RESSALVA

Atendendo solicitação do
autor, o texto completo
desta dissertação será
disponibilizado somente a
partir de 13/10/2025.

UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"

Sean Keuroghlian-Eaton

How do different fire regimes affect anuran taxonomic and functional diversity in the Pantanal?

São José do Rio Preto
2023

RESSALVA

Atendendo solicitação do
autor, o texto completo
desta dissertação será
disponibilizado somente a
partir de 13/10/2025.

Sean Keuroghlian-Eaton

How do different fire regimes affect anuran taxonomic and functional diversity in the Pantanal?

Dissertação apresentada no dia 13/10/2023 como parte dos requisitos para obtenção do título de Mestre em Biodiversidade, junto ao Programa de Pós-Graduação em Biodiversidade, doInstituto de Biociências, Letras e Ciências Exatas da Universidade Estadual Paulista "Júlio de Mesquita Filho", Câmpus de São José do Rio Preto.

Financiadora: CAPES – Processo: 001

Orientador: Prof. Dr. Diego José Santana Silva

São José do Rio Preto
2023

K43

Keuroghlian-Eaton, Sean
How do different fire regimes affect anuran taxonomic and functional diversity in the Pantanal? / Sean Keuroghlian-Eaton. -- SãoJosé do Rio Preto, 2023
39 p. : il., tabs., mapas

Dissertação (mestrado profissional) - Universidade Estadual Paulista (Unesp), Instituto de Biociências Letras e Ciências Exatas,São José do Rio Preto
Orientador: Diego José Santana Silva

1. Fogo. 2. Ecologia. 3. Anura. 4. Diversidade funcional. 5.

Sistema de geração automática de fichas catalográficas da Unesp. Biblioteca do Instituto de Biociências Letras e Ciências Exatas, São José do Rio Preto. Dados fornecidos pelo autor(a).

Essa ficha não pode ser modificada.

Sean Keuroghlian-Eaton

How do different fire regimes affect anuran taxonomic and functional diversity in the Pantanal?

Dissertação apresentada no dia 13/10/2023 como parte dos requisitos para obtenção do título de Mestre em Biodiversidade, junto ao Programa de Pós-Graduação em Biodiversidade, doInstituto de Biociências, Letras e Ciências Exatas da Universidade Estadual Paulista "Júlio de Mesquita Filho", Câmpus de São José do Rio Preto.

Financiadora: CAPES – Processo: 001

Orientador: Prof. Dr. Diego José Santana Silva

Comissão Examinadora

_____

Profa. Dra. Milena Wachlevski

Universidade Federal Rural do Semi-Árido

_____

Prof. Dr. Iberê Farina Machado

Instituto Boitatá

_____

Prof. Dr. Diego José Santana Silva

Universidade Federal de Mato Grosso do Sul

Orientador

São José do Rio Preto
13 de outubro de 2023

Agradecimentos

Ao meu orientador, Diego José Santana Silva, agradeço pela sua paciência, amizade e orientação durante o meu mestrado. Além disso, por criar um ambiente de laboratório incrível com colegas maravilhosos que tornaram possível a realização do meu sonho de pesquisar herpetofauna.

Obrigado a todos que auxiliaram no campo durante a coleta e processamento de dados do meu mestrado.

À Karol Ceron, agradeço por me ensinar, ajudar e sugerir várias análises que tornaram este projeto muito melhor.

À Priscila Carvalho, agradeço por me auxiliar em muitas burocracias, fornecer ideias e dicas quando eu estava enfrentando dificuldades para avançar, e por ser uma grande amiga durante todo esse processo.

A Juan Carrillo e Hugo Cabral, agradeço por revisarem a escrita e o script em R da minha dissertação, e por me fazerem rir constantemente durante todo o processo.

Aos membros do laboratório Mapinguari, Diego é em grande parte a razão pela qual esse espaço é tão incrível. No entanto, não posso negar que todas as pessoas neste lugar são incríveis. Seja no campo, no laboratório ou nas festas, não importa o quão estressado eu esteja, todo dia vou para o trabalho animado porque é um ambiente divertido onde todos ajudam o outro. Além disso, nunca imaginei que encontraria tantas pessoas com uma paixão tão intensa pela herpetologia.

À banca, por aceitar e interessar nesse projeto, e pelos seus comentários e sugestões que elevou a qualidade desse projeto.

Aos meus pais por além de me ensinar tanto na área de biologia, também sugerir ideias para meus projetos, e recomendar eu falar com o Diego para iniciar meu mestrado.

Aos meus amigos não biólogos que me ajudam a relaxar e recarregar completamente para voltar ao meu trabalho com energia cheia.

Por liderarem as queimadas, selecionarem as áreas para queima, fornecerem recursos de campo e tornarem tudo isso possível, quero agradecer às pessoas incríveis do PELD, IBAMA Prev Fogo, Nefau, IMASUL e PPBio Rede Pantanal envolvidas nesses projetos, que trabalham para entender e minimizar o impacto do fogo em nosso Pantanal. A ciência não é feita individualmente, e ao ver tantos projetos associados a esta única pesquisa, prova isso.

Ao IBILCE pelo suporte burocrático e técnico.

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001*, à qual agradeço.

Resumo

O fogo representa uma perturbação frequente em muitos ecossistemas, e o maior fator na modificação de habitats afeta as espécies de maneiras diferentes. Neste estudo, temos como objetivo desvendar quais são os impactos de diferentes tratamentos de incêndio na diversidade de anuros no Pantanal brasileiro, e se os traços da diversidade são afetados de maneira diferente pelos tratamentos de incêndio. Armadilhas de queda foram instaladas para amostrar populações de anuros em locais onde incêndios controlados foram realizados, juntamente com um número igual de locais de controle não queimados. Os incêndios foram divididos em dois tipos: incêndio na metade da estação seca (a partir de agora conhecido como modal-MDS) e incêndio no final da estação seca (a partir de agora conhecido como tratamento tardio-LDS). Não houve diferença estatisticamente significativa entre o controle, o incêndio modal e o incêndio tardio em relação à diversidade ou abundância de anuros. No entanto, a diversidade funcional mostrou que o controle era o mais diverso, com o incêndio tardio apresentando maior diversidade quando comparado ao incêndio modal. Diferentes tratamentos de incêndio afetam os anuros de forma negativa em diferentes níveis em sua diversidade funcional, ao observar o tamanho, massa, deposição de ovos e uso do habitat dos anuros. Entre os dois tratamentos de incêndio, o incêndio tardio teve um impacto significativamente menor em sua diversidade funcional quando comparado ao incêndio modal. Nossa pesquisa sugere que o uso da diversidade funcional pode ser uma abordagem mais eficaz para avaliar os impactos da escala do fogo sobre os anuros em comparação com a diversidade taxonômica. Essas descobertas podem potencialmente informar futuras estratégias de queimadas controladas, recomendando queimadas no final da estação seca para mitigar o impacto de incêndios futuros.

Palavras-Chave: Fogo. Ecologia. Anura. Diversidade. Funcionalidade. Escala. Pantanal.

Abstract

Fire represents a frequent disturbance in many ecosystems, and the biggest factor in habitat conversion affects species in different ways. In this study we aim to disentangle what impacts different fire regimes have on anuran diversity in the Brazilian Pantanal, and if diversity facets are affected differently by the fire regimes. Pitfall traps were installed to sample anurans at sites where controlled fires were set at, along with an equal number of unburned control sites. The fires were divided into two types: middle dry season fire (from here on known as MDS), and late dry season fire (from here on known as LDS). There was no statistically significant difference between the control, MDS and LDS fire for anuran diversity or abundance. Functional diversity on the other hand showed that the control was the healthiest collection site with LDS fire having higher diversity when compared to MDS fire. Different regimes of fire affect anurans negatively at different levels in their functional diversity, when looking at size, mass, egg deposition, and habitat use of anurans. Among the two fire regimes LDS fire had a significantly lessened impact on their functional diversity when compared to MDS fire. Our research suggests that using functional diversity may be a more effective approach for assessing the impacts of fire scale on anurans compared to taxonomic diversity. These findings could potentially inform future controlled burn strategies, recommending late dry season burns to mitigate the impact of future fires.

Key Words: Fire. Ecology. Anuran. Diversity. Functionality. Scale. Pantanal.

LISTA DE ILUSTRAÇÕES

LISTA DE TABELAS

LISTA DE ABREVIATURAS E SIGLAS

MDS – middle of dry season fire

LDS – late dry season fire

SUMÁRIO

1. Introduction

Fire represents a frequent disturbance in many ecosystems and is the primary factor in habitat conversion, impacting various species interactions around the world (Peralta et al., 2017). Fire disturbances harbor the potential to diminish both the taxonomic and functional diversity within neotropical seasonal flooded forests (Meza et al., 2023). Taxonomic diversity observes the abundance and quantity of species in a community (Moore, 2013), while functional diversity pertains to the distribution of species within a functional space, where the axes represent the functional traits of species in their environment (Rosenfeld, 2002; Hutchinson, 1957). Impacts such as fire can lead to a prevalence of fire-resistant species and homogenizing the animal-plant dispersion, as well as the plant and soil characteristics (Da Silva, 2008)). In ecosystems, fire exerts a significant influence on the species composition, biodiversity, and operation by profoundly altering their physical, chemical, and biological characteristics (Buscardo et al., 2015). The effect of fire can be beneficial or detrimental depending on the organism (Bixby et al., 2015). For instance, the carandá palm (*Copernicia alba*), indigenous to the Pantanal, exhibits improved seed germination in response to fire (Fabri, 2018). This is why when discussing ecosystems impacted by fire, functional diversity should be assessed by examining the traits that assist species in surviving either during or after a fire (Pausas, 2019). In Brazil, biomes such as the Amazon, Cerrado and the Pantanal are under great threat of intensive agriculture, which regularly uses illegal fire to clear native habitat (de Oliveira, 2021).

The Pantanal encompasses over 190,000km² and ranks as the world's largest temporary wetland, extending across Bolivia, Brazil, and Paraguay (Fraser et al., 2005). The temporary nature of the Pantanals' wetlands imparts distinct wet and dry seasons

experienced annually by species inhabiting the region (Junk et al., 1989; Junk & Wantzen, 2004). The occurrence of fire in the Pantanal predates human habitation (Power et al., 2016; Junk et al., 2006). Naturally ignited fires typically happen in between seasons, such as the beginning or ending of the rainy season, usually caused by lightning strikes on the dry vegetation (Pivello et al., 2021). These fires are rapid, low intensity surface burns that are extinguished by subsequent rainfall, typically occurring every three to six years (Ramos-Neto & Pivello, 2000; Medeiros & Fiedler, 2004). However, recent data reveals that only around 3% of the fires in the Pantanal are non-human-induced (Marengo et al., 2016; Pivello et al., 2021). Alarming statistics further indicate that, throughout the past four decades, the Pantanal has witnessed the highest incidence of wildfires among all Brazilian biomes (MapBiomas, 2022). In the years 2020 and 2021 specifically, fires were record breaking in quantity and intensity (Garcia, 2021; INPE, 2022). These recent fires have directly killed millions of vertebrates, and among one of the most impacted groups was amphibians (Tomas et al., 2021).

Amphibian populations worldwide are declining (Luedke et al. 2023), and current estimates show that 41% of amphibians in the world are endangered (IUCN 2020; Luedke et al. 2023). Climate change, pollution, disease, and habitat loss are the main factors contributing to declining amphibian populations (da Costa Araujo et al., 2020; Zhang et al., 2018; Luedke et al. 2023). Despite the considerable data on how fire affects climate, vegetation (Veldman et al. 2015), animals (Gibb, 2003), and mutualistic interactions (Peralta et al., 2017), very little is known about how different fire levels affect anuran populations. Depending on the scale, fire can affect amphibians directly (by killing the individuals), or indirectly (by altering their habitats) (Pilliod et al. 2003). The majority of habitat modifications affecting anurans are associated with vegetation and water dynamics (Gonçalves et al., 2015; Gangenova et al., 2018). Amphibians are

particularly susceptible to the adverse effects of habitat alteration because of many characteristics, such as permeable skin, unshelled eggs and limited capacity of dispersal, for example (Green, 2003). On a larger scale, fire can cause the local extinction of amphibian species in isolated bodies of water (Pilliod et al. 2003), these can trigger cascading effects over a broader metapopulation (Marsh & Trenham, 2001). While on a smaller scale, the increase of solar radiation, loss of vegetation, elevated water temperature, altered hydroperiods reduces functional characteristics related to reproduction, increasing tadpole death, and affecting amphibian metamorphosis (Pilliod et al., 2003; Newman, 1998; Häkkinen et al., 2001; Russell et al., 1999).

Functional diversity has long served as an alternative approach for quantifying the level of diversity within a habitat, enabling the examination of the diverse array of functions performed by species within that particular environment (Tilman, 2001). Functional traits that can include habitat preferences (such as fossorial, arboreal, terrestrial or aquatic tendencies (Neves et al., 2020) or egg deposition strategies (such as in water, in a basin, arboreally, on the ground, in burrows or into foam (Neves et al., 2020). These are possible impacts that could emerge from fire and cannot be examined through taxonomic diversity or species richness alone, yet they should be considered when looking at fire impacts on any species (Westgate et al., 2012).

Our objective is to investigate the effects of different fire regimes on anuran diversity. The fire regimes were classified as the middle of dry season fire treatment (MDS) and the late dry season fire treatment (LDS). We hypothesize that the control group will exhibit higher levels of both taxonomic and functional diversity compared to the two fire regimes. We anticipate that the LDS fire treatments will have a lesser impact due to the increased moisture content in the organic material towards the end of

the dry season and the onset of the rainy season, which would more closely mimic natural fires in the Pantanal (Ramos- Neto & Pivello, 2000; Medeiros & Fiedler, 2004). This higher moisture content may result in a less intense fire and subsequently lead to a reduced degree of environment modification.

5. Conclusions

Different controlled fire regimes affect anurans negatively at different levels, but not in the way we initially expected such as species abundance, diversity or richness. It did affect anurans negatively through functional diversity, when looking at size, mass, egg deposition, and preferred habitat use of anurans. Among the two fire regimes LDS fire had a significantly lessened impact on their functional diversity when compared to MDS fire. This may be due to the MDS fire regime having a longer lasting and more intense fire, possibly homogenizing the environment more than the LDS regime, which simulates a more naturally occurring fire in the Pantanal. Results like these can aid fire brigades in setting less impactful controlled burned in floodplains like the Pantanal as well as floodplains in other tropical climates.

6. References

Anderson MJ, Walsh DC (2013) PERMANOVA, ANOSIM, and the Mantel test in the face of heterogeneous dispersions: what null hypothesis are you testing? *Ecological monographs* **83**(4), 557-574.

Alves VDS, Fermiano EC, Seba MDFR, dos Santos MK, da Silva OD, Silva DJ (2022) Representatividade de anfíbios na coleção herpetológica celbe/unemat para região norte da bacia do alto rio Paraguai, Brasil. *Revista Ibero-Americana de Ciências Ambientais* **13**(11).

Bamford MJ (1992) The impact of fire and increasing time after fire upon Heleioporus eyrei, Limnodynastes dorsalis and Myobatrachus gouldii (Anura: Leptodactylidae) in Banksia woodland near perth, western Australia. *Wildlife Research* **19**(2), 169-178.

Barreto L, Andrade GV (1995) Aspects of the reproductive biology of Physalaemus cuvieri (Anura, Leptodactylidae) in northeastern Brazil.. Amphibia-Reptilia **16**: 67–76.

Blonder B (2018) Hypervolume concepts in niche-and trait-based ecology. *Ecography* **41**(9), 1441-1455.

Bixby RJ, Cooper SD, Gresswell RE, Brown LE, Dahm CN, Dwire KA, (2015) Fire effects on aquatic ecosystems: an assessment of the current state of the Science. *Freshw Sci* **34**, 1340–1350.

Bokermann, WCA (1962) Observaç[otilde]es biológicas sobre *Physalaemus cuvieri* Fitz, 1826 (Amphibia, Salientia).. *Revista Brasileira de Zoologia*, **22**: 391–399.

Buscardo E, Rodríguez-Echeverría S, Freitas H, De Angelis P, Pereira JS, Muller LA (2015) Contrasting soil fungal communities in Mediterranean pine forests subjected to different wildfire frequencies. *Fungal Diversity* **70**, 85-99.

Cardoso AJ (1981) Biologia e sobrevivência de *Physalaemus cuvieri* Fitz., 1826 (Amphibia, Anura) na natureza.. *Ciencia e Cultura* **33**: 1224–1228.

Cardoso P, Rigal F, Carvalho JC (2015) BAT–Biodiversity Assessment Tools, an R package for the measurement and estimation of alpha and beta taxon, phylogenetic and functional diversity. *Methods in Ecology and Evolution* **6**(2), 232-236.

Cechin SZ, Martins M (2000). Eficiência de armadilhas de queda (pitfall traps) em amostragens de anfíbios e répteis no Brasil. *Revista brasileira de zoologia* **17**, 729-740.

Chao A, Chazdon RL, Colwell RK, Shen TJ (2005) A new statistical approach for assessing similarity of species composition with incidence and abundance data. *Ecology letters* **8**(2), 148-159.

CIMI (2020) Regionais da CNBB lamentam "desmonte das instâncias de fiscalização" e cobram investigação sobre queimadas no Pantanal. https://cimi.org.br/2020/09/regionais-cnbb-lamentam-desmonte-fiscalizacaocobram-investigacao-queimadas-pantanal/

da Costa Araújo AP, de Melo NFS, de Oliveira Junior, AG, Rodrigues FP, Fernandes T, de Andrade Vieira JE, ... & Malafaia G (2020) How much are microplastics harmful to the health of amphibians? A study with pristine polyethylene microplastics and Physalaemus cuvieri. *Journal of hazardous materials*, **382**, 121066.

Da Silva FR, Gonçalves-Souza T, Paterno GB, Provete DB, Vancine MH (2022) Análises ecológicas no R. Nupeea : *Recife, PE, Canal 6 : São Paulo* **640** p. ISBN 978-85-7917-564-0.

Da Silva DM, Batalha MA (2008) Soil–vegetation relationships in cerrados under different fire frequencies. *Plant and Soil* **311**, 87-96. doi: 10.1007/s11104-008-9660-y

de Oliveira, MM (2021) Paradise Lost?

dos Anjos AG, Solé M, Benchimol M (2021) Fire effects on anurans: what we know so far?. *Forest Ecology and Management* **495**, 119338.

Dray S, Dufour AB, Chessel D (2007) The ade4 package-II: Two-table and K-table methods. *R news* **7(**2), 47-52.

Driscoll DA, Lindenmayer DB, Bennett AF, Bode M, Bradstock RA, Cary GJ, York A (2010) Fire management for biodiversity conservation: key research questions and our capacity to answer them. *Biological conservation* **143**(9), 1928-1939.

Fabri JR (2018) Efeitos de inundação e fogo na germinação de sementes de Copernicia alba MORONG EX MORONG & BRITTON (Arecaceae)= flood and fire effects on seed germination of copernicia alba MORONG EX MORONG & BRITTON (Arecaceae). *Master's thesis, Universidade Brasil.*

Fraser LH, Keddy PA (2005) The world's largest wetlands: ecology and conservation. *Cambridge University Press.*

Ferraro DP (2022) Combined phylogenetic analysis of Pleurodema (Anura: Leptodactylidae: Leiuperinae). *Cladistics* **38**(3), 301-319.

Friend GR (1993) Impact of fire on small vertebrates in mallee woodlands and heathlands of temperate Australia: a review. *Biological conservation* **65**(2), 99-114.

Gangenova E, Zurita G, Marangoni F (2018) Changes to anuran diversity following forest replacement by tree plantations in the southern Atlantic forest of Argentina. *Forest Ecology and Management*https://doi.org/10.1016/J.FORECO.2018.03.038.

Giaretta AA Menin M (2004) Reproduction, phenology and mortality sources of a species of Physalaemus (Anura: Leptodactylidae). *Journal of Natural History* **38**: 1711–1722.

Gibb H (2003) Dominant meat ants affect only their specialist predator in an epigaeic arthropod community. *Oecologia* **136**: 609–615.

Gonçalves D, Crivellari L, Conte C (2015) Linking environmental drivers with amphibian species diversity in ponds from subtropical grasslands. *Anais da*

Academia Brasileira de Ciencias. https://doi.org/10.1590/0001-3765201520140471

Green DM (2003) The ecology of extinction: population fluctuation and decline in amphibians. *Biological conservation* **111**(3), 331-343.

Häkkinen J, Pasanen S, Kukkonen JV (2001) The effects of solar UV-B radiation on embryonic mortality and development in three boreal anurans (Rana temporaria, Rana arvalis and Bufo bufo). *Chemosphere* **44**(3), 441-446.

INPE. 'Queimadas'. Op. cit.

IUCN (2020) The IUCN Red List of Threatened Species. Available at: http://www.iucnredlist.org.

Junk WJ, Bayley PB, Sparks RE (1989) The flood pulse concept in river-floodplain systems. *Canadian special publication of fisheries and aquatic sciences* **106**(1), 110-127.

Junk WJ, Wantzen KM (2004) The flood pulse concept: new aspects, approaches and applications-an update. In Second international symposium on the management of large rivers for fisheries. *Food and Agriculture Organization and Mekong River Commission, FAO Regional Office for Asia and the Pacific* pp. 117-149.

Junk WJ, Brown M, Campbell IC, Finlayson M, Gopal B, Ramberg L, Warner BG (2006) The comparative biodiversity of seven globally important wetlands: a synthesis. Aquatic Sci. **68**:400–414

Kim BR, Shin J, Guevarra RB, Lee JH, Kim DW, Seol KH, Isaacson RE (2017) Deciphering diversity indices for a better understanding of microbial communities. *Journal of Microbiology and Biotechnology* **27**(12), 2089-2093.

Köppen W (1884) Die Wärmezonen der Erde, nach der Dauer der heissen, gemässigten und kalten Zeit und nach der Wirkung der Wärme auf die organische Welt betrachtet. *Meteorologische Zeitschrift* **1**(21), 5-226.

Libonati R, Geirinhas JL, Silva PS, Monteiro dos Santos D, Rodrigues JA, Russo A, Trigo RM (2022) Drought–heatwave nexus in Brazil and related impacts on

health and fires: A comprehensive review. *Annals of the New York Academy of Sciences* **1517**(1), 44-62. doi: 10.1111/nyas.14887

Littlejohn MJ (1977) Long-range acoustic communication in anurans: an integrated and evolutionary approach. In *The reproductive biology of amphibians* pp. 263-294. (Boston, MA: Springer USA).

Magneville C, Loiseau N, Albouy C, Casajus N, Claverie T, Escalas A, Villéger S (2022) mFD: an R package to compute and illustrate the multiple facets of functional diversity. *Ecography* **2022**(1).

Mammola S, Cardoso P (2020) Functional diversity metrics using kernel density n-dimensional hypervolumes. *Methods in Ecology and Evolution* **11**(8), 986-995.

MAPBIOMAS. O Projeto. [s. l.], 2019. Disponível em: https://mapbiomas.org/o-projeto.

Marengo JA, Alves M, Torres, RR, (2016) Regional climate change scenarios in the Brazilian Pantanal watershed. *Climate Research* vol. **68**, no. 2-3, pp. 201-213. http://dx.doi.org/10.3354/cr01324.

Marsh DM, Trenham PC (2001) Metapopulation dynamics and amphibian conservation. *Conservation Biology* **15**, 40–49.

Medeiros MBD, Fiedler NC (2004) Incêndios florestais no Parque Nacional da Serra da Canastra: desafios para a conservação da biodiversidade. *Ciência Florestal* **14**, 157-168.

Meza MC, Espelta JM, González TM, Armenteras D (2023) Fire reduces taxonomic and functional diversity in Neotropical moist seasonally flooded forests. *Perspectives in Ecology and Conservation*.

Newman RA (1998) Ecological constraints on amphibian metamorphosis: interactions of temperature and larval density with responses to changing food level. *Oecologia* **115**, 9-16.

Oliveira BF, São-Pedro VA, Santos-Barrera G, Penone C, Costa GC (2017) AmphiBIO, a global database for amphibian ecological traits. *Scientific data* **4**(1), 1-7.

Pausas JG, Keeley JE (2019) Wildfires as an ecosystem service. *Frontiers in Ecology and the Environment* **17**(5), 289-295.

Pavoine S, Vallet J, Dufour AB, Gachet S, Daniel H (2009) On the challenge of treating various types of variables: application for improving the measurement of functional diversity. *Oikos* **118**(3), 391-402.

Peralta G, Stevani EL, Chacoff NP, Dorado J, Vázquez DP (2017) Fire influences the structure of plant–bee networks. *J. Anim. Ecol.* **86**: 1372–1379.

Pereira AA, Pereira JMC, Libonati R, Oom D, Setzer AW, Morelli F, d Carvalho LMT (2017) Burned area mapping in the Brazilian Savanna using a oneclass support vector machine trained by active fires. *Remote Sensing* **9**(11). https://doi.org/10.3390/rs9111161

Pilliod DS, Bury RB, Hyde EJ, Pearl CA, Corn PS (2003) Fire and amphibians in North America. *Forest ecology and management* **178**(1-2), 163-181.

Pinto MM, Libonati R, Trigo RM, Trigo IF, DaCamara CC (2020) A deep learning approach for mapping and dating burned areas using temporal sequences of satellite images. *ISPRS Journal of Photogrammetry and Remote Sensing* **160**(July 2019), 260–274. https://doi.org/10.1016/j.isprsjprs.2019.12.014

Pivello VR, Vieira I, Christianini AV, Ribeiro DB, da Silva Menezes L, Berlinck CN, Overbeck GE (2021) Understanding Brazil's catastrophic fires: Causes, consequences and policy needed to prevent future tragedies. *Perspectives in Ecology and Conservation* **19**(3), 233-255.

Power MJ, Whitney BS, Mayle FE, Neves DM, De Boer EJ, Maclean KS (2016) Fire, climate and vegetation linkages in the Bolivian Chiquitano seasonally dry tropical forest. *Philosophical Transactions of the Royal Society B: Biological Sciences* **371**(1696), 20150165

Prado C, Uetanabaro M, Haddad C (2005) Breeding activity patterns, reproductive modes, and habitat use by anurans (Amphibia) in a seasonal environment in the Pantanal, Brazil. *Amphibia-reptilia* **26**(2), 211-221.

QGIS Development Team (2021) QGIS Geographic Information System. *Open Source Geospatial Foundation Project*. http://qgis.osgeo.org

Ramos-Neto MB, Pivello VR (2000) Lightning fires in a Brazilian savanna national park: rethinking management strategies. *Environmental management* **26**, 675-684.

Ribeiro J, Colli GR, Batista R, Soares A (2017) Landscape and local correlates with anuran taxonomic, functional and phylogenetic diversity in rice crops. *Landscape Ecology* **32**, 1599-1612.

Ruskey F, Weston M (2012) Venn diagrams. *The electronic journal of combinatorics*, DS5-Jun.

Russell KR, Van Lear DH, Guynn, Jr DC (1999) Prescribed fire effects on herpetofauna: review and management implications. *Wildlife Society Bulletin* **27**(2):374-384.

SEMAC (2011) Secretaria de Estado de Meio Ambiente,do Planejamento, da Ciência e Tecnologia. Caderno Geoambiental das Regiões de Planejamento de MS – 5. Região do Pantanal. Governo do Estado de Mato Grosso do Sul. Campo Grande, MS.

Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues ASL, Fischman DL, Waller RW (2004) Status and Trends of Amphibian Declines and Extinctions Worldwide. *Science* **306**: 1783–1786.

Tilman D (2001) Functional diversity. *Encyclopedia of biodiversity* **3**(1), 109-120.

Tomas WM, Berlinck CN, Chiaravalloti RM, Faggioni GP, Strüssmann, C, Libonati R, Morato R (2021) Distance sampling surveys reveal 17 million vertebrates directly killed by the 2020's wildfires in the Pantanal, Brazil. *Scientific Reports* **11**(1), 1-8.

Veldman JW, Buisson E, Durigan G, Fernandes GW, Le Stradic S, Mahy G, Negreiros D, Overbeck GE, Veldman RG, Zaloumis NP (2015) Toward an old-growth concept for grasslands, savannas, and woodlands. *Front. Ecol. Environ* **13**: 154–162.

Westgate MJ, Driscoll DA, Lindenmayer DB (2012) Can the intermediate disturbance hypothesis and information on species traits predict anuran responses to fire?. *Oikos* **121**(10), 1516-1524.

Wogel H, Abrunhosa PA, Pombal JP (2002) Atividade reprodutiva de Physalaemus signifer (Anura, Leptodactylidae) em ambiente temporário. *Iheringia, Série Zoologia* **92**: 57–70.

Zhang W, Guo R, Ai S, Yang Y, Ding J, Zhang Y (2018) Long-term heavy metal pollution varied female reproduction investment in free-living anura, Bufo raddei. *Ecotoxicology and environmental safety* **159**, 136-142