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LETÍCIA RODRIGUES MORETTO

Behavioral and spatial responses of Brazilian native species to invasive species

Jaboticabal,

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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(a) em Biodiversidade.

Orientador(a): Prof. Dr. Rita Bianchi

Coorientador(a): Prof. Dr. Roland Kays

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IMPACTO POTENCIAL DESTA PESQUISA

A pesquisa apresenta elevado potencial científico e inovador ao avançar a compreensão dos efeitos comportamentais e não letais de espécies invasoras sobre mamíferos brasileiros, um tema ainda pouco explorado. A integração de análises temporais e espaciais, com o uso de modelos avançados e dados de longo prazo, contribui de forma relevante para a ecologia de mamíferos, se aprofundando nas dinâmicas da paisagem do medo. Do ponto de vista técnico, o estudo fornece ferramentas analíticas robustas e replicáveis que podem ser aplicadas em programas de monitoramento da biodiversidade, avaliação de risco ecológico e planejamento da conservação, com potencial uso por órgãos ambientais, gestores de unidades de conservação e consultorias ambientais.

O impacto social e ambiental é significativo, uma vez que os resultados subsidiam estratégias de manejo de espécies invasoras, com reflexos diretos na conservação da fauna nativa e na redução de conflitos entre atividades humanas e vida silvestre. Ao evidenciar o papel funcional de predadores de topo, a pesquisa reforça a importância da conservação desses grupos para a manutenção de ecossistemas mais equilibrados. A pesquisa também possui forte potencial de internacionalização, ao dialogar com debates globais sobre invasões biológicas, conservação em paisagens modificadas e ecologia comportamental, além de utilizar métodos comparáveis a estudos realizados em outras regiões do mundo. Quanto à inserção local, regional e nacional, os resultados são diretamente aplicáveis a biomas brasileiros prioritários, como o Cerrrado, fornecendo subsídios científicos para ações de manejo, educação ambiental e conservação em diferentes escalas territoriais.

POTENTIAL IMPACT OF THIS RESEARCH

The research demonstrates Strong scientific and innovative potential by advancing the understanding of the behavioral and non-lethal effects of invasive species on Brazilian mammals, a topic that remains poorly explored. The integration of temporal and spatial analyses, using advanced models and long-term data, makes a significant contribution to mammal ecology by providing deeper insight into the dynamics of the landscape of fear. From a technical perspective, the study offers robust and replicable analytical tools that can be applied in biodiversity monitoring programs, ecological risk assessment, and conservation planning, with potential use by environmental agencies, protected area managers, and environmental consultancy firms.

The social and environmental impact is also significant, since the results support strategies for invasive species management, with direct implications for native fauna conservation and for reducing conflicts between human activities and wildlife. By highlighting the functional role of apex predators, the research reinforces the importance of conserving these groups to maintain more balanced ecosystems. The study also has strong internalization potential, as it engages with global discussions on biological invasions, conservation in human-modified landscapes, and behavioral ecology, while employing methods comparable to those used in studies conducted in other parts of the world. Regarding local, regional, and national relevance, the findings are directly applicable to priority Brazilian biome such as the Cerrado, providing scientific support for management actions, environmental education, and conservation across different territorial scales.

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RESUMO

As invasões biológicas representam uma grande ameaça à biodiversidade, porém seus efeitos não letais e mediados pelo comportamento sobre a fauna nativa ainda permanecem pouco compreendidos, especialmente em sistemas tropicais. O cão doméstico (*Canis familiaris*) e o javaporcos (*Sus scrofa*) estão entre as piores espécies invasoras do mundo e são reconhecidos por seus impactos negativos significativos sobre os ecossistemas. Utilizando dados de longo prazo obtidos por armadilhas fotográficas em duas áreas protegidas no Cerrado, investigamos como as espécies invasoras influenciam mamíferos nativos em dimensões temporais e espaciais. Os efeitos de ambas as espécies invasoras foram avaliados sobre sete mamíferos nativos com características ecológicas contrastantes: canídeos (lobo-guará e cachorro-do-mato), predador de topo (onça-parda), e espécies de presas (tamanduá-bandeira, tatu-galinha, gambá-de-orelha-branca e um cervídeo). Avaliamos: (i) mudanças nos padrões de atividade por meio da sobreposição de densidade de kernel, (ii) atração ou evitação em curto período utilizando modelos mistos (*piece-wise exponential aditive mixed model*), e (iii) respostas espaciais por meio de modelos *multi-species* de ocupação mediados por abundância. Nossos resultados revelam que as espécies nativas responderam principalmente por meio de ajustes temporais, em vez de exclusão espacial. Os xenarthros foram particularmente afetados, apresentando alterações nos padrões de atividade que podem acarretar custos energéticos devido às suas limitações fisiológicas como homeotérmicos imperfeitos. Cachorros-do-mato e gambás apresentaram respostas flexíveis e dependentes do contexto da área. Encontramos ainda uma hipótese exploratória baseada nas tendências espaciais, sugerindo que predadores de topo podem criar refúgios espaciais que amortecem a pressão exercida por espécies invasoras sobre espécies nativas. Esses achados destacam a urgência do controle de cães domésticos, reforçam que a conservação de predadores de topo podem ser um componente crítico para o manejo eficaz de espécies invasoras e indicam que esse manejo deve ser dependente do contexto da área.

Palavras-chave: invasões biológicas; paisagem do medo; monitoramento da fauna; interações entre espécies.

ABSTRACT

Biological invasions represent a major threat to biodiversity, yet their non-lethal and behaviorally mediated effects on native wildlife remain poorly understood, particularly in tropical systems. Domestic dogs (*Canis familiaris*) and wild boars (*Sus scrofa scrofa*) rank among the world's worst invasive species and are recognized for their significant negative impacts on the ecosystem. Using long-term camera-trap data from two protected areas in Cerrado, we investigated how invasive species influence native mammals across temporal and spatial dimensions. The effects of both invasive species were evaluated on seven native mammals with contrasting ecological traits: canids (maned wolf, crab-eating fox, apex predator (puma), and prey species (giant anteater, nine-banded armadillo, white-eared opossum, and deer). We assessed (i) changes in activity patterns through kernel density overlap, (ii) short-term attraction or avoidance using piece-wise exponential additive mixed models, and (iii) spatial responses via abundance-mediated multi-species occupancy models. Our results reveal that native species responded primarily through temporal adjustments rather than spatial exclusion. Xenarthrans were particularly affected, exhibiting activity pattern shifts that could carry energetic costs given their physiological constraints as imperfect homeotherms. Crab-eating foxes and opossums showed flexible, context-dependent responses. We found an exploratory hypothesis based on spatial trends, suggesting that apex predators may create spatial refugia that buffer native species from invasive species pressure. These findings highlight the urgency of domestic dog control, underscore that apex predator conservation could be a critical component of effective invasive species management, and that their management must be context-dependent.

Keywords: biological invasions; landscape of fear; wildlife monitoring; species interactions.

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1 INTRODUÇÃO

Since humans began expanding across the globe, the modification of natural environments has triggered severe ecological consequences, reshaping ecosystems and pushing many species toward extinction (Barnosky et al., 2011; Dirzo et al., 2014). Land use change, urbanization, and agricultural expansion have increasingly benefited generalist species while creating conditions that favor the establishment of non-native taxa, contributing to a progressive simplification of biological communities (Romanillos et al., 2024; Keck et al., 2025). Beyond direct killing, invasive species affect native wildlife through subtler pathways. Changes in behavior, heightened predation risk perception, and shifts in space and time use can all emerge even in the absence of actual predation events. These non-lethal effects, central to the landscape of fear concept (Gaynor et al., 2019; Laundre et al., 2010), can be as ecologically significant as mortality itself, reshaping how native species move, forage, and share their environment with invaders. Domestic dogs (*Canis familiaris*) and wild pigs (*Sus scrofa*) stand out as particularly impactful invasive species globally (Lowe et al., 2000), affecting native fauna across multiple ecological levels. In Brazil, despite their widespread presence in and around protected areas, most research efforts have concentrated on disease-related and economic dimensions of these invasions (Gianetti et al., 2025; Machado et al., 2021; Perin et al., 2023), leaving a substantial gap in our understanding of how native mammals behaviorally and spatially cope with their presence. To address this gap, we investigated how a functionally diverse set of native mammals responds to both invaders across temporal and spatial dimensions, using long-term camera-trap data from two Cerrado protected areas. Our goal was to identify which species are most vulnerable, and whether responses are primarily temporal or spatial.

3 CONCLUSÃO

Native species responses to biological invasions were primarily expressed through temporal adjustments rather than spatial exclusion, reshaping activity patterns and short-term space use in ways that varied across taxa and study areas. This context-dependence was one of the most consistent findings across the study, reinforcing that the impacts of invasive species cannot be generalized. Physiologically constrained species, particularly giant anteaters and nine-banded armadillos (McNab, 1980; Superina and Loughry, 2012), emerged as especially vulnerable. Their limited capacity to compensate for behavioral shifts through alternative strategies makes any disruption to their activity patterns potentially costly, raising conservation concerns that extend beyond simple presence-absence assessments of invasive species impacts. Generalist species such as opossums and crab-eating foxes displayed more flexible responses, adjusting their behavior according to local conditions. In some cases, could even be benefited from resources associated with invasive species presence (Davies et al., 2021). This behavioral plasticity appears to buffer these species against the more severe consequences observed in physiologically restricted taxa. Perhaps the most unexpected finding was the potential role of apex predators as indirect buffers against invasive species pressure. In the area where pumas were present, sensitive native species showed spatial associations suggesting refuge effects mediated by predator presence, a pattern consistent with trophic cascade dynamics and mesopredator suppression theory (Ripple et al., 2014; Ritchie and Johnson, 2009). These results point to three urgent management priorities: controlling domestic dog populations through stronger legislation, community engagement, and large-scale sterilization programs; conserving apex predators as functional components of invasion mitigation; and adopting context-dependent management strategies tailored to the specific ecological conditions of each protected area.

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