



UNIVERSIDADE DE BRASÍLIA
INSTITUTO DE CIÊNCIAS BIOLÓGICAS
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA

**EFEITOS SINÉRGICOS ENTRE REGIMES DE QUEIMA E CLIMA
SOBRE A DEMOGRAFIA DE UM LAGARTO NEOTROPICAL
VIVÍPARO**

Tânia Andrade de Queiroz

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Dissertação apresentada ao Programa de Pós-Graduação em Ecologia da Universidade de Brasília como parte dos requisitos para a obtenção do título de Mestre em Ecologia.

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INTRODUÇÃO EM PORTUGUÊS

As atividades humanas e o desenvolvimento têm precipitado mudanças ambientais profundas, levando a uma crise global da biodiversidade (Midgley et al. 2002, Van Der WAL et al. 2008, Lewis e Maslin 2015, Barlow et al. 2016). Essa crise é impulsionada principalmente por perturbações do habitat e, cada vez mais, pelas mudanças climáticas (Brook et al. 2008). Esses drivers são centrais para as extinções de espécies, impactando os padrões de temperatura e precipitação, que são cruciais para as populações animais, particularmente os ectotermos (Ceia-Hasse et al. 2014, Pontes-da-Silva et al. 2018, Diele-Viegas et al. 2019).

As mudanças climáticas desafiam os ectotérmicos de várias maneiras. Elas não só representam uma ameaça à sua termorregulação (Sears et al. 2015), mas também influenciam sua história de vida (Diele-Viegas et al. 2019, Caetano e Colli 2021), distribuição geográfica e risco de extinção (Sinervo et al. 2010, Pontes-da-Silva et al. 2018). A extinção, fundamentalmente um processo demográfico (Lande 1993), requer a compreensão de como as variações ambientais influenciam as taxas vitais das espécies - sobrevivência, reprodução e recrutamento - para uma conservação eficaz em um mundo em mudança (Boyce et al. 2006).

O clima é um preditor chave da dinâmica de biomas, comunidades e populações (Pfister 1998, Letnic et al. 2004, Bost et al. 2015, Sousa et al. 2015, Caetano e Colli 2021). A temperatura e a precipitação regulam os recursos alimentares e as condições ambientais, moldando os ciclos de vida das espécies. Os ectotermos, que dependem das condições ambientais para a homeostase, são particularmente vulneráveis (White 2008). Aumentos da temperatura induzidos pelas mudanças climáticas podem ter impacto negativo na sobrevivência e na reprodução, potencialmente levando a extinções locais (Sinervo et al. 2010, Diele-Viegas et al. 2019). Além disso, mudanças nos padrões de precipitação podem exacerbar os efeitos da temperatura, levando a um aumento da mortalidade e declínios reprodutivos (Ryan et al. 2015, Wang et al. 2016). Além das tendências médias, a temperatura e a precipitação são previstas para se tornarem mais imprevisíveis e extremas com as mudanças climáticas (IPCC 2023). Tais extremos climáticos e imprevisibilidade podem afetar significativamente as taxas de sobrevivência e recrutamento nas populações de lagartos (Caetano e Colli 2021). Embora algumas populações tenham estratégias para lidar com variações climáticas, existe um ponto de inflexão além do qual elas podem não ser capazes de se adaptar às crescentes variações ambientais (Rodríguez-Caro et al. 2021).

As queimadas também desempenham um papel crucial na moldagem da ecologia e evolução dos ecossistemas e espécies (Pausas e Schwilk 2012, Keeley e Pausas 2022). Sua intensidade, frequência e extensão afetam de forma variável as espécies animais (Letnic et al. 2004, Pianka e Goodyear 2012, Robertson et al. 2022). As respostas dos lagartos às queimadas são diversas, dependendo das características da história de vida e das alterações na estrutura do habitat que afetam a disponibilidade de recursos alimentares e os locais de reprodução e termorregulação (James e M'Closkey 2003, Pianka e Goodyear 2012, Sousa et al. 2015, Costa et al. 2020). As respostas demográficas dos lagartos às queimadas são variadas e complexas, particularmente no contexto dos efeitos de longo prazo das queimadas (Costa et al. 2020). Enquanto a abundância de algumas espécies de lagartos tende a aumentar com a severidade das queimadas, as populações de *Copeoglossum nigropunctatum* mostram uma redução na abundância em regimes de queima de médio prazo (Costa et al. 2020). Além disso, parâmetros como sobrevivência, recrutamento e taxas de recaptura de outras espécies de lagartos também parecem ser responsivos a diferentes regimes de queima, potencialmente influenciando o declínio nas taxas de crescimento populacional (Sousa et al. 2015, Costa et al. 2020, Caetano e Colli 2021, Machado et al. 2023).

O clima intensifica os efeitos de fatores que promovem a perda de biodiversidade (Mantyka-pringle et al. 2011). Com as mudanças climáticas, prevê-se que os regimes de queimadas aumentem em frequência e intensidade, especialmente em regiões mais secas e quentes (Kloster et al. 2012, Flannigan et al. 2016). Embora os efeitos separados do clima e das queimadas sobre a biodiversidade sejam relativamente bem estudados, pouco se sabe sobre os efeitos sinérgicos entre esses fatores. Os especialistas do IPCC destacaram a importância de investigar os efeitos interativos entre esses fatores, especialmente na América do Sul, devido à sua intensa propensão a incêndios (Shukla 2019). A interação entre clima e queimadas deve modificar a estrutura da vegetação através de mudanças no balanço de energia da superfície, no balanço do estoque de carbono orgânico no solo, na qualidade do leito de sementes e na disponibilidade de nutrientes (Penman et al. 2015, Mekonnen et al. 2019). A resposta das populações naturais aos efeitos interativos é complexa e pouco estudada. No entanto, sabemos que as mudanças causadas pela interação entre clima e fogo na adequação estrutural do habitat afetam negativamente o parâmetro de abundância em populações de pequenos roedores e a viabilidade de metapopulações de anfíbios (Magnusson et al. 2010, Penman et al. 2015). Entretanto, são necessários estudos de longo prazo que analisem a interação entre as variáveis

climáticas, especialmente seus componentes como tendências (variação interanual), sazonalidade (padrão cíclico) e seus extremos (variação aleatória), e diferentes regimes de queima sobre a dinâmica das populações.

Neste estudo, nosso objetivo foi investigar efeitos sinérgicos de longo prazo entre o clima e diferentes regimes de queima sobre os parâmetros populacionais do lagarto neotropical *Copeoglossum nigropunctatum* no Cerrado brasileiro. A vegetação do Cerrado é estruturada pelo fogo, pelas condições edáficas e pela disponibilidade de água, tendo desenvolvido características adaptativas para resistir e se recuperar de incêndios e secas (Miranda 2002, Simon et al. 2009). As respostas dos lagartos às queimadas são variáveis e dependem das características do ciclo de vida da espécie e das modificações na estrutura do habitat, como disponibilidade de recursos alimentares, locais de termorregulação e características do microhabitat (James e M'Closkey 2003, Pianka e Goodyear 2012, Sousa et al. 2015, Costa et al. 2020). As respostas demográficas desses organismos também podem variar dependendo dos efeitos de curto e longo prazo do fogo nas taxas de sobrevivência e recrutamento (Sousa et al. 2015, Costa et al. 2020, Caetano e Colli 2021, Machado et al. 2023). O *Copeoglossum nigropunctatum* possui ampla distribuição na América do Sul, sendo mais abundante em florestas e savanas do Cerrado com cobertura florestal (Vitt e Blackburn 1991, Vitt et al. 1997). Possui estratégia reprodutiva vivípara e período gestacional longo, variando de 9 a 12 meses, com os filhotes nascendo na transição da estação seca para a chuvosa (Vitt e Blackburn 1991, Vitt et al. 1997). A reprodução vivípara ocorre em cerca de 20% das espécies de lagartos e está associada à adaptação a ambientes com temperaturas mais baixas (Shine 2014), tornando-as intrinsecamente sensíveis ao aquecimento global (Sinervo et al. 2010). Sua dieta é composta principalmente por cupins, besouros e aranhas (Vitt et al. 1997), que são mais abundantes nos meses chuvosos no Cerrado (Pinheiro et al. 2002).

Portanto, hipotetizamos que (H1) o clima e os regimes de queima afetam de forma interativa a abundância relativa de *Copeoglossum nigropunctatum*, aumentando o número de capturas nos períodos mais secos e quentes, regimes de queima menos severos e habitats com cobertura vegetal fechada (Vitt e Blackburn 1991, Vitt et al. 1997, Sousa et al. 2015, Costa et al. 2020); (H2) o clima e os regimes de queima interagem sobre a estrutura etária de *C. nigropunctatum* através do fornecimento de recursos e recrutamento populacional, diminuindo o tamanho/estrutura etária das populações (indivíduos menores e mais jovens) em períodos úmidos e regimes de queima menos severos e habitats com cobertura vegetal fechada (James

e M'Closkey 2003, Pianka e Goodyear 2012, Sousa et al. 2015, Costa et al. 2020, Caetano e Colli 2021); e (H3) o clima interage com os regimes de queima sobre a sobrevivência de *C. nigropunctatum* ao afetar o fornecimento de recursos para a população, com menor sobrevivência em períodos mais secos e regimes de queima mais severos e habitats abertos (Sousa et al. 2015, Costa et al. 2020, Machado et al. 2023). Decompomos os padrões de temperatura e precipitação em previsíveis, tendências interanuais e componentes imprevisíveis para retratar os efeitos climáticos sobre os parâmetros populacionais de *C. nigropunctatum* e para melhor compreender como as mudanças climáticas podem afetar as populações no futuro (IPCC 2023). Esperamos que regimes de queima menos severos e habitats com cobertura vegetal mais fechada amortecem os efeitos dos componentes climáticos sobre os parâmetros populacionais, especialmente as tendências interanuais e os componentes imprevisíveis.

RESUMO EM PORTUGUÊS

Nós investigamos os efeitos sinérgicos de longo prazo dos componentes climáticos (sazonalidade, tendência e residual) e diferentes regimes de fogo na sobrevivência, captura, recaptura e tamanho corporal (como indicador da estrutura etária) do lagarto *Copeoglossum nigropunctatum* no Cerrado do Brasil Central. Foram utilizados dados de 22 anos de captura-marcação-recaptura de sete áreas de estudo com gradiente de regimes de queima: cinco no Cerrado *sensu stricto* e duas em mata de galeria. Nossa hipótese é que existe sinergia entre os componentes climáticos e os diferentes regimes de fogo que afetam o tamanho do corpo, a frequência de captura, a taxa de recaptura e a taxa de sobrevivência de *C. nigropunctatum*. Nossos resultados apoiaram parcialmente nossas hipóteses. Verificamos que o tamanho corporal não é afetado pela sinergia, mas foram encontrados indivíduos menores na área de mata não sujeita a queima, evidenciando maior presença de indivíduos jovens nesta área. Além disso, a estrutura etária responde aos padrões de sazonalidade da precipitação. Descobrimos também que a sinergia entre a precipitação residual e os regimes de fogo foi negativamente associada à frequência de captura, com taxas de captura mais baixas em áreas com regimes de fogo mais severos, indicando um efeito de sinergia na movimentação de indivíduos. Verificamos também que a sinergia entre a sazonalidade da precipitação e os regimes de fogo afetou a taxa de recaptura com valores mais baixos em regimes extremos de queima e apresentando uma relação negativa com este componente. Finalmente, a taxa de sobrevivência responde à interação entre os regimes de queimadas e a sazonalidade e tendência da precipitação, mantendo taxas de sobrevivência mais baixas nos regimes de queimadas mais extremos. Nosso estudo sugere que, para compreender os efeitos das mudanças climáticas e dos regimes de fogo, o efeito sinérgico nas populações de lagartos não deve ser descartado, e que esses efeitos podem ser complexos e variar dependendo dos componentes climáticos específicos e dos regimes de fogo envolvidos. Nossas descobertas têm implicações importantes para a conservação das populações de lagartos no Cerrado, um ecossistema ameaçado e altamente suscetível às mudanças climáticas e ao fogo.

Palavras-chave: Mudanças climáticas, regimes de fogo, lagartos, Cerrado, *Copeoglossum nigropunctatum*, sinergia.

Abstract

We investigated the long-term synergistic effects of climate and fire on the demography of the lizard *Copeoglossum nigropunctatum* in the Cerrado of central Brazil. We used data from 22 years of mark-recapture from seven study areas across two main habitats (savanna and forest) and a gradient of fire regimes. We hypothesize that there is synergy between climatic components and different fire regimes affecting age/size structure, relative abundance, and survival of *C. nigropunctatum*. Our results partially supported our hypotheses. We found that age/size structure is not affected by synergy. Still, we captured more juveniles in the forest area that was not subject to burning and the seasonal and predictable patterns of precipitation. We also found that the synergy between the unpredictable patterns of precipitation and fire regimes negatively affected the relative abundance, with lower captures in areas with more severe fire regimes. Finally, survival responds to the interaction between fire regimes and the seasonal patterns and interannual trends of precipitation, maintaining lower survival in the most extreme fire regimes. Our study suggests that to understand the effects of climate change and fire regimes, the synergistic effect on lizard populations should not be disregarded and that these effects may be complex depend on the climate components, habitat structure, and fire regimes. Our findings have important implications for the conservation of lizard populations in the Cerrado, a threatened ecosystem highly susceptible to climate change and fire.

Keywords: Cerrado savannas, Climate change, *Copeoglossum nigropunctatum*, Ectotherm Mark-Recapture, Survival.

1. INTRODUCTION

Human activity and economic development have precipitated profound environmental changes, leading to a global biodiversity crisis (Midgley et al. 2002, Van Der WAL et al. 2008, Lewis and Maslin 2015, Barlow et al. 2016). This crisis is primarily driven by habitat disturbances and, increasingly, by climate change (Brook et al. 2008). These drivers are central to species extinctions, impacting temperature and precipitation patterns which are crucial for animal populations, particularly ectotherms (Ceia-Hasse et al. 2014, Pontes-da-Silva et al. 2018, Diele-Viegas et al. 2019). The climatic changes challenge ectotherms in several ways. They not only pose a threat to their thermoregulation (Sears et al. 2015) but also influence their life history (Diele-Viegas et al. 2019, Caetano and Colli 2021), geographic distribution, and extinction risk (Sinervo et al. 2010, Pontes-da-Silva et al. 2018). Extinction, fundamentally a demographic process (Lande 1993), requires understanding how environmental variations influence species' vital rates—survival, reproduction, and recruitment—for effective conservation in a changing world (Boyce et al. 2006).

Climate is a key predictor of biome, community, and population dynamics (Pfister 1998, Letnic et al. 2004, Bost et al. 2015, Sousa et al. 2015, Caetano and Colli 2021). Temperature and precipitation regulate food resources and environmental conditions, shaping species' life cycles. Ectotherms, reliant on environmental conditions for homeostasis, are particularly vulnerable (White 2008). Climate change-induced temperature increases could negatively impact survival and reproduction, potentially leading to local extinctions (Sinervo et al. 2010, Diele-Viegas et al. 2019). Furthermore, changes in precipitation patterns may exacerbate temperature effects, leading to increased mortality and reproductive declines (Ryan et al. 2015, Wang et al. 2016). Besides mean trends, temperature and precipitation are predicted to become more unpredictable and extreme with climate change (IPCC 2023). Such climate extremes and unpredictability could significantly affect survival and recruitment rates

in lizard populations (Caetano and Colli 2021). While some populations have strategies to cope with climate variations, there is a tipping point beyond which they may not be able to adapt to increasing environmental variations (Rodríguez-Caro et al. 2021).

Fires also play a crucial role in shaping the ecology and evolution of ecosystems and species (Pausas and Schwilk 2012, Keeley and Pausas 2022). Their intensity, frequency, and extent variably affect animal species (Letnic et al. 2004, Pianka and Goodyear 2012, Robertson et al. 2022). Lizard responses to fires are diverse, depending on life-history traits and habitat structure changes affecting food resource availability and breeding and thermoregulation sites (James and M'Closkey 2003, Pianka and Goodyear 2012, Sousa et al. 2015, Costa et al. 2020). The demographic responses of lizards to fire are varied and complex, particularly in the context of long-term fire effects (Costa et al. 2020). While the abundance of some lizard species tends to increase with the severity of burns, populations of *Copeoglossum nigropunctatum* show a reduction in abundance in medium-term burning regimes (Costa et al. 2020). Furthermore, parameters such as survival, recruitment, and recapture rates of other species of lizards also appear to be responsive to different burning regimes, potentially influencing the decline in population growth rates (Sousa et al. 2015, Costa et al. 2020, Caetano and Colli 2021, Machado et al. 2023).

The climate intensifies the effects of factors that promote biodiversity loss (Mantyka-pringle et al. 2011). With climate change, fire regimes are predicted to increase in frequency and intensity, especially in drier and hotter regions (Kloster et al. 2012, Flannigan et al. 2016). Although the separate effects of climate and fires on biodiversity are relatively well studied, little is known about the synergistic effects between these factors. The IPCC experts highlighted the importance of investigating the interactive effects between these factors, especially in South America, due to its intense propensity to fires (Shukla 2019). The interaction between climate and burning should modify the vegetation structure through

changes in the surface energy balance, the balance in the organic carbon stock in the soil, changes in the quality of the seedbed, and the availability of nutrients (Penman et al. 2015, Mekonnen et al. 2019). The response of natural populations to interactive effects is complex and little studied. However, we know that changes caused by the interaction between climate and fire in the structural suitability of the habitat negatively affect the abundance parameter in small rodent populations and the viability of amphibian metapopulations (Magnusson et al. 2010, Penman et al. 2015). However, long-term studies analyzing the interaction between climate variables, especially their components such as trends (inter-annual variation), seasonality (cyclical pattern), and their extremes (random variation) and different burning regimes on population dynamics are necessary.

Here, we aimed to investigate the long-term synergistic effects between climate and different fire regimes on the populations' parameters of the Neotropical lizard *Copeoglossum nigropunctatum* in the Brazilian Cerrado savannas. Cerrado vegetation is structured by fire, edaphic conditions, and water availability and has evolved adaptive traits to resist and recover from fires and droughts (Miranda 2002, Simon et al. 2009). Lizard responses to fires are variable and depend on the species' life traits and modification in the structure of the habitat, such as availability of food resources, thermoregulation sites, and microhabitat characteristics (James and M'Closkey 2003, Pianka and Goodyear 2012, Sousa et al. 2015, Costa et al. 2020). The demographic responses of these organisms can also vary depending on fire's short- and long-term effects on survival and recruitment rates (Sousa et al. 2015, Costa et al. 2020, Caetano and Colli 2021, Machado et al. 2023). *Copeoglossum nigropunctatum* has a wide distribution throughout South America and is more abundant in forests and forested Cerrado savannas (Vitt and Blackburn 1991, Vitt et al. 1997). It has a viviparous reproduction strategy and has a long gestation period ranging from 9 to 12 months, with newborns hatching in the transition of the dry to the wet season (Vitt and

Blackburn 1991, Vitt et al. 1997). Viviparous reproduction occurs in about 20% of lizard species and is associated with adaptation to environments with lower temperatures (Shine 2014), giving them an intrinsic sensitivity to global warming (Sinervo et al. 2010). Its diet mainly comprises termites, beetles, and spiders (Vitt et al. 1997), which are more abundant in the rainy months in the Cerrado (Pinheiro et al. 2002).

Thus, we hypothesize that (H₁) climate and fire regimes interactively affect the relative abundance of *Copeoglossum nigropunctatum*, increasing the number of captures in the driest and hottest periods and less severe fire regimes and closed canopy cover habitats; (H₂) climate and fire regimes interact upon the age structure of *C. nigropunctatum* through the resources supply and populations' recruitment, decreasing the populations' size/age structures (smaller and younger individuals) in wet periods and less severe fire regimes; and (H₃) the climate interact with fire regimes upon the survival of *C. nigropunctatum* by affecting the resources supply for the population, with lower survival in drier periods and more severe fire regimes and open habitats. We decomposed the temperature and precipitation patterns into predictable, interannual trends, and unpredictable components to depict the climate effects upon the populations' parameters of *C. nigropunctatum* and to better understand how climate change might affect the populations in the future. We expect that less severe fire regimes and more closed canopy cover habitats will buffer the effects of the climate components upon the populations' parameters, especially the interannual trends and unpredictable components.

2. MATERIALS AND METHODS

2.1 Study area

We collected the demographic data of *C. nigropunctatum* in five plots of cerrado *sensu stricto* and two plots of gallery forest inside two protected areas: IBGE Ecological Reserve

(RECOR; 15°56'41" S, 47°53'07" W) and Brasília Botanical Garden Reserve (JBB; 15°52'00" S, 47°47'21" W). Both protected areas are part of the Environmental Protection Area *Gama-Cabeça de Veado* located in Brasília, Federal District. The cerrado *sensu stricto* vegetation is characterized by a defined herbaceous layer and dominant trees and shrubs 3-8 m tall, and the gallery forest is a riparian forest associated with small-width streams, presenting trees of 20-30 m tall, absence of an herbaceous layer and canopy cover varying around 70 and 95% (Ribeiro and Walter 1998).

RECOR was created in 1975 and remained protected from fires until 1988, when the Fire Project began, aiming to study Cerrado fire ecology through multidisciplinary approaches. We used five 200 x 500 m Fire Project plots since November of 2005 until April 2022. Each plot received a different treatment, following the order of increasing severity: no burning (Control - C), burning every four years in the middle of the dry season (Quadrennial - Q), burning every two years at the beginning of the dry season (Early biennial - EB), burns every two years in the middle of the dry season (Mid Biennial - MB) and burns every two years at the end of the dry season (Late Biennial - LB). In 2011, an unplanned fire partially burned plots C and BT. Although the Fire Project ended in 2008, herpetological collections are still ongoing to create a long-term database. Even if controlled burning regimes are not occurring, it is assumed that possible differences between plots result from the applied regime since all plots have the same physiognomy. Experimental studies with controlled fires have legal restrictions, and therefore, Fire Project does not have replicas of the burning regimes. The gallery forest areas are in RECOR and JBB, opened in 1985. JBB and IBGE are in the Environmental Protection Area (APA) Gama- Cabeça de Veado. The IBGE gallery forest was protected from fire until 1994, when an accidental burning occurred. Two other fires occurred in July 2005 and October 2011.

2.2 Population data

To monitor the populations of *Copeoglossum nigropunctatum*, we installed 20 pitfall traps in each forest plot in June 2000 and 10 pitfall traps in each Cerrado plot in November 2005. Each trap comprises four PVC pipes or buckets buried to ground level and interconnected by 6m-long galvanized steel sheets. The arrangement of the pipes/buckets is Y-shaped, with one central and three peripherals (Costa et al. 2020, Caetano and Colli 2021)). Each trap is approximately 20 m apart from one another. Until April 2022, we opened the traps to sample the lizards for six consecutive days with one-month intervals in the cerrado plots; in the forests, the traps were continuously opened, and we revised them twice a week. Therefore, we monitored the populations of *C. nigropunctatum* continuously for 22 years at the forest plots and 17 years at the Cerrado plots (excluding the period between May and August 2020 due to the COVID-19 pandemic restrictions). After capturing the lizards, we measured their snout-vent length (SVL) with a ruler (1 mm precision) and marked them individually and permanently through toe-clipping, a method that has no detectable effect on survival and recapture rates (Jones and Bell 2010)

2.3 Climate data

To investigate the effects of climate on the demography of *Copeoglossum nigropunctatum*, we used the local climate variables between January 1968 and December 2021 from the meteorological station n. 83377, located in Brasília, available from the INMET (National Institute of Meteorology; available at [INSERT WEB LINK](#)) database. We checked the missing data using the VISDAT package (Tierney 2017) and imputed them using the MISSFOREST package (Stekhoven and Bühlmann 2011). From the 648 monthly mean observations for all climate variables, only 0.3% were missing. From the six climate variables related to temperature (monthly means of daily means, minimum, and maximum

temperatures) and precipitation patterns (monthly accumulated precipitation and mean insolation), we selected the least collinear variables using the stepwise procedure *vifstep* from the USDM package (Naimi 2023) using variance inflation factor ($VIF < 2$). We used only two climate variables in the following analyses: monthly means of daily maximum temperatures and monthly accumulated precipitation.

2.4 Data analyses

2.4.1 Climate time series decomposition

We conducted all the statistical analyses in the R program (R Core Team 2013). To depict the predictable, interannual trends, and unpredictable patterns from the monthly means of maximum temperature and monthly accumulated precipitation, we decomposed each time series into their seasonal, trend (moving average), and irregular components using the X-13ARIMA-SEATS decomposition method (Sax and Eddelbuettel 2018) with package RJDOMETRA (Quartier-la-Tente et al. 2023). The X-13ARIMA-SEATS method is a seasonal adjustment tool that uses Autoregressive Integrated Moving Average (ARIMA) models to decompose time series into their seasonal, trend, and irregular components. It helps remove seasonal influence from data, allowing an efficient analysis of underlying patterns (Sax and Eddelbuettel 2018).

The seasonal component refers to recurring patterns or cycles that repeat at regular intervals – the predictable patterns; the trend component represents the general direction of the time series over time, indicating whether the series is increasing, decreasing, or remaining stable over the years – the interannual variation; and the irregular component represents what remains after removing trend and seasonality (the residuals) – the unpredictable and unsystematic patterns (Sax and Eddelbuettel 2018). We used six climate components in the subsequent analyses: the seasonal components of maximum temperature and precipitation

($tmax_s$ and $precip_s$), the trend components ($tmax_t$ and $precip_t$), and the irregular components ($tmax_i$ and $precip_i$).

To check for trends in the raw data and in the components of the maximum temperatures and precipitation, we built linear mixed-effects models (LMEMs) using continuous time (months) as a fixed factor and the years as a random variable, using the LME4 package (Bates et al. 2015). We compared the models to null models (without the fixed factor of continuous time) using likelihood ratio tests (Crawley 2013).

2.4.2 Relative abundance and age/size structure

To test H1, whether climate and fire regimes interactively affect the relative abundance of *Copeoglossum nigropunctatum*, we used the monthly number of captures per plot as the response variable in generalized linear mixed models (GLMM) with the GLMMTMB package (Bolker 2023). We first compared eight distributions for count data: Poisson, generalized Poisson, negative binomial with linear and quadratic parameterization, and their respective truncated versions to consider the presence of inflated zeros. We used the information theory approach based on Akaike's Information Criterion (AIC) to select the best model. With the best error distribution for our data (negative binomial with quadratic parameterization), we used the MUMIN package (Bartón 2014) to build 793 models with all the predictors' combinations (plots, six climate components, and their interactions) and evaluate their importance with AIC and model weighting. We also controlled for pseudoreplication and temporal autocorrelation among our measurements by using month (1-12) as a random variable in all models. Afterwards, we tested for the significance of the best predictors with an Analysis of Deviance Table (Type III Wald chi-square tests) with the aid of the CAR package (Fox and Weisberg 2019). We also performed pairwise multiple comparisons between plots with the EMMEANS package (Lenth and Lenth 2018).

To test H2, whether temperature and precipitation patterns and fire regimes interact upon the age/size structure of *C. nigropunctatum*, we used the monthly means of SVL measurements by plot as a proxy for the age structure of the populations since body size is proximally related to age in reptiles (Reinke et al. 2022). We imputed the missing and possible outliers (probability less than 0.001% of occurrence) of SVL measures using the body mass and the size of the intact tail as predictors using the MISSFOREST package (Stekhoven and Bühlmann 2011). We used the same approach as the number of captures, using the MUMIN package to compare mixed-effects models with all predictor combinations (plots, six climate components, and their interactions) and evaluate their importance over the mean SVL. We built the models using the LME4 package (Bates et al. 2015) and controlled for pseudoreplication and temporal autocorrelation using month (1-12) as a random variable. To test the significance of the best predictors of mean SVL, we performed Analyses of Deviance Table (Type III with Satterthwaite's method) with the aid of the LMERTEST package (Kuznetsova et al. 2017). We checked model assumptions by analyzing the residuals (Zuur et al. 2010).

2.4.3 *Survival*

To test whether climate and fire regimes interactively affect the survival (H3) of *C. nigropunctatum*, we built Cormack-Jolly-Seber (CJS) demographic models (Cormack 1964) using the MARKED package (Laake et al. 2013). We used the individuals' capture histories to relate the apparent survival (ϕ) and recapture (p) probabilities with plots–fire regimes, the seasonal and trend components of precipitation ($precip_s$ and $precip_t$), and their interactions. We chose these variables because precipitation is an essential variable for Cerrado reptiles (Costa et al. 2007) and were the only predictors of the number of captures and mean SVL that interacted significantly with plots–fire regimes. We created 100 models with all combinations

of these parameters and their interactions. We compared all the combinations among the predictors using the AIC and selected the best models when $\Delta AIC \leq 2$ (Burnham and Anderson 2002).

3 RESULTS

3.1 Climate, relative abundance, and age/size structure

The local climate of our study area is getting hotter and drier, since 1968 until 2022, the period of climate data. We recovered significant trend and seasonally adjusted components among all climate variables. These components increased for insolation and minimum, average, and maximum temperature over time but decreased for precipitation (Table S1). Between June 2000 and April 2022 (22 years), we recorded 3,070 occurrences of *Copeoglossum nigropunctatum*, comprising 2,118 capture and 894 recapture events, resulting in an average of 0.296 recaptures per individual. From the 2,118 individuals we captured, 82.81% ($n = 1,754$) were captured only once, 17.09% ($n = 362$) were captured twice, 5.7% ($n = 122$) were captured three times, and 1.27% ($n = 27$) were captured four times.

We found a general trend of lower relative abundance of *C. nigropunctatum* with increasing fire severity (Fig. 1). However, we found the lowest number of captures in the JBB gallery forest, which never burned since the creation of the Reserve (Fig. 1). According to our model selection, the seasonal and irregular components of precipitation ($precip_s$ and $precip_i$) and the seasonal and trend components of maximum temperature ($tmax_s$ and $tmax_t$) are the best climate predictors of the relative abundance of *C. nigropunctatum* (Fig. 2; $\chi^2_{48} = 365.22$; $P < 0.001$; Table S2). We found significant interactions between these climate components and fire regimes, except for the irregular component of precipitation (Fig. 2; Table S2). In general, the relative abundance of *C. nigropunctatum* decreases with the seasonal and predictable amount of precipitation. However, in intermediate severity fire

regimes (MB), we found the opposite (Fig. 2A). Unpredictable and irregular amounts of precipitation decrease the relative abundance of the species, regardless of the fire regimes (Fig. 2B). In the gallery forests, the relative abundance of *C. nigropunctatum* increases with the predictable and seasonal higher maximum temperatures, but not in the cerrado s.s. populations (Fig. 2C). In general, higher maximum temperatures over the years (trend) increase the relative abundance of the species, especially under severe fire regimes and in open habitats (Fig. 2D).

In general, we captured more younger individuals at the beginning of the rainy season, between September and February (Fig. 3), confirming the seasonal reproduction in the species (Vitt and Blackburn 1991). We also found a relatively high overlap of adults between consecutive years (Fig. 3A), an indication of overlapping generations and considerable interannual survival. The JBB gallery forest population presented the lowest age/size structure among the other populations subjected to different fire regimes (Fig. 4). The seasonal and predictable component of precipitation ($precip_s$) was the only significant predictor of the age/size structure of *C. nigropunctatum* ($\chi^2_{13} = 98.55$; $P < 0.001$), regardless of fire regimes (Fig. 4; Table S3). Average body size (age) decreases with more predictable precipitation (Fig. 4).

3.2 Survival

According to our model selection, fire regimes and precipitation interactively affect survival and recapture probabilities (single model selected with $\Delta AIC \leq 2$: $\phi \sim plot * precip_t * precip_s$, $p \sim plot * precip_s$; Table S4), supporting our hypothesis (H3). In severe fire regimes, the recapture probability tends to increase with higher amounts of predictable and seasonal precipitation; in the gallery forests, where fires are unusual, we found the opposite pattern (Fig. 5). Regarding survival, we found a complex interaction between fire regimes and the

seasonal and trend components of precipitation (Fig. 6). We found strikingly different patterns between the gallery forest and cerrado s.s. populations (Fig. 6). In the gallery forest, the interannual trend of precipitation (trend component) is more important than the predictable (seasonal) precipitation for the individuals' survival. In intermediate fire regimes (more visible in C and Q plots), we found that high seasonal precipitation and low interannual precipitation decrease survival, as well as low seasonal precipitation and high interannual precipitation. Surprisingly, we found the opposite pattern in the most severe fire regime, with lower survival when seasonal and interannual precipitation increase (Fig. 6).

4 DISCUSSION

The hypothesis of synergistic effects between climate components and burning regimes was corroborated for survival and recapture rates but not for age structure and was partially corroborated for relative abundance. Our results indicate that the age structure of populations of *Copeoglossum nigropunctatum* is primarily affected by precipitation's seasonal component, regardless of the burning regime. The relative abundance of the species decreases with the irregular precipitation component in all burning regimes. However, the synergistic effects between climate components and burning regimes demonstrate complex effects on recapture rates, survival, and relative abundance.

4.1 Age structure and frequency of captures (relative abundance)

Temperature and precipitation are interconnected variables that affect ecophysiological traits, the availability of food resources, and the thermoregulation of lizard species (Pontes-da-Silva et al. 2018, Machado et al. 2023). The interaction between precipitation and burning regimes affects the relative abundance of *Copeoglossum nigropunctatum* in a way that intensifies the adverse effects in areas subject to burning. Another medium-term study for the same area

showed a decline in capture frequency in more severe burning regimes for this species (Costa et al. 2020), corroborating the adverse effects of burning. Fire affects food availability for lizards, and precipitation affects arthropod abundance that are food items for this species, especially those most important for the species' diet (the orders of insects and arachnids: Isoptera, Coleoptera, and Araneae) can offer significant advantages to the accumulation of energy required for the reproduction of the species (Vitt and Blackburn 1991, Pinheiro et al. 2002). The seasonal temperature component intensifies the adverse effects of the burning regime on the species. Since viviparity in lizard species is associated with the thermal protection of fetuses, temperature must be a limiting factor for reproduction (Shine 2014), showing that changes in cyclical temperature patterns can reduce the abundance of individuals in more severe regimes.

In the cerrado, precipitation's seasonal component affects recruitment rates (Caetano and Colli 2021). The average size (age) of *Copeoglossum nigropunctatum* decreases with increased precipitation's seasonal component. In general, the age structure of Cerrado lizards follows precipitation seasonality, with most species breeding during the beginning of the rainy season when food availability is greatest (Vitt and Blackburn 1991, Caetano and Colli 2021, Machado et al. 2023). The reduction in the average size of individuals in a population results from a decrease in the number of adults in relation to juveniles. Therefore, our results indicate lower recruitment in forest areas and a possible decrease in this rate concerning precipitation's irregular component. The increased climatic variation and extremes have become increasingly worrying since previous studies have demonstrated the difficulty of organisms in adapting to unusual variations in their habitats (IPCC 2023). Precipitation not only affects the availability of food resources but also affects thermoregulatory behavior and environmental suitability (Wang et al. 2016). The average size is larger in burned areas, so *Copeoglossum nigropunctatum* may present strategies to deal with environmental variations

in precipitation by increasing recruitment since the increase in the number of young individuals in variable environments (under the influence of anthropogenic action) helps to compensate for decreases in the survival of adult individuals, a strategy known as compensatory recruitment (Cayuela et al. 2022).

4.2 Demographic modeling (survival)

Temperature and precipitation are two climatic variables that cannot be neglected, especially in the cerrado. Temperature is increasing and precipitation is reducing in the region, as observed in previous studies (Hofmann et al. 2021, Ferreira et al. 2023). Precipitation is a variable that influences survival and recruitment rates in Cerrado lizards (Caetano and Colli 2021, Machado et al. 2023). In our study, the interaction between precipitation seasonality and precipitation trend affected the survival rate, reducing it in the most extreme burning regimes (plots BT, Q, IBGE, and JBB). Since viviparity in lizards is associated with colder temperatures (Shine 2014), we expected that areas of forests and less severe regimes would present higher survival rates since, in situations of extreme temperatures, the decrease in precipitation affects not only reproductive characteristics, such as conditions and the number of neonates but also the survival rate for viviparous lizards (Wang et al. 2016). However, the result showed the opposite. Time series decomposition can help understand the relationships between climate variables and demographic rates. These lizards may be more sensitive to seasonal variation interacting with the trend of variables than just the monthly averages of these variables.

5 CONCLUSIONS

Studying population responses to climate change and burning regimes without considering the interaction between these factors can lead to misleading or superficial conclusions. The

conservation of species and possible fire management in natural reserves must consider essential factors in the demographics of the populations and this interaction with the abiotic components, including the decomposition of climatic variables as predictors since the trend, seasonality, and irregularity of these measures affect populations. It is also essential to observe the life strategies of each species to select the most appropriate management for preservation, considering that extinction processes act at the population level.

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Table S1. ANOVA results for comparison between the null model and complete mixed model, where $Inso_y$ = monthly averages for insolation, $Inso_s$ = seasonal component for insolation, $Inso_t$ = trend component for insolation. $Precip_y$ = monthly averages of precipitation, $precip_s$ seasonal component of precipitation, $precip_t$ = trend component of precipitation, $tmax_y$ = monthly averages maximum temperature, $tmax_s$ = seasonal component of maximum temperature, $tmax_t$ = trend component of maximum temperature, $tmed_y$ = monthly averages for medium temperature, $tmed_t$ = trend component of medium temperature, $tmed_s$ = seasonal component of medium temperature, $tmed_t$ = trend component of temperature, $tmin_y$ = monthly average of temperature, $tmins$ = seasonal component of minimum temperature, $tmint$ = trend component of minimum temperature.

Climate					
Components	Estimate	SE	χ^2	GL	P
$Inso_y$	0.01	0.01	13.96	1	0.24
$Inso_s$	1.47E-02	8.73E-03	843.3	1	2.20E-16
$Inso_t$	1.50E-02	7.81E-03	2263	1	2.20E-16
$Precip_y$	-0.01	0.03	0.09	1	0.76
$Precip_s$	-0.01	0.02	719.04	1	2.20E-16
$Precip_t$	-0.02	0.01	2658.9	1	2.20E-16
$Tmax_y$	1.77E-03	4.22E-04	15.95	1	6.52E-05
$Tmax_s$	1.75E-03	4.21E-04	614.18	1	2.20E-16
$Tmax_t$	1.76E-03	4.26E-04	1614.90	1	2.20E-16
$Tmed_y$	2.37E-03	2.79E-04	52.18	1	5.08E-13
$Tmed_s$	2.36E-03	2.54E-04	995.06	1	2.20E-16
$Tmed_t$	2.40E-03	2.53E-04	2070.50	1	2.20E-16
$Tmin_y$	0	0	39.71	1	2.95E-10
$Tmed_s$	2.36E-03	2.39E-04	1549.30	1	2.20E-16
$Tmed_t$	2.14E-03	2.21E-04	2887.20	1	2.20E-16

Table S2. Selection of Linear mix models for Frequency of capture for lizard *Copeoglossum nigropunctatum* between 2000 and 2022, in control and treatment plots with different burn severities, in an area of cerrado *sensu stricto* at IBGE Reserva Ecológica, Brasília, Brazil and two forest areas at Reserva Ecológica do IBGE and Brazilian Botanical Garden, where: **plot** = burning regime; **precip_s** = seasonal component of precipitation; **precip_i**= irregular component of precipitation; **tmax_s** = seasonal component of maximum temperature; **tmax_t**= trend component of maximum temperature.

Component models	df	logLik	AICc	delta	weight
$(plot)+(precip_i)+(precip_s)+(tmax_s)+(tmax_t)+(plot:precip_s)+(plot:tmax_s)+(plot:tmax_t)$	32	-2581.70	5228.91	00.00	00.46
$(plot)+(precip_i)+(precip_s)+(tmax_i)+(tmax_s)+(tmax_t)+(plot:precip_s)+(plot:tmax_s)+(plot:tmax_t)$	33	-2581.60	5230.80	10.89	00.18
$(plot)+(precip_i)+(precip_s)+(precip_t)+(tmax_s)+(tmax_t)+(plot:precip_s)+(plot:tmax_s)+(plot:tmax_t)$	33	-2581.69	5230.99	02.08	00.16
$(plot)+(precip_i)+(precip_s)+(precip_t)+(tmax_i)+(tmax_s)+(tmax_t)+(plot:precip_s)+(plot:tmax_s)+(plot:tmax_t)$	34	-2581.59	5232.88	30.97	00.06
$(plot)+(precip_s)+(tmax_i)+(tmax_s)+(tmax_t)+(plot:precip_s)+(plot:tmax_s)+(plot:tmax_t)$	32	-2584.06	5233.63	40.72	00.04
$(plot)+(precip_s)+(tmax_s)+(tmax_t)+(plot:precip_s)+(plot:tmax_s)+(plot:tmax_t)$	31	-2585.62	5234.66	50.75	00.03
$(plot)+(precip_s)+(precip_t)+(tmax_i)+(tmax_s)+(tmax_t)+(plot:precip_s)+(plot:tmax_s)+(plot:tmax_t)$	33	-2584.02	5235.64	60.73	00.02
$(plot)+(precip_i)+(precip_s)+(precip_t)+(tmax_s)+(tmax_t)+(plot:precip_s)+(plot:precip_t)+(plot:tmax_s)+(plot:tmax_t)$	9	-2577.88	5236.00	07.09	00.01

<i>(plot)+(precip_s)+(precip_t)+(tmax_s)+(tmax_t)+(plot:precip_s)+(plot:tmax_s)+(plot:tmax_t)</i>	32	-2585.59	5236.70	70.79	00.01
<i>(plot)+(precip_i)+(precip_s)+(tmax_s)+(tmax_t)+(plot:tmax_s)+(plot:tmax_t)</i>	26	-2592.26	5237.51	80.60	00.01

Table S3. Selection of Linear mix models for SVL of the lizard *Copeoglossum nigropunctatum* between 2000 and 2022, in control and treatment plots with different burn severities, in an area of cerrado *sensu stricto* at IBGE Reserva Ecológica, Brasília, Brazil and two forest areas at Reserva Ecológica do IBGE and Brazilian Botanical Garden, where: **plot** = burning regime; **precip_s** = seasonal component of precipitation; **precip_t** = trend component of precipitation; **tmax_s** = seasonal component of temperature; **tmax_t** = trend component of temperature.

Component	df	logLik	AIC	ΔAIC	weight
$(plot)+(precip_s)+(tmax_i)+(tmax_s)$ $)+(tmax_i)+(plot:tmax_i)+(plot:tmax_s)+(pl$ $ot:tmax_t)$	1	-3649.70	7363.59	0.00	0.27
$(plot)+(tmax_i)+(tmax_s)+(tmax_t)$ $+(plot:tmax_i)+(plot:tmax_s)+(plot:tmax_t)$	0	-3651.11	7364.28	0.69	0.19
$(plot)+(precip_s)+(tmax_i)+(tmax_t)$ $)+(plot:tmax_i)+(plot:tmax_t)$	4	-3657.81	7364.94	1.35	0.14
$(plot)+(precip_s)+(tmax_i)+(tmax_s)$ $)+(tmax_i)+(plot:tmax_i)+(plot:tmax_t)$	5	-3657.20	7365.82	2.23	0.09
$(plot)+(tmax_i)+(tmax_s)+(tmax_t)$ $+(plot:tmax_i)+(plot:tmax_t)$	4	-3658.60	7366.51	2.92	0.06
$(plot)+(tmax_i)+(tmax_t)+(plot:tm$ $ax_i)+(plot:tmax_t)$	3	-3659.71	7366.63	03.04	0.06
$(plot)+(precip_s)+(tmax_s)+(tmax_t)$ $)+(plot:tmax_s)+(plot:tmax_t)$	4	-3659.77	7368.86	5.27	0.02
$(plot)+(tmax_s)+(tmax_t)+(plot:tm$ $ax_s)+(plot:tmax_t)$	3	-3661.30	7369.81	6.22	0.01
$(plot)+(precip_s)+(tmax_i)+(tmax_s)$ $)+(plot:tmax_i)+(plot:tmax_s)$	4	-3660.27	7369.85	6.27	0.01
$(plot)+(precip_s)+(precip_t)+(tma$ $x_i)+(tmax_s)+(tmax_t)+(plot:tmax_i)+(plot:t$ $max_s)+(plot:tmax_t)$	2	-3651.85	7370.03	6.44	0.01
$(plot)+(precip_s)+(tmax_i)+(tmax_s)$ $)+(tmax_i)+(plot:tmax_i)+(plot:tmax_s)$	5	-3659.39	7370.20	6.61	0.01

$(plot)+(precip_s)+(tmax_i)+(tmax_s)$ $)+(tmax_t)+(plot:tmax_s)+(plot:tmax_t)$	5	-3659.45	7370.32	6.73	0.01
$(plot)+(precip_s)+(tmax_t)+(plot:t$ $max_t)$	7	-3667.84	7370.34	6.75	0.01
$(plot)+(tmax_t)+(tmax_s)+(plot:tm$ $ax_t)+(plot:tmax_s)$	3	-3661.72	7370.65	07.06	0.01
$(plot)+(precip_t)+(tmax_t)+(tmax_s$ $)+(tmax_t)+(plot:tmax_t)+(plot:tmax_s)+(pl$ $ot:tmax_t)$	1	-3653.24	7370.68	07.09	0.01
$(plot)+(tmax_t)+(tmax_s)+(tmax_t)$ $+(plot:tmax_t)+(plot:tmax_s)$	4	-3660.83	7370.98	7.39	0.01
$(plot)+(precip_s)+(tmax_s)+(tmax_t$ $)+(plot:tmax_t)$	8	-3667.22	7371.18	7.59	0.01
$(plot)+(tmax_t)+(tmax_s)+(tmax_t)$ $+(plot:tmax_s)+(plot:tmax_t)$	4	-3660.99	7371.30	7.72	0.01
$(plot)+(precip_s)+(tmax_t)+(plot:t$ $max_t)$	7	-3668.33	7371.32	7.73	0.01
$(plot)+(precip_s)+(precip_t)+(tma$ $x_t)+(tmax_t)+(plot:tmax_t)+(plot:tmax_t)$	5	-3659.96	7371.35	7.76	0.01

Table S4. Selection of Cormack–Jolly–Seber demographic models for the lizard *Copeoglossum nigropunctatum* between 2000. and 2022, in control and treatment plots with different burn severities, in an area of Cerrado *sensu stricto* at Reserva Ecológica do IBGE, Brasília, Brazil and areas of Galery Forest. Where: Φ = survival probability; p = capture probability; precip = precipitation, parcela = fire regime.

Model		par	AIC	delta	-2lnl
AIC					
8	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{parcela} * \text{ptot}_s)$	2	6348.66	0.00	6264.66
9	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{parcela} + \text{ptot}_t)$	6	6352.12	0.46	6280.12
2	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$	6	6352.66	0.01	6240.66
1	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{parcela} + \text{ptot}_t + \text{ptot}_s)$	7	6352.67	0.02	6278.67
7	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{parcela} + \text{ptot}_s)$	6	6354.85	0.19	6282.85
6	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{parcela})$	5	6359.96	1.30	6289.96
0	$\Phi(\sim\text{parcela} * \text{ptot}_s)$ $p(\sim\text{parcela} * \text{ptot}_s)$	8	6362.68	4.02	6306.68
2	$\Phi(\sim\text{parcela} * \text{ptot}_s)$ $p(\sim\text{parcela} * \text{ptot}_t)$	8	6364.02	5.36	6308.02
4	$\Phi(\sim\text{parcela} * \text{ptot}_s)$ $p(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$	2	6364.32	5.66	6280.32
8	$\Phi(\sim\text{parcela} + \text{ptot}_s)$ $p(\sim\text{parcela} * \text{ptot}_s)$	2	6365.10	6.44	6321.10
3	$\Phi(\sim\text{parcela} * \text{ptot}_s)$ $p(\sim\text{parcela} + \text{ptot}_t + \text{ptot}_s)$	3	6365.17	6.51	6319.17
1	$\Phi(\sim\text{parcela} * \text{ptot}_s)$ $p(\sim\text{parcela} + \text{ptot}_t)$	2	6365.68	7.03	6321.68

2	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{parcela} * \text{ptot_t} * \text{ptot_s})$	6	6366.88	8.22	6294.88
6	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{parcela} * \text{ptot_s})$	3	6367.09	8.44	6321.09
0	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{parcela} * \text{ptot_t} * \text{ptot_s})$	7	6367.90	9.24	6293.90
0	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{parcela} * \text{ptot_t})$	2	6368.05	9.39	6324.05
1	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$	7	6368.47	9.81	6334.47
9	$\Phi(\sim\text{parcela} * \text{ptot_s})$ $p(\sim\text{parcela} + \text{ptot_s})$	2	6368.76	0.11	6324.76
8	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{parcela} * \text{ptot_t})$	3	6368.97	0.31	6322.97
9	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{parcela} + \text{ptot_t})$	6	6369.04	0.39	6337.04
8	$\Phi(\sim\text{parcela} * \text{ptot_s})$ $p(\sim\text{parcela})$	1	6369.35	0.69	6327.35
9	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$	8	6369.74	1.08	6333.74
7	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{parcela} + \text{ptot_t})$	7	6370.27	1.61	6336.27
0	$\Phi(\sim\text{parcela} * \text{ptot_t} * \text{ptot_s})$ $p(\sim\text{parcela} * \text{ptot_t})$	2	6371.11	2.45	6287.11
7	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{parcela} + \text{ptot_s})$	6	6372.28	3.62	6340.28
6	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{parcela})$	5	6373.11	4.45	6343.11
5	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{parcela} + \text{ptot_s})$	7	6374.28	5.62	6340.28
4	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{parcela})$	6	6375.10	26.44	6343.10

6	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	*	1	6381.54	2.88	6339.54
0	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	*	5	6382.49	3.84	6312.49
6	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	+	6	6382.69	4.04	6310.69
2	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	+	2	6383.54	4.88	6339.54
8	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	*	1	6383.56	4.90	6341.56
4	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	+	2	6383.67	5.01	6339.67
7	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	+	5	6384.75	6.09	6354.75
9	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	+	6	6384.97	6.32	6352.97
3	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	+	6	6385.38	6.72	6353.38
5	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	+	7	6385.63	6.97	6351.63
8	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	*	2	6385.84	7.19	6301.84
4	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	*	8	6386.52	7.86	6330.52
6	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	*	8	6387.28	8.62	6331.28
5	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	*	2	6387.56	8.90	6343.56
7	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	*	3	6387.80	9.15	6341.80
5	$\Phi(\sim\text{parcela})$	$p(\sim\text{parcela})$	+	5	6389.34	0.68	6359.34

0	$\Phi(\sim\text{parcela} + \text{ptot}_t)$ $p(\sim\text{parcela})$	5	6391.31	2.66	6361.31
1	$\Phi(\sim\text{parcela} + \text{ptot}_t)$ $p(\sim\text{parcela} + \text{ptot}_s)$	6	6391.33	2.67	6359.33
3	$\Phi(\sim\text{parcela} * \text{ptot}_t)$ $p(\sim\text{parcela} + \text{ptot}_s)$	2	6394.05	5.39	6350.05
2	$\Phi(\sim\text{parcela} * \text{ptot}_t)$ $p(\sim\text{parcela})$	1	6394.09	5.43	6352.09
4	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{ptot}_s + \text{ptot}_t)$	1	6396.49	7.83	6334.49
6	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{ptot}_t)$	0	6398.15	9.49	6338.15
27	$\Phi(\sim\text{ptot}_s * \text{ptot}_t) p(\sim\text{parcela} + \text{ptot}_t + \text{ptot}_s)$	3	6401.00	2.35	6375.00
3	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{ptot}_s)$	0	6401.31	2.65	6341.31
5	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim\text{ptot}_s * \text{ptot}_s)$	0	6401.31	2.65	6341.31
28	$\Phi(\sim\text{ptot}_s * \text{ptot}_t) p(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$	2	6402.02	3.36	6338.02
26	$\Phi(\sim\text{ptot}_s * \text{ptot}_t) p(\sim\text{parcela} * \text{ptot}_t)$	8	6402.51	3.85	6366.51
25	$\Phi(\sim\text{ptot}_s * \text{ptot}_t) p(\sim\text{parcela} + \text{ptot}_t)$	2	6402.55	3.89	6378.55
24	$\Phi(\sim\text{ptot}_s * \text{ptot}_t) p(\sim\text{parcela} * \text{ptot}_s)$	8	6407.60	8.94	6371.60
5	$\Phi(\sim\text{parcela} * \text{ptot}_t * \text{ptot}_s)$ $p(\sim 1)$	9	6409.21	0.55	6351.21
23	$\Phi(\sim\text{ptot}_s * \text{ptot}_t) p(\sim\text{parcela} + \text{ptot}_s)$	2	6412.56	3.90	6388.56
6	$\Phi(\sim\text{parcela} * \text{ptot}_s) p(\sim\text{ptot}_s + \text{ptot}_t)$	7	6414.54	5.88	6380.54

22	$\Phi(\sim\text{ptot_s} * \text{ptot_t})$ $p(\sim\text{parcela})$	1	6414.89	6.24	6392.89
03	$\Phi(\sim\text{ptot_s}) p(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$	1	6415.75	7.09	6393.75
00	$\Phi(\sim\text{ptot_s}) p(\sim\text{parcela} * \text{ptot_s})$	6	6416.04	7.38	6384.04
15	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$	2	6416.40	7.75	6392.40
8	$\Phi(\sim\text{parcela} * \text{ptot_s})$ $p(\sim\text{ptot_t})$	6	6416.49	7.83	6384.49
04	$\Phi(\sim\text{ptot_s}) p(\sim\text{parcela} * \text{ptot_t} * \text{ptot_s})$	0	6416.54	7.88	6356.54
16	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim\text{parcela} * \text{ptot_t} * \text{ptot_s})$	1	6416.90	8.24	6354.90
4	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{ptot_s} + \text{ptot_t})$	1	6417.43	8.77	6395.43
02	$\Phi(\sim\text{ptot_s}) p(\sim\text{parcela} * \text{ptot_t})$	6	6417.48	8.82	6385.48
01	$\Phi(\sim\text{ptot_s}) p(\sim\text{parcela} + \text{ptot_t})$	0	6417.52	8.86	6397.52
14	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim\text{parcela} * \text{ptot_t})$	7	6417.78	9.12	6383.78
12	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim\text{parcela} * \text{ptot_s})$	7	6417.98	9.32	6383.98
13	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim\text{parcela} + \text{ptot_t})$	1	6418.10	9.44	6396.10
5	$\Phi(\sim\text{parcela} * \text{ptot_s})$ $p(\sim\text{ptot_s})$	6	6418.62	9.97	6386.62
7	$\Phi(\sim\text{parcela} * \text{ptot_s}) p(\sim\text{ptot_s} * \text{ptot_s})$	6	6418.62	9.97	6386.62
2	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{ptot_s} + \text{ptot_t})$	2	6418.86	0.20	6394.86

6	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{ptot_t})$	0	6419.06	0.40	6399.06
4	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{ptot_t})$	1	6420.45	1.79	6398.45
7	$\Phi(\sim\text{parcela} * \text{ptot_s})$ $p(\sim 1)$	5	6420.97	2.31	6390.97
9	$\Phi(\sim\text{ptot_s})$ $p(\sim\text{parcela} + \text{ptot_s})$	0	6421.62	2.97	6401.62
3	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{ptot_s})$	0	6421.78	3.12	6401.78
5	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim\text{ptot_s} * \text{ptot_s})$	0	6421.78	3.12	6401.78
11	$\Phi(\sim\text{ptot_s} + \text{ptot_t})$ $p(\sim\text{parcela} + \text{ptot_s})$	1	6423.55	4.89	6401.55
1	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{ptot_s})$	1	6423.71	5.05	6401.71
3	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim\text{ptot_s} * \text{ptot_s})$	1	6423.71	5.05	6401.71
5	$\Phi(\sim\text{parcela} + \text{ptot_s})$ $p(\sim 1)$		6423.80	5.14	6405.80
8	$\Phi(\sim\text{ptot_s})$ $p(\sim\text{parcela})$		6425.50	6.84	6407.50
10	$\Phi(\sim\text{ptot_s} + \text{ptot_t})$ $p(\sim\text{parcela})$	0	6425.70	7.04	6405.70
3	$\Phi(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$ $p(\sim 1)$	0	6425.72	7.06	6405.72
4	$\Phi(\sim\text{parcela})$ $p(\sim\text{parcela})$	4	6436.69	8.03	6408.69
38	$\Phi(\sim\text{ptot_t})$ $p(\sim\text{parcela} * \text{ptot_t})$	6	6437.66	9.01	6405.66
40	$\Phi(\sim\text{ptot_t})$ $p(\sim\text{parcela} * \text{ptot_t} * \text{ptot_s})$	0	6438.03	9.37	6378.03

39	$\Phi(\sim\text{ptot_t}) p(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$	1	6438.37	9.71	6416.37
	$\Phi(\sim 1) p(\sim\text{parcela} * \text{ptot_t})$	5	6438.55	9.89	6408.55
37	$\Phi(\sim\text{ptot_t}) p(\sim\text{parcela} + \text{ptot_t})$	0	6438.68	0.02	6418.68
	$\Phi(\sim 1) p(\sim\text{parcela} + \text{ptot_t} + \text{ptot_s})$	0	6438.72	0.06	6418.72
	$\Phi(\sim 1) p(\sim\text{parcela} * \text{ptot_t} * \text{ptot_s})$	9	6438.86	0.20	6380.86
	$\Phi(\sim 1) p(\sim\text{parcela} + \text{ptot_t})$		6439.07	0.41	6421.07
	$\Phi(\sim 1) p(\sim\text{parcela} * \text{ptot_s})$	5	6439.59	0.93	6409.59
36	$\Phi(\sim\text{ptot_t}) p(\sim\text{parcela} * \text{ptot_s})$	6	6441.52	2.86	6409.52
2	$\Phi(\sim\text{parcela}) p(\sim\text{ptot_s} + \text{ptot_t})$	0	6443.41	94.75	6423.41
4	$\Phi(\sim\text{parcela}) p(\sim\text{ptot_t})$		6443.95	95.29	6425.95
8	$\Phi(\sim\text{parcela} + \text{ptot_t}) p(\sim\text{ptot_s} + \text{ptot_t})$	1	6444.17	5.52	6422.17
0	$\Phi(\sim\text{parcela} + \text{ptot_t}) p(\sim\text{ptot_t})$	0	6444.67	6.01	6424.67
	$\Phi(\sim 1) p(\sim\text{parcela} + \text{ptot_s})$		6445.13	6.47	6427.13
	$\Phi(\sim 1) p(\sim\text{parcela})$		6445.77	7.11	6429.77
0	$\Phi(\sim\text{parcela} * \text{ptot_t}) p(\sim\text{ptot_s} + \text{ptot_t})$	7	6446.61	7.95	6412.61
35	$\Phi(\sim\text{ptot_t}) p(\sim\text{parcela} + \text{ptot_s})$	0	6447.04	8.39	6427.04
2	$\Phi(\sim\text{parcela} * \text{ptot_t}) p(\sim\text{ptot_t})$	6	6447.16	8.50	6415.16

34	$\Phi(\sim\text{ptot_t}) p(\sim\text{parcela})$		6447.70	9.04	6429.70
1	$\Phi(\sim\text{parcela}) p(\sim\text{ptot_s})$		6448.59	9.93	6430.59
3	$\Phi(\sim\text{parcela}) p(\sim\text{ptot_s} * \text{ptot_s})$		6448.59	9.93	6430.59
30	$\Phi(\sim\text{ptot_s} * \text{ptot_t}) p(\sim\text{ptot_s} + \text{ptot_t})$		6448.85	00.19	6434.85
3	$\Phi(\sim\text{parcela}) p(\sim 1)$		6449.45	00.79	6433.45
32	$\Phi(\sim\text{ptot_s} * \text{ptot_t}) p(\sim\text{ptot_t})$		6450.19	01.53	6438.19
7	$\Phi(\sim\text{parcela} + \text{ptot_t}) p(\sim\text{ptot_s})$	0	6450.59	01.93	6430.59
9	$\Phi(\sim\text{parcela} + \text{ptot_t}) p(\sim\text{ptot_s} * \text{ptot_s})$	0	6450.59	01.93	6430.59
9	$\Phi(\sim\text{parcela} + \text{ptot_t}) p(\sim 1)$		6451.45	02.79	6433.45
9	$\Phi(\sim\text{parcela} * \text{ptot_t}) p(\sim\text{ptot_s})$	6	6453.44	04.79	6421.44
1	$\Phi(\sim\text{parcela} * \text{ptot_t}) p(\sim\text{ptot_s} * \text{ptot_s})$	6	6453.44	04.79	6421.44
1	$\Phi(\sim\text{parcela} * \text{ptot_t}) p(\sim 1)$	5	6454.42	05.76	6424.42
29	$\Phi(\sim\text{ptot_s} * \text{ptot_t}) p(\sim\text{ptot_s})$		6460.43	11.77	6448.43
31	$\Phi(\sim\text{ptot_s} * \text{ptot_t}) p(\sim\text{ptot_s} * \text{ptot_s})$		6460.43	11.77	6448.43
06	$\Phi(\sim\text{ptot_s}) p(\sim\text{ptot_s} + \text{ptot_t})$		6461.96	13.30	6451.96
21	$\Phi(\sim\text{ptot_s} * \text{ptot_t}) p(\sim 1)$		6462.38	13.72	6452.38

18	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim\text{ptot_s} + \text{ptot_t})$	6462.78	14.13	6450.78
08	$\Phi(\sim\text{ptot_s}) p(\sim\text{ptot_t})$	6463.54	14.88	6455.54
20	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim\text{ptot_t})$	6467.33	18.68	6457.33
05	$\Phi(\sim\text{ptot_s}) p(\sim\text{ptot_s})$	6468.11	19.46	6460.11
07	$\Phi(\sim\text{ptot_s}) p(\sim\text{ptot_s} * \text{ptot_s})$	6468.11	19.46	6460.11
17	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim\text{ptot_s})$	6470.10	21.44	6460.10
19	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim\text{ptot_s} * \text{ptot_s})$	6470.10	21.44	6460.10
7	$\Phi(\sim\text{ptot_s}) p(\sim 1)$	6470.76	22.10	6464.76
09	$\Phi(\sim\text{ptot_s} + \text{ptot_t}) p(\sim 1)$	6472.11	23.45	6464.11
42	$\Phi(\sim\text{ptot_t}) p(\sim\text{ptot_s} + \text{ptot_t})$	6484.53	35.87	6474.53
0	$\Phi(\sim 1) p(\sim\text{ptot_s} + \text{ptot_t})$	6484.67	36.01	6476.67
44	$\Phi(\sim\text{ptot_t}) p(\sim\text{ptot_t})$	6484.91	36.25	6476.91
2	$\Phi(\sim 1) p(\sim\text{ptot_t})$	6485.11	36.45	6479.11
	$\Phi(\sim 1) p(\sim\text{ptot_s})$	6491.57	42.92	6485.57
1	$\Phi(\sim 1) p(\sim\text{ptot_s} * \text{ptot_s})$	6491.57	42.92	6485.57
	$\Phi(\sim 1) p(\sim 1)$	6492.33	43.67	6488.33
41	$\Phi(\sim\text{ptot_t}) p(\sim\text{ptot_s})$	6493.53	44.87	6485.53

43	$\Phi(\sim\text{ptot}_t) p(\sim\text{ptot}_s * \text{ptot}_s)$		6493.53	44.87	6485.53
33	$\Phi(\sim\text{ptot}_t) p(\sim 1)$		6494.31	45.65	6488.31

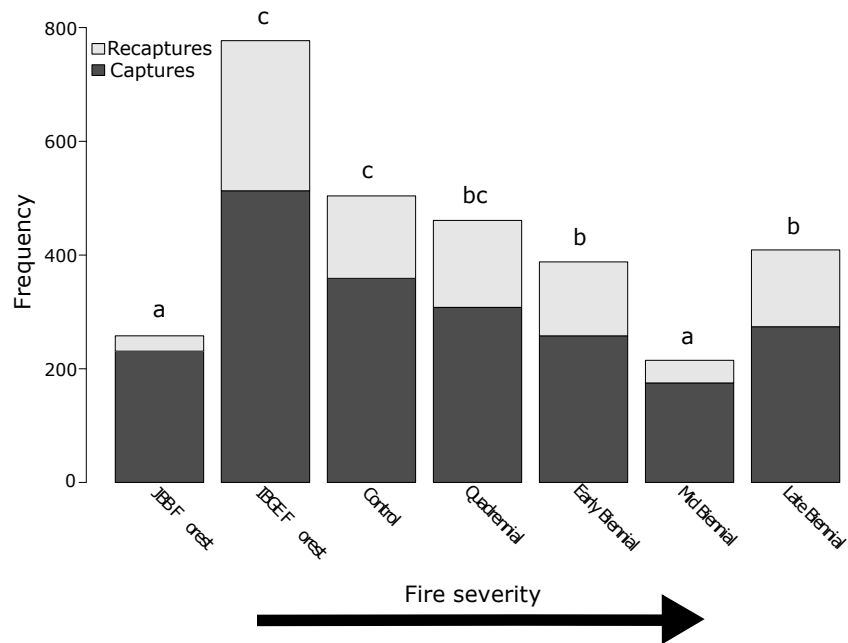


Figure 1. Captures and recaptures of *Copeoglossum nigropunctatum* in control and treatment plots with different burn severities, in an area of cerrado *sensu stricto* and gallery forest in central Brazil,. The order of the plots follows the burn severity gradient.

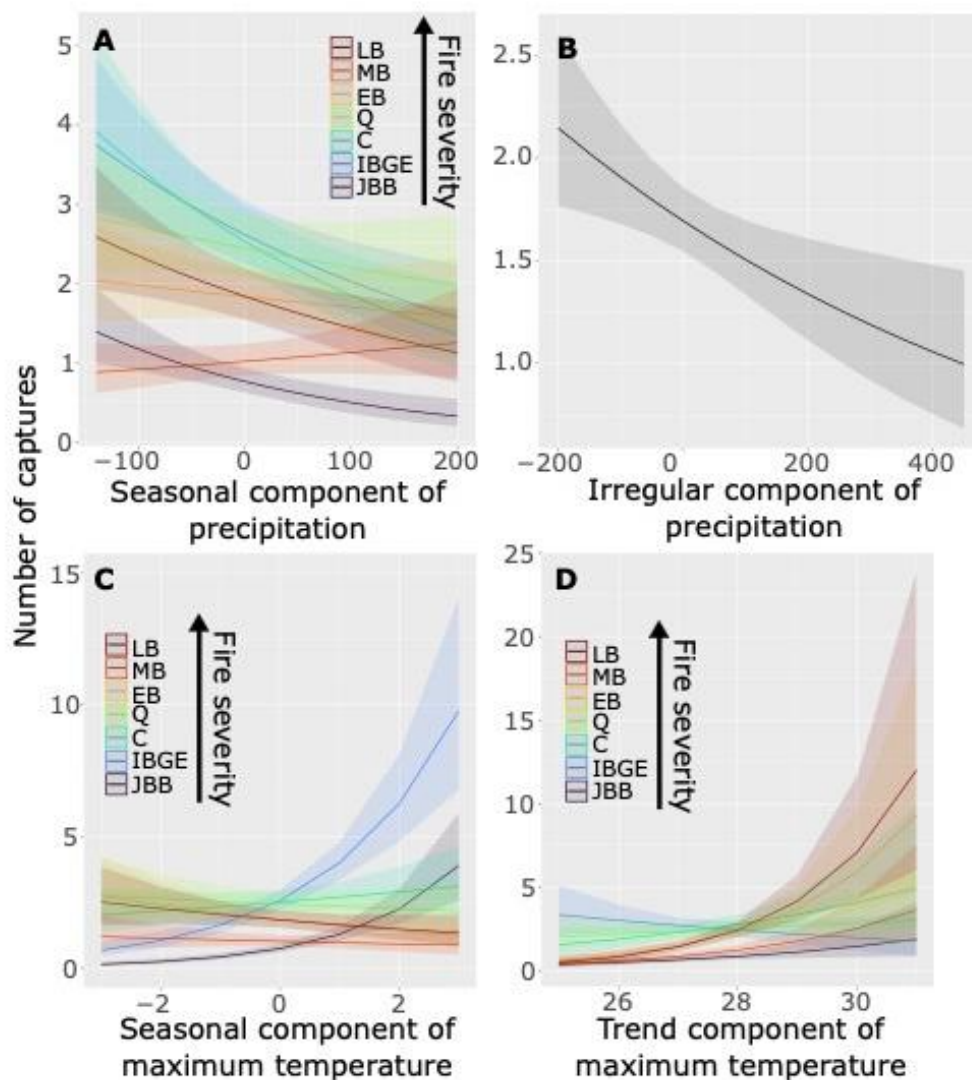


Figure 2. Relationship between number of captures and climatic components for *Copeoglossum nigropunctatum* captured from 2000 to 2022, in control and treatment plots with different burn severities, in a Cerrado *sensu stricto* area and gallery forest in central Brazil. A) The X-axis presents the precipitation seasonality component, in B) the X-axis presents the precipitation irregularity component, C) The X-axis presents the temperature seasonal component, D) The X-axis presents the temperature trend. Where: LB = late biennial fire regime; MB = modal biennial fire regime; EB = earle biennial fire regime; Q = quadriennial fire regime; C = control; IBGE = gallery forest of RECOR reserve with fire; JBB = gallery forest of JBB reserve without fire.

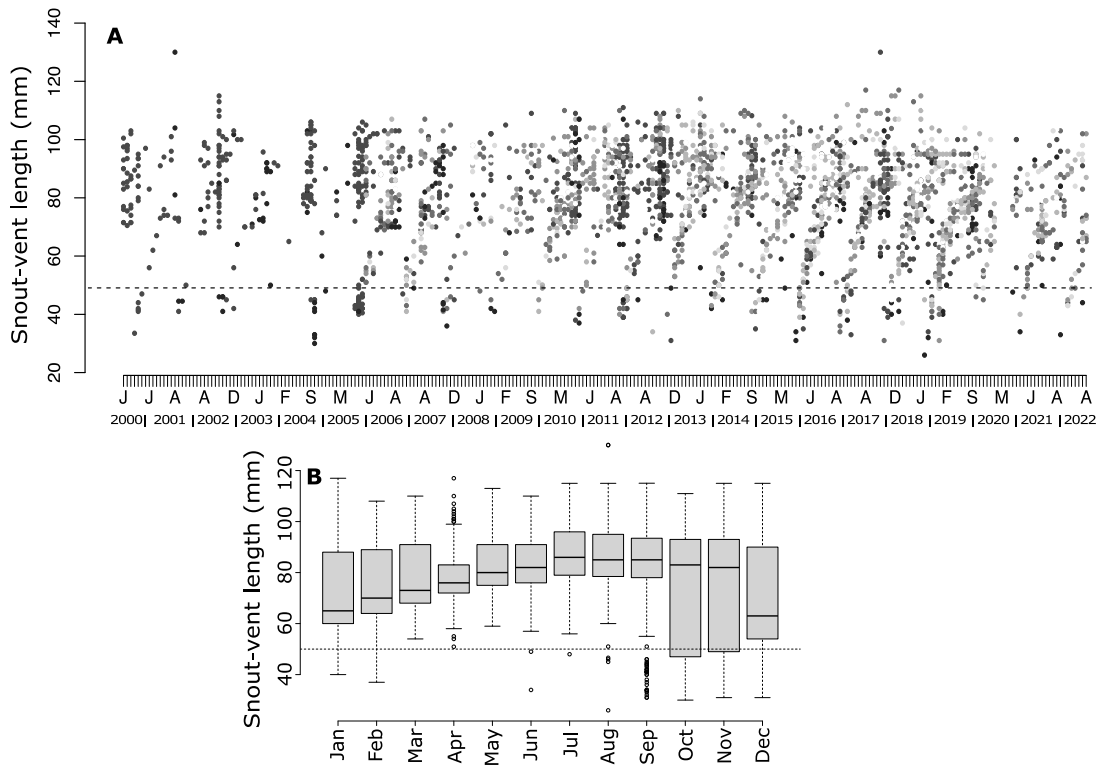


Figure 3. A) Snout-vent length (SVL) of *Copeoglossum nigropunctatum* captured from 2000 to 2022, in control and treatment plots with different burn severities, in a Cerrado *sensu stricto* area and Gallery Forest in central Brazil. The dashed lines indicate the SVL at sexual maturity. B) Monthly snout-vent length (SVL) of *Copeoglossum nigropunctatum*. The dashed lines indicate the SVL at sexual maturity.

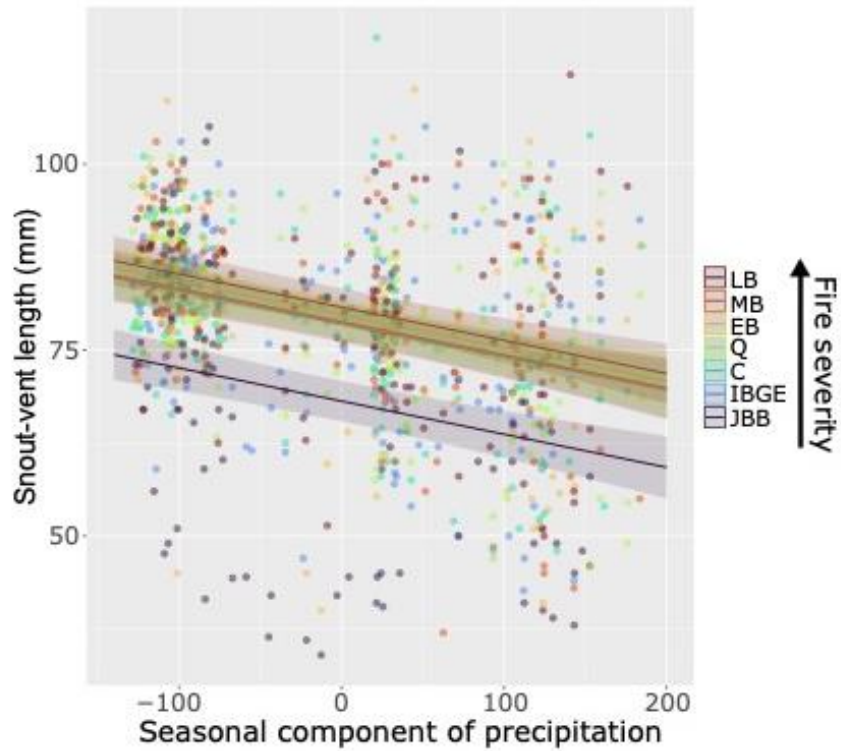


Figure 4. Relationship between Snout-vent length in mm (SVL) and seasonal component of precipitation for *Copeoglossum nigropunctatum* captured from 2000 to 2022, in control and treatment plots with different burn severities, in a Cerrado *sensu stricto* area and Galery Forest in central Brazil. Where: LB = late biennial fire regime; MB = modal biennial fire regime; EB = earle biennial fire regime; Q = quadriennial fire regime; C = control; IBGE = galery forest of RECOR reserve with fire; JBB = galery forest of JBB reserve without fire.

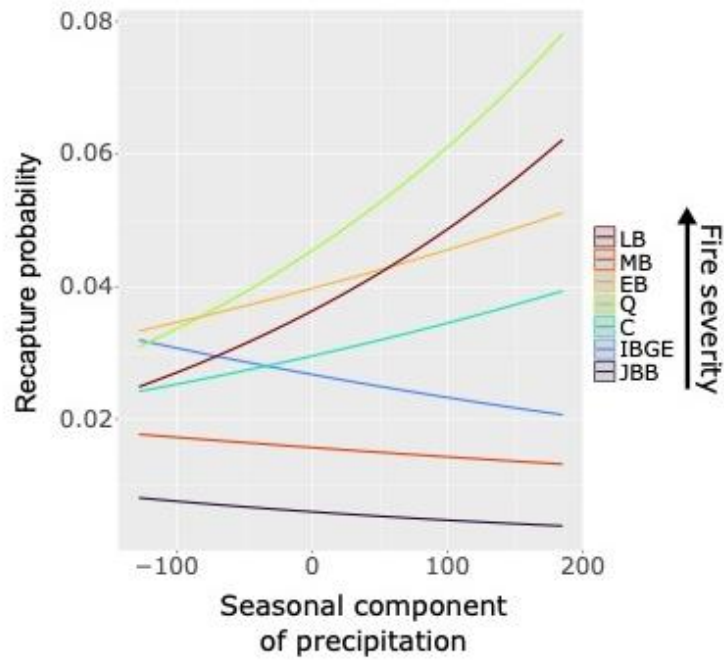


Figure 5. Relationship between recapture probability and seasonal component of precipitation for *Copeoglossum nigropunctatum* captured from 2000 to 2022, in control and treatment plots with different burn severities, in a Cerrado *sensu stricto* area and Galery Forest in central Brazil. Where: LB = late biennial fire regime; MB = modal biennial fire regime; EB = early biennial fire regime; Q = quadriennial fire regime; C = control; IBGE = galery forest of RECOR reserve with fire; JBB = galery forest of JBB reserve without fire.

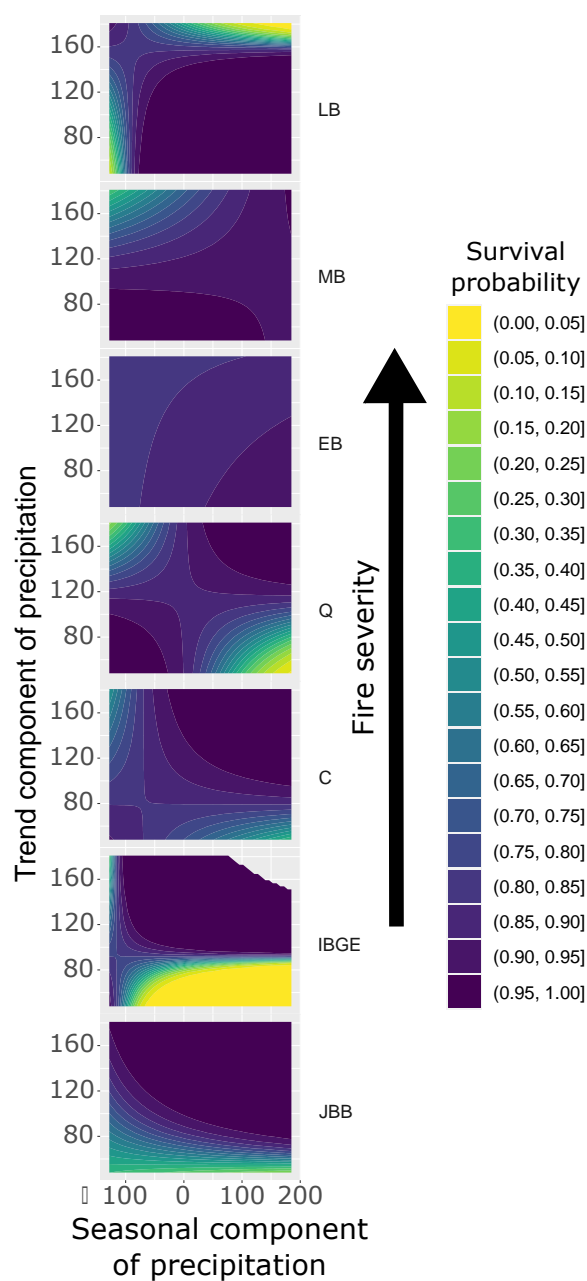


Figure 6. Relationship between survival probability and the interaction of the seasonal component of precipitation and trend component of precipitation for *Copeoglossum nigropunctatum* captured from 2000 to 2022, in control and treatment plots with different burn severities, in a cerrado *sensu stricto* area and gallery forest in central Brazil. Where: LB = late biennial fire regime; MB = modal biennial fire regime; EB = earle biennial fire regime; Q = quadriennial fire regime; C = control; IBGE = galery forest of RECOR reserve with fire; JBB = galery forest of JBB reserve without fire.