	4665	1291	348	328	207 (59.5)
2022	4719	1453	408	279	215 (52.7)
2023	4765	1637	342	266	208 (60.8)
2024	3689	1724	274	125	145 (52.9)
Total	5071 [†]	1724	2360	1356	1248 (52.9)
Median	3689	162	274	125	145
IQR [§]	4037	97	220	223	140

Across all habitat types, cavities that had been disturbed at least once by poachers fell more frequently than those that had never been disturbed, regardless of the direct cause of the death (Appendix 3). Poachers disturbed 1292 cavities (74.9%) during the study period, with the majority of disturbances occurring in pastures (942). However, there were no significant differences in the proportion of poacher disturbances among habitats types ($\chi^2 = 2.055$, $df = 2$, $p = 0.358$) (Appendix 3).

In general, nearly 80% of the palm cavities survived at least five years, and the median lifespan occurred between six and seven years. By the ninth year, only 19.5% (95% CI = 0.176–0.216) of the cavities remained standing and suitable for nesting (Table 2, Fig. 2).

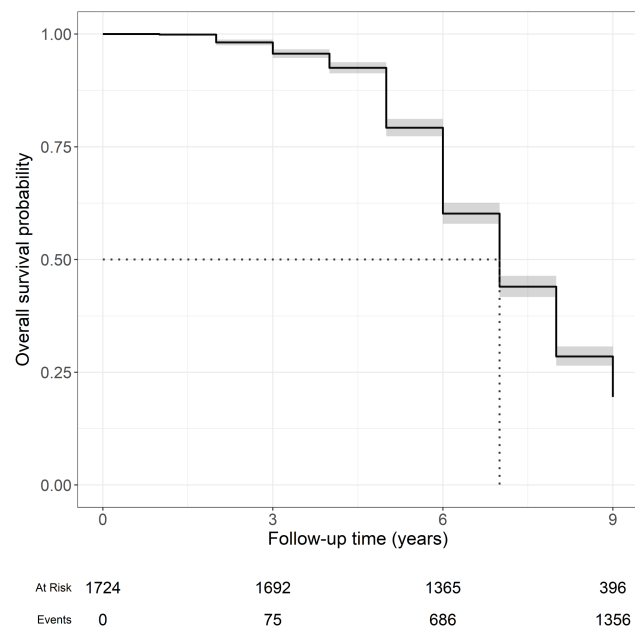
We applied a Cox proportional hazards model to assess how poacher disturbance frequency and vegetation cover affected cavity survival. In this model, the exponential of the coefficient (β) corresponds to the hazard ratio, representing the change in risk per unit of a continuous variable or compared to a control in categorical variables (Edworthy et al. 2012). The frequency of poacher disturbances significantly increased the risk of cavity loss ($z = 12.003$, $\beta = 0.477$, $SE = 0.040$, hazard ratio = 1.611, $p < 0.001$). Compared to wetlands, cavities in agricultural areas had a significantly higher risk of loss ($z = 7.986$, $\beta = 1.134$, $SE = 0.142$, hazard ratio = 3.107, $p < 0.001$), which was about twice the risk observed in pastures ($z = 3.469$, $\beta = 0.462$, $SE = 0.133$, hazard ratio = 1.588, $p < 0.001$) (Appendix 4; Fig. 3).

We used the Cox model to predict cavity survival under two scenarios: no poacher disturbance versus repeated disturbance for five years, across vegetation types. In wetlands, undisturbed cavities had a median survival time exceeding nine years, whereas disturbed cavities had a median survival of four to five years. In pastures, median survival of undisturbed cavities was between seven and eight years, whereas disturbed cavities survived in

Table 2. Kaplan–Meier survival estimates for macaúba palm (*Acrocomia aculeata*) cavities in west-central Brazil. Cavities were monitored annually from 2016 to 2024 across an area of up to 5071 km². [†] n.risk indicates the number of palm cavities available at that time; [‡] n.event indicates the number of cavities that fell at that time.

Follow-up time (years)	n.risk [†]	n.event [‡]	survival	se	Lower 95% CI	Upper 95% CI
1	1724	2	0.999	0.00082	0.997	1.000
2	1722	30	0.981	0.00325	0.975	0.988
3	1692	43	0.956	0.00491	0.947	0.966
4	1648	54	0.925	0.00634	0.913	0.939
5	1594	229	0.792	0.00977	0.773	0.812
6	1365	328	0.602	0.01179	0.579	0.625
7	1036	279	0.440	0.01196	0.417	0.464
8	756	266	0.285	0.01088	0.264	0.307
9	396	125	0.195	0.00999	0.176	0.216

Fig. 2. Survival curve of macaúba palm (*Acrocomia aculeata*) cavities available for Blue-fronted Amazon nesting in west-central Brazil. Gray bands represent 95% confidence intervals; the dotted line indicates the median survival. The table beneath shows the number of cavities at risk and cumulative number of fallen palms every three years.

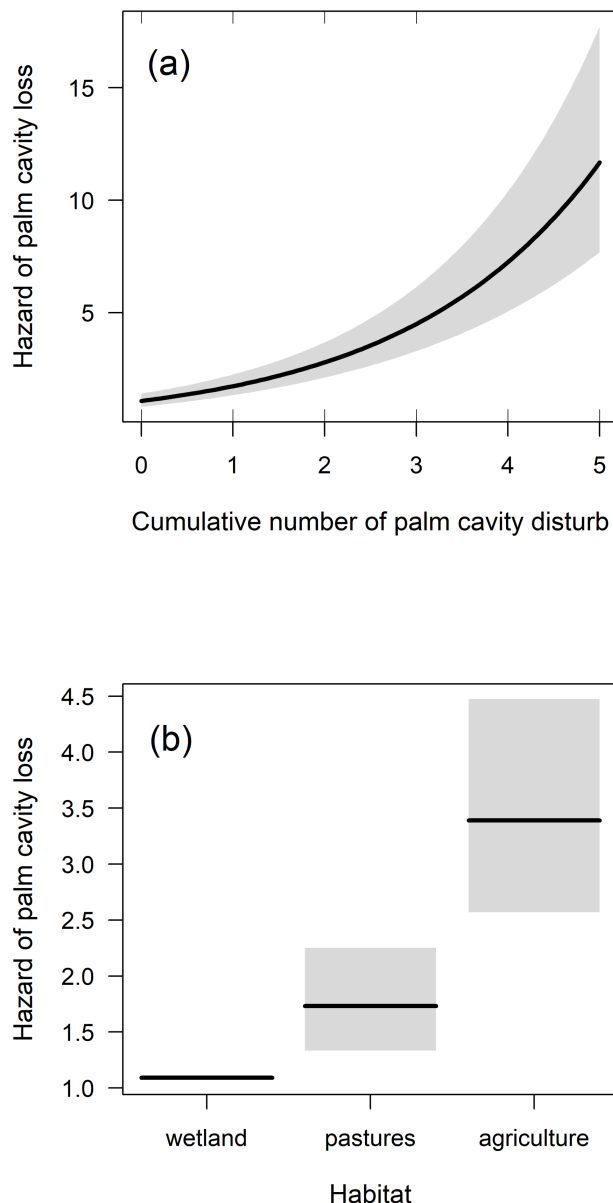


median four to five years. In agriculture, undisturbed cavities survived six to seven years in median, but disturbed cavities fell in median between years three and four, with zero or near zero survival by year six (Fig. 4).

Land cover in the study area had already undergone substantial modification by 1985. Initially, pasture area expanded through forest clearing up to the early 1990s. From the 2000s onward, agriculture began expanding, mostly replacing pastures (Fig. 5).

Between 1985 to 2023, the area under agriculture increased by more than 330% (~3870 km²), whereas the pasture area declined by approximately 3865 km² (56.6%) from 1994 to 2023. Wetland area decreased slightly by 4.9% (from 1782 to 1694 km²) from 2016 and 2023. Forest cover declined from 1985 to the late 1990s and has since stabilized, accounting for about 9.5% of the total area across the seven municipalities.

Fig. 3. Effect of (a) the cumulative number of poacher-inflicted disturbances and (b) vegetation cover on the risk of loss of palm cavity suitable for Blue-fronted Amazon nesting. Gray bands indicate the 95% confidence intervals. Results based on a Cox proportional hazards model, using data from 2016 to 2024.



DISCUSSION

Many palm species are known to provide food or suitable cavities for the nesting of different birds, especially psittacids. Thus, palms are often considered essential resources for these birds (Yamashita and Barros 1997, Brightsmith 2005). In our study area, covering 5000 km² in west-central Brazil, approximately 95% of Blue-fronted Amazon nests occurred in cavities of dead individuals of a single palm species, the macaúba palm. This is a much higher percentage than the 30% recorded in the Pantanal wetlands (Seixas and Mourão 2002), underscoring the critical role of this palm species in supporting the persistence of this parrot in our site.

Although we did not study the recruitment of the palm cavities, the estimated median lifespan of existing cavities was approximately six to seven years, with some persisting up to nine years, without the effects of covariates. Although the most common direct causes of cavity loss were natural (e.g., wind or decay), disturbances caused by poachers (especially when repeated annually) significantly reduced palm cavity survival. The illegal collection of Blue-fronted Amazon nestlings and eggs is intense in MS; thousands have been confiscated by the environmental authorities and sent to a wildlife rehabilitation center (Centro de Reabilitação de Animais Silvestres [CRAS], unpublished data). However, this likely represents only a fraction of the total number poached. Blue-fronted Amazons are in high demand as pets (e.g., Berkunsky et al. 2017, Seixas and Mourão 2000), providing strong economic incentives for poachers. Pires et al. (2016) suggested that most illegally hunted parrots in Bolivia originated from just seven municipalities. However, Romero-Vidal et al. (2025) report that parrots kept as pets in Bolivia are usually taken from diffuse rural areas. We do not have a comprehensive picture of the poaching and illegal trade of parrots across Brazil, but at least in MS, our study area appears to be a focal point of Blue-fronted Amazon trafficking, likely supplying both domestic and international pet markets (G. H. F. Seixas, personal observation; CRAS, unpublished data).

Parrots often reuse the same cavity for nesting year after year (Berkunsky and Rebores 2009). This behavior facilitates poachers' ability to locate nests across years, leading to repeated disturbances and increasing the likelihood of cavity destruction. Vegetation cover also significantly influences palm cavity survival: more human-modified habitats were associated with lower cavity persistence. Our model showed that both poaching frequency and vegetation type significantly affected the cavity survival probabilities.

Looking to the past to better understand the future

In Brazil, Blue-fronted Amazons are typically found in savannas, wetlands (Seixas and Mourão 2002), and dry forests (Sick 1984). In the study area, the conversion of forested areas into pastures began in the 1960s, but many palms were retained, supporting the continued presence of the species. Similar persistence has been observed in eastern Amazonia, where parrots survive in deforested areas if palms are maintained (Araújo and Lopes 2012). Although forest conversion to pasture likely reduced parrot populations, given that fledgling success is positively associated with woodland availability (Seixas and Mourão 2022), the recent expansion of industrial agriculture has further exacerbated this situation.

Fig. 4. Predicted survival curves based on a Cox model, showing effect of poacher disturbance and vegetation cover over macaúba palm (*Acrocomia aculeata*) cavities available for Blue-fronted Amazon nesting in west-central Brazil. Data were taken from 2016 to 2024.

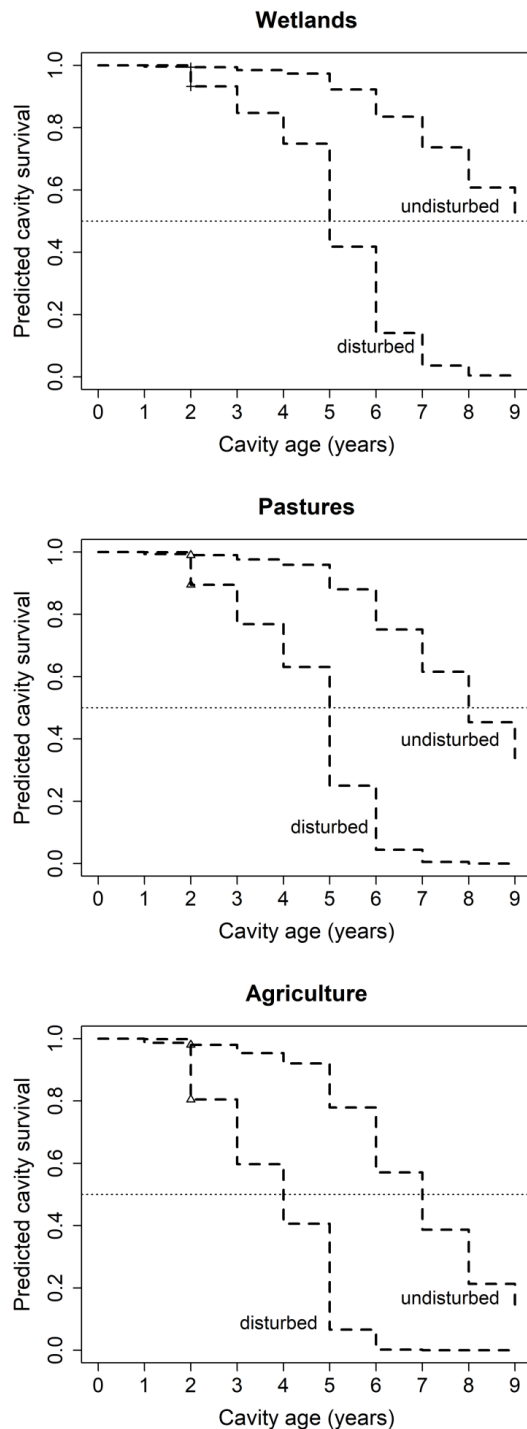
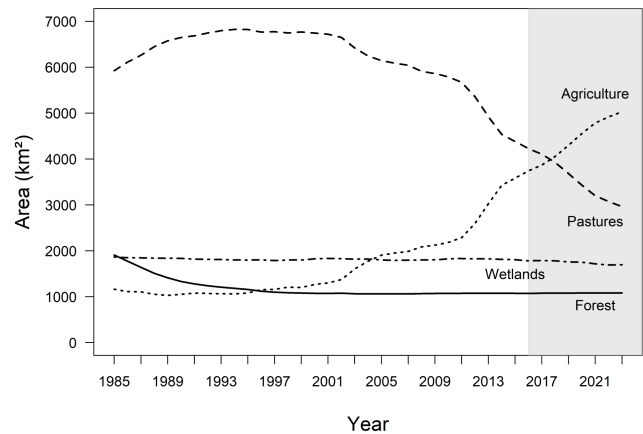


Fig. 5. Changes in the vegetation cover types from 1985 to 2023 in the seven municipalities included in the study. The light gray band represents the duration of the field study (2016–2024). Source: MapBiomass 2024.



From the 2000s onward, agricultural development (primarily soy, corn, and sugarcane) has replaced pastures, effectively doubling the risk of cavity loss (this study). Macaúba cavities typically form as the palms die and lose their crowns. Although a full demographic study of macaúba palms was beyond our scope, it is evident that cavity recruitment in areas dominated by industrial agriculture is negligible. If current land use trends persist, soon there will not be enough nesting cavities in that part of Brazil.

Conservation recommendations for palm cavities and cavity nesters

Most legally available land in our study area had been converted to pastures by the 1990s, negatively affecting the survival of palms and reducing the number of mature trees, which are prone to forming viable nesting cavities. Reduced cavity availability is known to negatively impact reproductive rates of cavity-nesting species (Edworthy et al. 2012), such as the Blue-fronted Amazon. This threat is worsened by the expansion of industrial agriculture, not only in our study area but also across vast regions of the Brazilian savanna (MapBiomass 2024). If the replacement of pastures with large-scale crops continues at this pace, cavity-nesting bird populations (including parrots) may become severely limited by a lack of suitable nesting sites.

Conservation actions such as maintaining mature trees and dead palm trees in pastures and, to some extent, in agricultural land, combined with the control of wildlife trafficking, could mitigate the reduction in survival of the cavities caused by human actions (Wesołowski 2007, Drever and Martin 2010, Bunnell 2013, Lindenmayer et al. 2014). In regions with limited remaining woodlands or intense poaching, environmental monitoring, educational outreach, and the installation of artificial nests could reduce species' dependence on natural cavities (Brightsmith 2005, Berkunsky et al. 2017, Tarazona-Tubens et al. 2022). Although few cavities were found in wetlands and wetland-forest boundaries, these areas remain critical refuges for cavity nesters. Given that wetlands are legally protected in Brazil, the recent agricultural expansion into these zones must be halted. Ideally,

restoration programs aimed at reestablishing the native land cover and supporting native fauna should be implemented (Lorimer et al. 2015). However, no conservation effort will be effective without the enforcement of environmental regulation and land use policies.

These proposed actions may seem like déjà vu, but in some instances in the past, they were effective. For example, Bolam et al. (2020) reported that conservation action have prevented many bird and mammal extinctions since the 1990s and extinction rates would have been approximately three to four times higher in their absence. Nonetheless, they emphasize the need to scale up conservation actions to prevent future extinctions (Bolam et al. 2020).

Author Contributions:

Gláucia Helena Fernandes Seixas: conceptualization, data curation, funding acquisition, investigation, methodology, project administration, resources, writing – original draft, writing – review & editing. Guilherme Mourão: formal analysis, funding acquisition, methodology, resources, writing – original draft, writing – review & editing.

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Data Availability:

Large amount of the relevant data supporting the findings of this study are within the paper and appendices tables supplied. If the initial submission is approved, additional data/code will be made available in an open access repository. This research did not demand capture or manipulation of the parrots, nor did it injure animals or plants. Licenses granted from the environmental Federal authority Ministério do Meio Ambiente/MMA allowing the conduction of this research were 12130–1; 12130–2; 324650; 43876–1; 43876–2; 43876–3.

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The availability of Blue-fronted Amazon nesting cavities is at risk in Central-West Brazil

Gláucia H. F. Seixas* and Guilherme Mourão
Corresponding author: glauucia@fundacaoneotropica.org.br

Appendix 1. Number of dead and alive trees with suitable cavities for nesting Blue-fronted Amazon found in the study area from 2016 to 2024 and its percentage in relation to the grand total.

Species	Local name	Dead	Alive	Total	%
<i>Acrocomia aculeata</i>	Macaúba	1724	0	1724	95.1
<i>Albizia niopoides</i>	Farinha seca	0	2	2	0.1
<i>Anadenanthera colubrina</i>	Angico branco	0	3	3	0.2
<i>Aspidosperma sp</i>	Peroba	0	1	1	0.1
<i>Caesalpinia peltophoroides</i>	Sibipiruna	0	3	3	0.2
<i>Campomanesia xanthocarpa</i>	Guabiroba	0	7	7	0.4
<i>Copaifera Langsdorffii</i>	Copaiba	0	2	2	0.1
<i>Gallesia intergrifolia</i>	Pau d'alho	0	2	2	0.1
<i>Grevillea robusta</i>	Grevílea	0	1	1	0.1
<i>Handroanthus avellaneda</i>	Ipê roxo	1	2	3	0.2
<i>Mauritia flexuosa</i>	Buriti	2	0	2	0.1
<i>Peltophorum dubium</i>	Canafistula	0	5	5	0.3
<i>Persea americana</i>	Abacate	0	2	2	0.1
<i>Sapindus saponaria</i>	Saboneteira	0	1	1	0.1
<i>Syagrus romanzoffiana</i>	Pindó	27	0	27	1.5
Not identified	NI	27	0	27	1.5
Grand total		1781	31	1812	100

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Corresponding author: glaucia@fundacaoneotropica.org.br

Appendix 2. Number and percentage of palm cavities occupied by birds, mammals and social insect in relation to 4,585 monitoring events carried out from 2016 to 2024 in a 5,071 km² area of the Central-West, Brazil.

Scientific name	Name	Number	%
Birds			
<i>Amazona aestiva</i>	Blue-fronted amazon	1248	27.2
<i>Gnorimopsar chopi</i>	Chopi blackbird	272	5.9
<i>Dendrocygna autumnalis</i>	Black-bellied whistling-duck	196	4.3
<i>Falco sparverius</i>	American kestrel	110	2.4
<i>Ramphastos toco</i>	Toco toucan	95	2.1
<i>Megascops choliba</i>	Tropical Screech-owl	54	1.2
<i>Xolmis irupero</i>	White monjita	42	0.9
<i>Tyto furcata</i>	American Barn owl	33	0.7
<i>Diopsittaca nobilis</i>	Red-shouldered macaw	19	0.4
<i>Psittacara leucophthalmus</i>	White-eyed parakeet	18	0.4
<i>Melanerpes candidus</i>	White woodpecker	10	0.2
<i>Pitangus sulphuratus</i>	Great kiskadee	8	0.2
<i>Colaptes campestris</i>	Campo flicker	5	0.1
<i>Coragyps atratus</i>	Black vulture	4	0.1
<i>Lepidocolaptes angustirostris</i>	Narrow-billed woodcreeper	3	0.1
Mammals			
<i>Didelphis albiventris</i>	White-eared opossum	36	0.8
<i>Artibeus</i> sp	Bats	14	0.3
Social insects			
<i>Pepsis</i> sp	Wasps	42	0.9
<i>Nasutitermes</i> sp	Termite	40	0.9
<i>Apis mellifera</i>	Bees	17	0.4

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Corresponding author: glaucia@fundacaoneotropica.org.br

Appendix 3. Number of macaúba palm (*Acrocomia aculeate*) cavities suitable for nesting by Blue-fronted Amazons tabulated by habitat type, status (standing-up or fallen) and by disturbed status (disturbed one or more times by poachers or undisturbed). Data were collected in Central-West Brazil from 2016–2024.

Habitat	Status	Poacher's action		Total
		Undisturbed	Disturbed	
Agriculture	Standing-up	0	3	3
	Fallen	80	275	355
	Total	80	278	358
Pastures	Standing-up	162	163	325
	Fallen	162	779	941
	Total	324	942	1266
Wetland	Standing-up	18	22	40
	Fallen	10	50	60
	Total	28	72	100
Total	Standing-up	180	188	368
	Fallen	252	1104	1356
Grand total		432	1292	1724

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Corresponding author: glaucia@fundacaoneotropica.org.br

Appendix 4. Result of a Cox proportional-hazards analysis to model the effects of habitat and poachers inflicted disturb on survival of palm-cavities suitable for Blue-fronted Amazon nests in mid-west Brazil.

```
coxph(formula = Surv(time, censo == 1) ~ habitat + disturbance,  
      data = cav.palm, model = T)
```

```
n= 1724, number of events= 1356
```

	coef	exp(coef)	se(coef)	z	Pr(> z)	
habitatpastures	0.46222	1.58759	0.13325	3.469	0.000523	***
habitatagriculture	1.13350	3.10652	0.14193	7.986	1.39e-15	***
disturbance	0.47699	1.61122	0.03974	12.003	< 2e-16	***

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

	exp(coef)	exp(-coef)	lower .95	upper .95
habitatpastures	1.588	0.6299	1.223	2.061
habitatagriculture	3.107	0.3219	2.352	4.103
disturbance	1.611	0.6206	1.490	1.742

```
Concordance= 0.64 (se = 0.008 )
```

```
Likelihood ratio test= 279 on 3 df, p=<2e-16
```

```
Wald test = 330.6 on 3 df, p=<2e-16
```

```
Score (logrank) test = 323.3 on 3 df, p=<2e-16
```