Mariana Napolitano e Ferreira

Planejamento sistemático das unidades de
conservação no Estado do Tocantins

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conservação no Estado do Tocantins

Systematic planning of protected areas in
Tocantins State

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Dedico essa tese à memória da minha avó, Maria do Rosário,
cuja herança de teimosia, ou perseverança,
foi essencial à conclusão desse trabalho.

Epígrafe

Man tries to make for himself in the fashion that suits him best a simplified and intelligent picture of the world; he then tries to some extent to substitute this cosmos of his for the world of experiences and thus to overcome it. This is what the painter, the poet, the speculative philosopher, and the nature scientist do, each in his own fashion.

Albert Einstein

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Sumário

Resumo	01
Abstract	02
Introdução Geral	03
Capítulo 1. Management effectiveness and threat assessment of protected areas in Tocantins State	14
Capítulo 2. Biodiversity, biogeography and conservation gaps in a critical region of the Cerrado hotspot	46
Capítulo 3. Integrating protected area status into systematic conservation planning: a case study in the Brazilian Cerrado	77
Discussão Geral e Conclusões	100
Anexos	107

Resumo

O crescimento dos sistemas de áreas protegidas nas últimas décadas é considerado um dos maiores esforços da humanidade para conter a atual crise da biodiversidade. No entanto, a cobertura da superfície global por áreas protegidas é um indicador simplificado, sendo necessário ir mais além e avaliar se os sistemas de áreas protegidas representam os diferentes componentes da biodiversidade e processos ecológicos e se estão sendo geridos de forma efetiva para garantir a manutenção da biodiversidade no longo prazo. O objetivo geral do presente estudo foi realizar uma análise da efetividade de gestão e representatividade biológica do sistema de unidades de conservação (UCs) no Estado do Tocantins, avaliando como os diferentes níveis de gestão de áreas protegidas podem interferir nos processos de planejamento sistemático da conservação. Os resultados indicaram a existência de lacunas significativas na implementação das áreas protegidas existentes, apesar do desempenho relativamente bom em alguns elementos. As quatro ameaças mais importantes para o sistema de UCs avaliado foram: infraestrutura, queimadas descontroladas, caça e pecuária. A análise da distribuição de 109 espécies de vertebrados e plantas indicou a presença de padrões biogeográficos claros na biota do Tocantins, que coincidem com padrões relatados por outros autores para alguns grupos taxômicos. No entanto, lacunas significativas foram observadas tanto na proteção das espécies, quanto na representação dos elementos bióticos identificados. Para testar os impactos dos baixos valores de efetividade e altos valores de ameaças das UCs no planejamento do sistema, reduzimos o estado de conservação das áreas protegidas em 25% e 50%. Isso resultou em acréscimos de 250.000 ha e 590.000 ha, respectivamente, no sistema de áreas protegidas, necessário ao cumprimento das metas de conservação. A representatividade dos sistemas de áreas protegidas depende da persistência da biodiversidade dentro dessas áreas, que é reconhecidamente comprometida por níveis elevados de ameaça associados à efetividade de gestão incipiente. Portanto, sugerimos que o estado de conservação da biodiversidade dentro das áreas protegidas seja incorporado a exercícios de planejamento sistemático de conservação. A definição de prioridades para a criação de novas áreas protegidas deve fazer parte de um planejamento integrado, que aborde também a consolidação de áreas protegidas existentes e estratégias mais amplas para mitigar os efeitos dos fatores principais da perda de biodiversidade fora das reservas.

Abstract

The growth of protected areas (PAs) in the last decades is considered one of the humanity's best efforts to refrain the current crisis of biodiversity. However, the global PA coverage is a simplified indicator; it is necessary to go further and assess whether PA systems represent the different components of biodiversity and ecological processes and are being managed effectively to ensure the maintenance of their values in the long term. The main goal of this study was to analyze the management effectiveness and representation of PA system in Tocantins State, assessing how the different levels of PA management may impact the systematic conservation planning process. Results indicated the existence of significant gaps in the implementation of Tocantins PAs, despite the relatively good performance found in some elements. The four most important threats to the PAs evaluated were: infrastructure, uncontrolled fires, hunting and cattle ranching. Analysis of the distribution of 109 vertebrates and plants indicated that selected species represent biogeographical patterns of Tocantins biota and that there are significant gaps in the protection of the species and biotic elements in the current PA system. In order to test for the effects of detected low management effectiveness and high levels of threat, we reduced the conservation status of protected areas by 25% and 50%. This resulted in an increase in the conservation area network needed to achieve targets of around 250,000 ha and 590,000 ha, respectively. Our results strongly indicate that the representation of PA systems depends on the persistency of biodiversity inside PAs, which are known to be impacted by high levels of threat associated to poor management effectiveness. Therefore, we advocate that biodiversity status within PAs should be incorporated in systematic conservation planning exercises. The definition of priority areas for the establishment of new reserves should be part of an integrated planning process that addresses both the consolidation of existing protected areas and broader strategies to mitigate the effects of major drivers of biodiversity loss outside reserves.

Introdução

Luciano Candisani

Estação Ecológica Serra Geral do Tocantins

Introdução

A crise da biodiversidade atinge as diferentes escalas de organização biológica (genética, específica e ecossistêmica) nas mais diversas regiões do planeta (Pimm & Raven, 2000; Loyola & Lewinsohn, 2009; Loreau et al., 2006). A maioria dos indicadores do estado da biodiversidade (tendências populacionais, risco de extinção, composição das comunidades, extensão e condição dos habitats) vem apresentando quedas nas últimas décadas, sem alterações significativas nas taxas mais recentes. Ao mesmo tempo, os indicadores de pressões sobre a biodiversidade (incluindo a conversão de habitats, o consumo de recursos, as espécies exóticas invasoras, a poluição por nitrogênio, a superexploração e os impactos das alterações climáticas), apesar de apresentarem declínio em algumas regiões, de forma geral continuam bastante elevados (Butchart et al., 2010).

O estabelecimento de áreas protegidas é reconhecido como uma das estratégias mais eficientes na contenção da crise da biodiversidade (Bruner et al., 2001; Balmford et al. 2002; Sinclair et al., 2002). Tais áreas têm a função de manter estoques básicos dos recursos naturais em diversos tipos de ecossistemas e garantir que os processos ecológicos se mantenham no longo prazo. O mundo vivenciou um aumento considerável no número de áreas protegidas a partir da década de 1980, em razão de um movimento ambiental forte e consciente da necessidade da existência de espaços naturais institucionalmente protegidos (Lockwood et al., 2006; Leverington et al., 2008). No Brasil, esse processo se manifestou pela criação de diversas unidades de conservação (UCs), além do estabelecimento do Sistema Nacional de Unidades de Conservação no ano de 2000 (SNUC – Lei 9.985 de 18 de julho de 2000) e do Plano Estratégico Nacional de Áreas Protegidas em 2006 (PNAP - Decreto nº 5.758 de 13 de abril de 2006).

Atualmente, estima-se que as áreas protegidas cubram aproximadamente 11% da superfície global (IUCN & UNEP-WCMC, 2010). No Brasil, são mais de 1.600 UCs, das quais um pouco mais da metade é pública, e que no total cobrem em torno de 17% do território brasileiro (MMA, 2010). No entanto, o número e extensão das áreas protegidas apenas fornece um indicador simplificado do compromisso político para a conservação da biodiversidade e de seus resultados práticos para conter a crise atual. É preciso ir mais além e avaliar se os sistemas de áreas protegidas representam os diferentes componentes da biodiversidade e processos ecológicos e se estão sendo geridos de forma efetiva para garantir a manutenção da biodiversidade no longo prazo.

A gestão efetiva de unidades de conservação envolve aspectos técnicos, políticos e econômicos (tais como desenho e conectividade, planejamento, capacidade institucional, aspectos legais, programas de desenvolvimento regional, fiscalização, dentre outros), e pode ser considerada condição essencial para o cumprimento dos objetivos de criação das unidades (Faria, 2004; Hockings et al.; 2006). A avaliação da efetividade de gestão de áreas protegidas busca, mais do que identificar um valor de eficiência, realizar um diagnóstico da situação atual de determinada área e fazer uma análise crítica sobre as estratégias adotadas para sua gestão, além de monitorar os resultados obtidos. Assim, pode-se corrigir rumos e direcionar ações, em busca de maior efetividade no cumprimento dos objetivos de conservação que motivaram a criação da UC (Hockings et al., 2006).

Em uma recente avaliação global da efetividade da gestão de 3.080 áreas protegidas pesquisadas, apenas 22% foram consideradas "sólidas", 13% "claramente insuficientes", e 65% apresentaram uma gestão "básica" (Leverington et al., 2010). No Brasil, os resultados da avaliação de mais de 400 unidades de conservação indicam que a maioria dessas áreas apresenta níveis inferiores a intermediários de efetividade (WWF-Brasil et al., 2004; Ibama & WWF-Brasil, 2007; WWF-Brasil et al., 2009 a,b,c). Dentre os principais entraves à gestão das unidades de conservação, encontram-se a ausência de demarcação e desapropriação das áreas, a falta e má distribuição dos recursos humanos, as atividades conflitantes no entorno e interior das UCs, além da falta de plano de manejo, de recursos humanos e financeiros adequados (Ferreira et al., 1999; Ibama & WWF-Brasil, 2007; Leverington et al., 2010)

Além da gestão efetiva de cada UC, o desenho e representatividade do sistema de áreas protegidas são determinantes para garantir a conservação da biodiversidade no longo prazo (Bakarr & Lockwood, 2006). As abordagens tradicionalmente utilizadas para seleção de áreas para a criação de unidades de conservação caracterizam-se muitas vezes por critérios como terras com baixo potencial econômico, propósitos turísticos, paisagens de grande beleza cênica, proteção de recursos hídricos e pressão de grupos de interesse (Pressey, 1994; Margules & Pressey, 2000; Yip et al., 2004). A consequência desse tipo de processo é normalmente um sistema de unidades de conservação com baixa representatividade, que contribui pouco para conservar os padrões e processos da biodiversidade regional, e que apresenta lacunas significativas na proteção de espécies ameaçadas ou endêmicas (Balmford et al., 2002).

Atualmente, o sistema global de áreas protegidas está longe de atingir níveis de representatividade satisfatórios, mesmo para grupos geralmente bem conhecidos, como os

vertebrados terrestres (Rodrigues et al., 2004). O sistema de unidades de conservação do Brasil também apresenta grandes lacunas de representatividade. No Cerrado, o tamanho insuficiente e a falta de planejamento resultaram em um sistema de UCs que não representa toda a biodiversidade da região e, portanto, deve ser urgente e significativamente adequado mediante cuidadosa seleção e criação de novas áreas (Cavalcanti & Joly, 2002; Silva & Bates, 2002; Diniz-Filho et al., 2008). Estima-se que pelo menos 20% das espécies ameaçadas e/ou endêmicas do Cerrado não ocorram em áreas protegidas (Klink & Machado, 2005). A má distribuição geográfica resulta em limitada representatividade da heterogeneidade regional do Cerrado, com alguns ambientes, especialmente os campos limpos, os campos rupestres e as florestas decíduas, muito mal representados no sistema atual de UCs (Olmos, 2007).

A melhor compreensão dos padrões de biodiversidade e das lacunas de conservação devem ser os primeiros passos para o desenvolvimento de uma sistema de áreas protegidas representativo, abrangente e eficaz (Langhammer et al., 2007). Estudos recentes mostraram que a qualidade dos dados, assim como a definição dos alvos de conservação, determina o sucesso do planejamento do desenho dos sistemas de áreas protegidas (Cabeza & Moilanen, 2001). A alegada falta de conhecimento sobre os padrões de distribuição (e processos biogeográficos associados) faz com que essas informações raramente sejam incluídas nos exercícios de planejamento e priorização de áreas (Crisci, 2000; Whittaker et al., 2005). Portanto, maximizar os esforços de coleta e compilação de dados biológicos de forma a tornar essa informação mais acessível para o planejamento da conservação representa um dos maiores desafios da Biologia da Conservação nos próximos anos.

Além disso, a grande maioria das abordagens atualmente adotadas assume que a proteção formal das áreas garante a imediata remoção das ameaças e a conservação da biodiversidade existente nos seus limites (Possingham et al., 2009), o que não costuma acontecer, especialmente em sistemas de áreas protegidas com gestão incipiente e altos níveis de ameaças (Bruner et al., 2001; Wilson et al., 2005; Pressey et al., 2007; Wilson et al., 2007). A caça, a extração madeireira e a invasão de espécies exóticas são exemplos de ameaças geralmente observadas dentro das áreas protegidas (Wilson et al., 2005; Leverington et al., 2008). Em algumas regiões, a proteção formal das áreas não evita sequer a perda de hábitat, com a conversão de áreas para agricultura, pecuária ou assentamentos humanos ocorrendo mesmo dentro de unidades de conservação (Peres & Terborgh, 1995; Menon et al., 2001). No Brasil, essa tendência é bastante evidente, especialmente nas regiões de maior crescimento urbano e desenvolvimento econômico, como o Cerrado. Algumas

unidades de conservação emblemáticas do Cerrado, como os parques nacionais Emas, Brasília e Chapada dos Veadeiros, por exemplo, encontram-se cada vez mais isolados pela expansão das áreas cultivadas no seu entorno. Ainda, grande parte das áreas protegidas do Cerrado é composta por áreas de proteção ambiental (APAs), categoria bastante vulnerável às pressões antrópicas e que de fato foi responsável pela maior parte do desmatamento observado entre 2002 e 2008 nas unidades de conservação do Cerrado (MMA, 2011).

O Cerrado é a maior e mais rica savana do planeta, detendo altos valores de biodiversidade global e níveis elevados de endemismos (Myers et al., 2000; Oliveira & Marquis, 2002; Silva & Bates, 2002; Klink & Machado, 2005). Ao mesmo tempo, o Cerrado representa a mais ameaçada região de savana do mundo, com menos 3% de sua superfície sob a forma de unidades de conservação de proteção integral (Klink & Machado, 2005). Até 2008, o Cerrado já havia perdido em torno de 48% de sua cobertura original (MMA, 2011), principalmente para agricultura e pecuária, sendo que uma grande parcela da vegetação remanescente sofreu algum nível de degradação ou encontra-se fortemente fragmentada (Klink & Machado, 2005). As taxas de desmatamento no Cerrado estão entre as mais elevadas dentre todas as regiões naturais do mundo, com valores médios de mais de 1.420.000 ha desmatados por ano (taxas médias entre 2002 e 2008, de acordo com MMA, 2011).

As elevadas taxas de desmatamento são contínuas e atualmente dependem da expansão da fronteira agrícola rumo à porção norte do Cerrado, nos estados da Bahia, Maranhão, Tocantins e Piauí (MMA, 2011). O Estado do Tocantins representa uma das principais fronteiras de expansão da agricultura e pecuária do país, tendo apresentado um crescimento bastante significativo dessas atividades nas últimas décadas. Embora ainda restem cerca 73% da área original do Cerrado no Estado do Tocantins (IBAMA, 2008), a produção de soja, por exemplo, saltou de 30 mil ha em 1990 para 355 mil ha em 2005. A pecuária, atividade tradicional que desbravou a região, cresceu a uma taxa anual média de 4,2% entre 1990 e 2005, e o rebanho atingiu quase 8 milhões de cabeças, ou mais de quatro vezes a população humana (Olmos, 2007). Outra ameaça bastante significativa são as frequentes queimadas antropogênicas que ocorrem de forma intensa na estação seca e têm efeitos particularmente graves nas unidades de conservação. Durante o ano de 2010, o Tocantins foi o estado situado na região do Cerrado com maior número de focos de incêndios acumulados até o mês de agosto (MMA, 2011). Apesar dos crescentes níveis de desmatamento, alguns dos maiores blocos vegetação nativa de Cerrado ainda são encontrados em localidades situadas no Estado do Tocantins, que possui aproximadamente 6% de sua área em

unidades de conservação de proteção integral e 9% em unidades de conservação de uso sustentável. As unidades de conservação no estado foram criadas sem nenhum tipo de planejamento, muitas unidades são recentes e apresentam grau mínimo de implantação.

A situação encontrada no Tocantins reflete o cenário brasileiro e de outras regiões tropicais, no que tange ao contexto dos sistemas de áreas protegidas. Nessas regiões, níveis crescentes de ameaças, associados ao baixo conhecimento básico sobre biodiversidade e à efetividade de gestão incipiente, podem impactar consideravelmente a integridade das áreas protegidas e seu papel na conservação da biodiversidade. Nessas situações, o comprometimento da persistência da biodiversidade dentro das áreas protegidas pode ser significativo e deveria ser considerado nos exercícios de planejamento sistemático (Wilson et al., 2005).

Objetivos

O objetivo geral do presente estudo foi realizar uma análise da efetividade de gestão e representatividade biológica do sistema de unidades de conservação do Estado do Tocantins, avaliando como os diferentes níveis de gestão de áreas protegidas podem interferir nos processos de planejamento sistemático da conservação. A partir da premissa de que a gestão e o planejamento do desenho dos sistemas de áreas protegidas são estratégias complementares para garantir a conservação da biodiversidade, buscou-se entender as principais relações e propor melhores formas de integração entre essas estratégias. Os resultados desse estudo são especialmente importantes para regiões com alta riqueza e pouco conhecimento biológico, geralmente associados a elevados níveis de ameaças e baixos níveis de proteção, como observado em grande parte das regiões tropicais.

A tese está organizada em três capítulos, precedidos por esta introdução geral, que apresenta as ideias centrais do estudo. No capítulo 1, são apresentados e discutidos os resultados da avaliação da efetividade de gestão das unidades de conservação de proteção integral do Estado do Tocantins, além de uma análise das principais ameaças que incidem sobre as unidades. No capítulo 2, foi feita a seleção e modelagem da distribuição potencial das espécies-alvo, buscando investigar a existência de padrões biogeográficos significativos e não aleatórios na biota do Tocantins e realizar uma análise de lacunas dos alvos de conservação e elementos bióticos identificados. Os mapas de distribuição potencial das 109 espécies selecionadas são apresentados no anexo desse capítulo. No capítulo 3, os resultados de efetividade de gestão, análise de ameaças

e representatividade biológica são discutidos de forma integrada por meio da análise de diferentes cenários de prioridades de conservação. Por fim, tem-se a discussão geral e as principais conclusões da tese. Os manuscritos publicados estão apresentados como anexos (1 a 3).

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Capítulo 1

Management effectiveness and threat assessment of protected areas in Tocantins State

Parque Estadual do Jalapão

Ferreira, M.N. & Pivello, V.R. Manuscrito em preparação a ser submetido ao periódico Environmental Management.

Management effectiveness and threat assessment of protected areas in Tocantins State

Resumo

A conservação do Cerrado depende do estabelecimento e proteção de áreas no Estado do Tocantins que ainda apresenta importantes remanescentes em bom estado de conservação e sem proteção formal. Apesar de sua importância e potencial para a conservação da biodiversidade, as unidades de conservação no estado estão submetidas a ameaças crescentes relacionadas principalmente ao crescimento da produção agropecuária na região. Este artigo apresenta os resultados da avaliação da efetividade de gestão e ameaças que incidem sobre as unidades de conservação de proteção integral do Estado do Tocantins. Os resultados foram obtidos por meio de questionários padronizados aplicados aos funcionários das sete unidades de conservação de proteção integral. A efetividade de gestão das áreas avaliadas variou entre 42 e 68%, sendo que a média da efetividade de todas as unidades foi de 52,5%. Apesar das unidades apresentarem um desempenho relativamente bom em alguns elementos, deficiências mundialmente comuns, como o número reduzido de funcionários, a inadequação das infraestruturas e a falta de organização, juntamente com questões de contexto relacionadas à presença humana, como por exemplo, ameaças advindas de assentamentos rurais e uso insustentável dos recursos no interior e entorno das áreas, contribuíram para a obtenção de valores inferiores no elemento Resultados e nos índices de efetividade de gestão. As quatro ameaças mais importantes, com valores elevados de intensidade e frequência, foram: infraestrutura, queimadas descontroladas, caça e pecuária. Iniciativas locais para solucionar questões mais específicas de cada unidade de conservação, associadas a estratégias de longo prazo direcionadas às causas subjacentes de problemas sistêmicos, são propostas para melhorar o atual cenário de efetividade de gestão das unidades avaliadas.

Abstract

Conservation of the Brazilian Cerrado critically depends on the establishment and long-term protection of areas in Tocantins State where large and preserved areas still remain. Besides their importance and potential for biodiversity conservation, protected areas in Tocantins face increasing threats as the state grows as one of the major frontiers for agriculture and cattle ranching expansion. This article summarizes the findings of management effectiveness and threat assessments of strictly protected areas in Tocantins. Results were obtained through the application of standard questionnaires to the staff of the seven strictly protected areas in the state.

Management effectiveness results varied between 42 and 68%, with an average value of 52,5%. Even though Tocantins protected areas had a relatively strong performance on Inputs, some globalized common weaknesses such as reduced staff, infrastructure inadequacy and lack of internal organization, combined with several human-related issues on protected areas' context, including threats from human settlements and unsustainable resource use within and around protected areas, have contributed to low results on Outputs and management effectiveness levels. The top four threats which combined high values of intensity and frequency were infrastructure, fire, hunting and livestock ranching. Local initiatives to solve specific problems combined to long-term strategies to address the underlying causes of systemic threats are suggested to improve management effectiveness status of surveyed protected areas.

1. Introduction

The importance of evaluating protected area (PA) management effectiveness has become increasingly relevant over the last years since the creation of PAs alone does not always result in adequate protection (Hockings & Phillips, 1999; Hockings et al., 2000; Ervin, 2003a). Since 2004, the evaluation and improvement of management effectiveness represent one of the goals of the Program of Work on Protected Areas from the Convention on Biological Diversity (CBD). In the final report of CBD's 10th Conference of the Parties that took place in 2010, countries are asked to continue to expand and institutionalize management effectiveness assessments in an effort to evaluate at least 60 per cent of their total area of PA by 2015 (UNEP/CDB, 2010).

Effective management of PAs involves technical, political, and economical aspects (such as planning, institutional capacity, policy, enforcement and outreach) and may be considered one of the most powerful strategies to achieve biodiversity conservation and sustainable use of natural resources (Faria, 2004; Hockings et al., 2006). Management effectiveness evaluation is defined as the assessment of how well the PA is being managed towards protecting its values and achieving goals and objectives (Hockings et al., 2006). Results from management effectiveness evaluations indicate broad trends in management strengths and weaknesses; reveal the scope, severity, prevalence, and distribution of an array of threats and pressures; and may support further analyses on the relationship between specific strategies and their impacts on PA effectiveness. By doing so, these assessments provide essential information for policymakers to plan the implementation of PAs systems, prioritize resource allocation and develop strategies to address the most significant threats and management gaps hampering the achievement of conservation goals (Ervin, 2003b). Moreover, monitoring and evaluation may deliver public and internal accountability and demonstrate results of

financial investments in conservation, which are essential under limited budget scenarios (Hockings et al., 2000; Stem et al., 2005).

In particular, the Management Effectiveness Evaluation Framework (Hockings, 2003; Hockings et al., 2006) from IUCN World Commission on Protected Areas (IUCN-WCPA) has oriented the proposal and application of many methods of assessments around the world (Stoll-Kleemann, 2010). The framework identifies context, planning, inputs, processes, outputs and outcomes as the crucial elements of the management cycle.

To date, more than 54 methodologies have been described and applied to more than 6200 PAs around the world (Leverington et al., 2010). In Brazil, 246 federal PAs were evaluated by the RAPPAM protocol (Rapid Assessment and Prioritization of Protected Area Management; Ervin, 2003c) between 2005 and 2006 (IBAMA & WWF-Brasil, 2007). These were also complemented by state level assessments in São Paulo (Faria, 2004), Rio de Janeiro (Primo & Pellens, 2000), Minas Gerais (Lima et al., 2005), Mato Grosso (Brito, 2000; Tocantins & Almeida, 2000; WWF-Brasil et al., 2009a), Acre (WWF-Brasil et al., 2009b), Amapá (WWF-Brasil et al., 2009c), Rondônia (WWF-Brasil et al., 2011a), Amazonas (WWF-Brasil et al., 2011b), and Pará (WWF-Brasil et al., 2011c). Results from more than 400 PAs evaluated in Brazil so far indicate that most PAs have low to intermediate levels of management effectiveness, with a great proportion of areas lacking management plans, adequate staff, infrastructure and resources. In general these areas also suffer from poor stakeholder participation, institutional support, and lack of monitoring and planning.

Tocantins State, in the northern region of Brazil, congregates important Cerrado-Amazônia transition areas and some of the largest blocks of Cerrado remnants (Klink & Machado, 2005; MMA, 2011). The state has 5.7% of its total area assigned as strictly PAs (IUCN categories I to III), and around 9% more as sustainable use areas (IUCN categories IV to VI). Besides their importance and potential for biodiversity conservation, PAs in Tocantins face increasing threats as the state grows as one of the major frontiers for agriculture and cattle ranching expansion promoted by infrastructure investments (Olmos, 2007). Given the size and integrity of natural Cerrado areas in Tocantins, the conservation of the Brazilian Cerrado necessarily relies on the establishment and long-term protection of Tocantins Cerrado areas. Therefore, a comprehensive assessment of Tocantins State PAs system is imperative to define strategies and priorities to ensure a fully representative and functional network of well managed PAs. One of the major components of this assessment is the management effectiveness evaluation, which has never been performed for the complete system of PAs in the state.

This article summarizes the findings of this evaluation and recommends priorities for improving the effectiveness of Tocantins PA system. Main questions were: how are Tocantins PAs

being managed? What are the major weaknesses and strengths of Tocantins PA management? What aspects mainly contribute to Tocantins PA management effectiveness? What are the most important threats to Tocantins PA system? Are trends in Tocantins PA management effectiveness and threats similar to the Cerrado, Brazilian and global scenarios?

2. Materials and Methods

Study sites

All seven strictly PAs from Tocantins State were evaluated in this study (Table 1). Three of them are managed by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBIO), the federal agency responsible for PAs in Brazil, while the remaining four are managed by the state level Instituto Natureza do Tocantins (NATURATINS). Sustainable use PAs from Tocantins, especially the environmental protection areas (APAs, IUCN category V), were subjected to a previous assessment (Bonatto et al., 2009) and were excluded from this analysis since they did not have staff and there was not available information for a more detailed management effectiveness evaluation.

Cantão State Park (CSP) and Araguaia National Park (ANP) are both located in western Tocantins (Figure 1), in the transition zone between the Cerrado and the Amazon rainforest, in a complex mosaic of typical Cerrado vegetation, broadleaf forests and flooded areas. These areas are adjacent to each other and are bounded by three major rivers, Araguaia, Coco and Javaés. ANP protects part of the world's largest fluvial island (*Ilha do Bananal*). Araguaia River is one of the largest Brazilian rivers still free from significant human impacts, such as hydroelectric dams or high levels of pollution. Main economic activities in the region are irrigated agriculture, cattle ranching and fishing. CSP is the only PA in Tocantins state supported by the Amazon Protected Areas Program (ARPA), a long-term initiative to promote the establishment and consolidation of PAs in the Brazilian Amazon (MMA, 2010).

Jalapão State Park (JSP), Serra Geral do Tocantins Ecological Station (SGTES) and Nascentes do Parnaíba National Park (NPNP) are located in eastern Tocantins and integrate the Jalapão-Mangabeiras biodiversity corridor (Figure 1). This region holds the largest tracts of natural remnants and the largest PAs in Central Brazil, altogether protecting almost three million hectares of well conserved Cerrado habitats. The region consists of extensive quartzitic sand depressions resulting from the erosion of isolated arenitic plateaus of the Serra Geral and Chapada das Mangabeiras, and is drained by the headwaters of the Tocantins and São Francisco river basins (Tocantins, 2003). Vegetation is typical of the Cerrado and is dominated by extensive *campos sujos* (scrub grasslands) and open savannah interspersed by *veredas* (wet grasslands with *Mauritia flexuosa* palm trees) and gallery forests (Oliveira-Filho & Ratter, 2002; Tocantins, 2003). SGTES has around 88% of its area in

Tocantins State (635,000 ha), with the remaining area in Bahia, while NPNP has approximately 13% of its area in Tocantins (close to 100,000 ha), extending to areas in Piauí, Maranhão and Bahia states. Local economy is based on subsistence agriculture, extensive cattle ranching and, more recently, handicraft making and tourism (Tocantins, 2003; Schmidt et al., 2007).

Lajeado State Park (LSP) is the smallest PA surveyed, and is located in the central portion of the state, close to its capital city, Palmas (Figure 1). It is composed of typical Cerrado vegetation, with mainly wooded savannas (*cerrado sensu strictu*) distributed along plateaus with mean altitudes of 500 m. Lajeado SP protects most of the headwaters that supply the city of Palmas. Agriculture and cattle ranching are the main activities around the park, but more urbanized land use is also observed closer to Palmas.

Árvores Fossilizadas Natural Monument (AFNM) is the only PA in this study that formally allows human settlements and private properties inside its boundaries. It was created in the northern portion of the state (Figure 1) to protect a palaeobotanical site harbouring remains of a petrified forest that represents the most important Permian tropical to subtropical floristic record in the southern hemisphere (Dias-Brito et al., 2007). The AFNM region includes natural Cerrado vegetation remnants fragmentes by large cattle farms. Natural areas are dominated by *cerrado sensu strictu*, although riparian forests and some small patches of semi-deciduous forests also occur.

Management effectiveness evaluation

Management effectiveness evaluation was based on the method known as Scenery Matrix, proposed by Faria (2004). It was primarily designed for the assessment of PA systems. The data is collected through a participatory process and it is flexible, i.e., it allows the PA representatives to propose their own set of indicators according to the PA current situation and optimum scenario. By making use of a standardized scoring scale, the management effectiveness is measured by comparing an 'optimum PA scenario' with the current situation (Leverington et al., 2008a).

This methodology is based on the use of previously selected indicators, which are defined in accordance with the management objectives of the PAs to be assessed (Faria, 2004). The indicators are qualified based on predefined scenarios and are scored based on a standardized scale for quantification, where the highest score corresponds to the 'optimum scenario' and the lowest one to the worst possible situation that may happen in the system, and is completely in conflict with the PA management (Leverington et al., 2008a).

We adapted the questionnaire proposed by Faria (2004) for the context and management objectives of the surveyed PAs, by removing indicators related to forest management and including some questions related to the local context of Tocantins PAs, such as fire management issues or

relationship with local communities (Table 2). The adopted questionnaire was composed of 54 indicators separated into five different management elements (context, planning, inputs, processes, outputs) according to the framework proposed by WCPA-IUCN for management effectiveness assessments (see Hockings et al., 2006 for further details).

Threats

The protocol for the assessment of PAs threats was based on RAPPAM methodology (Ervin, 2003c). Threats included both legal and illegal activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity targets (Salafsky et al., 2008). Examples of threats considered in the PA assessment included logging, mining, agriculture, hunting, non-timber forest products (NTFP) collection, recreation and invasive alien species. A list of potential threats was available for managers and they could also include any additional threat that was not previously identified. The definition of most threats followed the standard classification developed by the Conservation Measures Partnership (Salafsky et al., 2008). However, some definitions were not standardized to better express local specificities of some threats.

Each threat was analyzed based on four criteria: trend, extent, impact and permanence (adapted from Ervin, 2003c). Trends evaluated the development of the threat in the last five years, or its probability of occurrence in the following five years. Extent related to the area impacted by the activity relatively to PA total area. Impact referred to the degree to which the pressure affects, either directly or indirectly, overall PA resources. Permanence refers to the length of time necessary to the recovery of an affected PA resource with or without human intervention. For each of these criteria, five different scenarios were scored from one (the best, ideal situation) to five (the worst scenario) according to the characteristics and dynamics of each threat (Table 3).

Data collection

Data collection procedures involved field trips to interview PA managers and staff and to analyze background information (management plans, articles, satellite images and others) in order to confirm and detail the obtained data. Field trips took place from April to October of 2007, and each trip lasted from three to five days depending on the size and accessibility of the area.

Questionnaires were answered by PA staff, which varied from two (in AFNM) to fourteen people (in CSP). Respondents in each PA had to consensually choose one alternative for each indicator that best represented PA reality. In the case when the available alternatives did not represent PA reality, the representatives could describe the current and the 'optimum' scenario of the PA and suggest new descriptors that would be then integrated to the assessment questionnaire.

Analyses

Management effectiveness was determined by integrating and comparing the results of the questionnaires. The sum of the highest possible scores for each indicator (value 4) resulted in a value defined as 'optimum total', which corresponded to 100% of the possible value to be achieved in the best overall scenario. The sum of scores obtained from the analysis of the current situation for each indicator resulted in a value defined as 'achieved total'. A proportional comparison between these two sums generated a percentage value that was then correlated to an evaluation scale, which defined the level of management effectiveness (Faria, 2004; Leverington et al., 2008a). The same procedure was used to evaluate the performance of PAs for each management element, and their combined result for each indicator.

Management effectiveness results were classified based on the scale proposed by Faria (2004), where values over 85% corresponded to an excellent standard of management; values between 70 and 84,99% to a superior standard; values between 55 and 69,99% to an intermediate standard; values between 41 and 54,99% to a low standard; and, values below 40% corresponded to a very low standard of management effectiveness. Tocantins results were compared to general results obtained for 246 federal PAs from Brazil (IBAMA & WWF-Brasil, 2007) and to a compilation of assessments performed by IUCN, including 2322 areas in Africa, Asia, Europe, Latin America and Oceania (Leverington et al., 2008b).

A multiple regression analysis (stepwise forward selection, Quinn & Keough, 2002) was applied to select which indicators would best explain the results obtained for management effectiveness. A cluster analysis of the results in each PA was performed to compare management patterns, using WPGMA as the grouping algorithm and Bray-Curtis index as a measure of similarity, in the software MVSP 3.2 (Kovach, 2000). The intensity of each threat was calculated by the average sum of its scores in the four assessed criteria (trend, extent, impact and permanence) for all PAs, and compared to the highest score possible. The same procedure was adopted to calculate the degree of threat for each PA.

3. Results

Management effectiveness

In average, Tocantins PAs showed low standard of management effectiveness (52,5%, Figure 2). Most of the areas presented values below 55% (low standard), except from CSP and JSP, which achieved intermediate levels of effectiveness. Detailed scores for each PA are summarized on Table 2. NPNP had the best performance in the Context element, followed by SGTES, JSP and CSP (Figure

3). AFNM and ANP compromised the system performance in this element, with much lower values (Figure 3). Scores from the Planning element also varied among the areas, with higher values associated to AFNM, ANP and CSP, and a much more critical situation in LSP and NPNP (Figure 4). Most of the PAs showed intermediate values of Inputs, which achieved the best average value among the different elements of management effectiveness (Figure 5). As for other elements, CSP had the best scores for Processes, followed by JSP and AFNM (Figure 6), while LSP had the worst performance concerning this element. Finally, the average scores for Outputs were the lowest among the other elements, with all PAs, except CSP and NPNP, showing a very low performance (Figure 7). Planning and Outputs scores were similar to the observed for Brazilian federal PAs, while Inputs and Processes were higher even when compared globally (Table 4). Management effectiveness average values were similar to results from Latin America and PAs worldwide, but higher than those of other Brazilian PAs, even when compared only with strict preservation areas (Table 4).

In a system-wide evaluation, some indicators showed much better results than others (Figure 8), including: connection and integrity (Context); planning tools and legal protection (Planning); biophysical, cartographic and legal information, manager and staff skills, budget regularity and internal communication (Inputs). There were no indicators of Processes or Outputs among the highly scored (above 65%). The lowest results (indicators with average values under 40%) were related to resource exploitation, threats, buffer zone use and presence of residents in Context; planning of recreational activities, boundary demarcation and zoning in Planning; number of staff, fund raising capacity, internal organization and infrastructure in Inputs; enforcement in Processes; and, implementation of management plan, compatibility of the land use and development of environmental education and recreational program in Outputs.

The stepwise regression analysis indicated that the compatibility of land use inside PA with their goals was the best predictor of management effectiveness ($F=8.516$, $r^2=0.63$, $p<0.05$), followed by implementation of the management plan ($F=33.66$, $r^2=0.94$, $p<0.01$) and, in a lesser extent, management plan existence and adequacy ($F=298.4$, $r^2=0.99$, $p<0.01$), and fundraising capacity ($F=8190$, $r^2=0.99$, $p<0.01$). A cluster analysis indicated higher similarities in management effectiveness between NPNP and SGTES, followed by a second group composed by JSP and CSP. AFNM, LSP and ANP showed gradually lower similarity values when compared to these initial groups (Figure 9).

Threats

In general, intensity of threats was high (above 50%) and did not vary significantly among PAs. The highest intensity of threats was observed in ANP, which also had the maximum number of perceived threats. LSP and NPNP presented the lowest intensities, while AFNM had the minimum number of threats among surveyed PAs (Figure 10). Detailed are available in Table 5.

Hunting, fire, livestock ranching and infrastructure showed high intensity of threat (trends, extent, impact and permanence) and also, high frequency of occurrence among PAs, indicating these threats as the most significant for the system. Even though human settlements, fishing and fossil collection also showed high levels of intensity, they only occurred in a small subset of PAs. On the other hand, agriculture and recreational activities were reported in most areas, but with lower values of trends, extent, impact and permanence (Figure 11).

4. Discussion

In summary, management effectiveness results suggests that even though PAs in Tocantins State showed a relatively strong performance concerning Inputs, some globalized common weaknesses such as reduced staff, infrastructure inadequacy and lack of internal organization, combined with several human-related issues on PA Context, including threats coming from human settlements and unsustainable resource use within and around PAs, have contributed to low scores on Outputs and management effectiveness levels. However, it is worth noting that Tocantins is not an exception and the scores obtained were similar or sometimes even better than those observed in other Brazilian states and developing countries (IBAMA & WWF-Brasil, 2007; Leverington et al., 2008b).

Among the indicators that best explained management effectiveness patterns were three major weaknesses of the system: compatibility of land use with PA goals, implementation of the management plan and fundraising capacity. Efforts to improve the status of these indicators would significantly contribute to overall management effectiveness. The best performance observed in CSP, a common trend found to other ARPA-supported PAs, reinforces the importance of long-term and system-wide strategies to support the establishment and consolidation of PAs, defining minimum standards that all areas of the system should achieve in a stepwise and more homogeneous procedure (Martin & Rieger, 2003; Leverington et al., 2008b).

The highest performance observed at the block of PAs from the Jalapão region (JSP, NPNP, SGTES) on Context was already expected, since this region represents the largest contiguous array of conserved areas in the entire Cerrado region (Klink & Machado, 2005), and one of the largest extensions of Cerrado remnants in Brazil, with over three million hectares of well conserved natural savanna vegetation mosaics.

Although ANP is considered a priority area for biodiversity conservation (MMA, 2007), the history of this park may account for its worst performance on management effectiveness, and in the elements Context, Inputs and Outputs. This park was established in 1959, covering all Bananal Island with over two million hectares. It had gradually suffered reductions in its size until it reached its present area of around 550,000 hectares. Currently, the park is subjected to an integrated regime of administration and is completely overlapped with two indigenous lands (Ricardo, 2004). This situation hampers the development of several conservation programs and activities, which directly impacts its management, as it is observed by its poor performance on management effectiveness indicators and high intensities of threats.

Overall, the existence and implementation of a management plan directly contributed to management effectiveness. PAs with adequate management plans (CSP, JSP, ANP, AFNM) showed better scores on the Planning and Processes elements. Management planning was also highly correlated with PA effectiveness worldwide (Leverington et al., 2008b). In a study performed with more than 600 PAs in Australia, having a draft or approved management plan was significantly associated to better management performance in areas of planning, information availability, community consultation, monitoring and management of PA threats (Hockings et al., 2009).

The top four threats with relative intensity values over 60% - infrastructure, fire, hunting and livestock ranching – were also present in more than five of the seven PAs surveyed. Infrastructure threats were mainly associated to the construction of local roads or predicted hydroelectric dams, and even though such threats tend to be restricted to a small portion of the area, they often cause severe and permanent impacts to PA natural resources. Extensive, low density livestock ranching for local consumption occurs in SGTES and LSP, but it tends to be a much higher threat to ANP, AFNM and NPMP, where it causes soil compaction and erosion. AFNM, for example, is located in the most important dairy production region of the state, while in ANP, livestock ranching used to be one of the core reasons for conflicts, since indigenous groups rented large portions of their territory to cattle ranchers (Ricardo, 2004).

Fire is widely used to clear land and to encourage pasture regrowth, besides its current use mainly in the Jalapão region to stimulate scape production (i.e., flowering) of *Syngonanthus nitens*, an important source of income through handicraft making for local communities in this region (Schmidt et al., 2007). Fire is considered one of the major problems that Brazilian reserves face today, especially in the Cerrado (Ramos-Neto & Pivello, 2000). Although most of Cerrado ecosystems are fire-adapted and must burn on a regular basis, uncontrolled fires during the dry season can cause severe damage including changes in floral composition, soil impoverishment, depletion of water sources and reduction of populations of some animal species (Klink & Machado, 2005). Significant

amounts of human and financial resources are applied to control burnings every year, but a systematic and integrated plan for fire management, including the design and maintenance of firebreaks, monitoring of burning regimes, and community outreach could be much more effective to reduce negative impacts of fires on PAs biodiversity and natural resources (Ramos-Neto & Pivello, 2000).

Hunting is still a common practice in most global and Brazilian PAs (Cullen Jr. et al., 2000; Leverington et al., 2008b). Although hunting may be a source of food for some families in Tocantins PAs, in most cases, it represents a cultural habit. Even small-scale subsistence hunting can result in significant population declines in several species (Peres, 1990, 2000; FitzGibbon et al., 1995). Deer (*Mazama americana* and *Ozotocerus bezoarticus*), tapirs (*Tapirus terrestris*), wild pigs (*Tayassu pecari* and *Pecari tajacu*) and armadillos (*Dasypus*, *Euphractus* and *Cabassous* spp) are the main targets, and it is believed that their populations are now severely depleted by decades of hunting in some of these areas (Tocantins, 2003).

Fire, livestock ranching and infrastructure are also major drivers of habitat loss and degradation in other PAs in the Cerrado (Klink & Machado, 2005), in Brazil (IBAMA & WWF-Brasil, 2007) and worldwide (Leverington et al., 2008b). The widespread incidence of these threats indicates their systemic pattern, which is suggested to reflect consistent underlying causes rather than the idiosyncratic result of the management of particular PAs (Ervin, 2003b). Therefore, the prevention and reduction of these threats and their consequent impacts will only be addressed by systemic policy reform, substantial resource allocation and large-scaled decisions, and not as a result of local and isolated actions.

It is worth noting that some threats, such as invasive alien species and large-scale agriculture, which are clearly major problems across the entire Cerrado (Klink & Machado, 2005), were not so important in Tocantins PAs. This may be related to the integrity of these areas, and also because Tocantins still harbours large natural areas under low human densities, remaining among the top three Brazilian states with lowest levels of Cerrado habitat loss (MMA, 2011). However, cash-crop agriculture has already caused severe damage and habitat destruction in Cerrado areas in Bahia, Piauí and Maranhão in the immediate boundaries of eastern Tocantins State (Batistella & Valladares, 2009; MMA, 2011). These threats and their associated impacts may become increasingly important for Tocantins State in the following years, especially around SGTES, JSP and NPNP, as the areas of cash crop plantations will probably continue to expand to other flat terrains, including some portions of the Jalapão region. Moreover, even though Tocantins PAs show low levels of habitat destruction, the frequency of threats recorded in this study from hunting, livestock ranching, fishing, fire, infrastructure and settlements, among others, confirms the concern that some PAs that seem to be

maintaining their values may, in fact, be experiencing more subtle declines in their biodiversity features (Carrillo et al., 2000; Redford & Feinsinger, 2001; Peres & Palacios, 2007).

In a context of poor management, high threat intensities and high local dependence on natural resources, the involvement of local communities in PA conservation can provide options for more sustainable monitoring and protection (Ostrom & Nagendra, 2006). Therefore, a great effort should be directed to community involvement and participation in PA planning and management, environmental education and recreational programs, and to the promotion of income generation from sustainable activities developed around PAs (see Ferreira & Freire, 2009, Appendix 1, for detailed recommendations). Local residents from state-managed PAs in Tocantins mentioned that the improvement in people's awareness concerning biodiversity conservation, and the reduction in illegal activities such as fires and hunting were a positive influence from the establishment of PAs (Ferreira & Freire, 2009). Therefore, any strategy to reduce these impacts must include continuous outreach activities and should take advantage of the fact that local residents perceive the positive benefits resulting from PAs in reducing human impacts on biodiversity (Ferreira & Freire, 2009).

Threats to PAs require attention if their values are to be conserved (Leverington et al., 2008b). As in other regions, many of the threats identified in Tocantins PAs relate to conflicts between conservation and human welfare, and, as such, are extremely challenging to resolve. We suggest two strategies to mitigate the threats faced by Tocantins PA system which can be applied to other regions. The first is the local management of the most important threats to each PA, such as fishing in CSP and ANP, and fossils collection in AFNM. The second strategy (which can be pursued concurrently) is to address long-term systemic threats and their underlying causes (such as fire, infrastructure and cattle ranching) through approaches such as economic incentives (Ferraro & Kiss, 2002; Heinen, 1996), community conservation initiatives (Adams & Hulme, 2001; Ferreira & Freire, 2009), integrated land use planning, by mainstreaming biodiversity conservation into regional development initiatives (Beresford & Phillips, 2000; Newmark & Hough, 2000).

Finally, it is highly recommended the establishment of a continuous program to monitor PA management effectiveness and threats, in order to understand the impacts of decisions and strategies adopted in PA effectiveness and biodiversity conservation and to improve PA system planning and management over the years. Most PA systems still need to improve the application and use of planning, evaluation and management tools to deliver good and consistent management on the ground (Caro et al., 2009; Leverington et al., 2010). The concept of minimum management standards for PAs and the gradual implementation of those standards through a stepwise and less heterogeneous dynamic has been successfully applied by different initiatives such as Parks in Peril Program in Latin America and the Caribbean (Martin & Rieger, 2003), the Proarca in Central America

(Corrales, 2004) and the ARPA program in the Brazilian Amazon (MMA, 2010). Leverington et al (2008b) suggests that if these types of approaches are complemented by additional funding, regular evaluations and a concentrated effort towards improving the fundamentals, significant improvement in PA systems can be seen over time.

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Tables

Table 1 – Protected areas from Tocantins State evaluated in this study and respective level of administration, size (ha), year of establishment and IUCN category.

Legend for IUCN categories: Ia: strict nature reserve; II: national park; III: natural monument or feature

Protected area	Administration	Area (ha)	Establishment	IUCN
Araguaia National Park (ANP)	Federal	557,708	1959	II
Nascentes do Parnaíba National Park (NPNP)	Federal	733,162	2002	II
Cantão State Park (CSP)	State	88,928	1998	II
Jalapão State Park (JSP)	State	158,885	2001	II
Lajeado State Park (LSP)	State	12,664	2001	II
Serra Geral do Tocantins Ecological Station (SGTES)	Federal	716,306	2001	Ia
Árvores Fossilizadas do Tocantins Natural Monument (AFNM)	State	32,152	2000	III

Table 2 – Performance of Tocantins protected areas according to 54 indicators of management effectiveness adapted from Faria (2004).

(Legend: AFNM: Árvores Fossilizadas Natural Monument, CSP: Cantão State Park, JSP: Jalapão State Park, LSP: Lajeado State Park, ANP: Araguaia National Park, NPNP: Nascentes do Parnaíba National Park, SGTES: Serra Geral do Tocantins Ecological Station)

Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
1. CONTEXT								
1.1 Size								
PA has over 90% of the ideal area to protect conservation targets	4	x					x	x
PA has between 76 and 89% of the ideal area to protect conservation targets	3		x	x				
PA has between 51 and 75% of the ideal area to protect conservation targets	2							
PA has between 36 and 50% of the ideal area to protect conservation targets	1							
PA has less than 35% of the ideal area to protect conservation targets	0				x	x		
1.2 Shape								
Nearly circular, regular, full	4					x		x
Nearly circular or oval, regular, fragmented	3						x	
Crenate, regular, full	2	x	x	x				
Very irregular or linear, but continuous	1				x			
Very irregular or linear, and fragmented	0							
1.3 Connection								
PA is connected to other protected areas	4			x	x		x	x
2 to 5 km from other protected areas	3	x	x					
5 to 10 km from other protected areas	2							
10 to 25 km from other protected areas	1							
More than 25 km from other protected areas	0					x		
1.4 Integrity								
1 - 10% of the area was already converted in other land uses	4		x	x			x	x
11 - 15% of the area was already converted in other land uses	3					x		
16 - 20% of the area was already converted in other land uses	2							
21 - 30% of the area was already converted in other land uses	1				x			
Over 30% of the area was already converted in other land uses	0	x						
1.5 Headwaters protection								
More than 90% of PA headwaters are protected and well conserved	4			x			x	x
76 - 89% of PA headwaters are protected and well conserved	3				x			
51 - 76% of PA headwaters are protected and well conserved	2							
36 - 50% of PA headwaters are protected and well conserved	1		x			x		
Less than 35% of PA headwaters are protected and well conserved	0	x						

Table 2 (continued)

Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
1.6 Resource exploitation								
There is no resource exploitation inside the PA	4							
Sporadic resource exploitation in less than 10% of the PA	3							
Systematic resource exploitation in less than 10% or sporadic exploitation in 10 - 50% of the PA	2		x	x				x
Systematic resource exploitation in 11 - 30% or sporadic exploitation in more than 50% of the PA	1				x	x	x	
Systematic resource exploitation in more than 30% of the PA	0	x						
1.7 Threats								
There are no threats to PA	4							
PA is subjected to threats that cause few impacts	3		x					
PA is subjected to threats that cause severe impacts, but may be easily managed or avoided	2			x	x		x	
PA is subjected to threats that cause severe impacts, but may be restored in the long term	1	x						
PA is subjected to threats that cause severe, irreversible impacts	0					x		x
1.8 Buffer zone use								
Buffer zone land use is in accordance with PA goals and management	4							
Buffer zone land use does not compromise the achievement of PA goals and its management	3							
Buffer zone land use partially compromises the achievement of PA goals and its management	2	x	x	x	x		x	
Buffer zone land use will hamper PA management and activities in the mid term	1							x
Buffer zone land use has already hampered PA management and activities	0					x		
1.9 Establishment process								
PA boundaries definition and establishment process were based on technical studies and local community participation	4						x	
PA boundaries definition and establishment process were based on technical studies, but local community participation was not representative	3							
PA boundaries definition and establishment process were based on technical studies, but without local community participation	2	x	x		x			
Technical studies did not provide enough information for PA boundaries definition and establishment	1			x		x		x
There were not any kind of studies or community participation to define boundaries and establish PA	0							
1.10 Residents								
There are no residents inside PA and population density around it is low	4							
There are no residents inside PA and population density around it is high	3				x			
Low population density inside PA (isolated family groups)	2		x					
Median population density inside PA (isolated communities)	1			x		x		x
High population density inside PA (villages)	0	x					x	
2. PLANNING								
2.1 Planning tools								
All activities developed in the PA integrate specific plans that are coordinated by a major planning instrument	4		x	x		x		x
Some activities developed in the PA does not integrate specific plans, although the area has management plan and programs	3							
Activities and plans are defined in central meetings	2	x					x	
Planning mechanisms are old and demand review	1							
There are no planning mechanisms to guide PA management	0				x			

Table 2 (continued)

Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
2.2 Zoning								
Zoning system with specific rules is well known by PA staff	4							
PA has a zoning system, but PA staff does not know it properly	3							
Current zoning must be reviewed due to changes in PA	2	x	x	x		x		
Current zoning is not in accordance with PA context, and the staff does not know or follow it	1				x			
PA does not have a zoning system	0						x	x
2.3 Protection planning								
Program is complete, predicting all actions needed to achieve PA goals, and all activities have been normally executed	4		x					
Program is complete, main activities have been normally executed	3	x						x
Program is partially complete and needs specific inputs to reach expected performance	2			x		x	x	
Some related activities are developed, but there is not a program	1				x			
There is not a program or related activities being developed	0							
2.4 Administration planning								
Program is complete, predicting all actions needed to achieve PA goals, and all activities have been normally executed	4							
Program is complete, main activities have been normally executed	3	x	x	x				x
Program is partially complete and needs specific inputs to reach expected performance	2					x	x	
Some related activities are developed, but there is not a program	1				x			
There is not a program or related activities being developed	0							
2.5 Environmental education planning								
Program is complete, predicting all actions needed to achieve PA goals, and all activities have been normally executed	4							
Program is complete, main activities have been normally executed	3	x	x			x		
Program is partially complete and needs specific inputs to reach expected performance	2			x			x	x
Some related activities are developed, but there is not a program	1				x			
There is not a program or related activities being developed	0							
2.6 Recreational activities planning								
Program is complete, predicting all actions needed to achieve PA goals, and all activities have been normally executed	4							
Program is complete, main activities have been normally executed	3	x						
Program is partially complete and needs specific inputs to reach expected performance	2			x				x
Some related activities are developed, but there is not a program	1		x		x			
There is not a program or related activities being developed	0					x	x	
2.7 Research planning								
Program is complete, predicting all actions needed to achieve PA goals, and all activities have been normally executed	4			x				
Program is complete, main activities have been normally executed	3	x						
Program is partially complete and needs specific inputs to reach expected performance	2		x			x	x	x
Some related activities are developed, but there is not a program	1				x			
There is not a program or related activities being developed	0							
2.8 Legal protection								
PA was created through a proper legal instrument, that is up-to-date and follows management needs	4		x		x		x	x
PA was established through a proper legal instrument, that must be reviewed due to local or regional changes	3	x		x		x		
PA was established through a legal instrument of moderate leverage that secure its persistency, but needs to be reviewed	2							
PA was established through a very fragile legal instrument that does not secure its persistency	1							
PA does not have any legal apparatus	0							

Table 2 (continued)

Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
2.9 Land tenure								
Over 90% of the area is in the ownership of the manager agency	4				x	x		
76 - 89% of the area is in the ownership of the manager agency	3	x						
51 - 75% of the area is in the ownership of the manager agency	2							
36 - 50% of the area is in the ownership of the manager agency	1		x					
< 35% of the area is in the ownership of the manager agency	0			x			x	x
2.10 Boundary identification								
Over 90% of PA boundary is clearly identified by natural or artificial limits	4		x					
76 - 89% of PA boundary is clearly identified	3							
51 - 75% of PA boundary is clearly identified	2					x		
36 - 50% of PA boundary is clearly identified	1							
Less than 35% of PA boundary is clearly identified	0	x		x	x		x	x
3. INPUTS								
3.1 Biophysical information								
Up-to-date and available information	4		x	x		x		
Up-to-date, but not available information / Available information is out of date	3	x					x	
Unavailable and out of date information; studies are being developed to gather new data	2				x			x
Unavailable and out of date information; there are not studies being developed	1							
There is no biophysical information available	0							
Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
3.2 Cartographic information								
Up-to-date and available information	4		x		x	x		
Up-to-date, but not available information / Available information is out of date	3	x		x			x	
Unavailable and out of date information; studies are being developed to gather new data	2							x
Unavailable and out of date information; there are not studies being developed	1							
There is no cartographic information available	0							
3.3 Socioeconomic information								
Up-to-date and available information	4	x						
Up-to-date, but not available information / Available information is out of date	3		x	x	x			
Unavailable and out of date information; studies are being developed to gather new data	2						x	x
Unavailable and out of date information; there are not studies being developed	1					x		
There is no socioeconomic information available	0							
3.4 Legal information								
Up-to-date and available information	4	x	x	x	x	x	x	x
Up-to-date, but not available information / Available information is out of date	3							
Unavailable and out of date information; studies are being developed to gather new data	2							
Unavailable and out of date information; there are not studies being developed	1							
There is no information on this topic	0							
3.5 Manager skills								
Post graduate degree, high motivation and presence at PA	4		x			x	x	x
Graduate degree, high motivation and presence at PA	3	x		x				
Graduate degree, median motivation and presence at PA	2							
No graduate degree, median motivation and presence at PA	1				x			
No graduate degree, low motivation and presence at PA	0							

Table 2 (continued)

Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
3.6 Number of staff								
PA has over 90% of the ideal number of employees	4							
PA has 76 - 89% of the ideal number of employees	3		x		x			
PA has 51 - 75% of the ideal number of employees	2			x				x
PA has 36 - 50% of the ideal number of employees	1						x	
PA has less than 35% of the ideal number of employees	0	x				x		
3.7 Staff skills								
High level of education, training and experience	4			x			x	x
High level of education, median level of training and experience	3	x	x					
Median level of education, training and experience	2				x			
Low level of education, with median levels of training and experience	1					x		
Low level of education, training and experience	0							
3.8 Career plan								
There is a career plan to PA staff that encourages their permanence in the PA	4					x	x	
Career plan is not adequate and staff receives sporadic benefits	3							x
A career plan will be developed in the midterm, and staff receives sporadic benefits	2	x						
There is not a career plan, but staff receives sporadic benefits	1		x	x	x			
There is not a career plan or benefits to PA staff	0							
3.9 Capacity building								
There is a structured training program that is fully implemented	4							
There is a program, not fully implemented, but staff receives enough training related to PA management	3	x					x	x
There is not a program, but staff receives some training related to PA management	2		x	x	x			
There is a program, but local conditions do not allow its implementation and staff receives minimum training	1							
There is not a program or any training to PA staff	0					x		
3.10 Funds								
PA receives over 90% of the optimum budget	4						x	
PA receives 76 - 89% of the optimum budget	3		x		x			
PA receives 51 - 75% of the optimum budget	2							x
PA receives 36 - 50% of the optimum budget	1			x				
PA receives less than 35% of the optimum budget	0	x				x		
3.11 Budget regularity								
Budget is always received at pre-defined dates	4	x	x		x		x	
Budget is received at pre-defined dates, with few variations	3							
Budget is received at pre-defined dates, with predictable delays	2							x
Budget is mostly received at undefined dates, compromising PA management	1			x		x		
Budget is always received at undefined dates, compromising PA management	0							
3.12 Extra funding								
It is very fast and easy to cover unpredictable expenses	4		x					
It is easy to cover unpredictable expenses through an emergency fund	3				x			
Unpredictable expenses are covered with some difficulty and delay	2	x		x			x	x
Unpredictable expenses are covered with a lot of difficulty and delay	1					x		
There are not any mechanisms or funds to cover unpredictable expenses	0							

Table 2 (continued)

Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
3.13 Fund raising capacity								
PA has legal and administrative mechanisms to generate income and apply them in its management	4							
PA has legal and administrative mechanisms to generate income, but formal obstacles delay their destination to management	3							
PA has legal and administrative mechanisms to generate income, but formal obstacles preclude their destination to management	2				x	x		x
PA does not have legal mechanisms to generate income, although its administrative system is able to deal with it	1			x				
PA does not have legal and administrative mechanisms to generate and manage income	0	x	x				x	
3.14 Internal organization								
There is a clear internal organization that fulfils all management elements and provides autonomy in decision making	4							
There is a clear internal organization related to management that provides some autonomy in decision making	3		x	x				
There is an internal organization related to management, but there are some overlapping roles	2				x			
The internal organization is hardly adopted and does not fulfill management demands	1							
There is not an internal organization for PA staff roles	0	x				x	x	x
3.15 Internal communication								
There is a good level of communication between PA manager and staff that promotes general involvement in the area management	4	x	x	x			x	x
Communication between PA manager and staff is sufficient, although it still could be improved	3				x	x		
Communication between PA manager and staff is sporadic and occurs during routine activities, but satisfies PA needs	2							
Communication between PA manager and staff does not fulfil PA needs	1							
There is not communication between PA manager and staff, what impacts PA management	0							
3.16 Infrastructure								
Current infrastructure quality and quantity is completely adequate to PA needs	4							
Current infrastructure quantity is not adequate to PA needs, although its quality allows the development of most PA activities	3			x				
Current infrastructure quality and quantity are not adequate to PA needs and must be adapted	2		x					
PA lacks essential infrastructure to its management	1	x			x		x	x
PA does not have any infrastructure and there is not a suitable work space to develop management activities	0					x		
3.17 Equipments and supplies								
PA has all the necessary equipments and supplies, and they are well maintained	4							
PA has all the necessary equipments and supplies, but they are not well maintained	3		x					
PA has some equipments and supplies, but they are not enough to support management activities	2	x		x	x	x		x
PA has equipments, but not supplies (or vice-versa)	1						x	
PA does not have any equipment or supply to support management activities	0							

Table 2 (continued)

Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
3.18 Office location								
Local office is located inside or close to PA limits (less than 10km)	4	x	x	x	x			
Local office is located at 10 - 30km from PA	3							
Local office is located at 31 - 50km from PA	2							
Local office is located over 50km from PA, but there is a field station closer	1						x	
Local office is located over 50km from PA, and there is not a field station closer	0					x		x
4. PROCESSES								
4.1 Management plan adequacy								
PA management plan was developed or reviewed in the last five years and has been used to implement the area	4	x	x	x				
PA management plan is at a final stage of elaboration or is being reviewed	3					x		
PA management plan has not been reviewed in the last five years; there are basic studies for the management plan development; there are other planning mechanisms	2							
PA management plan has not been reviewed in the last ten years and it is not used to PA management	1				x		x	x
PA does not have a management plan	0							
4.2 Management plan elaboration team								
Interdisciplinary team with community participation	4		x			x		
Interdisciplinary team without community participation	3	x		x	x			
Small team with community participation	2							
Small team without community participation	1							
No team (only 1 or 2 analysts)	0						x	x
4.3 Local community involvement and support								
There are formal mechanisms of community participation, support to PA is strong, PA benefits to local communities are high	4	x						
There are no formal mechanisms of participation, but community leaders are involved with the PA, benefits to local communities are median	3		x					
There is a mutual support between community and PA staff, but not a clear involvement in management, benefits are median	2			x		x	x	x
There is no support from local communities, although they recognize PA importance, benefits are low	1							
There is not any form of relationship or support by local communities to PA and benefits are low or does not exist	0				x			
4.4 Relationship with other institutions								
Clear institutional roles, integration for problem solving, non-conflictive goals	4							
Clear institutional roles, information and resources exchange with other institutions	3							
Most institutions work in accordance but there are few conflictive goals	2	x	x	x		x	x	x
There is no interaction with any other institution	1				x			
Uncertain institutional roles, no interaction, conflictive goals	0							
4.5 Institutional support								
There is full support from the institution to PA staff	4						x	
There is enough support from the institution, even though some elements are lacking	3	x						
Institution is not able to provide stable support to PA management activities	2							x
There is not enough support and communication between the institution and PA staff	1		x	x	x	x		
There is not any form of support from the institution to PA	0							

Table 2 (continued)

Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
4.6 Research results								
Research results are available to the PA staff and are applied to its management	4		x	x				
Research results are partially available and applied to PA management	3							
Some research results are available and partially applied to PA management	2						x	x
Research results are available at central offices and are seldom applied to PA management	1				x	x		
Research results are not available or known by PA staff	0	x						
4.7 Monitoring and feedback								
There are efficient monitoring and feedback systems to guide PA planning and management	4							
There are enough monitoring and feedback systems to guide PA planning and management	3	x	x					
There are some monitoring and feedback systems that are not enough to guide PA planning and management	2			x		x	x	x
Monitoring and feedback systems are not organized or systematically applied on PA planning and management	1							
There are not any monitoring or feedback system to guide PA planning and management	0				x			
4.8 Enforcement								
PA rules and regulations are followed by all users and there are adequate efforts towards their enforcement	4							
PA rules and regulations are followed by most users and there are adequate efforts towards their enforcement	3							
PA rules and regulations are followed by some users even though there are adequate efforts towards their enforcement	2		x	x	x		x	x
PA rules and regulations are often followed by some users and there are not adequate efforts towards their enforcement	1					x		
PA rules and regulations are rarely followed by users and there are not adequate efforts towards their enforcement	0	x						
5. OUTPUTS								
5.2 Management plan implementation								
Over 90% of the management plan has already been implemented	4							
76 - 89% of the management plan has been implemented	3							
51 - 75% of the management plan has been implemented	2							
36 - 50% of the management plan has been implemented	1		x					
Less than 35% of the management plan has been implemented	0	x		x	x	x	x	x
5.2 Compatibility of land use inside PA								
Compatible uses, according to PA carrying capacity and under good management practice	4							
Compatible uses, according to PA carrying capacity and under fair management practice	3							
Compatible uses that are over PA carrying capacity / Incompatible uses that cause few impacts to PA natural resources	2		x	x			x	x
Incompatible uses that cause intermediate impacts to PA natural resources	1	x			x			
Incompatible uses that cause severe impacts to PA natural resources	0					x		
5.3 Protection program implementation								
Over 90% of the program has been implemented	4		x					
76 - 89% of the program has been implemented	3					x		x
51 - 75% of the program has been implemented	2						x	
36 - 50% of the program has been implemented	1				x			
Less than 35% of the program has been implemented	0	x		x				

Table 2 (continued)

Elements / Indicators	Score	AFNM	CSP	JSP	LSP	ANP	NPNP	SGTES
5.4 Administration program implementation								
Over 90% of the program has been implemented	4							
76 - 89% of the program has been implemented	3		x					x
51 - 75% of the program has been implemented	2			x	x	x	x	
36 - 50% of the program has been implemented	1							
Less than 35% of the program has been implemented	0	x						
5.5 Education program implementation								
Over 90% of the program has been implemented	4							
76 - 89% of the program has been implemented	3		x					
51 - 75% of the program has been implemented	2						x	x
36 - 50% of the program has been implemented	1	x				x		
Less than 35% of the program has been implemented	0			x	x			
5.6 Recreational program implementation								
Over 90% of the program has been implemented	4							
76 - 89% of the program has been implemented	3							
51 - 75% of the program has been implemented	2							
36 - 50% of the program has been implemented	1			x				
Less than 35% of the program has been implemented	0	x	x		x	x	x	x
5.7 Research program implementation								
Over 90% of the program has been implemented	4							
76 - 89% of the program has been implemented	3	x		x	x			
51 - 75% of the program has been implemented	2						x	
36 - 50% of the program has been implemented	1		x					x
Less than 35% of the program has been implemented	0					x		
5.8 Fire management								
Fire prevention and control activities are regular and have been able to reduce PA wildfires	4							
Fire prevention and control activities are regular, but have not been able to reduce PA wildfires	3	x	x		x		x	x
Only fire prevention activities are regular, and combat is sporadic	2							
Fire prevention and combat activities are sporadic and according to resources availability	1			x		x		
Fire prevention and combat activities are not developed in the PA	0							

Table 3 – Scores used in the evaluation of each criteria of threat in Tocantins PAs (adapted from Ervin, 2003c).

Trend	Extent	Impact	Permanence
(5) increased in the last five years	(5) throughout (>50%)	(5) severe	(5) permanent (>100 years)
(4) remained constant	(4) generalized (30 - 50%)	(4) high	(4) long term (20 - 100 years)
(3) decreased in the last five years	(3) widespread (15 - 30%)	(3) moderate	(3) medium term (5 - 20 years)
(2) high probability of occurrence in the next five years	(2) scattered (5-15%)	(2) mild	(2) short term (1 - 5 years)
(1) intermediate to low probability of occurrence in the next five years	(1) localized (<5%)	(1) low	(1) immediate (<1 year)

Table 4 – Comparative results of management effectiveness evaluations of PAs in Tocantins, Brazil, Latin America and worldwide.

Element	Tocantins	Brazil (strict PAs)*	Brazil*	Latin America**	Global**
Context	52%	66%	65%	--	--
Planning	52%	55%	56%	60%	64%
Inputs	51%	36%	32%	48%	50%
Processes	59%	46%	42%	49%	49%
Outputs	35%	39%	35%	54%	53%
Total	52%	43%	41%	52%	53%

* IBAMA & WWF-Brasil, 2007 ** Leverington et al., 2008b

Table 5 – Results of the threat assessment of protected areas in Tocantins State.

(Legend: AFNM: Árvores Fossilizadas Natural Monument, CSP: Cantão State Park, JSP: Jalapão State Park, LSP: Lajeado State Park, ANP: Araguaia National Park, NPNP: Nascentes do Parnaíba National Park, SGTES: Serra Geral do Tocantins Ecological Station)

Protected area	Threat	Trend	Extent	Impact	Permanence
SGTES	Hunting	5	3	4	4
	Agriculture	2	4	5	5
	Invasive alien species	4	1	4	3
	NTFP use	5	1	2	2
	Mining and quarrying	2	1	5	5
	Infrastructure	2	1	5	5
	Livestock ranching	5	3	3	3
	Fire	5	4	4	2
	Recreational activities	2	1	3	2
AFNM	Hunting	3	4	3	2
	Fossils collection	3	3	3	5
	Livestock ranching	3	4	3	3
	Fire	3	4	3	2
CSP	Human settlements	4	2	4	4
	Hunting	3	4	3	3
	Agriculture	4	1	2	3
	Infrastructure	4	1	3	1
	Fishing	5	4	5	3
	Fire	4	3	4	2
	Recreational activities	3	1	2	1
JSP	Human settlements	1	1	4	3
	Hunting	4	2	3	3
	Agriculture	4	1	2	3
	Logging and wood harvesting	4	1	2	3
	NTFP use	1	3	3	3
	Infrastructure	2	3	4	5
	Fire	4	3	4	3
	Recreational activities	5	1	3	2
LSP	Hunting	3	3	3	3
	Logging and wood harvesting	3	2	1	2
	Invasive alien species	4	2	3	4
	NTFP use	3	4	1	1
	Livestock ranching	3	4	4	2
	Recreational activities	5	3	3	1
ANP	Human settlements	5	2	3	4
	Hunting	5	3	3	4
	Agriculture	2	4	4	4
	Invasive alien species	5	2	4	5
	Infrastructure	2	5	5	5
	Livestock ranching	5	4	4	4
	Fishing	5	5	5	3
	Fire	4	5	3	3
	Recreational activities	5	3	3	2
NPNP	Hunting	4	3	3	4
	Agriculture	3	2	2	2
	Logging and wood harvesting	3	2	1	2
	Infrastructure	4	1	2	1
	Livestock ranching	4	3	3	2
	Fire	4	4	4	3
	Wildlife trade	3	1	3	3

Figures

Figure 1 – Location of Tocantins State strictly protected areas evaluated in this study.

(Legend: AFNM: Árvores Fossilizadas Natural Monument, CSP: Cantão State Park, JSP: Jalapão State Park, LSP: Lajeado State Park, ANP: Araguaia National Park, NPNP: Nascentes do Parnaíba National Park, SGTES: Serra Geral do Tocantins Ecological Station)

Figure 2 – Overall and average “management effectiveness” scores for protected areas in Tocantins State.

Figure 3 – Overall and average “context” scores for protected areas in Tocantins State.

Figure 4 - Overall and average “planning” scores for protected areas in Tocantins State.

Figure 5 - Overall and average “inputs” scores for protected areas in Tocantins State.

Figure 6 - Overall and average “processes” scores for protected areas in Tocantins State.

Figure 7 - Overall and average “outputs” scores for protected areas in Tocantins State.

Figure 8 – Combined performance of each indicator of management effectiveness for protected areas in Tocantins State. (Legend: CON: Context, PLAN: Planning, INP: Inputs, PRO: Processes and OUT: Outputs)

Figure 9 – Cluster analysis (WPGMA, Bray-Curtis index) for Tocantins PAs concerning management effectiveness. (Legend: AFNM: Árvores Fossilizadas Natural Monument, CSP: Cantão State Park, JSP: Jalapão State Park, LSP: Lajeado State Park, ANP: Araguaia National Park, NPNP: Nascentes do Parnaíba National Park, SGTES: Serra Geral do Tocantins Ecological Station)

Figure 10 – Relative intensity and number of threats in protected areas from Tocantins State.

(Legend: AFNM: Árvores Fossilizadas Natural Monument, CSP: Cantão State Park, JSP: Jalapão State Park, LSP: Lajeado State Park, ANP: Araguaia National Park, NPNP: Nascentes do Parnaíba National Park, SGTES: Serra Geral do Tocantins Ecological Station)

Figure 11 - Relative intensity and frequency of each threat in Tocantins State PAs.

Capítulo 2

Biodiversity, biogeography and conservation gaps in a critical region of the Cerrado hotspot

Parque Estadual do Cantão

Ferreira, M.N.; Nogueira, C.; Valdujo, P.H. Silvano, D.; Silveira, L.F.; Carmignotto, A.P.; Pivello, V.R. Manuscrito em preparação a ser submetido ao periódico *Diversity and Distributions*.

Biodiversity, biogeography and conservation gaps in a critical region of the Cerrado hotspot

Resumo

O estabelecimento de sistemas de áreas protegidas eficazes e representativos em regiões tropicais pouco conhecidas e com alta biodiversidade representa um grande desafio para a conservação, especialmente em áreas sujeitas à alta pressão antrópica e perda de habitats. A avaliação da representatividade do sistema de áreas protegidas no Estado do Tocantins foi realizada com base na distribuição de 109 espécies de vertebrados e plantas. Os objetivos principais foram selecionar e mapear a distribuição das espécies-alvo na área de estudo, investigar a existência de padrões biogeográficos significativos e não aleatórios na biota regional e realizar uma análise de lacunas dos alvos de conservação e elementos bióticos. Os resultados indicaram que as espécies selecionadas representam padrões biogeográficos claros existentes na biota do Tocantins. Lacunas significativas foram observadas tanto na proteção das espécies, quanto na representação dos elementos bióticos identificados. Evidencia-se a importância de se considerar padrões biogeográficos ao selecionar as espécies-alvo para o planejamento da conservação e incluir espécies de distribuição restrita, que são reconhecidamente vulneráveis à perda de habitat, além de importantes indicadores de processos históricos geradores da biodiversidade. Os resultados também mostraram que a escassez de dados biológicos não pode mais ser apontada como empecilho à aplicação de abordagens sistemáticas e objetivas para a definição de áreas prioritárias nas regiões onde são mais relevantes: regiões tropicais com elevada biodiversidade e sistemas de áreas protegidas incipientes.

Abstract

The establishment of a representative and effective system of protected areas in poorly studied, biologically diverse tropical areas poses a serious challenge to conservation, especially in regions suffering extensive human pressure and habitat loss. An assessment of the representativeness of the regional protected area system in the Brazilian state of Tocantins was performed based on the distribution of 109 species of vertebrates and plants. The major aims of the study are to select and map surrogates of biodiversity in the study area, to investigate the existence of significant, non-random biogeographical patterns in Tocantins, and to perform a gap analysis of conservation targets. Results indicated that selected species represent biogeographical patterns of Tocantins biota and that there are significant gaps in the protection of the species and biotic elements in the current PA system. It is suggested the importance of considering biogeographical patterns when selecting target species for conservation planning and including small range species that are both vulnerable to habitat loss and important surrogates of evolutionary

processes of speciation and diversification. Results also showed that the scarcity of detailed biodiversity data may no longer be accounted as an impediment to systematic approaches to the definition of priority areas in regions where they would be more relevant: tropical regions with high biodiversity levels and incipient reserve systems.

1. Introduction

The establishment of representative and effective protected area (PA) systems in poorly studied, biologically diverse tropical areas poses a serious challenge to conservation, especially in regions subjected to severe and extensive human pressure and habitat loss (Myers, 2003; Gaston & Rodrigues, 2003; Rodrigues et al., 2004). Conservation measures in such circumstances must be fast, and rely on limited, inaccessible or often insufficient knowledge. The successful definition of PA systems design requires reliable information about species distribution, which is not always readily available (Cabeza & Moilanen, 2001). Recent results show that data quality, as well as the choice of surrogates for biodiversity, could be critical for successful reserve design (Cabeza & Moilanen, 2001). Thus, maximizing the amount of high quality biological information, and integrating sound biological and biogeographical data into conservation planning in highly threatened tropical regions represent a major challenge to biodiversity science in the 21st century (Loyola & Lewinsohn, 2009).

The first step of an integrated strategy for developing a comprehensive and representative network of PAs should be the assessment of biodiversity patterns and conservation gaps of the current reserve system (Langhammer et al., 2007). Even though PAs are considered the single most important tool for addressing the global challenge of conserving biological diversity (Bruner et al., 2001; Balmford et al., 2002; Sinclair et al., 2002), numerous regional analyses over the last decade have revealed that the coverage of biodiversity in PAs is woefully inadequate (Pressey et al., 1996; Williams et al., 1996; Scott et al., 2001; Rodrigues et al., 2004). Furthermore, many PA systems are highly biased towards particular ecosystems, leaving other more important areas inadequately protected (Pressey, 1994; Margules & Sarkar, 2007). While it is likely that each individual PA has significant biological value, the overall biological value of current PA systems may be significantly overestimated by the hectares they occupy (Pressey & Cowling, 2001).

Despite data incompleteness, the most meaningful measure of the representativeness of current PA system is its representation of biodiversity, for which knowledge on species diversity and distribution is critical (Cabeza & Moilanen, 2001; Brooks et al., 2004a). However, PA systems have been seldom evaluated against significant biogeographical patterns (Whittaker et al., 2005; Carvalho et al., 2011). Moreover, lack of integrating current biodiversity knowledge into conservation strategies may lead to omission errors of serious consequences (Brooks et al., 2004b), especially in regions where conservation

actions are urgent, given recent alarming levels of habitat loss, such as in the Cerrado region, which lost 14,179 km² of natural habitats per year between 2002 and 2008 (MMA, 2011).

Despite its status of global conservation priority region (Myers et al., 2000), and alarming levels of habitat loss, conservation efforts in the Cerrado are still modest (Klink & Machado, 2005; Marris, 2005). PAs in the region cover less than 9% of the original Cerrado area, and this value is drastically reduced to less than 3% when considering only strictly PAs from IUCN categories I to III (MMA, 2011). Previous studies have indicated that the current reserve system fails to adequately protect Cerrado biodiversity, and thus needs to be urgently and significantly improved by careful selection and establishment of new PAs (Cavalcanti & Joly, 2002; Silva & Bates, 2002; Diniz-Filho et al., 2008). Most of the original vegetation cover in the Cerrado has already been irreversibly replaced by mechanized agriculture, pastures and urban areas, especially in its south-central portion (Cavalcante & Joly 2002; Klink & Machado, 2005), and agricultural expansion is now moving fast towards its northern, less occupied frontiers (Batistella & Valladares, 2009; MMA, 2011). The conservation of the Cerrado region critically depends on the establishment and long-term protection of areas in these expansion frontiers, harbouring the largest remnants of original Cerrado vegetation. Tocantins State, in the northern region of Brazil, harbours important Cerrado-Amazonia transition areas and some of the largest blocks of Cerrado remnants (Klink & Machado, 2005; MMA, 2011). However, the heterogeneity of the state, dominated by hydrographic basins with distinct characteristics and presenting a north-south ecological gradient between the Cerrado and the Amazon, implies the need for a complex system of PAs to preserve samples of all its biodiversity (Tocantins, 2008a).

Herein we provide an assessment of the representativeness of the regional PA systems in the Brazilian state of Tocantins, a critical, biologically diverse, poorly known and highly threatened portion of the Brazilian Cerrado. The first objective was to select and map biodiversity surrogates based on strong criteria, careful compilation of available data and expert-opinion review. Mapped surrogates were then used to investigate the existence of significant, non-random biogeographical patterns in Tocantins biota. Finally, a gap analysis of conservation targets was performed in order to evaluate the representativeness of the regional PA system in protecting known and mapped biogeographical and biodiversity patterns. This study aimed to provide not only an unavailable and timely baseline for site conservation action in a significant portion of a biodiversity hotspot, but also to provide guidelines for the integration of biodiversity and biogeographical data in order to solve similar problems in highly diverse, threatened and poorly studied regions throughout the world.

2. Methods

Study area

Tocantins State covers an area of 277,620 km² in the northern region of Brazil, congregating important Cerrado-Amazonia transition areas and some of the largest blocks of Cerrado remnants (Klink & Machado, 2005; MMA, 2011). Tocantins is characterized by a mosaic of different vegetation types, although widely dominated by the Cerrado domain (88% of the state area). Forested areas were originally abundant in the northern portion of the state, while the south is characterized by the presence of dry forests, the east is composed of Cerrado vegetation influenced by the contact with the Caatinga domain and elevated areas in the Serra Geral sandstone plateau, while lower areas, dominated by flooded savannas and extensive wetlands are dominant at the western portions drained by the Araguaia River (Tocantins, 2008a).

Currently, the state has 5.7% of its total area preserved as strictly PAs, and 9.1% in sustainable use PAs. Although these values may seem high when compared to other Brazilian states in the Cerrado region, the establishment of PAs in Tocantins lacked a systematic approach and was concentrated in two major areas: Jalapão and Araguaia regions. The State Program on Protected Areas defined 12 priority areas for the establishment of PAs, based on results from inventories developed between 2002 and 2007. It adopted some prioritization criteria, such as ecological singularity, threats, occurrence of rare, endemic or threatened species, integrity and extension of natural landscapes, and habitats heterogeneity (Tocantins, 2008b). However, a systematic conservation planning framework has never been adopted based on the assumption that adequate biological data was still unavailable (Olmos, 2007).

Even though recent assessments indicate that Tocantins harbours 73% of its original vegetation (MMA, 2011; Tocantins, 2008b), significant portions of forest ecosystems in the north of the state were already converted and the remaining Cerrado areas are subjected to intense pressure. Major drivers of habitat loss include cattle ranching and mechanized agriculture, which expanded significantly in the last decade. Soybean plantation area, for example, has increased three times between 2002 and 2006 (Tocantins, 2008a). Furthermore, no new strictly PA has been created in the state since 2002, while habitat loss accounted for over 1,2 million hectares between 2002 and 2008 (Tocantins, 2008b).

Target selection

Because data on the distribution of most species are limited, evaluating the efficiency of PA systems in conserving overall biodiversity requires the use of surrogates (henceforth referred as 'target species'). Therefore, the first step of this study consisted in compiling and revising a preliminary database of georeferenced point-locality records for potential target species of vertebrates, the best known taxonomic group of organisms (Brooks et al., 2001) and commonly used in systematic conservation planning (see Tognelli, 2005 and Loyola et al., 2007 for more examples). Target species were defined following global guidelines for site-conservation priority setting analyses (Key Biodiversity Areas, KBAs,

Eken et al., 2004): (i) threatened species (criterion 1 in Eken et al., 2004) according to the Brazilian national list (MMA, 2003) or the global redlist (IUCN, 2010); (ii) restricted range species (species with known ranges not exceeding 10,000 km², an adaptation of the 50,000 km² threshold proposed for birds and in previous regional studies – see Nogueira et al., 2010a and Giulietti et al., 2009); and (iii) wide species ranging outside the study area but restricted to specific portions of Tocantins State. A hierarchical classification of species from criteria (i) to (iii) was adopted when species were included in more than one criterion. The list of targets was continuously revised by experts in each taxonomic group, who decided on the inclusion, exclusion and correction of point-locality data, and on the composition of the final list of target species.

Locality data for each target was obtained based on literature, museum specimens and unpublished data gathered and critically evaluated by experts. Resulting maps were discussed with experts and records were complemented or revised based on their comments, in an iterative process until all point locality maps and range inferences were considered satisfactory for depicting known distribution of selected target species in the study area. Major data sources included: Machado et al. (2008) for threatened vertebrate species; Carmignotto (2004), Gregorin et al. (2011), and Carmignotto & Aires (2011) for mammals; Nogueira (2006), Dornas (2009) and Nogueira et al. (2010b) for reptiles; Nogueira et al. (2010a) and Lima & Caires (2011) for fishes; Pacheco & Olmos (2006), Dornas (2009), Pinheiro & Dornas (2009), and Rego et al. (2011) for birds; Valdujo et al. (2011) and Valdujo (2011) for amphibians. Reports from inventories developed for PAs management plans, as well as the identification of priority areas in Tocantins, were also an important source of biological data, especially for some species of birds and large mammals, for which recent field records show a high level of accuracy. We also included data points for species whose distributions spanned beyond Tocantins boundaries, because characteristics of these sites could help identifying suitable regions for species occurrence within the studied region. To complement vertebrate data and to add another well studied, data rich taxonomic group, we included as targets species restricted range vascular plant species found in Tocantins, based on data from Giulietti et al. (2009).

Species distribution maps

Species distribution models provide detailed predictions of distributions by relating presence or abundance of species to environmental predictors. This approach has been widely used in conservation research and planning during recent years (Elith et al., 2006). Species distribution modeling was applied to species known from at least 10 locality records (including localities outside the study area), in order to minimize effects of incomplete sampling on the definition of the range of target species. From the several methods available to predict species distributions, MAXENT algorithm was chosen since it combines ease of use with proven predictive ability, especially for presence-only data (Phillips et al., 2006; Elith & Leathwick, 2009).

Species distribution models in MAXENT were based on 30'' ($\sim 1\text{km}^2$) resolution environmental variables from the Worldclim project (Hijmans et al., 2005). We selected a subset of environmental layers including only variables that were not highly correlated ($r > 0.9$, as in Costa et al., 2010): altitude, annual precipitation, isothermality, maximum temperature of warmest month, mean diurnal range, mean temperature of warmest quarter, mean temperature of wettest quarter, minimum temperature of coldest month, precipitation of coldest quarter, precipitation of driest month, precipitation of warmest quarter, precipitation of wettest month, precipitation seasonality, temperature annual range, temperature seasonality.

MAXENT output models are presented as probability values for each grid cell ($\sim 1\text{km}^2$), ranging from zero to one. To transform these outputs into discrete presence-absence distributions, we defined thresholds based on a parameter (E), related to the amount of error associated with the presence localities dataset (see Peterson et al., 2007 for details). Since there could be georeferencing uncertainties associated to species records, even though they have been reviewed by experts, the E parameter was initially set at 10%. The lowest predicted value associated with any one of the observed presence records [i.e., lowest presence threshold 'LPT' (Pearson et al., 2007)] was determined and threshold was set at $\text{LPT} - E$ (i.e., from the distribution of predicted values associated with presence records, we eliminated the lowest 10% and set our threshold at the remaining lowest value). After experts review, species ranges were adjusted by reducing or increasing E value, in an iterative process of model fitting, evaluation and refinement that can significantly improve prediction quality (Graham & Hijmans, 2006; Elith & Leathwick, 2009).

For restricted range species (all with less than 10 locality records) ranges were defined by the intersection of locality points and small-scale catchment areas, defined as 6th order Ottobasins (ANA, 2006), resulting in small polygons with total coverage of less than $10,000\text{ km}^2$. Microbasins were chosen since they provide a unique possibility for integrating freshwater and terrestrial species data and habitats in ecologically and biogeographically sound conservation initiatives (Nogueira et al., 2010a). They provide better understanding of the distribution of riparian and aquatic species (associated with wetlands, floodplains, riparian or gallery forests), and also of species that occur in interfluvies (high altitude grasslands, rocky fields, upland forests or grasslands), for which they might represent potential barriers to dispersal (Kasecker et al., 2009; Nogueira et al., 2010a). They are easily delimited, and have been widely used as planning units for different purposes and more recently, for the delimitation of important areas for species conservation (Santos, 2004; Kasecker et al., 2009).

Biogeographical patterns

The existence of non-random biogeographical patterns on the distribution of selected target species was tested using biotic elements analysis (Hausdorf, 2002; Hausdorf & Hennig, 2003), based on a matrix of

species presence-absence in 116 30' degree grid cells covering the entire study area. Biotic elements are defined as groups of species whose ranges are significantly more similar to each other than to those taxa of other groups (Hausdorf & Hennig, 2003; Carvalho et al., 2011). It is based on a central prediction of the vicariance model of diversification: the division of ancestral biotas by vicariant processes should produce regionalized groups of taxa (biotic elements) sharing significantly clustered and overlapping ranges (Hausdorf, 2002; Hausdorf & Hennig, 2003). It is assumed that these groups may share a common biogeographic history and also similar ecological traits (Morrone, 2001; Hausdorf, 2002). Moreover, these groups of significantly co-occurring taxa are interpreted as useful surrogates of elusive and complex patterns of speciation and biological diversification, thus providing critical and otherwise unavailable information for the protection and persistence of evolutionary processes (Carvalho et al., 2011).

Biotic element analysis was implemented in *prabclus* (Hausdorf & Hennig, 2003), an add on package for the statistical software R (available at <http://cran.r-project.org>). To test if there was a significant non-random clustering of species ranges, the *Kulczynski* distance between each pair of species was calculated and compared to the distances provided by 1000 simulations under a null model. The comparison is done using the T statistics, which is the ration between the 25% smallest and the 25% largest *Kulczynski* distance. The T value is expected to be smaller for clustered ranges than homogeneous distributed data. When the T statistics is significant, clusters of species ranges can be defined with model-based Gaussian clustering, implemented in the software *mclust*, as proposed in Hausdorf & Hennig (2003). This model considers species whose ranges cannot be assigned to any biotic element as the noise component. As suggested in Hausdorf & Hennig (2003) we used constant $k = \text{number of species}/40$, rounded up to integers for detecting noise component. A non-metric multidimensional scaling was performed on the matrix of *Kulczynski* distances and four MDS dimensions to define the clusters and the noise component.

Gap analysis

Gap analysis was performed to assess species coverage in the existing PA network, and to determine which elements were not well represented in Tocantins PAs system. Representation targets were defined for each species as the percentage of their original range (not considering habitat loss) that should be protected. Three main thresholds were adopted for calculating representation targets: species with ranges smaller than 500,000 ha (which included all restricted range species) should have at least 50% of its original range covered; species with ranges between 500,000 and 5 million ha should have at least 20% coverage, and species with ranges larger than 5 million ha should have at least 10% coverage. An additional target from zero to 20% was defined based on the percentage of habitat loss divided by five, with maximum additional targets (20%) applied to hypothetical cases of total loss of original habitat. Habitat loss was evaluated by estimating the amount of converted areas in each species distribution based on the Brazilian

deforestation map from 2008 (IBAMA, 2008). The final target in area was calculated by multiplying the final representation target by the species original distribution area.

The remaining area of each species' range (original ranges excluding areas of habitat loss) was overlapped with strictly PAs to identify covered and gap species. Species whose representation target was met by remaining areas inside the existing PA network were considered 'covered'; species whose remaining area partially overlapped PAs but still needed additional areas to meet their targets were considered 'partial gaps'; species whose remaining range overlapped no PAs were considered 'gap species' (as in Rodrigues et al., 2004). All procedures that involved area overlapping and calculations were performed using the Geographic Information System (GIS) software ArcView (ESRI 2000).

In order to test if there were any features more represented in PAs than others, we compared the percentage of protection (based on the PA coverage of species original range) and habitat loss of species in each of the following groups: biotic element, criteria of selection and taxonomic group. The existence of significant differences among each group was tested using a Kruskal-Wallis analysis, in the statistical software *R* version 2.12.1. Finally, we evaluated the contribution of PA creation per year based on the reduction of the total gap (in area) provided by the establishment of Tocantins PAs.

3. Results

Target selection and species distribution modelling

An initial set of more than 150 species was narrowed down to the final list of 109 taxa (Table 1), based on adequacy to the selection criteria and availability and reliability of range inferences. In total, 2523 records were compiled for the final 109 target species, representing areas inside and outside Tocantins State. Lack of data (and consequently poor modelling outputs) was responsible for the exclusion of some threatened species known to occur in Tocantins, but whose regional distribution patterns remain largely uncertain (e. g. *Speothos venaticus*, *Leopardus tigrinus* and *Leopardus wiedii*). The final species target list included 23 species of vascular plants, 23 fishes, 11 amphibians, 16 reptiles, 16 birds and 20 mammals (Table 1). Thirty-three of these species were chosen due to their threat status (criterion 1), fifty-three were restricted range species (criterion 2), and 23 species were restricted to specific portions of the state (criterion 3). Sixty-three species with less than 10 locality records were not subjected to species distribution modelling. The distribution of the remaining 46 species was modelled (Table 1). Final maps with the inferred distribution of each species are offered as supplementary material.

Biogeographical patterns

The result of biotic element analysis on the distribution of the 109 target species in 116 grid cells corroborates the central prediction of the vicariant model of diversification. The T statistics was

significantly smaller than expected under the null model ($T = 0.3986$; $p < 0.001$), indicating that species ranges are significantly clustered, forming largely allopatric, regionalized biotas. Model-based Gaussian clustering detected six major biotic elements (Figure 1), formed by 44 species belonging to significant clusters of species ranges (Table 2): five of these elements are completely allopatric, and are restricted to different portions of the study region (Figure 2), including southern plateaus & Paranã valley (biotic element 1, 11 species); Araguaia valley (biotic element 2, eight species); Peixe region (biotic element 3, eight species); Jalapão and Serra Geral region (biotic element 4, seven species); and Tocantins River (biotic element 5, five species). The sixth biotic element is composed of five widespread species with largely overlapping ranges throughout the Cerrado region in Tocantins, adding little information to regional distribution patterns. Among the 44 species that composed these clusters, eleven were threatened (four of which were also restricted-range species), 29 were restricted-range and 4 were restricted to some portions of the state, even though they have wide ranges beyond Tocantins. Sixty-five species were not related to any specific cluster and, thus, were included in the noise component.

Gap analysis

Twenty species (18% of total) were considered covered, i. e., had their representation target met inside the current network of strictly PAs (Table 3). Partial gaps accounted for 35 species (32%), and 54 species (50%) showed no overlap with PAs. Levels of protection (Kruskal-Wallis test; $X^2 = 30,44$; d.f. = 5; $p < 0,001$) and levels of habitat loss (Kruskal-Wallis test; $X^2 = 35,31$; d.f. = 5; $p < 0,001$) were significantly different among species in each of the six biotic elements. PAs were mainly concentrated in Araguaia and Jalapão biotic elements, while three biotic elements (Paraná valley, Peixe and Tocantins River, Figure 2) were completely unprotected and showed higher levels of habitat loss (Table 4). Levels of protection were also significantly different among different groups of targets (Kruskal-Wallis test; $X^2 = 13,19$; d.f. = 2; $p = 0,001$). However, these levels have not differed among different taxonomic groups (Kruskal-Wallis test; $X^2 = 2,95$; d.f. = 4; $p = 0,5669$), as well as the levels of habitat loss among taxonomic groups (Kruskal-Wallis test; $X^2 = 3,94$; d.f. = 4; $p = 0,4142$) and target types (Kruskal-Wallis test; $X^2 = 0,68$; d.f. = 2; $p = 0,7113$).

Major reductions in the total representation gap (sum of all species gap area to meet targets) were achieved with the creation of Araguaia National Park, in 1959, and the establishment of Lajeado State Park, Jalapão State Park and Serra Geral do Tocantins Ecological Station, in 2001 (Figure 3). The contribution of Nascentes do Parnaíba National Park area inside Tocantins State has not significantly changed the scenario concerning the representation of conservation targets.

4. Discussion

One of the major criticisms to the application of species data for conservation analyses is the widely acknowledged gaps on taxonomic and species distribution information (Margules & Pressey, 2000; Cabeza & Moilanen, 2001; Whittaker et al., 2005). Our results, however, show that careful data compilation, driven by taxonomic experts, followed by adequate analyses using current techniques to infer about original ranges and biogeographical patterns, can provide useful guidance to regional and site-scale conservation strategies, even in data-poor regions. Although a portion of the available data in Tocantins and in the entire Cerrado resulted from major events of habitat loss from recent infrastructure developments (see Nogueira et al., 2010a), especially in areas impacted by hydroelectric dams along the Tocantins River, many other inventories (e. g. Vitt et al., 2002; Carmignotto, 2004; Olmos, 2007; Pinheiro & Dornas, 2009) took place in a targeted fashion, in previously poorly studied sites, providing a critical contribution to the database analyzed herein. Since 1988, 340 new vertebrate species were described from Cerrado localities, many of which were collected in the less known regions of the domain, as in the northern portions of Piauí, Tocantins, Maranhão and Bahia (Machado et al., 2008). Therefore, lack of data (the default conclusion on Cerrado biodiversity descriptions) should no longer be considered a real impediment to properly describe regional biogeographical patterns and their underlying conservation values, even in relatively data poor regions such as the Brazilian Cerrado (see Bini et al., 2006; Costa et al., 2007).

Despite being located mostly within a single large ecoregion (see Olson et al., 2001), results clearly indicate that Cerrado areas in Tocantins are far from being homogeneous in biodiversity and biogeographical patterns. Biotic elements seemed to follow to geomorphological variation and interactions with other domains, as a possible response to historical landscape evolution (see Machado et al., 2008). The riverine forests of the Araguaia and Tocantins valleys represent lowlands with higher influence of the Amazon region, both in environmental conditions and evolutionary processes (see Valdujo, 2011 for the Amazon influences on amphibian fauna). In the other hand, the seasonally dry forests of the Paranã River valley, between plateaus of the Serra Geral and the Planalto Central, represent enclaves of forested areas developed over fertile soils, where several restricted range species were already indentified, such as the parakeet *Pyrrhura pfrimeri* and the rodent *Kerodon acrobata*. The dryer cerrados of the Jalapão region are located at arenitic plateaus of the Serra Geral, which are recently revealing many local endemic species (for example, *Ouratea acicularis*, *Anops acrobeles* and *Cnemidophorus mumbuca*), probably associated to the complex topography of the plateau and upper portions of the Tocantins drainage.

Biogeographical patterns found for Tocantins were also highlighted in previous studies for the whole Cerrado region. The Araguaia and Paranã River valleys, for example, were two of the three areas of Cerrado avian endemism (Silva & Bates, 2002). The Araguaia and other areas, such as the Jalapão and Serra

Geral regions and the Tocantins River valley, were identified as areas of reptile endemism (Nogueira et al., in press). Areas in the southern Tocantins and the western Bahia (an extension from the Serra Geral) were also highlighted as one of the eight plant biodiversity centres in the whole Cerrado (Ratter et al., 2003).

High concentration of PAs in two main regions (Araguaia and Jalapão) of the study area resulted in important conservation gaps. Half of target species and three entire biotic elements showed no representation in strictly PAs. This pattern follows a global trend of PAs concentration in sites with low development values, such as remote or unproductive areas, leaving some species, communities, or ecosystems unprotected (Pressey, 1994; Margules & Pressey, 2000; Yip et al., 2004). PAs in Araguaia and Jalapão cover significant portions of the distribution of endemic, small-range species, and also represent the largest remnants of natural areas for threatened species. However, if one of the major goals of Tocantins PA system is to adequately represent regional biodiversity patterns, the establishment of new areas is urgent and must address conservation gaps in the southern and northern portions of the state.

The significant reduction in total species gap mainly associated to the creation of Araguaia National Park, and the establishment of PAs in Jalapão region correspond to the two main large efforts for the overall protection of the Cerrado domain: the first between 1959 and 1961, during the government of the President Juscelino Kubitschek, in which more than 2.6 million ha of PAs were created (including the national parks of Araguaia, Emas, Brasília and Tocantins – former Chapada dos Veadeiros), and the second, in 2001 and 2002, with the establishment of areas in the north-eastern region of the Cerrado (Marinho-Filho et al., 2010).

Another key aspect of our results is the applicability of quantitative assessments of non-random distribution patterns for evaluating 1) the value of chosen target species as indicators of biogeographical patterns (and, as a result, their usefulness for inferring historical evolutionary processes, see Carvalho et al., 2011) and 2) the representativeness of current PA systems in preserving original biodiversity and biogeographical patterns. Thus, although species distribution data is a key component for conservation assessments, few studies actually test if these data are capturing non-random biogeographical patterns. This may stem from the lack of integration between biogeographical science and conservation biology (see Crisci, 2000; Whittaker et al. 2005).

Moreover, the lack of significant differences in habitat loss and PA coverage among taxonomic groups, contrasting to significant differences in biotic elements indicate that the debate on taxonomic surrogatability (see Margules & Pressey, 2000; Bertrand et al., 2006) should be complemented to assess if targets are adequately representing biogeographical variations, detected by significant, non-random patterns of species distributions. The question may not be whether all relevant taxonomic groups are included, but whether the included target species are good candidates for representing larger, biogeographical patterns and underlying diversification processes (Loyola & Lewinsohn, 2009).

Some indications of the importance of taking into consideration the biogeographical information to select species for conservation planning are becoming gradually consistent in the last years. Howard et al. (1998) stated that successful indicators of complementarity will share 'similar patterns of biogeography' with the group of species to be indicated. Networks of areas encompassing complementary biotas represent much more biodiversity than networks chosen on the basis of richness alone (Williams et al., 1996; Howard et al., 1998; Reyers et al., 2000; Justus & Sarkar, 2002). Thus, a search for indicator groups for species richness (Prendergast et al., 1993) has shifted towards a search for groups of species whose individual distributions complement one another, and which when taken together capture much of the biodiversity of the region (Manne & Williams, 2003; Tognelli, 2005; Loyola & Lewinsohn, 2009).

Our study thus corroborates the idea that the inclusion of endemic and restricted range species in conservation planning exercises is essential, since these species highlight areas of biological singularity, a central requirement for representative PA systems (Margules & Pressey, 2000; Manne & Williams, 2003; Eken et al. 2004). Species with small ranges tend to be rare, not only in terms of range size but also in terms of local abundance (Hanski, 1982; Brown, 1984; Gaston et al. 1997). Moreover, apart from being intrinsically susceptible to natural or anthropogenic disturbance (Whittaker et al., 2005), localized endemism is often poorly represented in prioritization schemes based on habitat classes or other coarse-scale biodiversity surrogates (Araújo et al., 2001; Brooks et al., 2004b). The lack of significant differences in habitat loss among threatened, restricted range and species related to specific portions of Tocantins State also indicate that restricted range species may be subjected to the same pressures related to habitat loss that impact species overall, with even more serious effects on these species due to their rarity, low densities and small ranges.

Biodiversity knowledge and PA coverage in Tocantins does not differ from the rest of the Cerrado domain and other Neotropical hotspots. Our results have shown that the scarcity of detailed biodiversity data may no longer be responsible for restricting the possibility of applying systematic approaches to the definition of priority areas in regions where they would be more relevant, such as poor tropical countries with high biodiversity levels and incipient reserve systems (Pimm, 2000; Gaston & Rodrigues, 2003). Moreover, our results indicate the importance of considering biogeographical patterns when selecting target species for conservation planning and including restricted range species that are vulnerable to habitat loss and important predictors of overall biodiversity distribution. We urge that similar efforts, combining biogeographical methods and conservation planning frameworks, should be directed to larger portions of the Cerrado region, and also to similarly poorly studied and highly threatened regions in the Neotropical region and worldwide. Conservation science depends on the optimal use of available biodiversity data, in the form of objective biogeographical synthesis. These studies, largely unavailable but

highly feasible, will be critical for steering action towards halting the loss of biodiversity patterns and processes.

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Tables

Table 1 – Species selected for analyzing biogeographical patterns and conservation gaps in Tocantins State, their status of threat according to the official Brazilian list (status, MMA) and IUCN list (status, IUCN), number of records compiled, species distribution modelling technique adopted (SDM) and criteria of inclusion (TH: threatened, RR: restricted range, MA: marginal species, restricted to specific portions of the state).

Species	Status (MMA)	Status (IUCN)	N. records	SDM	Target type
Plants					
<i>Aiouea macedoana</i> Vattimo	NE	VU	1	basin	TH
<i>Borreria burchelli</i> (K. Schum.) E.L. Cabral & Bacigalupo	NE	NE	1	basin	RR
<i>Borreria irwiniana</i> E.L. Cabral & Bacigalupo	NE	NE	1	basin	RR
<i>Borreria tocantinsiana</i> E.L. Cabral & Bacigalupo	NE	NE	1	basin	RR
<i>Diodia macrophylla</i> Bacigalupo, N.M. & E.L. Cabral.	NE	NE	1	basin	RR
<i>Diplusodon decussatus</i> Gardner	NE	NE	1	basin	RR
<i>Diplusodon gracilis</i> Koehne	EN	NE	1	basin	TH
<i>Diplusodon petiolatus</i> (Koehne) T.B.Cavalc.	NE	NE	1	basin	RR
<i>Diplusodon trigintus</i> T.B.Cavalc.	NE	NE	1	basin	RR
<i>Ditassa emmerichae</i> Fontella	NE	NE	1	basin	RR
<i>Duguetia rotundifolia</i> R.E.Fr.	NE	NE	1	basin	RR
<i>Gomphrena hillei</i> Suess	NE	NE	1	basin	RR
<i>Hyperia concinna</i> (Benth.) Harley	NE	NE	1	basin	RR
<i>Hyptis arenaria</i> Benth.	VU	NE	2	basin	TH
<i>Hyptis caduca</i> Epling	NE	NE	1	basin	RR
<i>Hyptis humilis</i> Benth.	NE	NE	3	basin	RR
<i>Lippia ciliata</i> Salimena	NE	NE	1	basin	RR
<i>Ouratea acicularis</i> R.G.Chacon & K.Yamam.	NE	NE	1	basin	RR
<i>Piriqueta araguaiana</i> Arbo	NE	NE	1	basin	RR
<i>Polygala pseudocoriacea</i> Chodat	NE	NE	1	basin	RR
<i>Staelia tocantinense</i> R.M. Salas & E.L. Cabral	NE	NE	1	basin	RR
<i>Tassadia rizoana</i> Fontella	NE	NE	1	basin	RR
<i>Turnera gardneriana</i> Arbo	NE	NE	1	basin	RR
Fish					
<i>Aguarunichthys tocantinsensis</i> Zuanon, Rapp Py-Daniel & Jégu, 1993	NE	NE	5	basin	MA
<i>Ammoglanis diaphanus</i> Costa 1994	NE	NE	1	basin	RR
<i>Brachyplatystoma filamentosum</i> (Lichtenstein, 1819)	NE	NE	1	basin	RR
<i>Crenicichla compressiceps</i> Ploeg 1986	NE	NE	1	basin	RR
<i>Hyphessobrycon gr. eques</i>	NE	NE	1	basin	RR
<i>Hyphessobrycon stegemanni</i> Géry 1961	NE	NE	2	basin	RR
<i>Maratecoara formosa</i> Costa & Brasil 1995	VU	NE	2	basin	TH
<i>Maratecoara lacortei</i> (Lazara 1991)	NE	NE	2	basin	RR
<i>Maratecoara splendida</i> Costa 2007	NE	NE	1	basin	RR
<i>Moenkhausia hysterostricta</i> Lucinda, Malabarba & Benine 2007	NE	NE	1	basin	RR
<i>Mylesinus paucisquamatus</i> (Jégu & dos Santos 1988)	VU	NE	20	maxent	TH
<i>Pituna compacta</i> (Myers 1927)	NE	NE	2	basin	RR
<i>Plesiolebias canabravensis</i> Costa & Nielsen 2007	NE	NE	1	basin	RR
<i>Plesiolebias filamentosus</i> Costa & Brasil 2007	NE	NE	1	basin	RR
<i>Plesiolebias fragilis</i> Costa 2007	NE	NE	1	basin	RR
<i>Plesiolebias lacerdai</i> Costa 1989	NE	NE	1	basin	RR
<i>Plesiolebias xavantei</i> (Costa, Lacerda and Tanizaki, 1988)	EN	NE	6	basin	TH
<i>Simpsonichthys costai</i> (Lazara 1991)	NE	NE	1	basin	RR
<i>Simpsonichthys flammeus</i> Costa 1989	EN	NE	2	basin	TH
<i>Simpsonichthys mutiradiatus</i> (Costa & Brasil 2004)	EN	NE	1	basin	TH
<i>Simpsonichthys semiocellatus</i> Costa & Nielsen 1997	NE	NE	2	basin	RR
<i>Trigonectes rubromarginatus</i> Costa 1990	NE	NE	1	basin	RR
<i>Trigonectes strigabundus</i> Myers 1925	NE	NE	1	basin	RR
Amphibians					
<i>Ameerega flavopicta</i> (A. Lutz 1925)	NE	LC	20	maxent	MA
<i>Bokermannohyla cf. pseudopseudis</i>	NE	LC	16	maxent	MA

Table 1 (continued)

Species	Status (MMA)	Status (IUCN)	N. records	SDM	Target type
<i>Dendropsophus leucophyllatus</i> (Beireis 1783)	NE	LC	15	maxent	MA
<i>Hypsiboas boans</i> (Linnaeus 1758)	NE	LC	23	maxent	MA
<i>Hypsiboas</i> sp.gr. <i>albopunctatus</i>	NE	NE	17	maxent	MA
<i>Ischnochnema</i> sp.	NE	NE	17	maxent	MA
<i>Leptodactylus sertanejo</i> Giaretta & Costa 2007	NE	LC	14	maxent	MA
<i>Pipa pipa</i> (Linnaeus 1758)	NE	LC	13	maxent	MA
<i>Pleurodema diplolister</i> (Peters 1870)	NE	LC	20	maxent	MA
<i>Pristimantis</i> sp.	NE	NE	34	maxent	MA
<i>Rhinella</i> gr. <i>margaritifera</i>	NE	LC	33	maxent	MA
Reptiles					
<i>Anops acrobeles</i> Ribeiro, Castro-Mello & Nogueira 2009	NE	NE	1	basin	RR
<i>Apostolepis longicaudata</i> Amaral 1921	NE	NE	2	basin	RR
<i>Apostolepis polylepis</i> (Amaral 1921)	NE	DD	2	basin	RR
<i>Bachia micromela</i> Rodrigues, Pavan & Curcio 2007	NE	NE	1	basin	RR
<i>Bachia oxyrhina</i> (Rodrigues et al. 2008)	NE	NE	4	basin	RR
<i>Bachia psamophila</i> Rodrigues, Pavan & Curcio 2007	NE	NE	1	basin	RR
<i>Bronia kraoh</i> Vanzolini 1971	NE	NE	3	basin	RR
<i>Bronia saxosa</i> (Castro-Mello 2003)	NE	NE	1	basin	RR
<i>Chelonoidis denticulata</i> (Linnaeus 1766)	NE	VU	80	maxent	TH
<i>Cnemidophorus jalapensis</i> Colli et al. 2009	NE	NE	3	basin	RR
<i>Cnemidophorus mumbuca</i> Colli et al. 2003	NE	NE	1	basin	RR
<i>Kentropyx</i> sp.	NE	NE	1	basin	RR
<i>Lachesis muta</i> (Linnaeus 1766)	NE	NE	45	maxent	MA
<i>Mabuya guaporicola</i> Dunn 1936	NE	NE	17	maxent	MA
<i>Mabuya heathi</i> Schmidt & Inger 1951	NE	NE	53	maxent	MA
<i>Phalotris labiomaculatus</i> Lema 2002	NE	NE	3	basin	RR
Birds					
<i>Alectrurus tricolor</i> Vielliot 1816	VU	VU	56	maxent	TH
<i>Anodorhynchus hyacinthynus</i> (Latham 1790)	VU	EN	60	maxent	TH
<i>Ara chloroptera</i> (Gray 1859)	NE	LC	19	maxent	MA
<i>Celeus obrieni</i> Short 1973	NE	CR	7	basin	TH
<i>Cercomacra ferdinandi</i> Snethlage 1928	VU	VU	54	maxent	TH
<i>Culicivora caudacuta</i> Vieillot 1818	VU	VU	93	maxent	TH
<i>Geositta poeciloptera</i> (Wied 1830)	VU	VU	76	maxent	TH
<i>Harpyhaliaetus coronatus</i> (Vieillot 1817)	VU	EN	165	maxent	TH
<i>Mergus octosetaceus</i> Vieillot 1817	CR	CR	86	maxent	TH
<i>Paroaria baeri</i> Hellmayr 1907	NE	LC	15	maxent	MA
<i>Penelope ochrogaster</i> Rafinesque 1815	VU	VU	95	maxent	TH
<i>Procnias averano averano</i> (Hermann 1783)	VU	LC	41	maxent	TH
<i>Pyrrhura pfrimeri</i> Miranda-Ribeiro 1920	VU	EN	23	maxent	TH
<i>Suiriri islerorum</i> Zimmer, Whitaker & Oren, 2001	NE	NT	15	maxent	TH
<i>Synallaxis simoni</i> Hellmayr 1907	VU	NE	11	maxent	TH
<i>Taoniscus nanus</i> (Temminck, 1815)	VU	VU	86	maxent	TH
Mammals					
<i>Blastocerus dichotomus</i> Illiger 1815	VU	VU	60	maxent	TH
<i>Calomys tocantins</i> Bonvicino, Lima & Almeida 2003	NE	LC	2	basin	RR
<i>Chrysocyon brachyurus</i> Illiger 1815	VU	NT	111	maxent	TH
<i>Kerodon acrobata</i> Moojen, Locks & Langguth, 1997	NE	DD	1	basin	RR
<i>Kerodon rupestris</i> (Wied, 1820)	NE	LC	33	maxent	MA
<i>Lonchophylla dekeyseri</i> Taddei et al. 1993	VU	NT	38	maxent	TH
<i>Makalata didelphoides</i> (Desmarest, 1817)	NE	LC	1	basin	RR
<i>Monodelphis kunsii</i> Pine 1975	DD	LC	32	maxent	MA
<i>Myrmecophaga tridactyla</i> Linnaeus 1758	VU	VU	183	maxent	TH
<i>Oligoryzomys moojeni</i> Weksler & Bonvicino, 2005	NE	DD	11	maxent	MA
<i>Oncifelis colocolo</i> (Molina 1782)	VU	NT	32	maxent	TH
<i>Panthera onca</i> Linnaeus 1758	VU	NT	128	maxent	TH

Table 1 (continued)

Species	Status (MMA)	Status (IUCN)	N. records	SDM	Target type
<i>Priodontes maximus</i> (Kerr 1792)	VU	VU	106	maxent	TH
<i>Pteronura brasiliensis</i> (Gmelin 1788)	VU	EN	144	maxent	TH
<i>Puma concolor</i> Linnaeus 1771	VU	LC	145	maxent	TH
<i>Rhipidomys nitela</i> Thomas 1901	NE	LC	1	basin	RR
<i>Thyroptera devivoi</i> Gregorin et al., 2006	NE	NE	1	basin	MA
<i>Tolypeutes tricinctus</i> (Linnaeus 1758)	VU	DD	42	maxent	TH
<i>Trichomys</i> sp.	NE	VU	17	maxent	MA
<i>Wiedomys pyrrhorhynchus</i> (Wied-Neuwied 1821)	NE	LC	10	maxent	MA

Table 2 – Species composition of each biotic element identified in the analysis of 109 taxa in Tocantins State.

Biotic element	Species
Biotic element 1 (Southern plateaus & Parana valley)	<i>Alectrurus tricolor</i> , <i>Borreria tocantinsiana</i> , <i>Diplusodon decussatus</i> , <i>Diplusodon gracilis</i> , <i>Diplusodon petiolatus</i> , <i>Duguetia rotundifolia</i> , <i>Hypernia concinna</i> , <i>Ischnochnema</i> sp., <i>Kerodon acrobata</i> , <i>Pyrrhura pfrimeri</i> , <i>Turnera gardneriana</i>
Biotic element 2 (Araguaia valley)	<i>Ammoglanis diaphanus</i> , <i>Maratecoara lacortei</i> , <i>Paroaria baeri</i> , <i>Plesiolebias lacerdai</i> , <i>Simpsonichthys costai</i> , <i>Simpsonichthys semiocellatus</i> , <i>Simpsonichthys flammeus</i> , <i>Trigonectes rubromarginatus</i>
Biotic element 3 (Peixe region)	<i>Aiouea macedoana</i> , <i>Diodia macrophylla</i> , <i>Ditassa emmerichae</i> , <i>Makalata didelphoides</i> , <i>Maratecoara splendida</i> , <i>Plesiolebias canabravensis</i> , <i>Polygola pseudocoriacea</i> , <i>Rhipidomys nittela</i>
Biotic element 4 (Jalapão and Serra Geral region)	<i>Anops acrobeles</i> , <i>Cnemidophorus mumbuca</i> , <i>Hyphessobrycon</i> gr. <i>eques</i> , <i>Kentropyx</i> sp., <i>Ouratea acicularis</i> , <i>Suiriri islerorum</i> , <i>Thyroptera devivoi</i>
Biotic element 5 (Tocantins river)	<i>Borreria irwiniana</i> , <i>Dendropsophus leucophyllatus</i> , <i>Hyptis caduca</i> , <i>Plesiolebias filamentosus</i> , <i>Tassadia rizzoana</i>
Biotic element 6 (General)	<i>Chrysocyon brachyurus</i> , <i>Myrmecophaga tridactyla</i> , <i>Oncifelis colocolo</i> , <i>Panthera onca</i> , <i>Priodontes maximus</i>

Table 3 – Results of the gap and biotic element analyses for the 109 species selected as conservation targets for Tocantins State.

Species	Original (ha)	Remaining (ha)	Habitat loss (ha)	Habitat loss (%)	Original protection (ha)	Current protection (ha)	Target (%)	Target (ha)	Classification	Biotic Element
Plants										
<i>Aiouea macedoana</i>	128,566	71,040	57,526	44.7	0	0	58.9	75,788	Gap	3
<i>Borreria burchellii</i>	137,288	68,432	68,855	50.2	0	0	60.0	82,415	Gap	5
<i>Borreria irwiniana</i>	72,237	38,156	34,081	47.2	0	0	59.4	42,935	Gap	N
<i>Borreria tocaninsiana</i>	185,663	168,758	16,905	9.1	0	0	51.8	96,212	Gap	1
<i>Diodia macrophylla</i>	128,566	71,040	57,526	44.7	0	0	58.9	75,788	Gap	3
<i>Diplusodon decussates</i>	153,213	91,125	62,087	40.5	0	0	58.1	89,024	Gap	1
<i>Diplusodon gracilis</i>	53,767	45,592	8,175	15.2	0	0	53.0	28,518	Gap	1
<i>Diplusodon petiolatus</i>	153,213	91,125	62,087	40.5	0	0	58.1	89,024	Gap	1
<i>Diplusodon trigintus</i>	43,642	39,769	3,873	8.9	0	0	51.8	22,596	Gap	N
<i>Ditassa emmerichae</i>	43,438	13,750	29,687	68.3	0	0	63.7	27,656	Gap	3
<i>Duguetia rotundifolia</i>	65,219	33,093	32,126	49.3	0	0	59.9	39,035	Gap	1
<i>Gomphrena hillei</i>	127,044	84,890	42,154	33.2	0	0	56.6	71,953	Gap	N
<i>Hyptis concinna</i>	185,663	168,758	16,905	9.1	0	0	51.8	96,212	Gap	1
<i>Hyptis arenaria</i>	210,104	140,978	69,125	32.9	0	0	56.6	118,877	Gap	N
<i>Hyptis caduca</i>	137,288	68,432	68,855	50.2	0	0	60.0	82,415	Gap	5
<i>Hyptis humilis</i>	450,178	363,829	86,349	19.2	0	0	53.8	242,359	Gap	N
<i>Lippia ciliate</i>	108,759	67,433	41,325	38.0	0	0	57.6	62,645	Gap	N
<i>Ouratea acicularis</i>	130,307	129,419	887	0.7	101,872	100,989	50.1	65,331	Covered	4
<i>Piriqueta araguaiana</i>	149,410	134,869	14,542	9.7	0	0	51.9	77,614	Gap	N
<i>Polygala pseudocoriacea</i>	128,566	71,040	57,526	44.7	0	0	58.9	75,788	Gap	3
<i>Staelia tocaninsense</i>	79,308	73,754	5,554	7.0	0	0	51.4	40,765	Gap	N
<i>Tassadia rizzoana</i>	140,305	72,325	67,980	48.5	0	0	59.7	83,749	Gap	5
<i>Turnera gardneriana</i>	65,219	33,093	32,126	49	0	0	60	39,035	Gap	1
Fish										
<i>Aguarunichthys tocaninsensis</i>	592,155	387,033	205,122	34.6	0	0	26.9	159,455	Gap	N
<i>Ammoglanis diaphanous</i>	356,099	233,239	122,860	34.5	0	0	56.9	202,621	Gap	2
<i>Brachyplatystoma filamentosum</i>	78,700	59,661	19,040	24.2	49,916	47,215	54.8	43,158	Covered	N
<i>Crenicichla compressiceps</i>	135,315	97,044	38,271	28.3	0	0	55.7	75,312	Gap	N
<i>Hyphessobrycon gr. Eques</i>	36,015	35,860	155	0.4	0	0	50.1	18,039	Gap	4
<i>Hyphessobrycon stegemanni</i>	136,022	135,605	417	0.3	0	0	50.1	68,094	Gap	N

Table 3 (continued)

Species	Original (ha)	Remaining (ha)	Habitat loss (ha)	Habitat loss (%)	Original protection (ha)	Current protection (ha)	Target (%)	Target (ha)	Classification	Biotic Element
<i>Maratecoara formosa</i>	273,468	137,501	135,968	49.7	0	0	59.9	163,928	Gap	N
<i>Maratecoara lacortei</i>	49,356	48,982	374	0.8	49,356	48,982	50.2	24,753	Covered	2
<i>Maratecoara splendida</i>	111,814	36,779	75,035	67.1	0	0	63.4	70,914	Gap	3
<i>Moenkhausia hysterostricta</i>	202,681	97,398	105,283	51.9	0	0	60.4	122,397	Gap	N
<i>Mylesinus paucisquamatus</i>	10,158,503	7,780,403	2,378,100	23.4	797,773	795,975	14.7	1,491,470	Partial gap	N
<i>Pituna compacta</i>	234,550	188,208	46,342	19.8	51,328	50,566	54.0	126,543	Partial gap	N
<i>Plesiolebias canabravensis</i>	111,814	36,779	75,035	67.1	0	0	63.4	70,914	Gap	3
<i>Plesiolebias filamentosus</i>	208,953	35,203	173,750	83.2	0	0	66.6	139,226	Gap	5
<i>Plesiolebias fragilis</i>	97,397	22,374	75,023	77.0	0	0	65.4	63,703	Gap	N
<i>Plesiolebias lacerdai</i>	49,356	48,982	374	0.8	49,356	48,982	50.2	24,753	Covered	2
<i>Plesiolebias xavantei</i>	1,284,605	707,645	576,960	44.9	0	0	29.0	372,313	Gap	N
<i>Simpsonichthys costai</i>	51,328	50,566	763	1.5	51,328	50,566	50.3	25,817	Covered	2
<i>Simpsonichthys flammeus</i>	51,328	50,566	763	1.5	51,328	50,566	50.3	25,817	Covered	2
<i>Simpsonichthys multiradiatus</i>	202,681	97,398	105,283	51.9	0	0	60.4	122,397	Gap	N
<i>Simpsonichthys semiozellatus</i>	141,848	133,214	8,634	6.1	85,339	84,851	51.2	72,651	Covered	2
<i>Trigonectes rubromarginatus</i>	51,328	50,566	763	1.5	51,328	50,566	50.3	25,817	Covered	2
<i>Trigonectes strigabundus</i>	183,222	137,642	45,580	25	0	0	55	100,727	Gap	N
Amphibians										
<i>Ameerega flavopicta</i>	2,808,949	2,285,134	523,816	18.6	48,023	46,968	23.7	666,553	Partial gap	N
<i>Bokermannohyla cf. pseudopseudis</i>	752,927	587,514	165,413	22.0	15,082	14,126	24.4	183,668	Partial gap	N
<i>Dendropsophus leucophyllatus</i>	1,039,289	429,189	610,100	58.7	0	0	31.7	329,878	Gap	5
<i>Hypsiboas boans</i>	5,199,951	3,120,462	2,079,489	40.0	119,875	110,025	18.0	935,893	Partial gap	N
<i>Hypsiboas sp. gr. albopunctatus</i>	9,592,819	6,773,884	2,818,935	29.4	675,412	653,554	15.9	1,523,069	Partial gap	N
<i>Ischnochnema sp.</i>	726,743	506,841	219,901	30.3	0	0	26.1	189,329	Gap	1
<i>Leptodactylus sertanejo</i>	1,254,221	1,040,499	213,722	17.0	205,727	201,559	23.4	293,589	Partial gap	N
<i>Pipa pipa</i>	7,226,324	4,755,224	2,471,100	34.2	669,033	646,420	16.8	1,216,852	Partial gap	N
<i>Pleurodema diplolister</i>	3,687,883	3,403,390	284,493	7.7	894,657	889,753	21.5	794,475	Covered	N
<i>Pristimantis sp.</i>	11,533,430	7,423,892	4,109,538	35.6	349,151	335,116	17.1	1,975,251	Partial gap	N
<i>Rhinella gr. margaritifera</i>	6,935,888	4,110,155	2,825,733	41	135,376	125,519	18	1,258,735	Partial gap	N
Reptiles										
<i>Anops acrobeles</i>	28,189	28,184	5	0.0	0	0	50.0	14,096	Gap	4

Table 3 (continued)

Species	Original (ha)	Remaining (ha)	Habitat loss (ha)	Habitat loss (%)	Original protection (ha)	Current protection (ha)	Target (%)	Target (ha)	Classification	Biotic Element
<i>Apostolepis longicaudatus</i>	151,123	120,300	30,823	20.4	0	0	54.1	81,726	Gap	N
<i>Apostolepis polylepis</i>	450,894	445,047	5,847	1.3	338,851	337,531	50.3	226,616	Covered	N
<i>Bachia micromela</i>	115,108	84,441	30,668	26.6	0	0	55.3	63,688	Gap	N
<i>Bachia oxyrhina</i>	168,997	164,192	4,804	2.8	114,103	113,665	50.6	85,459	Covered	N
<i>Bachia psamophila</i>	152,875	80,715	72,161	47.2	0	0	59.4	90,870	Gap	N
<i>Bronia kraoh</i>	299,181	248,505	50,677	16.9	60,722	60,587	53.4	159,726	Partial gap	N
<i>Bronia saxosa</i>	106,259	54,950	51,309	48.3	0	0	59.7	63,391	Gap	N
<i>Chelonoidis denticulata</i>	8,261,993	5,363,764	2,898,229	35.1	530,658	514,051	17.0	1,405,845	Partial gap	N
<i>Cnemidophorus jalapensis</i>	287,914	282,768	5,147	1.8	0	0	50.4	144,987	Gap	N
<i>Cnemidophorus mumbuca</i>	103,794	103,414	379	0.4	61,865	61,731	50.1	51,973	Covered	4
<i>Kentropyx</i> sp.	28,189	28,184	5	0.0	0	0	50.0	14,096	Gap	4
<i>Lachesis muta</i>	6,765,090	4,265,961	2,499,129	36.9	492,640	479,159	17.4	1,176,335	Partial gap	N
<i>Mabuya guaporicola</i>	4,718,786	3,384,855	1,333,931	28.3	598,972	582,988	25.7	1,210,543	Partial gap	N
<i>Mabuya heathi</i>	8,218,649	6,531,381	1,687,268	20.5	894,572	889,674	14.1	1,159,318	Partial gap	N
<i>Phalotris labiomaculatus</i>	142,274	90,810	51,464	36	0	0	57	81,430	Gap	N
Birds										
<i>Alectrurus tricolor</i>	208,380	157,077	51,303	24.6	0	0	54.9	114,451	Gap	1
<i>Anodorhynchus hyacinthinus</i>	14,493,672	11,032,804	3,460,868	23.9	911,411	903,853	14.8	2,141,541	Partial gap	N
<i>Ara chloroptera</i>	10,415,573	7,766,699	2,648,873	25.4	946,134	940,052	15.1	1,571,332	Partial gap	N
<i>Celeus obrieni</i>	398,443	224,758	173,685	43.6	0	0	58.7	233,959	Gap	N
<i>Cercomacra ferdinandi</i>	5,578,040	3,554,004	2,024,036	36.3	642,048	620,312	17.3	962,611	Partial gap	N
<i>Culicivora caudacuta</i>	3,015,777	2,765,176	250,601	8.3	895,189	890,078	21.7	653,276	Covered	N
<i>Geositta poeciloptera</i>	566,711	500,581	66,130	11.7	0	0	22.3	126,568	Gap	N
<i>Harpyhaliaetus coronatus</i>	8,929,011	7,392,811	1,536,200	17.2	900,824	895,270	13.4	1,200,141	Partial gap	N
<i>Mergus octosetaceus</i>	2,364,829	2,147,277	217,552	9.2	678,800	677,226	51.8	1,225,925	Partial gap	N
<i>Paroaria baeri</i>	2,767,013	2,283,870	483,143	17.5	488,857	477,382	23.5	650,031	Partial gap	2
<i>Penelope ochrogaster</i>	3,812,999	2,852,445	960,554	25.2	659,620	638,700	25.0	954,711	Partial gap	N
<i>Procnias averano averano</i>	2,685,000	2,350,776	334,225	12.4	711,767	710,504	22.5	603,845	Covered	N
<i>Pyrrhura pfrimeri</i>	979,551	634,157	345,394	35.3	0	0	27.1	264,989	Gap	1
<i>Suiriri islerorum</i>	1,174,721	1,123,749	50,972	4.3	475,962	472,530	20.9	245,139	Covered	4
<i>Synallaxis simoni</i>	3,193,523	2,445,602	747,921	23.4	586,670	568,169	24.7	788,289	Partial gap	N

Table 3 (continued)

Species	Original (ha)	Remaining (ha)	Habitat loss (ha)	Habitat loss (%)	Original protection (ha)	Current protection (ha)	Target (%)	Target (ha)	Classification	Biotic Element
<i>Taoniscus nanus</i>	1.024.949	975.250	49.699	5	470.173	468.888	21	214.930	Covered	N
Mammals										
<i>Blastocerus dichotomus</i>	7,811,949	5,909,811	1,902,138	24.3	1,138,746	1,115,083	14.9	1,161,622	Partial gap	N
<i>Calomys tocantinsi</i>	97,397	22,374	75,023	77.0	0	0	65.4	63,703	Gap	N
<i>Chrysocyon brachyurus</i>	17,740,337	13,194,384	4,545,953	25.6	1,547,396	1,522,474	15.1	2,683,224	Partial gap	6
<i>Kerodon acrobata</i>	65,219	33,093	32,126	49.3	0	0	59.9	39,035	Gap	1
<i>kerodon rupestris</i>	679,005	574,550	104,455	15.4	58	57	23.1	156,692	Partial gap	N
<i>Lonchophylla dekeyseri</i>	1,371,058	1,164,998	206,059	15.0	376,097	375,393	23.0	315,423	Covered	N
<i>Makalata didelphoides</i>	129,644	65,208	64,436	49.7	0	0	59.9	77,709	Gap	3
<i>Monodelphis kunsii</i>	3,976,725	3,225,890	750,835	18.9	556,357	551,723	23.8	945,512	Partial gap	N
<i>Myrmecophaga tridactyla</i>	18,969,984	13,959,950	5,010,033	26.4	1,504,800	1,480,879	15.3	2,899,005	Partial gap	6
<i>Oligoryzomys moojeni</i>	5,749,964	4,258,476	1,491,488	25.9	152,338	151,279	15.2	873,294	Partial gap	N
<i>Oncifelis colocolo</i>	18,167,352	13,262,593	4,904,758	27.0	1,269,572	1,252,617	15.4	2,797,687	Partial gap	6
<i>Panthera onca</i>	19,162,189	13,845,845	5,316,344	27.7	1,569,686	1,542,923	15.5	2,979,488	Partial gap	6
<i>Priodontes maximus</i>	19,904,210	14,145,236	5,758,974	28.9	1,537,933	1,511,219	15.8	3,142,216	Partial gap	6
<i>Pteronura brasiliensis</i>	1,760,348	1,338,294	422,054	24.0	544,302	527,965	24.8	436,480	Covered	N
<i>Puma concolor</i>	15,424,590	11,450,609	3,973,981	25.8	1,130,755	1,113,765	15.2	2,337,255	Partial gap	N
<i>Rhipidomys nittela</i>	129,644	65,208	64,436	49.7	0	0	59.9	77,709	Gap	3
<i>Thrichomys</i> sp.	2,136,962	2,014,826	122,136	5.7	783,468	778,970	21.1	451,820	Covered	N
<i>Thyroptera devivoi</i>	136,196	136,040	155	0.1	100,181	100,181	50.0	68,129	Covered	4
<i>Tolypeutes tricinctus</i>	4,692,481	3,926,722	765,758	16.3	684,098	681,581	23.3	1,091,648	Partial gap	N
<i>Wiedomys pyrrhorhinos</i>	2,680,193	2,365,836	314,357	12	366,880	366,628	22	598,910	Partial gap	N

Table 4 – Mean relative gap and standard deviation (SD) values of original range in PAs and habitat loss for each biotic element, and number of gap, partial gap and covered species in each group.

Biotic element	Original range protected (%)		Habitat loss (%)		Number of species		
	Mean	SD	Mean	SD	Gap	Partial gap	Covered
1. Southern plateaus & Paranã valley	0.0	0.0	32.0	15.6	11	0	0
2. Araguaia valley	72.2	41.7	8.0	12.1	1	1	6
3. Peixe region	0.0	0.0	54.5	11.0	8	0	0
4. Jalapão and Serra Geral region	36.0	35.7	0.9	1.6	3	0	4
5. Tocantins River	0.0	0.0	58.1	14.6	5	0	0
6. Cerrado (general)	8.0	1.0	27.0	1.0	0	5	0

Figures

Figure 1 - Species clusters in the first two dimensions (mds[1] and mds[2]) of a non-metric multidimensional scaling, obtained according to the ranges of 109 species analysed in *mclust* (Hausdorf & Hennig, 2003). Characters indicate model-based clustering with noise (“N”).

Figure 2 – Location of biotic elements in Tocantins State according to the distribution of 109 species. Biotic element 1: Southern plateaus & Paranã valley; biotic element 2: Araguaia valley; biotic element 3: Peixe region; biotic element 4: Jalapão and Serra Geral region; biotic element 5: Tocantins River. Biotic element 6 is composed by wide range species from the Cerrado region and is represented by light grey grids. Biotic elements are mapped as grid cells containing at least one species of each cluster.

Figure 3 – Cumulative area protected and total gap (sum of all species gap area to meet targets) according to the years of establishment of strictly protected areas in Tocantins State.

(ANP: Araguaia National Park, CSP: Cantão State Park, AFNM: Árvores Fossilizadas Natural Monument, JSP: Jalapão State Park, LSP: Lajeado State Park, SGTES: Serra Geral do Tocantins Ecological Station, NPNP: Nascentes do Parnaíba National Park).

Capítulo 3

Integrating protected area status into systematic conservation planning: a case study in the Brazilian Cerrado

Monumento Natural das Árvores Fossilizadas do Tocantins

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Integrating protected area status into systematic conservation planning: a case study in the Brazilian Cerrado

Resumo

O planejamento sistemático da conservação tem evoluído nos últimos anos para lidar com aspectos dinâmicos das paisagens, como a incorporação de dados de ameaça ou vulnerabilidade na definição de áreas prioritárias para a conservação. No entanto, a maioria das abordagens não leva em consideração o estado da biodiversidade dentro das áreas protegidas, que pode variar consideravelmente, principalmente em sistemas de áreas protegidas recentes, com gestão incipiente e altamente ameaçados, típicos de países em desenvolvimento. Neste estudo, integramos resultados de efetividade da gestão e avaliação de ameaças de um sistema de unidades de conservação na porção norte do Cerrado brasileiro, e desenvolvemos diferentes cenários de planejamento sistemático baseados em 139 alvos. Nossos resultados indicaram que o sistema de unidades de conservação do Tocantins ainda está longe de representar todos os alvos de conservação propostos, apresentando ainda lacunas significativas na implementação das áreas protegidas existentes. Para testar os impactos dos baixos valores de efetividade e altos valores de ameaças das áreas protegidas, reduzimos o estado de conservação das áreas protegidas em 25% e 50%. Isso resultou em acréscimos de 250.000 ha e 590.000 ha, respectivamente, no sistema de áreas protegidas, necessário ao cumprimento das metas de conservação. A representatividade dos sistemas de áreas protegidas depende da persistência da biodiversidade dentro dessas áreas, que é reconhecidamente comprometida por níveis elevados de ameaça associados à efetividade de gestão incipiente. Portanto, sugerimos que o estado de conservação da biodiversidade dentro das áreas protegidas seja incorporado a exercícios de planejamento sistemático de conservação. A definição de prioridades para a criação de novas áreas protegidas deve fazer parte de um planejamento integrado, que aborda também a consolidação de áreas protegidas existentes e estratégias mais amplas para mitigar os efeitos dos fatores principais da perda de biodiversidade fora das reservas.

Abstract

Systematic conservation planning has evolved in the last years to deal with the dynamic aspects of landscapes, including the incorporation of threat or vulnerability data in the design of conservation area networks. However, most approaches neglect the status of biodiversity inside protected areas (PAs), which may be highly variable, especially in large, poorly managed and severely threatened protected area systems in developing countries. In order to evaluate how different levels of PA status may impact conservation area networks, we integrated results from management effectiveness and threat assessments of a PA system in the northern portion of the Brazilian Cerrado, and performed different systematic conservation planning scenarios based on 139 biodiversity surrogates. Our results indicated

that Tocantins PA system is still far from achieving conservation targets, with significant gaps in coverage, representation and management effectiveness. In order to test for the effects of detected low management effectiveness and high levels of threat, we reduced the conservation status of protected areas by 25% and 50%. This resulted in an increase in the conservation area network needed to achieve targets of around 250,000 ha and 590,000 ha, respectively. Our results strongly indicate that the representation of PA systems depends on the persistency of biodiversity inside PAs, which are known to be impacted by high levels of threat associated to poor management effectiveness. Therefore, we advocate that biodiversity status within PAs should be incorporated in systematic conservation planning exercises. The definition of priority areas for the establishment of new reserves should be part of an integrated planning process that addresses both the consolidation of existing protected areas and broader strategies to mitigate the effects of major drivers of biodiversity loss outside reserves.

1. Introduction

Systematic conservation planning (SCP) is the process of identifying conservation area networks (CANs) that promote the persistence of biodiversity and other natural values (Margules & Sarkar, 2007). It has traditionally been formulated as a static problem (Possingham et al., 2009), where biodiversity distribution, threats and the conservation status of sites do not change over time. However, new approaches indicate that conservation prioritization should be viewed as a dynamic process where natural and anthropogenic features and events change the landscape structure and its conservation status (Nicholson et al., 2006; Possingham et al., 2009; Pressey et al., 2007).

Due to its high complexity, dynamic conservation prioritization should simplify the problem structure and concentrate on those components that have a major influence on solutions, and those for which data can be obtained (Possingham et al., 2009). Change in location, intensity or type of threats may significantly impact biodiversity persistency over time, representing a major driver of dynamic conservation systems (Pressey et al., 2007). The most extensive and serious direct threats to biodiversity are habitat conversion by agriculture, plantations or human settlements, harvesting of timber, fish and other natural resources, and invasive plants and animals (Wilson et al., 2005; Pressey et al., 2007; Leverington et al., 2008). Even though there are some research on how to integrate threat dynamics into conservation planning, they are mainly focused on how threats can impact the selection and prioritization of new areas for conservation (Pressey et al., 2004; Wilson et al., 2005; Nicholson et al., 2006). However, the significant majority of current conservation planning approaches assumes that when a site is reserved the biodiversity in it is saved and the threat is removed (Possingham et al., 2009).

In fact, some threats may not end just by reserving areas for conservation (Bruner et al., 2001; Wilson et al., 2005; Pressey et al., 2007; Wilson et al., 2007), especially in large, poorly managed and highly threatened protected area (PA) systems in developing countries. Hunting and exotic species are usually

present inside PA boundaries (Wilson et al., 2005), while in some regions PAs are not even secure from vegetation clearing within their boundaries (Peres & Terborgh, 1995; Menon et al., 2001). In order to mitigate threats from external and internal sources and to maintain their conservation values, PAs should be effectively managed (Hockings et al., 2006). Therefore, maintaining the status of biodiversity in areas under high levels of threat demands stronger and more oriented management efforts (Hockings et al., 2006).

Identifying the status of biodiversity inside reserved areas is one of the steps of SCP (Margules & Pressey, 2000; Sarkar & Ioldi-Rangel, 2010). This step is usually done by determining the distribution of target conservation features, such as species or ecosystem types, and evaluating how much of each target (in percentage of area or number of records) is already represented inside reserves (Margules & Pressey, 2000; Sierra et al., 2002; Sarkar & Ioldi-Rangel, 2010). Threats associated to poor management effectiveness may significantly alter the real status and persistency of some or most conservation targets inside PAs. In other words, in poorly managed systems the real value of target representation may not be equal to the area covered by PAs. Therefore, in these cases, there might be necessary to reviewing usual approaches to locate and design new PAs (Wilson et al., 2005), that generally fail to account for target status inside reserves.

In this study, we combined SCP with threat assessment and management effectiveness evaluations in the PA system of Tocantins State, northern portion of the highly threatened Brazilian Cerrado, in order to better understand how different levels of PA status may impact conservation prioritization results. Obtained results were also compared to priority areas established by distinct processes and currently adopted by federal and state governments. Our aim was to provide evidence that combined high levels of threat and poor management effectiveness could significantly impact the design and representation of PA systems and should be considered as an integral part of conservation planning exercises.

2. Methods

Study area

Tocantins State covers an area of 277,620 km² in the northern region of Brazil, harbouring important Cerrado-Amazonia transition areas and some of the last large blocks of Cerrado remnants (Klink & Machado, 2005; MMA, 2011). Although widely dominated by the Cerrado savannas (88% of the state area), Tocantins is characterized by a mosaic of different vegetation types. Lowland evergreen forest areas were originally abundant throughout the northern portion of the state, while the south is characterized by the presence of dry forest and savanna mosaics, the east is composed of Cerrado vegetation influenced by the contact with the Caatinga domain and elevated grassland areas in the Serra Geral sandstone plateau. Lower areas in the west are dominated by flooded savannas and extensive wetlands drained by the Araguaia River drainage (Tocantins, 2008a). The heterogeneity of Tocantins State, with a north-south

ecological gradient between the Cerrado and Amazon, and an east-west elevation gradient ranging from sandstone plateaus to low lying flooded savannas calls for a complex system of PAs to preserve representative samples of its biodiversity (Tocantins, 2008a).

Currently, the state has 5.7% of its total area preserved as strictly PAs and 9.1% in sustainable use PAs. Although these values are relatively high when compared to other Brazilian states in the Cerrado region, Tocantins PAs were created without any kind of systematic approach, and are concentrated in two major blocks: Jalapão (in the eastern portion of the state) and Araguaia region (western portion). The state Program on Protected Areas defined 12 priority areas for the establishment of new PAs based on results from inventories developed between 2002 and 2007, adopting general prioritization criteria, such as ecological singularity, threats, occurrence of rare, endemic or threatened species, integrity and extension and habitat heterogeneity (Tocantins, 2008b). However, a SCP framework was not adopted due to lack of adequate data (Olmos, 2007).

In 2007 the Brazilian Environmental Ministry established priority areas in the Cerrado region based on a systematic approach (MMA, 2007a). Even though it was a broad and expert-oriented process, some important targets for the conservation of Tocantins biodiversity were not included (especially restricted-range species). Following a wider trend of recent increase in scientific knowledge on the Cerrado (see Oliveira & Marquis, 2002) since 2007, new inventories and biodiversity syntheses have overcome significant gaps in the biodiversity knowledge in Tocantins State, including the work of Dornas (2009), Nogueira et al. (2010a,b, 2011), Pacheco & Olmos (2010), Giulietti et al. (2009), Pinheiro & Dornas (2009), Gregorin et al. (2011), Carmignotto & Aires (2011), Lima & Caires (2011), Rego et al. (2011) and Valdujo et al. (2011).

Management effectiveness and threat assessment

Management effectiveness and threat assessments were applied for the seven strictly PAs in Tocantins State. Management effectiveness protocol was based on the method known as Scenery Matrix, proposed by Faria (2004). By making use of a standardized scoring scale and previously selected indicators, the management effectiveness is measured by comparing an 'optimum PA scenario' with the current situation (Leverington et al., 2008). The adopted questionnaire was composed of 54 indicators, separated in five different management elements (context, planning, inputs, processes, outputs) according to the framework proposed by IUCN for management effectiveness assessments (see Hockings et al., 2006 for further details). The context accounts for the analysis of vulnerabilities and biological and socioeconomic importance of each PA. The planning element comprises PAs objectives, legal framework, and the design and planning of PA sites. Input assesses all available human resources, means of communication and information, infrastructure and financial resources. Processes are assessed by the management planning, existing models used in the decision-making process, mechanisms for assessing and monitoring, and by the

relationship between research carried out and the area's needs. Outputs are related to results and achievements of PA management in the last years.

The protocol for the assessment of threats to PAs was based on RAPPAM methodology (Ervin, 2003). Threats included both legal and illegal activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity targets (Salafsky et al., 2008). Each threat was analyzed based on four criteria: trend, extent, impact and permanence (adapted from Ervin, 2003). Trends evaluated the development of the threat in the last five years, or its probability of occurrence in the following five years. Extent related to the area impacted by the activity. Impact referred to the degree to which the pressure affects, either directly or indirectly, overall PA resources. Permanence refers to the length of time necessary to the recovery of an affected PA resource with or without human intervention. For each of these criteria, five different scenarios were scored from one (the best, ideal situation) to five (the worst scenario) according to the characteristics and dynamics of each threat. Questionnaires were applied to each PA staff between April to October of 2007 (see Ferreira & Pivello, *in prep.* for more details).

Surrogates selection and mapping

Surrogates of overall biodiversity included two data rich taxonomic groups: vertebrates and vascular plants. Species from these groups were selected based on at least one of the following criteria, adapted from global standards for detecting key biodiversity areas (Eken et al. 2004): (i) threatened species according to the Brazilian national list (MMA, 2003) or the global redlist (IUCN, 2010); (ii) restricted range species (species with known ranges not exceeding 10,000 km², an adaptation of the 50,000 km² threshold proposed for birds and adopted in previous regional studies – see Nogueira et al., 2010a and Giuliatti et al., 2009); and (iii) species that have a wide range outside the study area, but were restricted to specific portions of Tocantins.

Point-locality records were mapped based on available information and the list of targets was continuously revised by experts in each taxonomic group, who decided on the inclusion, exclusion and correction of point-locality records and on the composition of the final list of 109 target species (for more detail, see Ferreira et al., *in prep.*). Species distribution modelling was applied to minimize effects of incomplete sampling on the definition of the range of target species with at least 10 locality records (including localities outside the study area). MAXENT algorithm was selected since it combines ease of use with proven predictive ability, especially for presence-only data (Elith & Leathwick, 2009). Species distribution models in MAXENT were performed based on 30'' resolution environmental variables from the Worldclim project (Hijmans et al., 2005) that were not highly correlated ($r > 0.9$, as in Costa et al., 2010). To transform probability values of output models into presence-absence distributions, thresholds were defined based on a parameter related to the amount of error associated with the presence localities dataset (see Peterson et al., 2007 and Ferreira et al., *in prep.* for further details). For restricted range species (total range smaller than 10,000 km²), all of which known from less than 10 locality records, ranges

were defined as small-scale catchment areas (6th order Ottobasins, ANA, 2006) intersecting locality points , and resulted in small polygons with total coverage of less than 10,000 km².

A previous analysis (biotic element analysis, see Hausdorf & Hennig, 2003) indicated that selected target species were able to inform on the existence of significant biogeographical patterns in the study area (Ferreira et al., in prep.), forming non-random groups of significantly co-occurring species, that conform to the predictions of the vicariant model of biological diversification (Hausdorf & Hennig, 2003). Thus, our choice of surrogates is not only representing geographical patterns but may also be considered as indicators of overall diversification processes (Carvalho et al., 2011).

As recommended by several studies (Bonn & Gaston, 2005; Margules & Sarkar, 2007; Sarkar & Ioldi-Rangel, 2010), thirty “environmental types” were also included as biodiversity surrogates in the analysis, in order to minimize the effects of possible gaps on the knowledge distribution of overall biodiversity in the study region. Environmental types were obtained from a previous compartmentalization map based on elevation, geomorphology and vegetation types (*compartimentação ambiental*, 1:250,000, Tocantins, 2003).

Three main thresholds were adopted for calculating representation targets: species with ranges below 500,000 ha (which included all restricted range species) should have at least 50% of its original range covered by the reserve system; species with ranges between 500,000 and 5 million ha should have at least 20% coverage, and species with ranges larger than 5 million ha should have at least 10% coverage. An additional target from zero to 20% was defined based on the percentage of habitat loss divided by five, with maximum additional targets (20%) applied to hypothetical cases of total loss of original habitat. Habitat loss was evaluated by estimating the amount of converted areas in each species distribution, based on the Brazilian deforestation map of 2008 (IBAMA, 2008). A 10% representation target was set for each environmental type.

Conservation planning

ConsNet software (Ciarleglio et al., 2008, 2009) was used to design the CAN scenarios. The probability of occurrence of each species in each cell above previously defined thresholds was obtained from niche model outputs in MAXENT, and total representation for each species was the sum of all the probabilities across the planning region. For those species with less than 10 records, for which MAXENT models were not applied, probability of occurrence was zero (absence) or one (presence). The study area was divided in 329,587 cells of ca. 85 ha, according to the resolution of input variables used in MAXENT (30'' resolution, Hijmans et al., 2005).

The polygons of strictly PAs (IUCN categories I to III) were included in the ConsNet prioritization analysis as permanently included cells (totalling 18,647 cells), from which site selection was initiated. Converted areas, obtained from the Brazilian deforestation map (IBAMA, 2008), were included in ConsNet

as permanently excluded cells (100,658 cells) and were not considered in the design of the CAN because they are presently unsuitable for survival of most species.

CANs were defined across 228,929 cells of the planning region (i.e., 329,587 cells of the study area minus the 100,658 cells excluded from the analysis) under four scenarios: (1) CAN100: PAs conserve the full range of its biodiversity. In this scenario, the original targets for each surrogate were not changed; (2) CAN75: PAs conserve 75% of its biodiversity. In this scenario, 25% of each surrogate representation inside PAs was added to original targets; (3) CAN50: PAs conserve 50% of its biodiversity. In this scenario, 50% of each surrogate representation inside PAs was added to original targets. Therefore, for a species with a total distribution of 1,000 ha, an original target of 50%, and 200 ha already represented inside strictly PAs, the target in area would be 500 ha in the first scenario, 550 ha in the second scenario (original target in area plus 25% of the 200 ha already protected) and 600 ha in the third scenario (original target in area plus 50% of the 200 ha already protected).

ConsNet software uses a metaheuristic algorithm called self-learning tabu search that uses memory to avoid revisiting solutions that were discovered in previous iterations (Ciarleglio et al., 2008). It supports objectives based on rules and a dynamic neighbourhood selection that controls possible movements during the search for solutions, and intelligently arranges the structure of the spatial problems (Ciarleglio et al., 2009). Using the surrogates probability distribution for each cell in a geographic grid, ConsNet makes a binary decision (to select or not a cell to be put under a conservation plan) and orders each cell hierarchically on the basis of its biodiversity value.

For each scenario, a three-step procedure was performed. The first step corresponded to a search for the minimum number of cells to achieve the overall target. The best solution found for this search was then used as the initial solution for a multi-criteria search including number of cells and shape. Once again, the best solution of this search was the initial solution for the final search, which included number of cells, shape and number of clusters. The same parameters were adopted for finding the best solution in all three scenarios: (i) number of cells: 60,000 to 100,000; (ii) shape: zero to one; and (iii) number of clusters: 100 to 1,000. For each run, at least 1.2 million iterations were performed to obtain a thorough search with three times as many iterations as the number of cells in the network ($n = 329,587$). The results of the four conservation scenarios solved by ConsNet were transformed into polygons, and we calculated the area of the polygons with the Spatial Analyst extension in ArcMap (version 10.0; ESRI 2010) with an equal-area cylindrical projection.

Finally, priority areas proposed by Tocantins State (Tocantins, 2008a) and by the Brazilian Environmental Ministry (MMA, 2007a) were evaluated based on their contribution to the CAN100 scenario. We also evaluated how CAN100 was distributed among Tocantins biotic elements, identified in a previous study (Ferreira et al., in prep.), in order to evaluate the representation of evolutionary patterns and processes in the regional reserve system.

3. Results

Threat assessment and management effectiveness evaluations results

Management effectiveness varied from 42% in Araguaia National Park to 68% in Cantão State Park, with an average value of 52,5% (Table 1). Indicators of Inputs showed the highest overall results, while Outputs had the worst average values. Management results varied among PAs, especially in Context, Planning and Processes indicators. Relative threat intensity varied from 54% in Nascentes do Parnaíba National Park to 77% in Araguaia National Park (Table 1). PAs were impacted by different number and type of threats (Table 1, Figure 1), even though hunting, fire, cattle raising, agriculture, infrastructure and tourism were common and had high intensity values in most of the areas (see Ferreira & Pivello, *in prep.* for more details).

Management effectiveness and threat intensity tended to be negatively correlated among Tocantins PAs (Figure 2, $R^2=0,248$). However, the reduced number of areas does not allow rigorous statistic comparisons and we cannot state this as a general trend for different sets of PAs. In general, intermediate levels of management effectiveness associated to medium to high values of threat might indicate that PAs in Tocantins State are not fully able to maintain their conservation status and the most vulnerable biodiversity features may not persist in the long-term within PA boundaries.

Current scenario and priority areas for conservation

The distribution of the representation values of 139 surrogates indicated some areas of higher overlap, or higher biological diversity and relevance, as for example, the Jalapão, Araguaia, Paranã regions and the central portion of Tocantins River (Figure 3). The CAN based on the original targets for each surrogate (CAN100) selected a total area of 5,472,372 ha (Table 2), which corresponds to 19.7% of the state area. Strictly PAs cover 28.5% of this scenario, while sustainable use PAs and indigenous lands contribute with 8% and 5.8% of the total CAN100 area, respectively (Table 2, Figure 4).

Priority areas proposed by Tocantins State contributed little (8.5%, Table 2) to CAN100 area outside PAs and indigenous lands, and only overlap with some areas in the state (Figure 5). Priority areas proposed by the federal government showed a higher contribution to achieve the area unprotected in the CAN100 scenario (38.5%, Table 2), covering areas indicated by the ConsNet solution in the Araguaia valley, southern, central and north-eastern portions of the state (Figure 6). Consensual areas in the three prioritization exercises are indicated by number one to six in Figure 5. Most of the CAN100 area (3,641,054 ha or 66% of its total area) is located within one of the five allopatric biotic elements previously identified for Tocantins biota (Figure 7).

CANs obtained by different scenarios

CAN100, CAN75 and CAN50 showed high levels of consensus, indicating areas that are largely irreplaceable to achieve representation targets (Figures 8 and 9). These areas cover important regions of

the state that are currently unprotected or poorly represented inside reserves, such as the southern Parana valley, the central portion along the Tocantins River and the northern areas in transition zones between Cerrado and the Amazon forests (indicated by the circles A to C, respectively, in Figure 9).

Reducing the conservation status of PAs by 25% (CAN75) and 50% (CAN50) resulted in an increase of around 250,000 ha and 590,000 ha, respectively, in the CANs to achieve conservation targets (Table 3). Compared to the original solution (CAN100), the number of clusters did not change in the CAN75, but was increased in the CAN50, indicating the need of completely new regions under the more drastic scenario. Representation also increased from CAN100 to CAN 75 and CAN50, mainly as a result of the larger area needed to achieve targets in each scenario, even though lower values of representation in the original scenario (CAN100) were already able to cover established targets for each surrogate.

4. Discussion

Tocantins PA system

The highly concentrated design of Tocantins PA system resulted in significant conservation gaps (Ferreira et al. *in prep*), and a large complementary area is still needed to achieve full representation of biodiversity, even if considering that surrogates are completely conserved inside strictly PAs (CAN100 scenario). The lack of a systematic approach in the regional PA system design is also evident by the relatively low spatial overlap between the CAN100 and sustainable use PAs. However, these areas may have other important roles in the system, such as providing ecosystem services, maintaining ecological processes or conserving social, and cultural attributes, which were not evaluated in this study. Even though their overall contribution to achieving representation targets was low, some important areas, especially inside large PAs, are proposed in the CAN and should be carefully considered in their respective management plan and zoning design.

The adoption of a complete systematic approach based on the selection of surrogates, definition of targets, and followed by expert opinion has resulted in more similarity between our results and the MMA exercise for the Cerrado region. However, priority areas defined by the state, even though generally based on SCP criteria, but without thoroughly following all the steps of a systematic framework, resulted in a limited consensus with present CAN. Overlapping sites should be considered as top priorities for PA establishment, since they were selected by three different prioritization exercises and are already included in state and federal environmental policy frameworks.

Although Tocantins still has low levels of habitat conversion when compared to other Brazilian states in the Cerrado region (MMA, 2011), highly fragmented areas, especially in its central and northern portions, accounted for a CAN with large number of clusters, where opportunities of establishing large and connected reserve systems are limited to some regions, mainly where PAs have already been established. This trend reflects the tendency to establish large reserves in previously unoccupied, low cost regions,

where competing economic activities are less prevalent (see Margules & Pressey, 2000), characterizing an opportunistic approach to reserve selection.

Methodological approaches for including PA status in systematic conservation planning

Currently, it is widely acknowledged that information on threats and how they impact the persistency of areas and features pervades the process of conservation planning (Wilson et al., 2005; Pressey et al., 2007). There is a variety of methods that identify, classify and map the distributions of threats across a planning region, and incorporate the vulnerability of areas in prioritization exercises (Nicholson et al., 2006). The probability of each surrogate occurrence was adopted by Williams & Araújo (2000) as a first approximation of persistency. Stochastic models were used to select areas with higher population growth rates (Calkin et al., 2002; Noss et al., 2002; Carroll et al., 2003) and were further developed to the adoption of stochastic metapopulation models (Root et al., 2003) and stochastic simulation models (Haight et al., 2002; Nalle et al., 2004).

Wilson et al. (2005) identified four major groups of methods based on the types of data used: (1) tenure and land use; (2) environmental or spatial variables; (3) threatened species; and (4) expert decision. According to these authors, only methods from group 1 and 2 are based on the assumption that PAs are not vulnerable, while methods from groups 3 and 4 could potentially incorporate threat information to assess the persistency of biodiversity inside reserves. The limited use of this approach may be related to their origins on developed countries, where PAs are managed effectively and land use is mostly consolidated, hampering the effects of major drivers of threats inside reserves.

Our study did not aim to propose a new or single method for assessing threat, vulnerability or the status of biodiversity conservation inside reserves. We do believe that there is a wide variety of methods available and they should be chosen based on the scale, availability of data and any other aspects from the planning region. However, our results are important in revealing the need to include PA status into systematic conservation planning exercises, especially in recently established, highly threatened and poorly managed PA systems, such as those in Tocantins State, and in similarly threatened portions of tropical biodiversity hotspots.

Conservation strategies

The extent to which PAs are able to conserve biodiversity is determined by how well a PA network represents the full range of biodiversity and how well the management of these areas ensures the long-term survival of the biodiversity, by maintaining natural processes and viable populations and excluding threats (Bakarr & Lockwood, 2006). In our study, reducing by half the contribution of Tocantins PAs in maintaining their biodiversity resulted in an additional area of almost 600,000 ha for achieving a comprehensive CAN. This is almost the size of the largest PA in the state (SGTES), which is also the second largest PA in the whole Cerrado domain.

PA management costs are significantly smaller when compared to the financial investments needed to create and establish new areas (MMA, 2007b; Muanis et al., 2009). Most PAs in Brazil still have land tenure problems, due to the undefined status of land ownership in some regions and high costs of acquiring land. More than 50% of the area designated as federal PAs requires some type of land-tenure regularization, and approximately 25% requires indemnification (Silva, 2005). Therefore, we strongly advocate that environmental policies related to the design and improvement of PA systems should also consider better inputs, financing and long-term strategies to existing PAs, in order to overcome management weaknesses, improve their ability of identifying and mitigating threats and consequently, guarantee the persistency of their biodiversity and other social and cultural values over the years.

Moreover, given the limitations of PAs in preventing all threats to biodiversity, conservation planning must operate as part of a broader conservation strategy that also addresses the ultimate causes of biodiversity loss, including actions on policy, legislation, education, and economic instruments (Wilson et al., 2005). In Tocantins, as in other Brazilian states, these mechanisms may include: (i) incentives to the establishment of private reserves; (ii) monitoring and enforcement towards the respect to the Brazilian Forest Code, which includes the protection of vulnerable areas and setting aside a proportion of every private land (35% in Tocantins) as legal reserves; (iii) promotion of sustainable land use alternatives; and (iv) regional and more integrative approaches to territorial planning and management, such as corridors or mosaics of different land uses.

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Tables

Table 1 – Management effectiveness results (total and per management element percentages), relative intensity and total numbers of threats for each strictly protected areas in Tocantins State.

Protected area	Management effectiveness	Context	Planning	Inputs	Processes	Outputs	Threat intensity	Number of threats
ANP	41.7	30.0	60.0	43.1	50.0	21.9	77.2	9
SGTES	52.3	62.5	45.0	56.9	40.6	43.8	65.0	9
NPNP	53.2	70.0	35.0	62.5	46.9	40.6	54.3	7
CSP	68.1	60.0	70.0	76.4	71.9	53.1	59.0	7
JSP	56.9	62.5	55.0	65.3	62.5	28.1	56.3	8
LSP	45.4	47.5	35.0	63.9	28.1	31.3	55.8	6
AFNM	50.0	35.0	62.5	58.3	59.4	25.0	63.8	4
Average	52.5	52.5	51.8	60.9	51.3	34.8	61.6	7

ANP: Araguaia National Park; SGTES: Serra Geral do Tocantins Ecological Station; NPNP: Nascentes do Parnaíba National Park; CSP: Cantão State Park; JSP: Jalapão State Park; LSP: Lajeado State Park; AFNM: Árvores Fossilizadas Natural Monument.

Table 2 – Comparative results between the conservation area network proposed by this study (CAN100). currently protected areas and priority areas proposed by Tocantins State (TO) and the federal government (MMA).

Layer	Area in CAN100 (ha)	Total area (ha)	Contribution to CAN100 (%)
CAN100	5,472,372	5,472,372	100.0*
Strictly PA	1,558,830	1,600,194	28.5*
Sustainable use PA	438,701	2,262,998	8.0*
Indigenous lands	319,651	2,008,985	5.8*
Priority areas TO	269,232	1,729,889	8.5**
Priority areas MMA	1,210,025	6,178,655	38.5**

* Proportional to total CAN100 area

** Proportional to CAN100 area minus areas already conserved (PAs and indigenous lands)

Table 3 – Area (in hectares). number of clusters and total representation in the best solution found for each conservation area network proposed for Tocantins State.

Scenario	Area (ha)	Number of clusters	Representation
CAN100	5,472,372,46	793	6.32E+14
CAN75	5,719,852,49	793	6.68E+14
CAN50	6,061,308,71	810	7.13E+14

Figures

Figure 5 – Cumulative values of threat intensity (trend, extent, impact and permanence) for strictly protected areas in Tocantins State.

Legend: ANP: Araguaia National Park; SGTES: Serra Geral do Tocantins Ecological Station; NPNP: Nascentes do Parnaíba National Park; CSP: Cantão State Park; JSP: Jalapão State Park; LSP: Lajeado State Park; AFNM: Árvores Fossilizadas Natural Monument. NTFP: non timber forest products.

Figure 6 – Relation between relative threat intensity and management effectiveness results for strictly protected areas in Tocantins State.

ANP: Araguaia National Park; SGTES: Serra Geral do Tocantins Ecological Station; NPNP: Nascentes do Parnaíba National Park; CSP: Cantão State Park; JSP: Jalapão State Park; LSP: Lajeado State Park; AFNM: Árvores Fossilizadas Natural Monument

Figure 3 – Distribution of the representation values of 139 surrogates included in Tocantins state conservation planning. Lighter colors indicate areas with higher overlap of representation values (“hotspots”).

Figure 4 – Consnet solution for scenario 1 (CAN100) and current protected areas in Tocantins State.

Figure 5 – Consnet solution for scenario 1 (CAN100) and Tocantins State priority areas for conservation (according to Tocantins, 2008). Numbers 1 to 6 indicate consensual areas indicated by this study. Tocantins and MMA prioritization exercises.

Figure 6 – Consnet solution for scenario 1 (CAN100) and Cerrado priority areas in Tocantins State (according to MMA, 2007).

Figure 7 – Consnet solution for scenario 1 (CAN100) and biotic elements (according to Ferreira et al., in prep) in Tocantins State.

Figure 8 – Comparison between Consnet solutions for scenario 1 (100% protected. CAN100) and scenario 2 (75% protected. CAN75).

Figure 9 - Comparison between Consnet solutions for scenario 1 (100% protected. CAN100) and scenario 3 (50% protected. CAN50). Circles A to C represent coverage of previously identified biotic elements for Tocantins biota.

Discussão geral e conclusões

Estação Ecológica Serra Geral do Tocantins

Discussão geral e conclusões

Essa tese abordou a gestão e representatividade biológica do sistema de unidades de conservação no Estado do Tocantins, na região de contato entre a porção norte do Cerrado e a Amazônia. A partir dos resultados encontrados são discutidas estratégias para superar as principais lacunas no conhecimento sobre representatividade biológica, análise e planejamento de sistemas de áreas protegidas em regiões tropicais, com elevada diversidade biológica e altos graus de ameaça.

Gestão e ameaças ao sistema regional de áreas protegidas

Os resultados apresentados no capítulo 1 indicam que a gestão das áreas protegidas no Estado do Tocantins, assim como das demais áreas no restante do Brasil e América Latina (Ibama & WWF-Brasil, 2007; Leverington et al., 2008), ainda é pouco desenvolvida, apresentando muitas lacunas a serem sanadas. Dentre as unidades de proteção integral do estado, apenas duas têm níveis intermediários de gestão, enquanto todas as demais apresentam níveis inferiores de efetividade, com lacunas significativas nos diferentes indicadores avaliados. Apesar das unidades apresentarem desempenho relativamente bom no elemento Insumos, deficiências como o pouco envolvimento das comunidades locais, número reduzido de funcionários e baixa implementação do plano de manejo, associadas a questões de contexto (pressões antrópicas no entorno e interior das áreas) foram comuns no sistema e contribuíram para a obtenção de valores inferiores no elemento Resultados e nos índices de efetividade de gestão em geral.

As ameaças mais importantes para o sistema de unidades de conservação do Tocantins foram a construção de obras de infraestrutura, as queimadas antrópicas, a caça e a pecuária. A incidência generalizada destas ameaças tanto no Tocantins como em outras UCs brasileiras, indica o padrão sistêmico das ameaças, com causas subjacentes que vão além do contexto local de cada unidade.

São propostas duas estratégias principais para mitigar as ameaças enfrentadas pelo sistema de áreas protegidas do Tocantins, e que também podem ser aplicadas a outras regiões. A primeira é a prevenção e minimização das ameaças mais importantes no contexto de cada área protegida por meio da atuação local da equipe da UC e parceiros. No entanto, no caso das ameaças sistêmicas, sugerem-se estratégias mais amplas, como o planejamento regional integrado e o estabelecimento de processos de tomada de decisões e políticas públicas que integrem os diferentes setores da sociedade e governo. Programas de longo prazo voltados à implementação e consolidação de sistemas de áreas protegidas, como, por exemplo, o programa Arpa (ver resultados de gestão em MMA, 2010), são reconhecidos como uma das melhores estratégias existentes para atingir melhorias significativas na gestão de sistemas de áreas protegidas.

Padrões biogeográficos e representatividade biológica

Os resultados do capítulo 2 indicam que a escassez de dados de biológicos não pode mais ser considerada como fator limitante à aplicação de abordagens sistemáticas para a definição de áreas prioritárias em regiões tropicais com elevada biodiversidade e sistemas de áreas protegidas incipientes, como a porção norte do Cerrado. Tais regiões são justamente onde essas abordagens são mais relevantes e urgentes. A compilação cuidadosa de dados, com apoio de especialistas, seguida por análises adequadas, por meio de técnicas recentes e amplamente utilizadas para inferir a distribuição dos alvos de conservação e representar padrões biogeográficos subjacentes, pode fornecer orientações cruciais para estratégias de conservação regional e local, provando-se eficiente mesmo em regiões pouco estudadas.

A inclusão de espécies de distribuição restrita mostrou-se mais uma vez essencial às análises de representatividade e planejamento sistemático da conservação. Além de estarem associadas a áreas insubstituíveis, um dos principais critérios para a priorização de áreas (Margules & Pressey, 2000; Manne & Williams, 2003; Eken et al. 2004), as espécies de distribuição restrita costumam ser raras (Hanski, 1982; Brown, 1984; Gaston et al. 1997) e especialmente suscetíveis a distúrbios naturais ou antrópicos (Whittaker et al., 2005).

A análise de elementos bióticos (Hausdorf & Hennig, 2003; Carvalho et al., 2011) visa detectar padrões não aleatórios e regionalizados de co-ocorrência de espécies, e mostrou-se bastante adequada para avaliar se o conjunto de alvos de conservação selecionados representam adequadamente os padrões biogeográficos (e processos históricos de vicariância associados) que se pretende conservar. A análise da proteção dos elementos bióticos indicou ainda possíveis lacunas biogeográficas de representatividade dos sistemas de áreas protegidas. Os resultados dessa análise demonstram claramente que áreas de Cerrado no Tocantins não são homogêneas em relação aos padrões de biodiversidade e biogeografia, sendo que as diferentes regiões biogeográficas identificadas apresentam níveis de proteção e perdas de hábitat bastante diferentes.

No Tocantins, a alta concentração de unidades de conservação em apenas duas regiões do estado - no extremo leste (Jalapão) e oeste (Araguaia) – resultou em importantes lacunas de representatividade do sistema de áreas protegidas. Pelo menos metade das espécies e elementos bióticos identificados não está protegida em UCs. Esse resultado reflete tendências globais de ausência de planejamento sistemático e adoção de outros critérios *ad hoc* para a localização de novas áreas protegidas, privilegiando regiões de baixo potencial econômico ou beleza cênica (Pressey, 1994; Margules & Pressey, 2000; Yip et al., 2004).

Planejamento sistemático para o sistema de unidades de conservação do Tocantins

Os resultados do planejamento sistemático baseado em 139 alvos de conservação para o Estado do Tocantins foram apresentados no terceiro capítulo. A comparação com exercícios anteriores indicou maior

consenso com as áreas prioritárias federais (MMA, 2007), que também foram propostas a partir de uma abordagem sistemática baseada na seleção de alvos, definição de metas e constante interação com especialistas. Em contraste, a proposta de áreas prioritárias estaduais (Tocantins, 2008), que não seguiu um processo sistemático, resultou em um consenso limitado. As áreas indicadas nos três exercícios devem ser consideradas prioridade máxima para a criação de novas UCs, uma vez que foram selecionadas mesmo a partir de diferentes critérios e procedimentos e já estão incluídas nas políticas estaduais e federais.

Além disso, buscou-se avaliar de modo pioneiro o impacto do estado de conservação das áreas protegidas no tamanho e configuração dos sistemas necessários ao cumprimento das metas de representatividade dos alvos de biodiversidade. Em geral assume-se que a mera criação das áreas protegidas garante a proteção dos padrões e processos de biodiversidade, o que nem sempre é observado na prática (Peres & Terborgh, 1995; Bruner et al., 2001; Menon et al., 2001; Wilson et al., 2005). Um cenário hipotético de redução em 50% na contribuição das UCs em manter os alvos que originalmente estariam protegidos por essas unidades resultou na necessidade de proteção de uma área adicional de 600 mil hectares no sistema, o que corresponde a aproximadamente o tamanho da maior UC existente no estado e segunda maior unidade de conservação do Cerrado, a Estação Ecológica Serra Geral do Tocantins. O presente estudo não teve como objetivo propor um novo método para avaliar a ameaça, vulnerabilidade ou o estado de conservação da biodiversidade dentro das reservas. Existe uma grande variedade de métodos disponíveis e aplicáveis a diferentes escalas, objetivos e disponibilidade de dados. Entretanto, os resultados aqui apresentados são importantes para destacar a necessidade de incluir o estado de conservação das áreas protegidas em exercícios de planejamento sistemático, especialmente em sistemas de áreas protegidas recentes, altamente ameaçados e pouco consolidados.

As políticas ambientais relacionadas ao estabelecimento dos sistemas de áreas protegidas devem considerar, além da criação de novas UCs, estratégias de longo prazo para prover insumos e demais condições favoráveis aos processos de gestão às unidades já existentes, a fim de superar deficiências de gestão, melhorar a sua capacidade de identificar e mitigar ameaças e, conseqüentemente, garantir a persistência da biodiversidade e outros valores sociais e culturais dessas áreas no longo prazo. Assim como o planejamento de criação de novas áreas, o planejamento da gestão das áreas existentes deve ser realizado de acordo com análises de contexto. Considerando as limitações das áreas protegidas na prevenção e eliminação de todas as ameaças à biodiversidade, as mesmas devem ser vistas como parte fundamental, mas não única, de estratégias amplas de conservação, que também devem abordar as causas subjacentes da perda da biodiversidade por meio da legislação, educação e instrumentos econômicos (Wilson et al., 2005). No Tocantins, como em outros estados brasileiros, mecanismos de conservação complementares à criação e gestão de áreas protegidas podem incluir: (i) incentivos para a criação de reservas particulares, (ii) monitoramento do cumprimento do Código Florestal Brasileiro, que

inclui a proteção de áreas vulneráveis e uma proporção de todas as terras privadas (35% no Tocantins), (iii) a promoção de alternativas de uso sustentável da terra e (iv) abordagens regionais e mais integradas de planejamento e gestão territorial, tais como mosaicos de áreas protegidas com gestão integrada e corredores ecológicos, interligando estratégias em unidades de conservação e terras privadas.

Dessa forma, as principais conclusões desta tese são:

1. O sistema de unidades de conservação no Estado do Tocantins se encontra ainda em fase inicial de implementação.
2. As ameaças que incidem sobre as UCs do Tocantins refletem padrões encontrados em demais regiões neotropicais.
3. A biota do Tocantins não se distribui de forma homogênea e os padrões biogeográficos identificados não estão igualmente representados no sistema de áreas protegidas.
4. Boas sínteses sobre biodiversidade, com apoio direto de especialistas fazendo o melhor uso da informação biológica acumulada, aliados a técnicas recentes são capazes de gerar bons conjuntos de dados sobre os padrões de distribuição da biodiversidade, mesmo em regiões relativamente pouco estudadas e de alta riqueza de espécies.
5. A inclusão de espécies de distribuição restrita é essencial para a compreensão dos padrões biogeográficos e, conseqüentemente, para os exercícios de planejamento da configuração do sistema de áreas protegidas.
6. Níveis relativamente elevados de ameaça associados a valores de efetividade de gestão intermediários podem afetar a persistência da biodiversidade dentro de UCs e, portanto, devem ser incorporados aos exercícios de planejamento sistemático de conservação.
7. A criação de novas áreas protegidas e a consolidação das áreas existentes devem ser complementadas por estratégias que vão além dos sistemas de áreas protegidas, a fim de reduzir as principais causas de perda de biodiversidade.

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Anexos

Anexo 1. Mapas da distribuição potencial de cada espécie-alvo, adotados nas análises de representatividade biológica e planejamento sistemático da conservação do Estado do Tocantins..... 108

Anexo 2. Artigo: Nogueira, C.; Ferreira, M.N.; Recoder, R.S.; Carmignotto, A.P.; Valdujo, P.H.; Lima, F.C.T.; Gregorin, R.; Silveira, L.F.; Rodrigues, M.T. 2011. Vertebrados da Estação Ecológica Serra Geral do Tocantins: faunística, biodiversidade e conservação no Cerrado brasileiro. *Biota Neotropica*, 1 (11).....136

Anexo 3. Artigo: Ferreira, M.N.; Freire, N.C. 2009. Community perceptions of four protected areas in the Northern portion of the Cerrado hotspot, Brazil. *Environmental Conservation*, 36 (2): 129–138.....159

Anexo 4. Artigo: Bonatto, F.; Ferreira, M.N.; Figueroa, F.E.V. 2009. Efetividade de gestão das unidades de conservação de uso sustentável do Estado do Tocantins. *Natureza & Conservação*, 7(1): 95-104.....170

ANEXO 1

Plants

Figure 1 – *Aiouea macedoana*

Figure 2 - *Borreria burchelli*

Figure 3 - *Borreria irwiniana*

Figure 4 - *Borreria tocantinsiana*

Figure 5 – *Diodia macrophylla* Figure 6 - *Diplusodon decussatus* Figure 7 – *Diplusodon gracilis* Figure 8 – *Diplusodon petiolatus*

Figure 9 – *Diplusodon trigintus*

Figure 10 - *Ditassa emmerichae*

Figure 11 – *Duguetia rotundifolia*

Figure 12 – *Gomphrena hillei*

Figure 13 – *Hypenia concinna* Figure 14 - *Hyptis arenaria* Figure 15 – *Hyptis caduca* Figure 16 – *Hyptis humilis*

Figure 17 – *Lippia ciliata* Figure 18 - *Ouratea acicularis* Figure 19 – *Piriqueta araguaiana* Figure 20 – *Polygola pseudocoriacea*

Figure 21 – *Staelia tocaninense*

Figure 22 - *Tassadia rizzoana*

Figure 23 – *Turnera gardneriana*

Fish

Figure 24 – *Aguarunichthys tocantinensis* Figure 25 - *Ammoglanis diaphanus* Figure 26 – *Brachyplatystoma filamentosum* Figure 27 – *Crenicichla compressiceps*

Figure 28 - *Hyphessobrycon gr. eques* Figure 29 – *Hyphessobrycon stegemanni* Figure 30 – *Maratecoara formosa* Figure 31 – *Maratecoara lacortei*

Figure 32 - *Marateocoara splendida*

Figure 33 – *Moenkhausia hysterostricta*

Figure 34 – *Mylesinus paucisquamatus*

Figure 35 – *Pituna compacta*

Figure 36 - *Plesiolebias canabravensis* Figure 37 – *Plesiolebias filamentosus* Figure 38 – *Plesiolebias fragilis* Figure 39 – *Plesiolebias lacerdai*

Figure 40 - *Plesiolebias xavantei* Figure 41 – *Simpsonichthys costai* Figure 42 – *Simpsonichthys flammeus* Figure 43 – *Simpsonichthys multiradiatus*

Figure 44 - *Simpsonichthys semiocellatus* Figure 45 – *Trigonectes rubromarginatus* Figure 46 – *Trigonectes strigabundus*

Amphibians

Figure 47 – *Ameerega flavopicta*

Figure 48 – *Bokermannohyla cf. pseudopseudis*

Figure 49 – *Dendropsophus leucophyllatus*

Figure 50 – *Hypsiboas boans*

Figure 51 – *Hypsiboas* sp. gr. *albopunctatus*

Figure 52 - *Ischnochnema* sp.

Figure 53 – *Leptodactylus sertanejo*

Figure 54 – *Pipa pipa*

Figure 55 – *Pleurodema diplolister* Figure 56 - *Pristimantis* sp. Figure 57 - *Rhinella cf. margaritifera*

Reptiles

Figure 58 – *Anops acrobelles*

Figure 59 - *Apostolepis longicaudatus*

Figure 60 – *Apostolepis polylepis*

Figure 61 - *Bachia micromela*

Figure 62 – *Bachia oxyrhina* Figure 63 – *Bachia psamophila* Figure 64 – *Bronia kraoh* Figure 65 - *Bronia saxosa*

Figure 66 – *Chelonoidis denticulata*

Figure 67 – *Cnemidophorus jalapensis*

Figure 68 – *Cnemidophorus mumbuca*

Figure 69 - *Kentropyx* sp.

Figure 70 – *Lachesis muta*

Figure 71 – *Mabuya guaporicola*

Figure 72 – *Mabuya heathi*

Figure 73 - *Phalotris labiomaculatus*

Birds

Figure 74 – *Alectrurus tricolor* Figure 75 - *Anodorhynchus hyacinthinus* Figure 76 – *Ara chloroptera* Figure 77 - *Celeus obrieni*

Figure 78 – *Cercomacra ferdinandi* Figure 79 – *Culicivora caudacuta* Figure 80 – *Geositta poeciloptera* Figure 81 - *Harpyhaliaetus coronatus*

Figure 82 – *Mergus octosetaceus* Figure 83 – *Paroaria baeri* Figure 84 – *Penelope ochrogaster* Figure 85 - *Procnias averano averano*

Figure 86 – *Pyrrhura pfrimeri* Figure 87 – *Suiriri islerorum* Figure 88 – *Synallaxis simoni* Figure 89 - *Taoniscus nanus*

Mammals

Figure 90 – *Blastocerus dichotomus*

Figure 91 - *Calomys tocantinsi*

Figure 92 – *Chrysocyon brachyurus*

Figure 93 - *Kerodon acrobata*

Figure 94 – *Kerodon rupestris* Figure 95 – *Lonchophylla dekeyseri* Figure 96 – *Makalata didelphoides* Figure 97 - *Monodelphis kunsii*

Figure 98 – *Myrmecophaga tridactyla* Figure 99 – *Oligoryzomys moojeni* Figure 100 – *Oncifelis colocolo* Figure 101 - *Panthera onca*

Figure 102 – *Prionates maximus*

Figure 103 – *Pteronura brasiliensis*

Figure 104 – *Puma concolor*

Figure 105 - *Rhipidomys nittella*

Figure 106 – *Thrichomys* sp. Figure 107 – *Thyroptera devioi* Figure 108 – *Tolypeutes tricinctus* Figure 109 - *Wiedomys pyrrhorhinos*

ANEXO 2

Vertebrados da Estação Ecológica Serra Geral do Tocantins: faunística, biodiversidade e conservação no Cerrado brasileiro

Vertebrate fauna of Estação Ecológica Serra Geral do Tocantins: biodiversity and conservation in the Brazilian Cerrado hotspot

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Abstract: *Basic taxonomic and distributional data on vertebrates are one of the most useful and reliable sources of information for conservation planning. Biological data are even more relevant in rich and highly threatened regions such as the Brazilian Cerrado, one of the least studied global biodiversity hotspots. Herein we provide a summary of the results of a vertebrate survey at Estação Ecológica Serra Geral do Tocantins (~716.000 ha), the second largest protected area in the Cerrado region. We recorded 450 species in EESGT and surroundings, including 17 threatened species, 50 Cerrado endemics and 11 potential restricted-range species. Our results also added 180 new vertebrate records for the Jalapão region. At least 12 species may represent undescribed taxa; four of these were recently described based on specimens obtained in the present study. Our results indicate that EESGT is among the most biologically relevant protected areas in the Cerrado. Proper management will favor the persistence of threatened vertebrates dependent on the last remaining large blocks of pristine Cerrado savannas. Moreover, EESGT and its major biological subunits contribute decisively to the representativeness of the protected areas' system in the Cerrado, conserving presumed narrow endemics with high intrinsic vulnerability and high potential value as indicators of biogeographic processes of diversification in rich and complex Neotropical biotas.*

Key-Words: Cerrado, savannas, conservation, critical sites, vertebrates, inventories

Resumo: *Inventários e estudos faunísticos detalhados sobre vertebrados são uma das fontes mais relevantes de dados para interpretações de padrões detalhados de diversidade biológica. Dados básicos e de boa qualidade sobre faunística são ainda mais urgentes em regiões pouco estudadas e sob intensa ameaça antrópica, tais como a região do Cerrado, um dos 34 hotspots globais para a conservação da biodiversidade. Apresentamos aqui uma síntese dos resultados dos inventários de vertebrados na Estação Ecológica Serra Geral do Tocantins (~716.000 ha), a segunda maior unidade de conservação em todo o Cerrado. Foram registradas 450 espécies de vertebrados na EESGT e entorno imediato, incluindo 17 espécies ameaçadas, 50 espécies endêmicas do Cerrado e 11 espécies com distribuição potencialmente restrita. Do total de espécies amostradas, 180 são novos registros para a região do Jalapão. Ao menos 12 espécies amostradas foram consideradas potenciais espécies novas, das quais quatro foram descritas recentemente, a partir do material obtido no inventário. Os resultados evidenciam que a EESGT é uma das mais importantes áreas protegidas no Brasil central, contribuindo para a persistência de espécies ameaçadas, dependentes dos últimos grandes blocos contínuos de vegetação nativa de Cerrado. Nossos resultados indicam ainda que a conservação da EESGT e suas principais subunidades é crucial*

para a representatividade do sistema de áreas protegidas do Cerrado, protegendo potenciais endemismos restritos que aliam alta vulnerabilidade intrínseca e valor como potencial indicadores de padrões e processos biogeográficos formadores da rica e cada vez mais ameaçada fauna Neotropical.

Palavras-Chave: Cerrado, savanas, conservação, vertebrados, áreas críticas, inventários

INTRODUÇÃO

O conhecimento científico básico sobre grande parte da diversidade biológica no planeta é ainda extremamente limitado, havendo grandes lacunas de informações fundamentais em taxonomia (impedimento Linneano) e distribuição geográfica (impedimento Wallaceano, ver Whittaker *et al.* 2005). Este quadro de desconhecimento é ainda mais grave na região Neotropical, com alta diversidade faunística, mas tradicionalmente pouco estudada (Lewinsohn & Prado 2005).

Inventários e estudos faunísticos detalhados sobre vertebrados, grupos de organismos sobre os quais há conhecimento relativamente amplo a respeito da história natural e taxonomia, são uma das fontes mais relevantes de dados de base para interpretações de padrões gerais de diversidade biológica (Brooks *et al.* 2004a, b, Lamoreux *et al.* 2006). Dados básicos sobre faunística são ainda mais urgentes em regiões pouco estudadas e sob intensa ameaça antrópica (Brooks *et al.* 2004a), tais como a região do Cerrado, uma das 34 grandes regiões prioritárias para a conservação da biodiversidade global (Myers *et al.* 2000, Myers 2003).

Porém, estudos sobre diversidade biológica do Cerrado foram sempre limitados pela dificuldade de acesso às regiões centrais do Brasil, um país colonizado a partir do litoral (Cavalcanti & Joly 2002). Estudos mais aprofundados, de médio a longo prazo, só foram realizados em localidades do Cerrado a partir do século XX (Marinho-Filho *et al.* 2010, Nogueira *et al.* 2010). Mesmo assim, as sínteses disponíveis nas décadas finais do século XX não reconheciam uma fauna de vertebrados típica dos Cerrados, mas sim uma fauna formada por elementos amplamente distribuídos ao longo da “diagonal de formações abertas Neotropicais” (Vanzolini 1963, Sick 1965), ou compartilhados com regiões vizinhas através de corredores florestais em matas de galeria (Redford & Fonseca 1986). Essas interpretações pouco contribuíram para a identificação da singularidade biológica do Cerrado e seu reconhecimento como prioridade global de conservação.

No entanto, sínteses recentes vêm apontando níveis de diversidade, regionalização faunística e endemismo elevados na região do Cerrado, indicando que as conclusões anteriores sobre baixa riqueza e endemismo resultaram de amostragens incompletas, escassez de estudos taxonômicos refinados e

interpretações precipitadas sobre uma das regiões naturais menos estudada do continente (Colli *et al.* 2002, Carmignotto 2005, Nogueira 2006, Nogueira *et al.* 2010). Como exemplo, entre 1980 e 2008 foram descritas para o Cerrado mais de 340 novas espécies de vertebrados, dentre os quais 222 peixes, 57 répteis, 40 anfíbios, 20 mamíferos e uma ave (Machado *et al.* 2008). Este conjunto de descobertas corresponde a cerca de um quarto do total de espécies descritas no Brasil no período (Machado *et al.* 2008), evidenciando o intenso aporte recente de novos dados sobre diversidade faunística no Brasil central.

Tal aporte de dados gera informações fundamentais para traduzir rapidamente o grau de prioridade global conferido ao Cerrado em ações locais e representativas de proteção e manejo. No entanto, paradoxalmente, o acúmulo de conhecimento básico sobre diversidade de vertebrados do Cerrado vem ocorrendo ao mesmo tempo em que vastas porções do Brasil central são irreversivelmente substituídas por pastagens, plantios mecanizados ou grandes empreendimentos de infraestrutura (Klink & Machado 2005, Machado *et al.* 2008, Nogueira *et al.* 2010). Em contraste com o grande número de estudos em áreas sob intenso impacto, – tais como grandes empreendimentos hidrelétricos (ver Nogueira *et al.* 2010) – grande parte das áreas protegidas no Cerrado encontra-se pouco estudada, evidenciando a falta de um planejamento estratégico na obtenção dos dados de faunística básica (Nogueira *et al.* 2010). O resultado da falta de inventários coordenados é a escassez de publicações reunindo dados de riqueza, composição e distribuição local dos diferentes grupos vertebrados em áreas protegidas no Cerrado. Entre as raras exceções estão os dados disponíveis para a Estação Ecológica de Águas Emendadas, na região de Brasília (Marinho-Filho *et al.* 1998), e os resultados de avaliação biológica rápida do Parque Nacional Noel Kempf Mercado, no sudeste da Bolívia (Killeen & Schulenberg 1998).

Nós desconhecemos estudos que sintetizem o conhecimento sobre a diversidade regional de vertebrados em áreas protegidas do Cerrado, publicados sob a forma de artigos científicos em periódicos indexados. Sem informações detalhadas a respeito da composição e distribuição da biota não há como avaliar se medidas apropriadas de conservação e manejo estão sendo aplicadas (Brooks *et al.* 2004a, b). Diante do conjunto de circunstâncias que aliam alta diversidade, lacunas de conhecimento científico básico e alto grau de ameaça, é urgente coletar, sintetizar e tornar acessíveis os dados sobre diversidade biológica nas cada vez mais raras e isoladas regiões abrigando os grandes (e últimos) remanescentes de vegetação nativa do Cerrado. A recente e elevada taxa de perda de hábitat no Cerrado (na ordem de 1.420.000 ha ao ano, MMA 2009) restringe cada vez mais os remanescentes em bom estado de conservação às áreas protegidas (ver Klink &

Machado, 2005). Assim, o conhecimento biológico é essencial para orientar ações de gestão destas áreas, reduzindo efetivamente as ameaças e garantindo a conservação da biodiversidade no longo prazo.

Neste trabalho apresentamos uma síntese de um inventário de vertebrados realizado na Estação Ecológica Serra Geral do Tocantins, a segunda maior área protegida no Cerrado brasileiro. Buscamos enfatizar os resultados obtidos em termos de três alvos principais para a seleção de áreas chave para a conservação (adaptado de Eken *et al.* 2004): espécies ameaçadas (critério 1 de Eken *et al.* 2004), espécies com distribuição restrita (critério 2 de Eken *et al.* 2004) e espécies endêmicas do Cerrado (adaptado do critério 4 de Eken *et al.* 2004). Assim, pretendemos avaliar e definir prioridades locais a partir da contextualização em termos biogeográficos (representada por endemismos restritos ou endemismos do Cerrado) e em termos de ameaças regionais (representadas por espécies ameaçadas). Ao enfatizar estas duas escalas de importância biológica, visamos evidenciar o elo crucial entre pesquisa básica de caracterização da biodiversidade e ações locais (porém contextualizadas) de proteção e manejo de uma das maiores e menos conhecidas áreas protegidas do Cerrado brasileiro.

MATERIAL E MÉTODOS

Área de estudo:

A Estação Ecológica Serra Geral do Tocantins (EESGT) é a segunda maior área protegida e a maior estação ecológica no Cerrado. Foi criada em setembro de 2001, com o objetivo de proteger e preservar amostras dos ecossistemas de Cerrado, bem como propiciar o desenvolvimento de pesquisas científicas (Dec s/nº de 27 de setembro de 2001). Com uma área de aproximadamente 716.306 ha, localiza-se na porção norte do Cerrado, no leste do estado do Tocantins, e extremo noroeste da Bahia (ver Figura 1). A EESGT situa-se na região do Jalapão, composta por um conjunto de depressões e planaltos adjacentes que formam um interflúvio entre três grandes sistemas hídricos do Brasil (Mamede *et al.* 2002, IBAMA 2004, Villela este volume): São Francisco, a sudeste, Tocantins a oeste-noroeste e Parnaíba, a norte-nordeste. A paisagem regional é composta por planaltos e chapadões aplainados, serras do tipo “mesa” e morros testemunhos (Villela, este volume). Os solos predominantes são os areno-quartzosos distróficos e álicos, mas também se registra a presença de latossolos (Mamede *et al.* 2002, IBAMA 2004). A região do Jalapão está protegida por duas outras grandes unidades de conservação: o Parque Estadual do Jalapão com 158.000 ha, ao norte da EESGT, e o Parque Nacional das Nascentes do Parnaíba (729.000 ha), a nordeste, representando a maior unidade de proteção

integral em todo o Cerrado. Além disso, a Área de Proteção Ambiental do Jalapão (462 mil ha), e as reservas particulares do patrimônio natural Mina d'Água (745 ha) e Catedral do Jalapão (326 ha) complementam o mosaico de áreas protegidas da região.

Segundo o mapa de vegetação do Brasil (IBGE 1993), os tipos de fisionomia vegetal dominante na região são cerrados abertos e campestres, como campo limpo, campo sujo e campo cerrado, com manchas de campo cerrado e cerrado *sensu stricto*. É também muito comum na região a presença de extensas veredas e campos úmidos ao longo das drenagens e nascentes, cortando as extensões de campos de interflúvio. Formações florestais são escassas, porém estão presentes em matas de galeria próximas a drenagens.

De modo geral, a região do Jalapão encontra-se em ótimo estado de conservação, apresentando grandes extensões pouco impactadas, e uma das menores densidades demográficas do país, com apenas 1,3 habitantes/km² (IBAMA 2004). No entanto, o amplo predomínio de formações campestres, determinadas pelos solos arenosos e pobres, e sob influência freqüente de queimadas, gera a noção equivocada de que a EESGT apresenta alto grau de perturbação e baixa diversidade biológica, um viés comum em paisagens campestres ou savânicas (Bond & Parr 2010). No entanto, embora relativamente rarefeita, a biota das paisagens abertas de Cerrado revela-se rica e regionalmente diversa, quando estudada através de amostragens intensivas e com o devido detalhe (ver discussões em Ratter *et al.* 1997).

Seleção de regiões e sítios amostrais:

A seleção das regiões e localidades de coleta foi orientada em função de grandes divisões topográficas regionais e de dados prévios de amostragens de fauna (Haseman & Eigenmann, 1911, Santos 2001, Arruda & Von Behr 2002, Vitt *et al.* 2005, ver também Lima & Caires e Rego *et al.*, este volume; Figura 1). Os métodos utilizados para a coleta de dados em cada grupo taxonômico estão descritos nos artigos específicos deste volume.

Como ponto de partida, dividimos a EESGT e seu entorno imediato em três grandes regiões, correspondendo a grandes blocos de unidades topográficas: 1) Depressões do rio Manoel Alves e do rio Balsas (alto curso da bacia do rio Ponte Alta, ambos na bacia do Tocantins), 2) Depressão do rio Novo e Serra do Espírito Santo e 3) Chapadão da Serra Geral na Bahia (Figura 2). A depressão do rio Novo, próxima ao Parque Estadual do Jalapão e município de Mateiros, é uma das mais porções mais acessíveis do Jalapão, e havia sido foco de inventários prévios (Arruda & Von Behr 2002, Vitt *et al.* 2005, ver Figura 1). Desta maneira,

concentramos os esforços de amostragem nas regiões onde havia maiores lacunas de inventários (Figura 2). Estas regiões (1 e 3, ver Figura 2) eram desconhecidas do ponto de vista faunístico, uma vez que quase todos os dados prévios na região do Jalapão foram obtidos em localidades ao norte da EESGT, nas imediações do Parque Estadual do Jalapão, ou onde hoje situa-se o Parque Nacional das Nascentes do Parnaíba (ver Figura 1). O único ponto amostral prévio na EESGT foi a coleta ictiológica nas nascentes do rio Sapão (Haseman & Eigenmann, 1911), no antigo povoado dos Prazeres (hoje no interior da unidade, ver Figura 1). Outros registros prévios no interior da EESGT, agregados às análises do presente projeto, foram obtidos por membros da equipe executora, durante estudos amplos e recentes sobre diversidade e padrões de distribuição de répteis (Nogueira 2006; Nogueira *et al.* 2009) e pequenos mamíferos (Carmignotto 2005, Gregorin *et al.* 2006) do Cerrado.

Durante o período de 23 de janeiro a 21 de fevereiro de 2008 uma equipe composta por 24 zoólogos, incluindo ictiólogos, herpetólogos, ornitólogos e mastozólogos, amostrou a fauna de vertebrados em 75 pontos amostrais no interior e entorno imediato da estação (ver Figura 2). A primeira parte do inventário, de 26 de janeiro a 04 de fevereiro, amostrou áreas localizadas nas depressões do alto curso do rio Manoel Alves e do rio Balsas, na porção sul da EESGT (região 1, ver Figura 2). A segunda parte das amostragens, de 08 a 17 de fevereiro, concentrou-se na porção leste da unidade, no Chapadão Ocidental da Bahia, entre as drenagens do rio Galhão (bacia do Tocantins) e do rio Sapão (Bacia do São Francisco), entre os municípios de Formosa do Rio Preto, BA e Mateiros, TO (região 3, ver Figura 2).

RESULTADOS

Nós amostramos um total de 450 espécies de vertebrados nos inventários realizados na EESGT e entorno imediato, incluindo 35 espécies de peixes, 36 de anfíbios, 45 de répteis, 254 de aves, 39 de quirópteros e 41 de mamíferos terrestres (Tabela 1). Considerando espécimes previamente depositados em coleções ou dados de literatura utilizados nas análises e comparações taxonômicas, os estudos na EESGT adicionaram 180 espécies à riqueza de vertebrados conhecida para a região do Jalapão (ver Tabela 1). Assim, dentre o total de 707 espécies da fauna regional de vertebrados, 64% foi registrada na EESGT e áreas imediatas.

Foram registradas na EESGT pelo menos 50 espécies de vertebrados endêmicas ao Cerrado, incluindo 15 anfíbios, 19 répteis, 11 aves, um morcego e quatro mamíferos terrestres (ver Tabela 1). Este total é subestimado, pois não inclui a ictiofauna, cujos padrões de distribuição não se ajustam a grandes domínios de vegetação terrestre, mas sim a limites de bacias hidrográficas, não havendo, até o presente, sequer listagens

preliminares de espécies de peixes endêmicas da região do Cerrado. Os inventários na EESGT revelaram ainda a presença de pelo menos 11 espécies com distribuição potencialmente restrita (ver Tabela 1), conhecidas de poucas localidades e muito provavelmente distribuídas apenas na região do Jalapão e regiões adjacentes à porção norte da Serra Geral.

Foram ainda registradas 17 espécies de vertebrados ameaçadas, incluindo duas de peixe, quatro de aves, uma de morcego e 10 de mamíferos terrestres (ver Tabela 1). Por fim, as amostragens revelaram a presença de pelo menos 12 prováveis novas espécies de vertebrados. Quatro delas foram descritas recentemente, com base em material proveniente das coletas aqui discutidas: *Thyroptera devivoi* Gregorin *et al.* 2006, *Bachia oxyrhina* Rodrigues *et al.* 2009, *Amphisbaena acrobeles* (Ribeiro *et al.* 2009) e *Siagonodon acutirostris* Pinto & Curcio 2011. Todas as demais dependem de estudos mais amplos e comparações detalhadas de taxonomia para que sejam confirmadas como novas espécies e, possivelmente, descritas formalmente.

De modo geral, a distribuição de espécies de vertebrados na região de estudo não se dá aleatoriamente, mas fortemente associada ao mosaico de ambientes típico das paisagens de Cerrado (ver Recoder *et al.* e Carmignotto *et al.* este volume). Portanto, existem conjuntos de ambientes críticos na área de estudo (Tabela 2), em geral localizados, e abrigando espécies-alvo prioritárias (espécies ameaçadas, endemismos do Cerrado, espécies de distribuição restrita, ou espécies localmente raras, associadas fortemente a um tipo de ambiente específico).

Afloramentos de arenito são comuns em praticamente todas as quebras de relevo e bordas de morros testemunho na Estação, representando um ambiente crucial para várias espécies de interesse direto para a conservação (ver Tabela 2). Paredões de arenito e cerrados rupestres são utilizados como sítios de abrigo e reprodução pelo psitacídeo *Anodorhynchus hyacinthinus* (Latham 1790), consistindo também no ambiente típico do roedor *Trichomys* sp., provável espécie nova e com distribuição potencialmente restrita, conhecida atualmente da região do Jalapão e de duas localidades na porção sul do Estado de Tocantins (Carmignotto 2005). Os afloramentos de arenito são ainda um dos ambientes típicos de *Lonchophylla dekeyseri* Taddei *et al.* 1993, espécie associada também a cerrados e campos em áreas de planalto, como os chapadões da Serra Geral (Gregorin *et al.* este volume).

Campos e cerrados sobre areia constituem o tipo de ambiente dominante na estação, e abrigam outro

conjunto importante de espécies (ver Tabela 2), incluindo os prováveis endemismos restritos de répteis *Cnemidophorus jalapensis* Colli *et al.*, 2009, *Amphisbaena acrobeles* (Ribeiro *et al.* 2009) e *Bachia oxyrhina* Rodrigues *et al.* 2008, aparentemente segregados entre diferentes porções da unidade (ver Recoder *et al.* este volume). Outro lagarto endêmico do Cerrado, *Stenocercus quinarius* Nogueira & Rodrigues 2006 está aparentemente associado a formas mais densas de cerrado típico, nas porções mais altas da unidade, nos planaltos do oeste baiano, na Serra Geral (ver Recoder *et al.*, este volume). Campos e cerrados são também o ambiente típico dos mamíferos ameaçados *Priodontes maximus* (Kerr, 1792), *Tolypeutes tricinctus* (Linnaeus, 1758) e *Myrmecophaga tridactyla* Linnaeus, 1758 (Carmignotto *et al.*, este volume). As formações mais abertas de cerrado de interflúvio, contendo campos limpos, abrigam ainda duas espécies de relativa importância para a conservação (ver Tabela 2): a ave ameaçada *Taoniscus nanus* Temminck, 1815 e o cada vez mais raro cervídeo *Ozotocerus bezoarticus* (Linnaeus, 1758).

Campos úmidos e veredas, outro tipo de ambiente bastante comum na unidade, são o hábitat principal de outro conjunto de espécies críticas (ver Tabela 2), incluindo o anfíbio *Leptodactylus sertanejo* (Giaretta & Costa, 2007), além da provável espécie nova de lagarto *Kentropyx* aff. *paulensis* e da suçupara (ou cervo-do-Pantanal), *Blastocerus dichotomus* (Illiger, 1815), este último ameaçado e dependente de grandes extensões de veredas e campos úmidos em bom estado de conservação, presentes ainda na região das nascentes do rio Sapão (Carmignotto *et al.* este volume). Outra espécie típica de formações de veredas (ver Tabela 2) ricas em plantas heliconiáceas, é o morcego recém descrito *Thyroptera devivoi* Gregorin *et al.* 2006, espécie até o momento muito pouco estudada, conhecida de poucas localidades e aparentemente endêmica das formações savânicas da América do Sul (ver Gregorin *et al.* este volume).

Outro conjunto de espécies está associado a matas de galeria (ver Tabela 2), incluindo grande parte dos felinos presentes na região, tais como a jaguatirica *Leopardus pardalis* (Linnaeus, 1758), o gato do mato *L. tigrinus* (Schreber, 1775), e a onça-pintada *Panthera onca* (Linnaeus, 1758), relativamente rara localmente. Outro mamífero raro e dependente de matas de galeria é o canídeo *Speothos venaticus* (Lund, 1842), cuja biologia é ainda pouco estudada. As matas de galeria são também o ambiente típico da ave ameaçada *Procnias averano* (Hermann, 1783), abrigando também uma provável nova espécie de ave, *Picumnus* sp. amostrada nas matas de galeria de drenagens protegidas na EESGT e áreas vizinhas.

Por fim, ambientes ripários como rios e riachos de cabeceira são também prioridades (ver Tabela 2), pois

abrigam um conjunto importante de prováveis endemismos da ictiofauna (ver Lima e Caires, este volume). Estes ambientes ripários são o habitat principal de espécies ameaçadas, tais como o criticamente ameaçado *Mergus octosetaceus* Viellot, 1817, dependente de drenagens com água corrente e transparente, como a calha principal do rio Novo e suas nascentes. Além disso, poças temporárias associadas a rios de maior porte são o provável ambiente reprodutivo dos anfíbios *Scinax constrictus* (Lima, Bastos & Giaretta, 2005), *Dendropsophus cruzi* (Pombal e Bastos, 1998) e *Osteocephalus cf. taurinus*. Por fim, corredeiras em riachos de cabeceira são o ambiente reprodutivo do anuro *Proceratophrys goyana*, endêmico do alto curso do rio Tocantins (Valdujo *et al.* este volume).

Ambientes de corredeira na bacia do rio Novo abrigam duas espécies ameaçadas de peixes (ver Tabela 2), *Aguarunichthys tocantinsensis* Zuanon, Rapp Py-Daniel & Jégu, 1993 e *Mylesinus paucisquamatus* (Jégu & dos Santos, 1988), registrados à jusante da Cachoeira da Velha, fora dos limites da EESGT (ver Lima e Caires, este volume). Embora estas duas espécies provavelmente não estejam presentes na unidade, a EESGT abriga o conjunto de nascentes e o alto curso do rio Novo, sendo crucial para a conservação destas espécies.

DISCUSSÃO

Recomendações para o zoneamento e manejo da fauna

Para a conservação da biota na EESGT é necessário ter atenção especial às populações de espécies que ocorrem em subunidades distintas da estação, que neste caso devem ser tratadas como diferentes unidades de manejo. Tais subunidades seriam, minimamente, as três grandes regiões definidas no planejamento da amostragem do presente estudo: 1) região da depressão do rio Manoel Alves e rio Balsas, 2) a região do alto rio Sono (rio Novo) e 3) a região da Cabeceira do rio Sapão, na porção leste da unidade, que protege uma porção dos campos gerais da Serra Geral, no oeste da Bahia. A presença de espécies aparentemente segregadas por barreiras de relevo ou hidrográficas (ver discussões em Rodrigues *et al.* 2008, Colli *et al.* 2009, ver também Lima e Caires, este volume) indica que a região do Jalapão abriga diferentes conjuntos faunísticos, provavelmente determinados por condições históricas e bastante remotas, vinculadas à geomorfologia regional.

Do ponto de vista da biota aquática ou ripária, o manejo da unidade deve ser planejado de acordo com as diferentes unidades hidrográficas, já que existe um intercâmbio muito restrito de espécies entre as cabeceiras do sistema do rio Manoel Alves, rio Novo e rio Sapão. Embora exista interligação física entre os sistemas do rio Novo (alto Tocantins) e rio Sapão (São Francisco) esta conexão favorece a dispersão de poucas

espécies da ictiofauna, sendo as demais espécies restritas a diferentes drenagens (ver Lima & Caires, neste volume).

Como principal drenagem regional, o alto curso do rio Novo é ambiente crítico para uma parcela importante da biodiversidade no Jalapão, abrigando componentes únicos e ameaçados. Além disso, o fluxo, a qualidade da água e integridade dos ecossistemas do rio Novo dependem diretamente da proteção das suas cabeceiras, contidas integralmente na unidade. Da mesma forma, a porção ao sul e leste da unidade abriga as cabeceiras dos rios Manoel Alves e Balsas, e contém importantes nascentes da bacia do alto rio Sono, cujas nascentes também estão contidas inteiramente na EESGT. Esta região da unidade abriga espécies potencialmente restritas (ver Tabela 2), possivelmente ausentes de outras porções da estação e provavelmente isoladas destas por quebras de relevo.

Já a região da Serra Geral e planalto do oeste baiano, além de também abrigar espécies ausentes ou raras nas demais unidades (ver Tabela 2), é uma das porções mais ameaçadas regionalmente. O amplo e contínuo processo de expansão da fronteira da agricultura mecanizada já se alastrou por praticamente todo o planalto do oeste baiano, até a fronteira leste da área protegida. Desta maneira, proteger as partes altas do leste da EESGT, nos cerrados de planalto da Serra Geral na Bahia, deve ser uma prioridade máxima da gestão. Como grande parte do planalto da Serra Geral já foi modificada pelo desmatamento, a proteção desta porção da EESGT representa uma das últimas chances de manter áreas representativas de cerrados e veredas neste que é um dos maiores, mais ameaçados e menos estudados blocos de planalto em todo o Cerrado.

Nas três grandes subunidades da EESGT ocorrem ambientes especiais, incluindo veredas, cerrados e campos sobre areia, matas de galeria, drenagens e afloramentos rochosos, dos quais dependem espécies críticas para a conservação regional e do Cerrado (ver Tabela 2). Assim, as ações de manejo e conservação deverão considerar a proteção especial de diferentes ambientes críticos. Como a biota na EESGT está distribuída de acordo com o mosaico típico de ambientes do Cerrado, as ações de manejo e conservação devem ser focadas em manter os diferentes componentes deste mosaico, uma vez que todos abrigam espécies de alta relevância para a conservação do Cerrado. Recomendamos que o futuro desenvolvimento do plano de manejo e zoneamento da UC considere as regiões e ambientes aqui mencionados, garantindo que ao menos parte destes estejam representada em zonas de menor intervenção humana possível (tradicionalmente denominadas “zona intangível” ou “zona primitiva”).

Outra ação imediata e necessária para o manejo de fauna e decorrente de nossa experiência durante o inventário é a intensificação do trânsito de funcionários e fiscais ao longo da estrada principal da EESGT, cruzando o centro da Estação no sentido norte e sul, entre a região do rio Novo e a cabeceira do rio Balsas, no município de Rio da Conceição. Durante o inventário a equipe de pesquisa se deparou com caçadores acampados na cabeceira do rio Balsas. Estes abateram espécimes de mamíferos, como a queixada, *Tayassu pecari* (Link, 1795), o veado-catingueiro, *Mazama gouazoubira* (Fischer, 1814) e uma anta, *Tapirus terrestris* (Linnaeus, 1758). A presença constante da equipe da UC no interior da unidade, especialmente nesta porção central e de difícil acesso, certamente reduziria a ação de caçadores, que devem causar impacto significativo na fauna local de vertebrados de grande porte, que já não é abundante regionalmente. Curiosamente, ao contrário de nossa expectativa inicial, os avistamentos de espécies visadas pela caça foram mais comuns na porção com melhor acesso, na borda norte da unidade (na estrada Mateiros - Ponte Alta). Já no interior da unidade, em áreas mais isoladas, como a cabeceira do rio Balsas, foram raros os avistamentos destas espécies. Embora nossos dados sejam insuficientes para uma análise quantificada do impacto de caça, é provável que o fluxo mais constante ao longo da estrada principal, Mateiros-Ponte Alta e sua proximidade com o Parque Estadual do Jalapão, de algum modo restrinjam a ação de caçadores.

Assim, recuperar os trechos críticos da estrada (nas quebras de relevo após o Morro do Fumo, próximo às cabeceiras do rio Balsas, no sentido Mateiros - Rio da Conceição) iria trazer maior facilidade de fiscalização e controle nesta porção interior da unidade. É nosso entendimento que o bom acesso deverá inibir a entrada de caçadores ou invasores, uma vez que a porção central da unidade estaria acessível a rondas mais constantes, e menos desgastantes para a equipe de gestores e fiscais. Facilitar a chegada e a presença destes gestores e fiscais às áreas mais afastadas, reduzindo o tempo e custo de deslocamento, seria um fator significativo para a redução da pressão de caça ou mesmo presença de pessoas sem autorização no interior da unidade. Além disso, o melhor acesso facilitaria o trabalho de detecção e combate às queimadas em toda a UC.

Idealmente, para que as ações de manejo, fiscalização e pesquisa ocorram dentro de uma rotina sistematizada, seria importante prover uma base de apoio e alojamento na porção central da estação, próximo à região do Morro do Fumo, ao longo da estrada principal entre Rio da Conceição e região do rio Novo. Uma base ali instalada facilitaria o acesso dos fiscais e pesquisadores às principais subunidades da estação e permitiria o pernoite no interior da área protegida, gerando rotinas de acesso controlado a regiões ainda muito remotas na unidade. Cabe ressaltar que a EESGT e toda a região do Jalapão é bastante extensa e

topograficamente complexa. A dificuldade de acesso constante e controlado é claramente um empecilho à melhor caracterização e proteção de sua biota.

Recomendações para pesquisa futura

Embora nossos estudos tenham revelado valores elevados de riqueza e um grande conjunto de espécies de alta prioridade para a conservação, dentre as quais espécies endêmicas, potencialmente raras e geograficamente restritas, ainda restam grandes lacunas sobre taxonomia e distribuição da fauna local e regional (ver Nogueira *et al.* 2010, Bernard *et al.* 2011).

Uma das principais ações de pesquisa que recomendamos é dar continuidade aos estudos taxonômicos, de maneira a tentar esclarecer o status das várias populações consideradas como potenciais espécies novas. O trabalho de inventário e caracterização faunística não termina na fase de coleta de dados em campo; ao contrário, é um esforço contínuo e integrado de comparação e análise de material depositado em coleções, que são uma rede de informações interligadas e unificadas pela ação dos especialistas (Graham *et al.* 2004). No entanto, mesmo para vertebrados, há poucos especialistas em taxonomia no Brasil (Carbayo & Marques, 2011), e o conjunto de espécies a descrever é sempre crescente, sendo ampliado com as coletas recentes em áreas pouco ou nunca amostradas (Carbayo & Marques, 2011). Estimular a continuidade de estudos em taxonomia e vincular tais resultados a ações de conservação e manejo da EESGT requer constante troca de informações entre os gestores da unidade e os especialistas, uma condição essencial para boas ações de conservação e caracterização da biodiversidade (ver Nogueira *et al.* 2009).

Outro conjunto de estudos prioritários seria descrever mais detalhadamente os padrões de distribuição local da fauna, visando delinear mais claramente os limites e possíveis barreiras geográficas à ocorrência de espécies entre diferentes porções da unidade e do Jalapão. Planejamento de conservação é uma tarefa altamente dependente de bons mapas de atributos da biodiversidade (Brooks *et al.* 2004a). Assim, entender em detalhe os limites entre a distribuição de espécies endêmicas (e. g. ictiofauna de cabeceiras, endemismos restritos da fauna de répteis e pequenos mamíferos) poderá trazer conhecimentos detalhados sobre mecanismos históricos e atuais de isolamento entre populações. Este tipo de informação seria fundamental à tarefa (ainda bastante incompleta) de compreender o papel das áreas protegidas na conservação de processos de formação da diversidade neotropical e do Cerrado. Diante dos vários exemplos descritos aqui de potenciais espécies segregadas entre unidades topográficas distintas, acreditamos que a

EESGT e o Jalapão fornecem oportunidades únicas para estudos de biogeografia e conservação em escalas locais, ainda incipientes no Brasil. Tais estudos seriam beneficiados com novas amostragens, focadas em grupos taxonômicos específicos e em espécies interesse direto em biogeografia e conservação (ver Tabela 2), em porções ainda pouco amostradas ou sem amostragens na EESGT (ver Figura 2). São exemplos de regiões ainda carentes de mais estudos as cabeceiras do rio Novo e rio Verde, na parte centro-sul da EESGT, a porção noroeste da Estação, nas áreas baixas da drenagem do rio Ponte Alta, além de estudos mais detalhados nos planaltos da Serra Geral e chapadões isolados da Serra do Meio e Serra do Cinzeiro, estas últimas em regiões de difícil acesso, mas que representam blocos isolados de planaltos que testemunham condições pretéritas de relevo e geomorfologia.

Outros estudos prioritários envolvem estudos de médio a longo prazo sobre impactos da caça na fauna de mamíferos de médio e grande porte. A caça é uma atividade antiga e bastante comum na região (Ferreira & Freire, 2009) e o monitoramento destas espécies poderia trazer uma melhor compreensão sobre os impactos danosos da caça sobre a fauna de vertebrados regional.

Outra frente prioritária de estudos é compreender mais detalhadamente o papel e representatividade da porção leste da unidade no contexto da proteção da biota do planalto da Serra Geral, oeste da Bahia. Essa região é uma das porções do Cerrado mais impactadas recentemente pela perda de habitats (Batistella & Valladares, 2009), e uma das maiores extensões de planaltos e cerrados de topo de chapada no Brasil. Este tipo de ambiente, em solos planos de topos de chapada, é ambiente altamente visado para a instalação de grandes projetos de agricultura mecanizada (Klink & Machado 2005). Entender quais as principais lacunas de conservação nesta região de planalto, e quantificar a importância biológica das áreas da EESGT no contexto da conservação da Serra Geral é um tema urgente para novos estudos. Tais estudos deverão trazer uma melhor compreensão dos impactos decorrentes do avanço da agricultura mecanizada, certamente a principal ameaça regional à biodiversidade na EESGT e no Jalapão, e a maior ameaça à biodiversidade no Cerrado (Klink & Machado 2005).

Por fim, estudos que busquem entender os efeitos de diferentes regimes de fogo sobre a fauna de pequenos vertebrados podem auxiliar o planejamento e implementação de estratégias para minimizar o impacto de queimadas antrópicas anuais, uma das ameaças principais sobre as áreas protegidas do Cerrado e uma ameaça bastante evidente à manutenção da biodiversidade da EESGT. Ressaltamos, entretanto, que a completa supressão do fogo seria inviável e deletéria à biota do Cerrado, adaptada a incêndios naturais e

periódicos (porém não anuais) provocados por tempestades com descargas elétricas. Assim, persistem historicamente no Cerrado mosaicos de áreas com diferentes históricos de queima (França *et al.* 2007, Ramos-Neto & Pivello 2000). Estudos mais aprofundados podem permitir a identificação das áreas, ambientes e espécies mais impactadas pelos incêndios antrópicos, fornecendo subsídios importantes para ações preventivas, como aceiros e monitoramento mais intenso nas áreas mais vulneráveis ou com maior incidência de focos de calor.

Conclusão final: conhecer para conservar

O projeto trouxe resultados inéditos sobre a fauna de vertebrados da segunda maior unidade de conservação no Cerrado. Antes da conclusão do projeto havia grande desconhecimento sobre a composição de espécies e riqueza de vertebrados na EESGT e região. Até mesmo estudos prévios, em coletas zoológicas anteriores às primeiras décadas do século XX (Haseman & Eigenmann, 1911; Pacheco 2004; ver artigos de avifauna e ictiofauna neste volume) eram muito pouco conhecidos, apesar de fornecerem os primeiros registros faunísticos desta região do Cerrado. A falta de levantamento de dados de literatura taxonômica levava, portanto, a que dados relevantes de faunística fossem negligenciados.

A compilação dos dados e os resultados gerados no projeto indicam que a EESGT abriga uma fauna rica e singular de vertebrados, contradizendo noções anteriores sobre homogeneidade e caráter generalista da fauna de Cerrado, e corroborando sínteses recentes, que indicam alto endemismo e compartimentalização da biota (ver Nogueira *et al.* 2010, ver também Carmignotto *et al.*, Recoder *et al.*, Lima & Caires, este volume). A presença de um conjunto expressivo de espécies endêmicas do Cerrado, somada à presença de espécies ameaçadas de extinção (tanto nas listagens da IUCN quanto na lista oficial brasileira) evidenciam a importância da área como uma das principais unidades de conservação para a manutenção da biodiversidade do Cerrado.

Embora ainda haja a necessidade de estudos complementares, especialmente no grupo da ictiofauna (que apresentou um grande conjunto de espécies potencialmente novas), os dados indicam que a EESGT é composta por um mosaico de áreas e habitats que abrigam um conjunto singular de espécies relativamente raras e com distribuição dependente de condições ecológicas localizadas e específicas. Embora tais espécies não figurem entre as dominantes nas faunas locais, merecem atenção especial pela sua restrição geográfica e provável endemismo local. Deste modo, diferentes porções da região do Jalapão e da EESGT merecem atenção

especial em estratégias de conservação, pois abrigam espécies não registradas em nenhuma outra porção do Cerrado.

Muitas destas espécies podem ser confirmadas como espécies de distribuição restrita, conhecidas de áreas menores do que 50.000 km², um dos alvos principais em estratégias de conservação (Eken *et al.* 2004). É possível que boa parte dos endemismos no Cerrado apresentem distribuições bastante localizadas (menores do que o limite de 50.000 km²), especialmente aqueles associados a manchas isoladas e descontínuas de hábitat.

Ainda, o registro de grandes mamíferos e de algumas espécies de aves (*Panthera onca*, *Mergus octosetaceus*, *Anodorhynchus hyacinthinus*) evidencia o papel da EESGT e do mosaico de áreas protegidas do Jalapão na manutenção de populações de espécies que necessitam de vastas áreas preservadas, cada vez mais raras no Cerrado brasileiro.

Assim, a gestão adequada da EESGT deverá assegurar a proteção de componentes singulares da biota do Cerrado, que não são conhecidos de nenhuma outra região. A criação da EESGT foi um marco para a proteção de populações únicas que poderiam estar sob intensa pressão de extinção, frente à ampla destruição de habitats no Cerrado, que já ameaça diretamente áreas no entorno da unidade (especialmente nos planaltos da Serra Geral, no oeste baiano). Cabe lembrar que a média recente de desmatamento anual no Cerrado é de 1.420.000 ha (MMA 2009), ou seja, a cada ano, em média, tem sido desmatada uma área equivalente ao dobro da extensão da EESGT.

No entanto, a gestão efetiva da unidade ainda é um desafio, cujo sucesso será determinante para garantir a proteção de diversas espécies de alta relevância para a conservação. Algumas lacunas importantes, como a falta de instrumento de planejamento robusto (plano de manejo), equipe, infraestrutura e equipamentos insuficientes, deficiências logísticas de acesso e transporte, além da pouca interação com as UCs do entorno são alguns dos problemas a serem superados para reduzir e evitar as crescentes ameaças à EESGT.

Espera-se que a conservação adequada da EESGT possa garantir que essa unidade cumpra os seus objetivos de criação e traga dois resultados principais e complementares para a conservação da biota Neotropical e do Cerrado: por um lado a EESGT é crucial do ponto de vista da representatividade do sistema de áreas protegidas no Cerrado, abrigando populações de um conjunto de espécies com distribuição potencialmente restrita. Tais espécies aliam alta vulnerabilidade intrínseca ao alto valor como indicadores de padrões e processos históricos e biogeográficos (ver discussões em Nogueira *et al.* 2009). Além disso, a EESGT contribui decisivamente para a persistência de espécies ameaçadas de aves e mamíferos, com distribuição mais

ampla, mas sob intensa pressão em toda a região do Cerrado. Tais espécies são dependentes dos últimos grandes blocos contínuos e protegidos de vegetação nativa de Cerrado, como os presentes na EESGT e região.

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TABELAS

Tabela 1 - Síntese de riqueza, endemismo e ameaças nos grupos de vertebrados na EESGT e Jalapão.

DR = distribuição restrita.

Table 1 – Richness, endemism and threat in major vertebrate groups in EESGT and Jalapão. DR = restricted range.

	Riqueza EESGT	Riqueza Jalapão	Novos registros	Endêmicas Cerrado	Potencia s DR	Ameaçadas IUCN/MMA	Nova s
Ictiofauna	35	111	67	NA	5	2	5
Herpetofauna (anfíbios)	36	39	7	15	0	0	2
Herpetofauna (répteis)	45	88	6	19	4	0	2
Avifauna	254	366	33	11	0	4	1
Mastofauna (quirópteros)	39	39	39	1	1	1	1
Mastofauna (terrestre)	41	64	28	4	1	10	1
Totais	450	707	180	50	11	17	12

Tabela 2 – Espécies, regiões e ambientes chave para a conservação e manejo da EESGT.

Table 2 – Species, regions and key habitats for management and conservation at EESGT.

Grupo	Espécie	Ambiente chave	Subunidade EESGT
ict	<i>Aguarunichthys tocantinsensis</i> Zuanon et al. 1993	rios (corredeiras)	Rio Novo
ict	<i>Mylesinus paucisquamatus</i> (Jégu & dos Santos, 1988)	rios (corredeiras)	Rio Novo
anf	<i>Eupemphix nattereri</i> (Steindachner, 1863)	campo e cerrado típico (poças temp.)	Ampla
anf	<i>Leptodactylus sertanejo</i> (Giaretta & Costa, 2007)	campo úmido e vereda	Serra Geral
anf	<i>Proceratophrys goyana</i> (Miranda-Ribeiro, 1937)	riachos com água corrente	Manoel Alves-Balsas
anf	<i>Dendropsophus cruzi</i> (Pombal e Bastos, 1998)	rios (poças marginais)	Rio Novo
anf	<i>Osteocephalus cf. taurinus</i>	rios (poças marginais)	Rio Novo
anf	<i>Scinax constrictus</i> (Lima, Bastos & Giaretta, 2005)	rios (poças marginais)	Rio Novo
rep	<i>Cnemidophorus jalapensis</i> Colli et al., 2009	campo e cerrado sobre areia	Rio Novo, Manoel Alves-Balsas
rep	<i>Amphisbaena acrobeles</i> (Ribeiro et al. 2009)	campo e cerrado sobre areia	Rio Novo
rep	<i>Bachia oxyrhina</i> Rodrigues et al., 2008	campo e cerrado sobre areia	Manoel Alves-Balsas
rep	<i>Kentropyx</i> aff. <i>paulensis</i>	campo úmido e vereda	Rio Novo
rep	<i>Stenocercus quinarius</i> Nogueira & Rodrigues, 2006	cerrado típico em planalto	Serra Geral
av	<i>Anodorhynchus hyacinthinus</i> (Latham 1790)	afloramentos de arenito	Ampla
av	<i>Taoniscus nanus</i> Temminck, 1815	campo limpo em planalto	Serra Geral
av	<i>Procnias averano</i> (Hermann, 1783)	mata de galeria	Serra Geral
av	<i>Mergus octosetaceus</i> Viellot 1817	Rios	Rio Novo
mast	<i>Lonchophylla dekeyseri</i> Taddei et al. 1993	campos e afloramentos de arenito	Serra Geral
mast	<i>Thyroptera devivoi</i> Gregorin et al. 2006	Vereda com Heliconiáceas	Rio Novo
mast	<i>Chrysocyon brachyurus</i> (Illiger, 1815)	campo e cerrado sobre areia	Ampla
mast	<i>Priodontes maximus</i> (Kerr, 1792)	campo e cerrado sobre areia	Ampla
mast	<i>Tolypeutes tricinctus</i> (Linnaeus, 1758)	campo e cerrado sobre areia	Serra Geral
mast	<i>Myrmecophaga tridactyla</i> Linnaeus, 1758	campo e cerrado sobre areia	Ampla
mast	<i>Blastocerus dichotomus</i> (Illiger, 1815)	campo úmido e vereda	Serra Geral
mast	<i>Leopardus pardalis</i> (Linnaeus, 1758)	mata de galeria	Ampla
mast	<i>Leopardus tigrinus</i> (Schreber, 1775)	mata de galeria	Ampla
mast	<i>Leopardus wiedii</i> (Schinz, 1821)	mata de galeria	Ampla
mast	<i>Panthera onca</i> (Linnaeus, 1758)	mata de galeria	Ampla
mast	<i>Speothos venaticus</i> (Lund, 1842)	mata de galeria	Ampla
mast	<i>Thrichomys</i> sp.	afloramentos de arenito	Ampla
mast	<i>Ozotocerus bezoarticus</i> (Linnaeus, 1758)	campo e cerrado sobre areia	Rio Novo

LEGENDA DAS FIGURAS

Figura 1 – Pontos amostrados em estudos prévios de fauna na região do Jalapão (Haseman & Eigenmann, 1911; Santos 2001, Arruda & Von Behr 2002, Vitt *et al.* 2005, ver também Lima & Caires e Rego *et al.* este volume). As variações de cor denotam gradiente de altitude, com áreas mais altas (até 890 m) em azul escuro, e áreas mais baixas (até 310 m) em amarelo. Linhas em verde escuro: limites da EESGT. Linhas em verde claro: limites das demais UCs de proteção integral no Jalapão. PEJ: Parque Estadual do Jalapão; PNNP: Parque Nacional Nascentes do Parnaíba. Em vermelho limites estaduais. Estrelas vermelhas: sedes municipais.

Figure 1 – Sites sampled in previous faunistic studies in the Jalapão region (Haseman & Eigenmann, 1911, Santos 2001, Arruda & Von Behr 2002, Vitt *et al.* 2005, see also Lima & Caires and Rego *et al.* this volume). Color shades indicate elevation gradients, with higher areas (up to 890 m) in dark blue, and lower areas (up to 310 m) in yellow. Dark green lines: EESGT boundaries. Light green lines: boundaries of other strictly protected areas in the Jalapão region. PEJ: Parque Estadual do Jalapão. PNNP: Parque Nacional Nascentes do Parnaíba. Red lines refer to state boundaries, and red stars to urban settlements.

Figura 2 – Pontos amostrados durante o inventário na EESGT e região. As variações de cor denotam gradiente de altitude, com áreas mais altas (até 890 m) em azul escuro, e áreas mais baixas (até 310 m) em amarelo. Linhas em verde escuro: limites da EESGT. Linhas em verde claro: limites das demais UCs de proteção integral no Jalapão. PEJ: Parque Estadual do Jalapão. Em vermelho limites estaduais. Estrelas vermelhas: sedes municipais. Números indicam as três principais subunidades de relevo na EESGT (ver texto).

Figure 2 – Sites sampled in EESGT during the present study. Color shades indicate elevation gradients, with higher areas (up to 890 m) in dark blue, and lower areas (up to 310 m) in yellow. Dark green lines: EESGT boundaries. Light green lines: boundaries of other strictly protected areas in the Jalapão region. PEJ: Parque Estadual do Jalapão. Red lines refer to state boundaries, and red stars to urban settlements. Numbers (1-3) refer to the three main subunits of the study region (see text).

ANEXO 3

Ferreira, M.N.; Freire, N.C. 2009. Community perceptions of four protected areas in the Northern portion of the Cerrado hotspot, Brazil. *Environmental Conservation*, 36 (2): 129–138.

ANEXO 4

Bonatto, F.; Ferreira, M.N.; Figueroa, F.E.V. 2009. Efetividade de gestão das unidades de conservação de uso sustentável do Estado do Tocantins. *Natureza & Conservação*, 7(1): 95-104.