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POND EDGE VEGETATION INFLUENCES MOVEMENT AND SPATIAL ECOLOGY IN THE MONKEY LEAF FROG (*Phyllomedusa iheringii* Boulenger, 1885) IN BRAZILIAN PAMPA GRASSLANDS

São José do Rio Preto
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Dissertação apresentada à Universidade Estadual Paulista (UNESP), Instituto de Biociências, Letras e Ciências Exatas, São José do Rio Preto, para obtenção do título de Mestre em Biodiversidade.

Orientadora: Profa. Dra. Denise de Cerqueira Rossa-Feres

Coorientador(a): Prof. Dr. Tiago Gomes dos Santos

Coorientador(a): Profa. Dra. Michelle Abadie de Vasconcellos

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IMPACTO POTENCIAL DESTA PESQUISA

Este trabalho teve como objetivo avaliar como as características das poças de reprodução influenciam a dinâmica espacial e a persistência populacional da *Phyllomedusa iheringii*, espécie endêmica e ameaçada do Pampa no sul do Brasil e Uruguai, sob a perspectiva da ecologia de metapopulações. Foram analisados fatores determinantes da imigração, emigração, ocupação temporal e abundância, com base em três temporadas de monitoramento e fotoidentificação individual. Os resultados indicam que a vegetação arbórea e arbustiva nas margens das poças é o principal fator associado à imigração e abundância, reduzindo o risco de extinção local por meio do efeito resgate. Esta pesquisa é fundamental para orientar ações de conservação e manejo, pois destaca a importância de preservar e restaurar a vegetação marginal como estratégia para manter a conectividade, a ocupação de habitats adequados e a viabilidade de metapopulações de anuros em paisagens fragmentadas.

POTENTIAL IMPACT OF THIS RESEARCH

This study aimed to evaluate how breeding pond characteristics influence the spatial dynamics and population persistence of *Phyllomedusa iheringii*, an endemic species of the Pampa in southern Brazil and Uruguay, within a metapopulation ecology framework. It investigated the factors driving immigration, emigration, temporal occupancy, and abundance, based on three breeding seasons of monitoring and individual photo-identification. Results show that arboreal and shrubby vegetation along pond edges is the main factor associated with immigration and abundance, reducing local extinction risk through the rescue effect. This research is crucial for guiding conservation and management strategies, as it highlights the importance of preserving and restoring pond-edge vegetation to maintain connectivity, occupancy of suitable habitats, and the viability of anuran metapopulations in fragmented landscapes.

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Data da defesa: 23/06/2025

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Dedico este trabalho a meus pais Nelson e Rosemeire, que caminharam sob muito sol para que eu chegasse até aqui, na sombra...

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"Quando pensamos em conservação, precisamos pensar em mosaicos, corredores e fragmentos, porque é no espaço que a vida se conecta, se move e persiste"
Ilkka Hanski (*Metapopulation Ecology*, 1999. Tradução própria)

RESUMO

Compreender a ecologia espacial de anfíbios é essencial para avaliar os fatores que moldam a dinâmica populacional e a seleção de habitat em populações espacialmente estruturadas. A perereca macaco (*Phyllomedusa iheringii* Boulenger, 1885) é endêmica da Savana Uruguaia, no bioma Pampa do extremo sul do Brasil e do Uruguai, uma ecorregião ameaçada pela perda e fragmentação de habitat. Investigamos neste estudo como as características da vegetação das poças reprodutivas influenciam os deslocamentos entre poças, a ocupação temporal das poças e a abundância de *P. iheringii*. As amostragens foram realizadas ao longo de três estações reprodutivas (2018–2021) em 12 poças permanentes, utilizando fotoidentificação individual para monitorar os movimentos dos indivíduos. Encontramos que a abundância local de indivíduos influenciou significativamente as taxas de emigração, onde maiores densidades acarretam aumento na emigração, refletindo provavelmente um balanço entre a disponibilidade de habitat e a densidade populacional. A porcentagem de vegetação arbórea e arbustiva na margem das poças foi o principal preditor da imigração, promovendo maior abundância de indivíduos, o que, por sua vez, resultou em maiores taxas de emigração. Além disso, a ocupação temporal das poças foi maior naquelas com mais indivíduos, possivelmente devido ao efeito mitigador da abundância sobre eventos estocásticos deletérios, como flutuações nas taxas de natalidade e mortalidade. Esses achados indicam que os movimentos e a seleção de poças por *P. iheringii* são guiados por uma combinação de fatores locais e sociais. A forte associação entre a vegetação marginal, a abundância de indivíduos e as taxas de imigração ressalta a importância da preservação da vegetação marginal para a manutenção de populações resilientes e conectadas.

Palavras-chave: dispersão; conectividade; seleção de habitat; dinâmica populacional.

ABSTRACT

Understanding the spatial ecology of amphibians is essential for assessing the factors that shape population dynamics and habitat selection in heterogeneous, patchy populations. The Monkey leaf frog (*Phyllomedusa iheringii* Boulenger, 1885) is endemic from the Uruguayan Savanna in Pampa of southernmost Brazil and Uruguay, an ecoregion threatened by habitat loss and fragmentation. This study investigated how breeding pond features influence displacement among ponds, breeding pond temporal occupancy, and abundance in *P. iheringii*. Field surveys were conducted over three reproductive seasons (2018–2021) in 12 permanent ponds, using individual photo-identification to track individual movements. Our results indicate that the local abundance of individuals significantly influenced emigration rates, with higher densities associated with increased emigration, likely reflecting trade-offs between habitat availability and population density. The percentage of arboreal/shrubby edge vegetation was the strongest predictor of immigration, leading to higher individual abundance, which in turn increased emigration rates from the pond. Additionally, breeding pond temporal occupancy was higher in ponds with more individuals, possibly because of the mitigating effect of the abundance of individuals on deleterious stochastic effects. These findings indicate that movement and pond selection in *P. iheringii* are driven by a combination of local and social factors. The strong association between edge vegetation, abundance of individuals, and immigration rates highlights the importance of preserving edge vegetation to maintain resilient and connected populations.
Keywords: dispersal; connectivity; habitat selection; population dynamics.

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SUMMARY

1 INTRODUCTION

Spatial dynamics of animal movement are foundational to populational regulation and long-term persistence of spatially structured populations (Hanski, 1982; Veit & Lewis, 1996; Hanski, 1998; Amarasekare, 2004; Sinsch, 2014). Understanding movement ecology of animals is also critical to many aspects of management and conservation such as proliferation of invasive species, impact of land use, responses to global climate change, and its impact on population dynamics, especially in threatened groups such as amphibians (Urban et al., 2008; Griffiths et al., 2010; Cayuela et al., 2015, 2019). Studies that focus on local processes of population dynamics are important for understanding ecological processes that operate at broader scales, connecting theoretical concepts of landscape ecology (Gamble et al., 2007; Baguette et al., 2013; Sinsch, 2014; Boualit et al., 2019).

Dispersal, together with birth and death rates, shapes life histories and population dynamics of species residing in spatially structured environments (Bonte et al., 2017; Bestion et al., 2024). Among these, dispersal rates are influenced by a trade-off between their associated costs, including energy expenditure, increased predation risk, and reduced survival (Lucas et al., 1994; Bowler & Benton, 2009), and the potential benefits, like accessing superior breeding sites, loose competition, finding more mates, and enhanced offspring heterozygosity (Aars & Ims, 2000; Boualit et al., 2019; Unglaub et al., 2021). As resources become scarcer, the costs associated with site fidelity increase until they surpass the potential benefits, ultimately leading to a decline in overall fitness (Grant, 1978; Bowler & Benton, 2009). In this context, habitat-specific individual fitness and source-sink dynamics play a crucial role in shaping population structure and persistence. Individuals dispersing from high-quality habitats (sources) may maintain or supplement populations in lower-quality sites (sinks), which otherwise could not persist independently. Such dynamics allow for the occupation of marginal habitats and may contribute to the stability of metapopulations by buffering local demographic fluctuations (Howe, 1991; Kristan, 2003).

Habitat suitability depends on behavioral, physiological, and morphological attributes of organisms (Griffis & Jaeger, 1998; Touchon et al., 2013; Pelinson et. al, 2016; Farina et al., 2021) combined with environmental features and resource availability, and is the main driver of site selection, occupancy (Joly et al., 2001; Dos Santos et al., 2012; Moreira et al., 2016) and dispersal rates (Boualit et al., 2019;

Unglaub, 2021). Environmental characteristics, such as patch size and connectivity, determine feeding (Maia-Carneiro et. al., 2013), moving (Pareja-Mejía et al., 2023), and breeding (Becker et. al., 2010) opportunities. Thus, they affect habitat suitability and occupancy dynamics (Dos Santos et al., 2012; Moreira et al., 2016; Bouliat et al., 2019). Spatially structured emigration and non-random immigration patterns may potentially affect colonization probability of breeding ponds on a landscape level, a traditional parameter for long-term population persistence (Hanski, 1998; Vos et al., 2000). It also highlights that habitat suitability at the local level is strongly influenced by the interaction between a species' spatial behavior and the landscape configuration, influenced by its specific natural history traits. As a result, habitat characteristics have traditionally been considered to predict species movement patterns, extinction rates, and occupancy dynamics, which are key processes that determine the long-term viability and regional persistence of metapopulations in heterogeneous landscapes (Hanski, 1998; Vos et al., 2000; Baguette et al., 2013; Rowland et al., 2022). Thus, due to the relatively low vagility and distribution in spatially discrete breeding habitats (ponds and wetlands) (Alex Smith & Green, 2005), amphibians are considered good models for metapopulational studies (Alex Smith & Green, 2005; Sinsch, 2014; Cayuela et al., 2015, 2019).

Habitat characteristics, such as water depth and the amount or type of vegetation at pond edges, are important drivers of anuran species composition and diversity (e.g., Silva et al., 2011; Silva et al., 2012; Provete et al., 2014). The Monkey leaf frog *Phyllomedusa iheringii* Boulenger, 1885 is a charismatic treefrog endemic to the Pampa biome (Maneyro & Carreira, 2012). Their oviposition sites typically consist of one or more broad leaves wrapped to form nests suspended above still water, where tadpoles drop upon hatching (Dias et al., 2017). Males exhibit territorial behavior within a lek mating system, often engaging in physical confrontations to defend calling sites (Dias et al., 2017). Their specialized reproductive (Mode 23 *sensu* Nunes-de-Almeida et al., 2021), depends heavily on the availability of suitable vegetation, highlighting the species' reliance on pond edge vegetation for successful reproduction (Neckel-Oliveira, 2004; García et al., 2013; Sánchez-Ochoa et al., 2020). Consequently, ponds with more abundant or structured edge vegetation are likely to have greater availability of oviposition and calling sites, increasing habitat suitability and potentially leading to higher rates of breeding pond occupancy. Furthermore, since males establish and defend territories, more densely populated ponds may generate stronger competitive interactions, promoting higher movement rates as individuals seek available territories elsewhere. Understanding the spatial ecology of this species is fundamental for evaluating how structural characteristics of breeding sites influence habitat use and displacement patterns among ponds in amphibians with specialized reproductive strategies. This information is critical to identify habitat features essential for population persistence.

In this study, we aimed to test the influence of local features of breeding ponds on movement patterns and temporal breeding pond occupancy in *P. iheringii*. We hypothesize that reproductive sites with more complex or suitable vegetation on the pond edges will exhibit higher rates of temporal breeding pond occupancy in *P. iheringii*, given its ecological dependence on edge vegetation for reproduction (Dias et al., 2017). We also predict that higher emigration rates will emerge from more populated ponds given the species' territorial behavior and limited calling territories (Dias et al., 2017).

Pampa spans the southernmost region of Brazil, Argentina and the entirety of Uruguay (Olson et al., 2001), and is increasingly threatened by human activities such as agriculture, forestry, mining, urbanization, and infrastructure development, leading to habitat loss, fragmentation, and habitat split, which pose significant changes to environmental characteristics (Wagner et al., 2013; Mengue et al., 2020), potentially threatening the persistence of *P. iheringii,* the only Phyllomedusinae species endemic to the Pampa biome (Maneyro & Carreira, 2012). Therefore, assessing these ecological relationships provides a foundation for developing targeted management actions aimed at mitigating the adverse effects of habitat degradation on amphibian biodiversity, especially in threatened ecosystems such as the Pampa biome.

6 CONCLUSION

This study aimed to investigate how breeding pond characteristics influence spatial dynamics, including individual movements, temporal pond occupancy, and abundance of individuals of the monkey leaf frog *Phyllomedusa iheringii*, a species endemic to the Pampa biome. We hypothesized that local habitat structure, particularly the percentage of arboreal/shrubby edge vegetation, would be a key driver of population abundance and spatial dynamics, and that population abundance would influence dispersal patterns through density-dependent mechanisms.

Our results confirmed these hypotheses, demonstrating that the percentage of arboreal and shrubby edge vegetation is the strongest predictor of immigration and local abundance. In turn, higher population densities were associated with increased emigration rates, suggesting density-dependent dispersal likely mediated by competition for reproductive resources and territorial interactions. Additionally, temporal breeding pond occupancy was positively associated with population abundance, indicating that larger populations may buffer the negative effects of environmental and demographic stochasticity, contributing to population stability over time.

Dispersal patterns were non-random, with individuals preferentially moving towards ponds with greater arboreal/shrubby structure, likely relying on visual or chemical cues rather than acoustic signals for habitat selection. Importantly, even though most displacements occurred over short distances (<100 m), all ponds were connected through individual movements, forming a cohesive local population that exhibits characteristics consistent with a source-sink dynamic, or an island-mainland metapopulation structure.

These findings highlight the critical role of habitat structure, particularly edge vegetation, in shaping the spatial ecology and population dynamics of *P. iheringii*, supporting population connectivity, resilience, and long-term viability of this amphibian species dependent on structurally complex breeding habitats.

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