UNIVERSIDADE FEDERAL DE MINAS GERAIS
Instituto de Ciências Biológicas
Programa de Pós-Graduação em Ecologia, Conservação e Manejo da Vida Silvestre

Amanda Monique da Silva Dias

A BIODIVERSIDADE NO CONTEXTO DA AVALIAÇÃO DE IMPACTOS AMBIENTAIS (AIA) BRASILEIRA: Decisões baseadas em estudos falhos

Belo Horizonte
2022

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Orientador: Prof. Dr. Adriano Paglia

Coorientador: Dr. Rodrigo Massara

Coorientador estrangeiro: Prof. Dra. Carly Cook

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Ata da Defesa de Tese

Nº 210
Entrada: 2017/2

Amanda Monique da Silva Dias

No dia 25 de julho de 2022, às 14:00 horas, por vídeo conferência, teve lugar a defesa de tese de doutorado no Programa de Pós-Graduação em Ecologia, Conservação e Manejo da Vida Silvestre, de autoria do(a) doutorando(a) Amanda Monique da Silva Dias, orientando(a) do Professor Adriano Pereira Paglia, intitulada: **"A biodiversidade no contexto da avaliação de impactos ambientais (AIA) brasileira: decisões baseadas em estudos falhos".** Abrindo a sessão, o(a) Presidente(a) da Comissão, Doutor(a) Adriano Pereira Paglia, após dar a conhecer aos presentes o teor das normas regulamentares do trabalho final, passou a palavra para o(a) candidato(a) para apresentação de seu trabalho. Estiveram presentes a Banca Examinadora composta pelos Doutores: Carlos Eduardo de Viveiros Grelle (UFRJ), Flávia Peres Nunes (Instituto Gestão Verde), Enrico Bernard (UFPE), Ricardo Ribeiro de Castro Solar (UFMG) e demais convidados. Seguiu-se a arguição pelos examinadores, com a respectiva defesa do(a) candidato(a). Após a arguição, apenas os senhores examinadores permaneceram no recinto para avaliação e deliberação acerca do resultado final, sendo a decisão da banca pela:

(X) Aprovação da tese, com eventuais correções mínimas e entrega de versão final pelo orientador diretamente à Secretaria do Programa, no prazo máximo de 30 dias;
( ) Reavaliação da tese com avaliação pelos membros da banca do documento revisado, sem nova defesa, no prazo máximo de 30 dias, sob possibilidade de reprovação;
( ) Reformulação da tese com indicação de nova defesa em data estabelecida a critério do Colegiado em observância às Normas Gerais da Pós-graduação na UFMG a ao Regimento do PPG-ECMVS;
( ) Reprovação

A banca indica esta tese aos Prêmios CAPES e UFMG de teses? (X) SIM ( ) NÃO

Nada mais havendo a tratar, o Presidente da Comissão encerrou a reunião e lavrou a presente ata, que será assinada por todos os membros participantes da Comissão Examinadora.

Belo Horizonte, 25 de julho de 2022.

Assinaturas dos Membros da Banca Examinadora

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Ao meu querido amigo, o Prof. Dr. (e "abelhológo") Fernando Silveira,
que me ajudou a escolher o meu lugar no mundo.

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RESUMO GERAL

No contexto global de perda da biodiversidade devido a pressões humanas, a Avaliação de Impacto Ambiental (AIA) no âmbito do licenciamento ambiental desempenha um importante papel de controle de empreendimentos impactantes. Entretanto, estudos limitados podem reduzir a efetividade desse instrumento. O presente estudo objetivou avaliar a qualidade dos estudos de base da biodiversidade no licenciamento de empreendimentos que causam impactos e as possíveis implicações disso no decorrer dos processos de AIA desses empreendimentos. Mais especificamente, o primeiro capítulo buscou avaliar 1) a qualidade dos estudos de base da biodiversidade; 2) a profundidade dos relatórios de impacto e sua relação com os estudos de base; e 3) o papel dos estudos de base e dos relatórios de impactos nas respectivas decisões de concessão da licença, por parte do órgão ambiental responsável. Para isso foram avaliados documentos provenientes de 78 processos de licenciamentos estaduais de Minas Gerais, Brasil, com foco em estudos de mamíferos de médio e grande porte. O segundo capítulo objetivou avaliar mais profundamente os dados de estudos de base e investigar quais fatores influenciam a probabilidade de detecção das espécies nesses estudos, comparando com estudos acadêmicos realizados na mesma região. Para isso foi utilizado um subconjunto de 34 processos de licenciamento, dentre aqueles avaliados no capítulo anterior (i.e., empreendimentos minerários localizados na região do Quadrilátero Ferrífero), além de 31 estudos acadêmicos. O primeiro capítulo mostrou que a qualidade técnica dos estudos de base avaliados foi aquém do desejável, sendo comprometida por fatores como a falta de rigor científico, de robustez analítica e de clareza no reporte de informações. Essas falhas limitaram as avaliações de impactos, mas não a obtenção de licenças ambientais. O segundo capítulo mostrou que a efetividade dos estudos de base em detectar corretamente as espécies em campo pode ter sido afetada por fatores ligados à qualidade desses estudos, além dos métodos de coleta utilizados, em comparação à estudos acadêmicos. Por fim, destacamos cinco oportunidades de melhores práticas para o tratamento da biodiversidade no âmbito da AIA e a importância de decisões baseadas em boas evidências para que esse processo seja mais do que mero cumprimento de protocolo para obtenção de licenças ambientais.

Palavras-chave: Licenciamento ambiental, meio biótico, estudos ambientais, inventário, diagnóstico de fauna, dados biológicos.

GENERAL ABSTRACT

In the global context of loss of biodiversity due to human pressures, the Environmental Impact Assessment (EIA) within the scope of environmental licensing plays a key role in controlling impacting projects. However, limited studies may reduce the effectiveness of this instrument. The present study aimed to evaluate the quality of biodiversity baseline studies in the licensing of projects that cause impacts and the possible implications of this during the EIA processes of these projects. More specifically, the first chapter aimed to assess 1) the quality of baseline biodiversity studies; 2) the comprehensiveness of impact reports and their relationship to baseline studies; and 3) the role of baseline studies and impact reports in the respective decisions to grant the license, by the responsible environmental agency. For this, documents from 78 licensing processes of state of Minas Gerais, Brazil were evaluated, focusing on studies of medium and large-sized mammals. The second chapter aimed to further evaluate data from baseline studies and investigate which factors influence the probability of species detection in these studies, comparing with academic studies conducted in the same region. For this, a subset of 34 licensing processes was used, among those evaluated in the previous chapter (i.e., mining projects located in the Iron Quadrangle region), in addition to 31 academic studies. The first chapter showed that the technical quality of the evaluated baseline studies was lower than the desirable, being compromised by factors such as the lack of scientific rigor, analytical robustness, and transparency in the reporting of information. These failures limited impact the assessments, but not from obtaining environmental licenses. The second chapter showed that the effectiveness of baseline studies in correctly detecting species in the field may have been affected by factors related to the quality of these studies, in addition to the sampling methods used, when compared to scientific studies. Finally, we highlighted five opportunities for better practices to address biodiversity within the scope of the EIA and the importance of decisions based on good evidence. Thus, this process may be more than mere protocol compliance for obtaining environmental permits.

Keywords: Environmental licensing, biotic environment, environmental studies, inventory, fauna diagnosis, biological data.

Sumário

INTRODUÇÃO GERAL

A Avaliação de Impacto Ambiental (AIA), ou *Environmental Impact Assessment* (EIA), em inglês, é um mecanismo de política ambiental empregado em diversas esferas governamentais e institucionais, em várias partes do mundo, para promoção do desenvolvimento sustentável e para gestão de danos ambientais (Sanchéz, 2013). A AIA surgiu nos Estados Unidos em 1969, através do *National Environmental Policy Act* (NEPA), como uma ferramenta para avaliar os impactos ambientais provenientes de atividades econômicas (Cashmore, 2004). Legalmente, a avaliação de impactos se estabeleceu no Brasil como instrumento da Política Nacional de Meio Ambiente na década de 1980, por meio da Lei Federal 6.938/81. Posteriormente, a Resolução CONAMA 237/97 dispôs sobre a realização de estudos ambientais, dentre eles o EIA/Rima (Estudo de Impacto Ambiental; Relatório de Impacto sobre o Meio Ambiente), como requisito para a obtenção de licenças ambientais por parte de empreendimentos causadores de impactos significativos:

> *Art. 3º - A licença ambiental para empreendimentos e atividades consideradas efetivas ou potencialmente causadoras de significativa degradação do meio dependerá de prévio estudo de impacto ambiental e respectivo relatório de impacto sobre o meio ambiente (EIA/RIMA), ao qual dar-se-á publicidade, garantida a realização de audiências públicas, quando couber, de acordo com a regulamentação.*

Em linhas gerais, empreendimentos de grande porte e potencial poluidor são submetidos ao licenciamento ambiental clássico, aquele com obrigatoriedade de elaboração de EIA/Rima, que ocorre em três fases, conforme Art. 8º da Resolução CONAMA 237/97:

> *I - Licença Prévia (LP) - concedida na fase preliminar do planejamento do empreendimento ou atividade aprovando sua localização e concepção, atestando a viabilidade ambiental e estabelecendo os requisitos básicos e condicionantes a serem atendidos nas próximas fases de sua implementação;*
>
> *II - Licença de Instalação (LI) - autoriza a instalação do empreendimento ou atividade de acordo com as especificações constantes dos planos, programas e projetos aprovados, incluindo as medidas de controle ambiental e demais condicionantes, da qual*

> *constituem motivo determinante;*
>
> *III - Licença de Operação (LO) - autoriza a operação da atividade ou empreendimento, após a verificação do efetivo cumprimento do que consta das licenças anteriores, com as medidas de controle ambiental e condicionantes determinados para a operação.*

Os tipos de licença e seus requisitos podem variar dentre as modalidades e esferas do licenciamento (Sanchéz, 2013). Por exemplo, no licenciamento estadual de Minas Gerais, em casos específicos em que os impactos de empreendimentos são menos significativos, pode haver licenciamento ambiental concomitante (e.g., LP e LI requeridas simultaneamente) e dispensa de EIA/Rima. Em alguns casos, pode ser exigido o Relatório de Controle Ambiental (RCA), que permite identificar não conformidades ambientais provenientes da instalação e/ou operação do empreendimento (SEMAD, 2022), mas costuma ser bem mais simples do que o EIA/Rima.

De maneira geral, no licenciamento trifásico, a obtenção da licença prévia é mandatória para continuidade do processo de licenciamento no que se diz respeito à obtenção das licenças de instalação e operação. Apesar de normalmente representar uma fatia muito pequena do total investido no empreendimento, os custos vinculados à Licença Prévia geralmente são os mais altos por causa dos estudos que precisam ser elaborados. Segundo a Comissão Europeia Sobre Custos e Benefícios da AIA, cerca de 60 a 90% do custo total do processo de AIA refere-se à elaboração do EIA/Rima (Sánchez, 2013). É nessa etapa que são produzidos os estudos de viabilidade locacional e tecnológica que compõem o EIA. Assim, considerando atributos dos meios físico, biótico e socioeconômico, são elaborados: *i*. Diagnósticos – que buscam, através dos estudos de base, conhecer as condições ambientais pré-existentes do local do empreendimento, a fim de subsidiar a avaliação de impactos; *ii*. Prognósticos – que buscam identificar, prever e avaliar os possíveis impactos do empreendimento, em sobreposição às informações de base compiladas durante o diagnóstico; e *iii*. Programas de controle, mitigação e monitoramento – que buscam atenuar e acompanhar os impactos, observando atributos relacionados à gravidade de cada impacto, definida no processo de avaliação do prognóstico (Geneletti, 2002; Sánchez, 2013). Esses programas de controle, mitigação e monitoramentos devem ser implantados nas etapas seguintes, para obtenção e/ou manutenção das licenças de instalação e/ou operação, de acordo com a finalidade para a qual se destina (Dias *et al.*, 2019) (**Figura 1**).

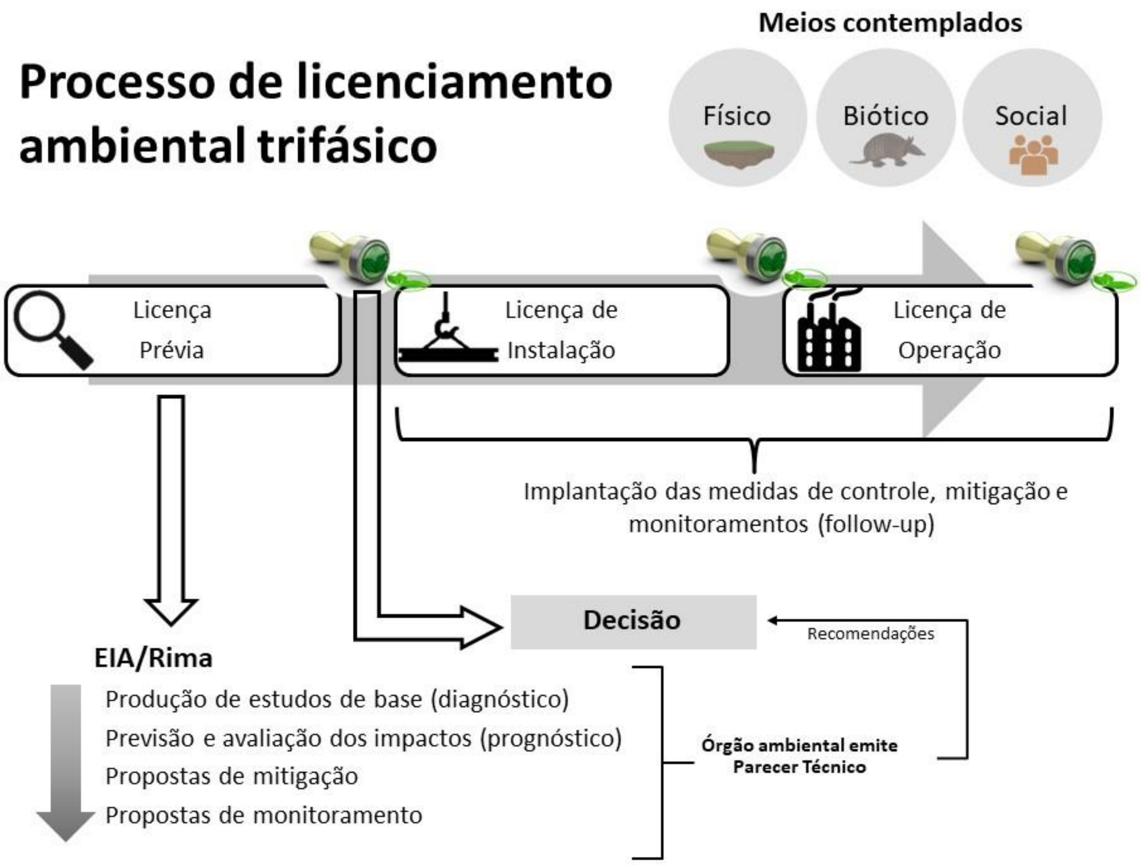


Figure 1. Etapas e atividades relacionadas ao processo de licenciamento Ambiental trifásico.

Conhecer as condições do ambiente é essencial para que previsões e avaliações sobre o comportamento de impactos provenientes de empreendimentos sejam robustas e, consequentemente, também sejam robustas as medidas propostas para tratá-los. Assim, os estudos de viabilidade, bem como as soluções propostas para mitigar e acompanhar os impactos, apresentados no EIA servem de base para que o órgão ambiental responsável pelo licenciamento decida sobre a pertinência da concessão da licença ao empreendimento. Nesse fluxo, a qualidade dos estudos prévios é essencial para que as decisões sejam robustas e bem fundamentadas. Entretanto, uma série de autores evidenciam limitações, no Brasil e no mundo, nesta etapa da AIA.

Especificamente em relação aos estudos de base da biodiversidade, destacam-se a ausência de dados quantitativos ou análises ecológicas robustas (Treweek *et al*., 1993; Le Maitre *et al*., 1998; Mandelik *et al*., 2005; Samarakoon and Rowan, 2008; Khera and Kumar, 2010), o uso de metodologias inadequadas e delineamentos amostrais despropositados (Silveira *et al.*, 2010), culminando na produção de listas de espécies que contribuem muito pouco para a avaliação dos impactos (Treweek *et al*., 1993; Le Maitre *et al*., 1998; Khera and Kumar, 2010). Em relação aos relatórios de impactos, há evidências de identificações imprecisas de impactos (Soderman, 2005; Gannon, 2021) e falta de conexão entre eles e atributos de seus respectivos estudos de base (Geneletti, 2002; Sánchez, 2013; Teixeira et al., 2020). Se vários empreendimentos obtêm suas licenças em estudos realizados nesses moldes, provavelmente prejuízos incalculáveis são causados à biodiversidade, o que pode ser ainda mais grave em regiões mega diversas. Por outro lado, se robustos, os dados gerados no processo de licenciamento, além de fomentar corretamente a tomada de decisão, têm um grande potencial de contribuir para o conhecimento da biodiversidade em volumes (ou em áreas) inacessíveis à estudos acadêmicos, que, apesar de aparentemente mais robustos, podem não dispor de recursos, como os estudos técnicos no âmbito do licenciamento.

O presente estudo foi desenvolvido com o objetivo de avaliar a qualidade dos estudos de base da biodiversidade no âmbito do licenciamento de empreendimentos que causam impactos e as possíveis implicações de estudos de qualidade insatisfatória no decorrer do processo de AIA desses empreendimentos, usando como modelo os mamíferos terrestres de médio e grande porte. Mais especificamente, essa avaliação foi operacionalizada em dois capítulos. O primeiro refere-se ao artigo intitulado *"Are Environmental Impact Assessments effectively addressing the biodiversity issues in Brazil?"*. Este capítulo buscou avaliar 1) a qualidade dos estudos de base da biodiversidade; 2) a profundidade dos relatórios de impacto e sua relação com os estudos de base; e 3) o papel dos estudos de base e dos relatórios de impactos nas respectivas decisões de concessão da licença, por parte do órgão ambiental responsável. Para isso foram avaliados documentos provenientes de 78 processos de licenciamentos estaduais de Minas Gerais, Brasil. O segundo capítulo refere-se ao artigo *"Imperfect detection of terrestrial mammal species in EIA baseline studies might be compromising decisions and mitigation measures for the group in Brazil"*. Este capítulo buscou avaliar mais profundamente os dados de estudos de base e investigar quais fatores influenciam a probabilidade de detecção das espécies nesses estudos, comparando com estudos acadêmicos realizados na mesma região. Para isso foi utilizado um subconjunto de 34 processos de licenciamento, dentre aqueles avaliados no capítulo anterior. Esse subconjunto incluiu empreendimentos minerários localizados na região do Quadrilátero Ferrífero, no estado de Minas Gerais. Os capítulos são apresentados a seguir.

CAPÍTULO 1- Are Environmental Impact Assessments effectively addressing the biodiversity issues in Brazil?

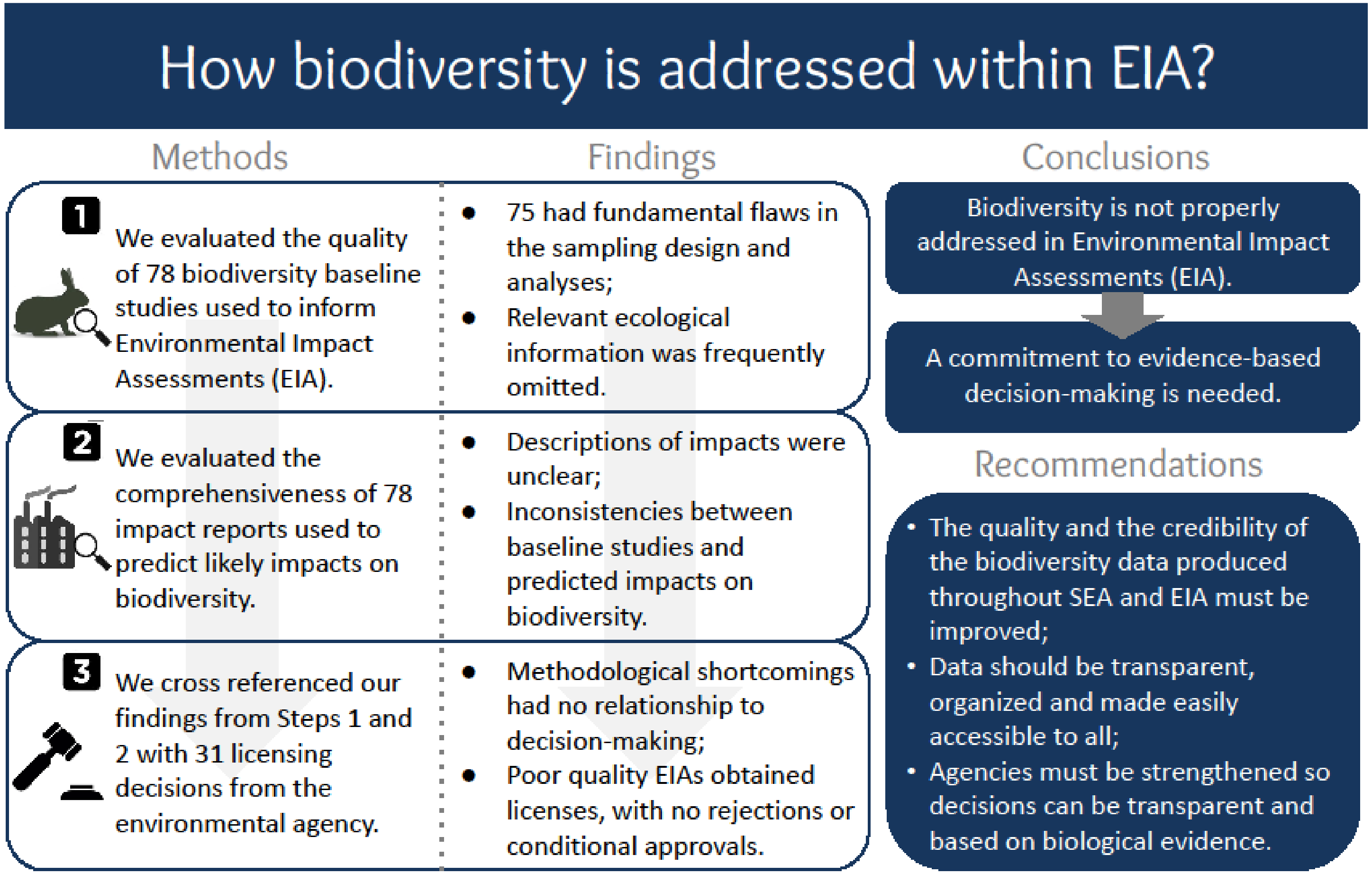
O presente capítulo foi publicado no periódico *Environmental Impact Assessment Review* (*EIA Review*; Fator de impacto 4.549) em abril de 2022. Trata-se de uma revista científica multidisciplinar, focada no campo da avaliação de impactos sobre o meio ambiente, que visa discutir e melhorar políticas, processos, produtos e decisões relacionadas à gestão do meio ambiente.

ABSTRACT

Environmental Impact Assessment (EIA) is the main legal instrument for controlling the impacts of human development projects in many countries, including Brazil. However, the way biodiversity is addressed as part of the EIA process has been discussed around the world, with concerns raised about poor-quality studies and a failure to achieve evidence-based decisions. To explore these concerns, we evaluated: 1) the quality of baseline biodiversity studies used to inform EIAs; 2) the predictions made about the impacts of the development on biodiversity and their relationship to baseline studies; and 3) the relevance of the quality of these baseline studies and the predicted impacts on the decisions made by the relevant licensing agency. To do this, we collected and analyzed EIAs associated with 78 development proposals from the State of Minas Gerais in southeastern Brazil, using medium and large-sized terrestrial mammals as indicators. We found baseline studies were basic and lacking scientific rigor, with no guiding questions or hypotheses, few ecological analyses, and that they omitted essential information about study design. The poor quality of biodiversity information in most baseline studies led to significant deficiencies in impact reports, with inadequate descriptions of the likely impacts of developments on biodiversity. Finally, we found that the shortcomings in both baseline studies and impact assessment reports had no relationship to decision-making, with poor quality EIAs still obtaining environmental licenses, which is alarming. Only in two decisions were cited some shortcoming of baseline studies as a reason for conditional approval. We conclude by providing a range of recommendations to help promote evidence-based decision-making in EIAs and improve the quality and transparency of the biodiversity data produced throughout Strategic Environmental Assessment (SEA) and EIA.

Keywords: Environmental permit, fauna, biological data, environmental diagnosis, impact evaluation, adaptive management.

GRAPHICAL ABSTRACT



1. INTRODUCTION

The preservation of biodiversity and ecological processes are important not only because of their intrinsic value, but also to guarantee the maintenance of the ecosystem services (e.g., pollination linked to food production, climate regulation, and maintenance of air and water quality) (Alho, 2008). However, habitat loss and degradation due to human activities are leading to an ongoing decline in biodiversity globally (WWF, 2020).

Brazil is a megadiverse country, yet 9.64% of fauna species evaluated are currently extinct or threatened (ICMBio, 2018). The recent history of degradation has had significant impacts on humans and biodiversity, with unprecedented man-made wildfires (Mega, 2020) and deforestation (INPE, 2020). Added to this, there are ongoing impacts of economic activities, such as agriculture, livestock, and mining, on ecosystems (Touma & Ramírez, 2019). In 2015 and 2019, the collapse of two large mine tailing dams in southeastern Brazil killed 289 people and destroyed over 1,325 ha of forest (Omachi et al., 2018). These dam collapses also led to fish mortality, water contamination, and accumulation of toxic chemicals along the food chain (Cordeiro et al., 2017; Hatje et al., 2017; Thompson et al., 2020; Vergilio et al., 2020). With many of these activities being state-sanctioned, questions have been raised about whether these impacts should have been predicted, and therefore avoided.

Environmental Impact Assessments (EIAs) are the main legal instrument for controlling human impacts on biodiversity in many countries. The EIA process was first introduced in 1969 in the United States but has since been adopted in many countries, influencing environmental policies worldwide, including in Brazil, where it was formally implemented in 1981 through the National Environmental Policy (Sánchez, 2013). Currently, EIAs are a widely recognized instrument to guide decisions about whether or not to authorize proposed development activities (Sánchez, 2013). The main objective of EIAs is to identify potential adverse effects on the environment that might arise from a proposed development project so these impacts can be avoided or mitigated during the project design, construction, and activity (Geneletti, 2002). However, the effectiveness of the EIA process at avoiding or mitigating negative impacts of development is only as good as the quality of the biodiversity data that underpins these assessments. Concerns about the implications of inadequate environmental impact assessment processes on biodiversity are growing across the world, including across North America (Beanlands & Duinker, 1983; Gannon, 2021; Atkinson et al., 2000), Europe (Treweek et al., 1993; Thompson et al., 1997; Soderman, 2005), Australia (Buckley, 1995; Thompson, 2007) and South Africa (Le Maitre et al., 1998).

A good quality EIA requires robust baseline studies to lay a foundation for evidence-based decisions (Teixeira et al., 2020). It is necessary to clearly define the footprint of the development, identifying which areas are likely to be impacted by the project (Sánchez, 2013). Baseline studies must be conducted in those areas, aiming to recognize the biodiversity values, so that the project's impacts can be predicted based on the spatial overlap (Teixeira et al., 2020). Therefore, baseline studies must be well designed and well-conducted because knowing the existing biodiversity is essential to forecast how it is likely to be affected, otherwise, the prediction of potential ecological impacts can be impaired (Treweek et al., 1993). However, where baseline studies have shortcomings, meaningful assessments are hampered with consequences for the quality of the decisions based on the EIAs (Fairweather, 1994; Milledge, 1998; Mandelik et al., 2005; Dias et al., 2019).

Previous studies have identified a range of shortcomings in baseline studies, including that they contain only basic information, such as species list (Treweek et al., 1993; Le Maitre et al., 1998; Khera and Kumar, 2010; Dias et al., 2019), with limited field surveys performed, often failing to account for the seasonal influence on the species of interest or a robust sampling effort (Hallatt et al., 2015; Dias et al., 2019; Gannon, 2021), and that they lack quantitative data or appropriate statistical analyses (Mandelik et al., 2005; Samarakoon and Rowan, 2008; Dias et al., 2019). The first consequence of poor-quality biodiversity baseline studies is the erroneous estimation of the development's impacts (Treweek et al., 1993; Thompson et al., 1997; Mandelik et al., 2005). Underestimating the impacts can impair the ability to identify appropriate mitigation measures to minimize the consequences for biodiversity. This sequence of failures may result in an ill-founded decision about granting a license (Fraser et al., 2003; Samarakoon and Rowan, 2008). Where these failures are systemic (i.e., most of EIAs being poor quality), the ecological integrity of ecosystems may be under threat due to pollution and ongoing habitat loss.

To further explore the role of baseline biodiversity studies in the EIA process, we evaluated how biodiversity information is used throughout all stages of the process, including in making the final licensing decision. Specifically, we: 1) assessed the quality of baseline studies; 2) evaluated the environmental impact reports used to predict likely impacts and their relationship with baseline studies; and 3) related the information in the baseline studies and impact reports to the final decision of the responsible environmental agency. As a case of study, we focused on EIAs that used M&L terrestrial mammals as indicators of the impact of development projects on biodiversity in the State of Minas Gerais, in southeastern Brazil.

2. METHODS

2.1 Study area

Located in the southeastern region of Brazil, Minas Gerais is the 4th largest Brazilian state, covering more than 580,000 km² (IBGE, 2020; DataViva, 2020). This region is home to rich biodiversity, with several endemic species (e.g., *Aparasphenodon pomba and Troglobius ferroicus* - MMA, 2018) and unique environments, distributed in three biomes: Cerrado, Caatinga, and Atlantic Forest (Drummond et al., 2005). However, these natural environments are affected by considerable anthropogenic pressures, as Minas Gerais is the second most populated state in the country (IBGE, 2020; DataViva, 2020) and makes a significant contribution to economic sectors with a large environmental footprint, including mining and agriculture. In 2018, revenue from raw ores, agricultural products, and processed metals represented 29.8%, 19.4%, and 18.5% of the total exports of the state, respectively (DataViva, 2020). Therefore, reconciling economic development and nature conservation is fundamental to the health of the people and biodiversity of this region.

Our study comprises the regions of Minas Gerais within the Atlantic Forest biome (Figure 1), which is composed mainly of seasonal deciduous and semi-deciduous forest, open, dense, or mixed ombrophilous forest, and fields located on top of mountains, therefore at high altitudes (in Portuguese “Campos de altitude”) (SOS Mata Atlântica, 2020). Atlantic Forest remnants in Brazil are home to 298 species of mammals (i.e., including all orders), 90 of which are unique to this biome (Paglia et al., 2012). In the Atlantic Forest of Minas Gerais, at least 33 species of medium-and large-sized, non-primate terrestrial mammals have been recorded (Lima et al., 2017), 11 of which, such as the jaguar (*Panthera onca*), the tapir (*Tapirus terrestris*), the giant anteater (*Myrmecophaga tridactyla*), and the southern tiger cat (*Leopardus guttulus*), are threatened with extinction (Subirá et al., 2018). Despite the importance of this biome for biodiversity, extensive habitat destructions mean only 28% of the Brazilian Atlantic Forest remains (Rezende et al., 2018), and it continues to be under significant pressure from human activities. Therefore, this region provides an excellent opportunity to explore EIA processes in an area where protecting the remaining biodiversity is directly in conflict with economically important developments.

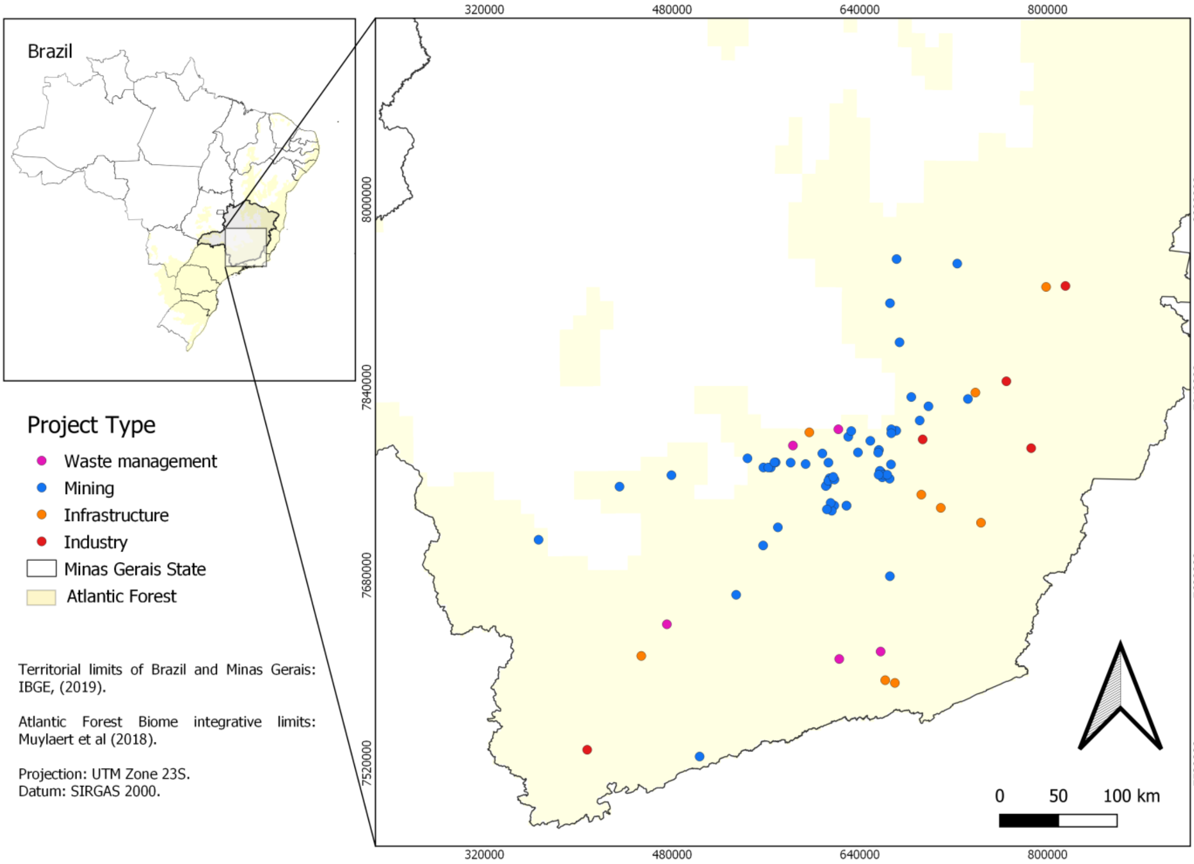


Figure 1. Location of the study area in the State of Minas Gerais (Brazil), and the original distribution of the Atlantic Forest biome (in yellow). The dots represent the locations of the 78 projects within the study, where an Environmental Impact Assessment was conducted including medium and large-sized mammals. Dot colors represent the type of development project (see section 3).

2.2 Sampling approach

Economic activities with the potential to cause environmental impacts in Brazil need to undergo the EIA process to obtain environmental licenses (Sánchez, 2013), but the administrative level of the licensing authority (federal, state, or municipal) is defined according to the geographic scope of the impacts (CONAMA, 1997). The permit types and so their requirements may vary according to the size and potential for environmental degradation of the project proposed (CONAMA, 1986). High-impact projects are usually developed in three stages: 1) Viability License: when the feasibility studies are conducted to better decide on technological alternatives as well as how to better avoid or mitigate the impacts; 2) Installation License: when the construction of development structures is authorized, following the standards defined in the previous step; and 3) Operation License: when development is finally allowed to proceed (Sánchez, 2013).

We searched for projects that applied for a viability license (i.e., the stage at which biodiversity assessments are undertaken). To be included in the study, the projects must be located in the domain of the Atlantic Forest of Minas Gerais and consider the impacts of development on medium and large-sized (M&L) terrestrial mammals between 2008-2018. These criteria ensured we could minimize differences in species composition, and considered a range of projects that had completed the full assessment process (from application to decision) under the current licensing processes and legislation. Furthermore, we selected M&L mammals because this group is commonly chosen as an indicator in EIAs of many types of projects and has well-established taxonomy and assessment methods. To maximize the comparability between projects we did not include linear projects, such as highways, railways, or electric power transmission. Projects were excluded if they did not have the relevant Environmental Impact Statement available.

The EIA documents are public by law in Brazil (CONAMA, 1997) and, in Minas Gerais, some of them can be accessed in SIAM (i.e., an online repository available in siam.mg.gov.br), where we collected the documents for this study. Two types of documents were collected from the viability stage of the selected developments: Environmental Impact Statement (EIS) – in Portuguese “Estudo de Impacto Ambiental” and its respective Technical Review Report (TRR) – in Portuguese “Parecer Técnico”.

The EIS is a massive document composed of a set of sequential reports, including baseline studies, environmental impact reports, and mitigation measure proposals on social, physical, and biotic attributes (Geneletti, 2002; Sánchez, 2013). Within the EIS, we selected only baseline studies of M&L mammals and their respective environmental impact reports. Baseline studies aim to describe the current environmental conditions before the project commences, while environmental impact reports aim to forecast and evaluate the future impacts caused by the project subject to the EIA (Sánchez, 2013).

The TRR is a report issued by the environmental agency resulting from the technical review of the EIS (Geneletti, 2002; Sánchez, 2013). After reviewing the EIS, the technicians of the environmental agency produce a report detailing whether or not the EIS demonstrates the project's environmental feasibility, which guides decision-makers. In general, TRRs are read and considered by decision-makers. There are three possible recommendations for decision: refuse the license, grant the license unconditionally, or grant the license under some conditions (Sánchez, 2013). Frequently these conditions aim to fill some gaps identified in the EIS. We focused on conditions associated with or justifications to refuse licenses related specifically to M&L mammals within the TRR.

2.3 Assessment of the biodiversity information in the Environmental Impact Statements

2.3.1 Quality assessment of the baseline studies

We assessed the quality of baseline studies used to identify biodiversity present using a set of 23 criteria (Appendix A), where criteria 1 to 17 related to study design and sampling and criteria 18 to 23 related to the ecological relevance of the data collected and the analyses used. Similar to Dias et al., 2019, these criteria were compiled based on a review of recommendations from the literature along with criteria from official Terms of Reference (ToRs) prepared by environmental agencies for guide fauna surveys in EIAs, including the ToRs on the Minas Gerais environmental agency website (SEMAD, 2019). Following similar studies, we adopted the approach of generating a quality index (Atkinson et al., 2000; Soderman, 2005; Khera & Kumar, 2010; and Dias et al, 2019). The Quality Index involved each criterion being given a score of 0 if the statement was not met; 0.5 if the statement was partially met; and 1 if the statement was completely met. These scores were then used to generate a Quality Index (QI) for each baseline study using the formula:

$$QI = \left(\frac{A + 0.5 * B}{C}\right) * 100$$

Where *A* is the number of criteria completely met, *B* is the number of statements partially met and *C* is the total number of criteria.

We compared the QI values between project types using a generalized linear model (GLM) with a quasi-binomial distribution in R software version 4.1.0 (R Core Team, 2020), using the package *stats* (version 4.1.0). Following Dias et al (2019), we adopted a QI threshold of 70 as a minimal desirable score. Whilst this cutoff point is arbitrary, it was used by Dias et al. (2019) to reflect that not all criteria are essential to an effective baseline study, but that as more criteria are removed the quality of the study is increasingly compromised.

2.3.2 Evaluation of the environmental impact reports for impact predictions and their relationship with baseline studies

We evaluated the biodiversity information in the environmental impact reports using an assessment matrix (Markowski and Mannan, 2008) that classified the level of detail provided for *who* would suffer the impact (the mammals' species included in EIS), and the detail about *how* the species would be impacted (Table 1). We classified the reports focusing on 1) whether or not they mention M&L mammals in the impact description and; 2) whether or not they described the impact *per se*.

We assessed the degree to which each report explained the species likely to be impacted (*who*) using an ordinal scale between 0 (Absent) and 4 (Satisfactory detail) (Table 1). A score of 0 indicated no mention of impacts on any fauna. A score of 1 (Very generic) was given if impacts on fauna in general were mentioned, and the understanding could be extrapolated to M&L mammals indirectly. A score of 2 (Generic) was given if impacts on M&L mammals were mentioned but did not specify which species or groups would be affected. A score of 3 (Middling detail) was given if either some M&L mammals or mammal groups were used to illustrate potential impacts. A score of 4 (Satisfactory detail) indicated that the M&L mammals or mammal groups potentially affected by the development were explained in detail. Mammal groups were considered any taxonomic or ecological grouping that justifies treating the likely impacts collectively. For example, carnivores, felines, fossorial mammals, M&L mammals that live at low densities, or M&L mammals threatened with extinction. Given all of the reports we considered were drawing on baseline studies directly focused on M&L mammals, they should at a minimum mention the potential impacts on one or more species from these groups.

We assessed the level of detail presented in the report about the types of impacts projects might have on M&L mammals (*how*) using the same 5-point scale (Table 1). Absent indicated that a list of impacts was presented but without any description. Very Generic was assigned if impact descriptions were very brief (comprising only a few lines) and oversimplified. Generic indicated that impact descriptions were presented but did not connect the impact descriptions to project activities. Middling Detail represented descriptions that outlined how M&L mammals would be impacted, connecting impact descriptions to project activities, but not considering secondary impacts. We define secondary impacts as those that were not directly related to the project activities but could be an indirect result of the project (e.g., fauna displaced by the noise of construction leads to increased competition in the surrounding area). Satisfactory Detail provided descriptions of how M&L mammals would be impacted with sufficient depth to connect the project activities to their respective primary and secondary impacts.

By combining the scores for species/groups impacted (*who*) and impact descriptions (*how*), we generated an assessment matrix on a scale from 0 (Very Poor) to 8 (Very Good) (Table 1).

Table 1. Matrix used to evaluate the quality of the Environmental Impact reports used to make impact predictions, combining the classifications of whether or not they included M&L mammals in the impact description (*who*) with the classifications of whether or not they described the impact *per se* (*how*). When combined, the reports were classified using an ordinal scale between 0 and 8 using a 5 by 5 category matrix, following the "Traditional risk assessment matrix approach" (Markowski and Mannan, 2008). The ordinal scale was used to create the impact report score.

			HOW: Description of the impacts and their consequences for the M&L mammals in the environmental impact reports					
			Satisfactory detail **4**	Middling Detail **3**	Generic **2**	Very Generic **1**	Absent **0**	
WHO: Inclusion of M&L mammals in the environmental impact reports	Satisfactory detail	**4**	8	7	6	5	4	Very good
	Middling Detail	**3**	7	6	5	4	3	Good
	Generic	**2**	6	5	4	3	2	Fair
	Very Generic	**1**	5	4	3	2	1	Poor
	Absent	**0**	4	3	2	1	0	Very poor

We also assessed whether there was a relationship between the QI score of the baseline studies and the score for the quality of the impact reports (i.e., Impact Report score; Table 1) and whether this relationship (positive, negative, or neutral) differed between project types. We used generalized linear models (GLMs) with a Poisson distribution with the impact report score as the dependent variable and the QI score and project type as predictor variables. First, we tested for an interaction between the predictor variables (i.e., Impact Report score ~ QI score * Project type). A significant interaction term would indicate that the relationships between the quality of the baseline studies and the comprehensiveness of the impact reports differ according to the project type. Second, we tested for an additive effect between the predictor variables (i.e., Impact Report score ~ QI score + Project type). A significant additive effect would indicate that the effect of the baseline studies quality on the comprehensiveness of the impact reports does not differ according to the project type, but that the effect size would differ among project types. All analyses were conducted in R software version 4.1.0 (R Core Team, 2020), using the packages *stats* (version 4.1.0) and *visreg* (version 2.7.0.1).

2.3.3 The relevance of the baseline studies and the impact reports on the licensing decision of the environmental agency

To evaluate the relevance of the baseline studies and impact reports on the decisions of the licensing agency, we identified the TRRs associated with each EIA. For each TRR, we recorded information about the decision type: license refused, unconditional license granted, or license granted under conditions. We then assessed whether the conditions or justifications for rejecting the license directly referenced or were indirectly related to M&L mammals.

We compared the licensing conditions to the Quality Index (QI) score for the baseline study and the impact report score. We then determined whether EIAs with poor quality baseline studies and/or superficial impact reports had license requests denied or had conditions imposed that required they address the shortcomings in the reports.

3. RESULTS

We collected documents from the licensing processes of 78 projects, which we grouped into 1) mining activities (75.6%); 2) infrastructure projects (11.5%); 3) industrial activities (6.4%); and 4) waste management projects (6.4%) (Figure 1). Mining activities included projects like mines, dams, and tailings piles. Infrastructure projects included the construction of structures for power generation (e.g., hydropower) or urban development (e.g., allotments for houses building). Industrial activities included steelmaking, sugar and alcohol refining, and cellulose manufacturing. Waste management projects included landfills and waste treatment plants. Although we acknowledge that each project sub-type (e.g., power generation versus urban development) may have distinct potential impacts on certain mammals, we grouped projects to provide a better overview of results considering that any variation in impacts is bigger between the project types than within the project sub-types.

Regarding the documents collected, a total of 78 EISs with M&L mammals' baseline studies and their respective environmental impact reports were collected, but only 31 of their corresponding TRRs. Ideally, each EIS should have a corresponding TRR, but 47 were not available for download in the repository.

3.1 Quality assessment of the baseline studies

The baseline studies scored an average QI of 45.7 (range: 21.7 - 78.3). Only three (out of 78) baseline studies scored more than the minimal desirable QI of 70, and a further six had a QI of just below (QI = 69.6; Figure 2A). There were no differences in the average scores among the type of projects (F = 0.1649, df = 3, p-value = 0.9197), and all types failed to meet the quality index threshold of 0.7 (or 70) (Figure 2B).

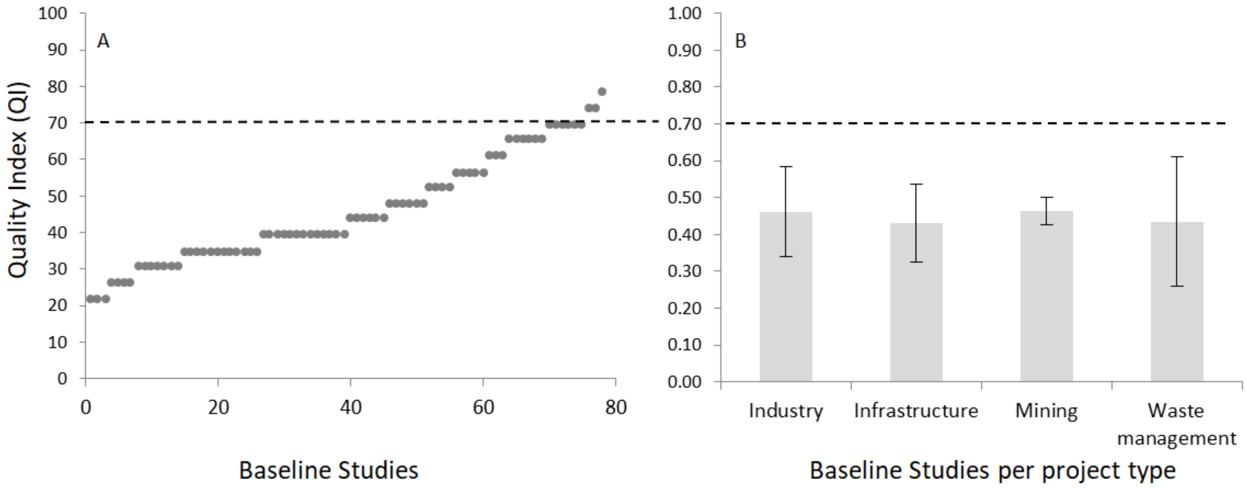


Figure 2. The Quality Index (QI) of 78 baseline studies of M&L mammals carried out under EIA in the

state of Minas Gerais, southeastern Brazil. The QIs are presented without grouping the studies (A) or comparing them between project types using a generalized linear model (GLM) with a quasi-binomial distribution (B). The dash lines indicate the minimal desirable QI score (i.e., 70 or 0.7) and the error bars are the 95% confidence intervals.

We found that the criteria studies most common failed to meet were being guided by questions and hypotheses (Criterion 1; 100%), a sample design aiming to directly answer questions about potential impacts (Criterion 2 – 100%) and accounting for imperfect detection in the analyses (Criterion 16 - 98.7%) (Figure 3). Other common failures were related to missing information about the sample units (Criterion 11 - 55.1%; Criterion 13 - 56.4%; Criterion 14 - 97.4%) and mapping or informing their location (Criterion 15 - 75.6%; Criterion 5 – 39.7%) (Figure 3). Moreover, less than 20% of studies identified relevant ecological processes (Criterion 22) and used appropriate quantitative data analyses (Criterion 23) (Figure 3). In contrast, almost all reports presented a species list (Criterion 19; 98.7%), containing information about the threat status of species (Criterion 20; 91%) and some kind of secondary data with confirmed or potential records of mammals for the study area or region (Criterion 18; 79.4%), although only a few of them (25 out of 62) using data from other local EIAs (Figure 3). Nevertheless, only 30% of the studies highlighted species with special importance, such as endemic, rare, or invasive species (Criterion 21; Figure 3).

Most studies (82%) used a sampling approach specifically designed to detect M&L mammals (Criterion 12). The majority of the studies used active search methods (Criterion 7; 98%) and interviews with locals (Criterion 8; 78%), however, only 28.2% of the studies used camera traps (Criterion 6). All studies except one used at least one direct method (i.e., active search and/or camera traps). However, over half of the studies did not include a clear description of how the methods were applied (Criterion 9) or the sampling effort applied (Criterion 10).

Although 100% of the evaluated studies conducted field surveys (Criterion 3), only 41% of them were performed considering seasonality (surveys in dry and rainy seasons) (Criterion 17). About 77% (i.e., 60 studies) included dates of field expeditions (Criterion 4). The studies for which this information is available, spent on average 9.6 days in the field (range 1 - 34), and 53 studies spent less than 15 days conducting surveys.

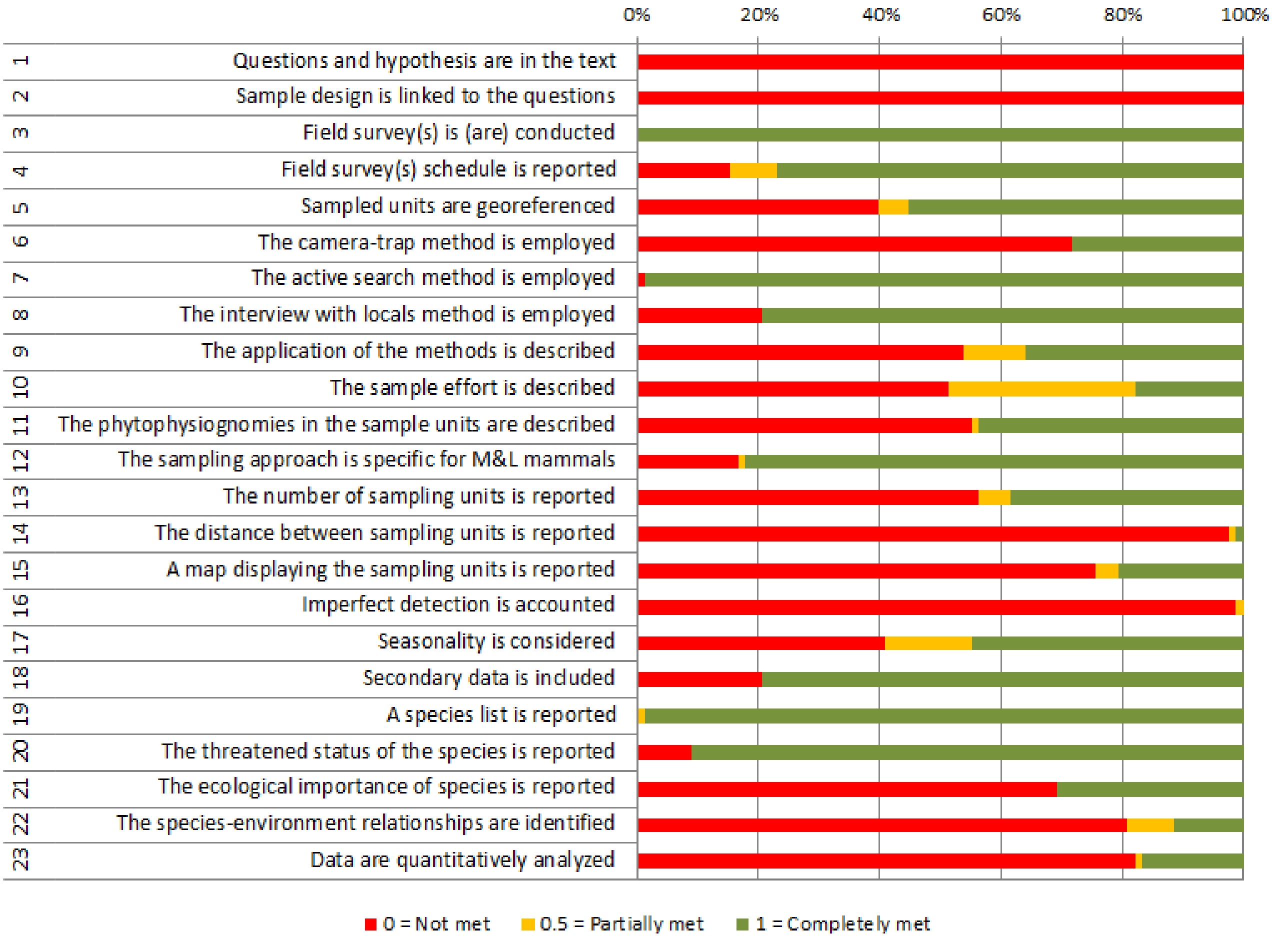


Figure 3. The percentage of baseline studies that addressed each of the criteria of good practice for surveys of M&L mammals (n=78). Criteria are detailed in Appendix A.

3.2 Evaluation of the environmental impact reports for impact predictions and their relationship with baseline studies

Most environmental impact reports scored 3 or below (“Absent”, “Very Generic” or “Generic”) in terms of how detailed the assessments were for the inclusion of M&L mammals (*who* = 65.3%) or in the descriptions of potential impacts of the development (*how* = 67.9%) (Figures 4A and 4B). When combining both the *who* and *how* assessments to calculate the final categories from impact report score, the reports were classified as “Poor” (28.2%), followed by “Fair” (26.9%), “Good” (23.1%), and “Very good” (16.7%), but few scored as “Very poor” (5.1%). Together, the “Very poor”, “Poor”, and “Fair” categories accounted for 60% of the reports, while “Good” and “Very good” categories made up only 40% (Figure 4C).

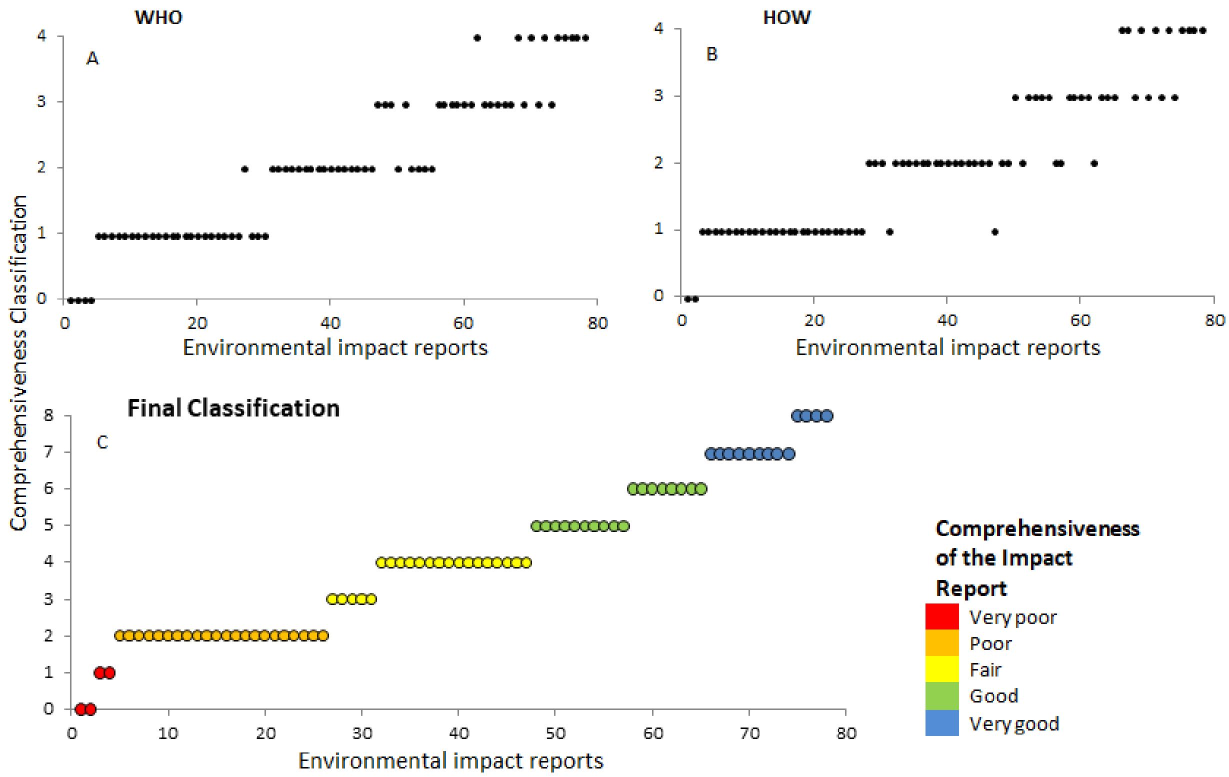


Figure 4. Classification of the 78 environmental impact reports, being: A) the M&L mammals' inclusion in the impact description (*who*), B) the impact description *per se* (*how*), and C) the final categories, resulting from a combination of *who* and *how*. Reports are in the same order in the three figures (A, B, and C), but lined up according to their final classification (C).

We found a significant and positive effect of the quality of baseline studies on the comprehensiveness of the impact reports for all project types (i.e., the additive model was significant; χ^2= 16.12, df = 3, p-value = 0.001; Figure 5). This direction of this effect was consistent across project types (i.e., the interaction model was not significant; χ^2= 1.52, df = 3, p-value = 0.676), but the effect size was higher for the mining projects (Figure 5).

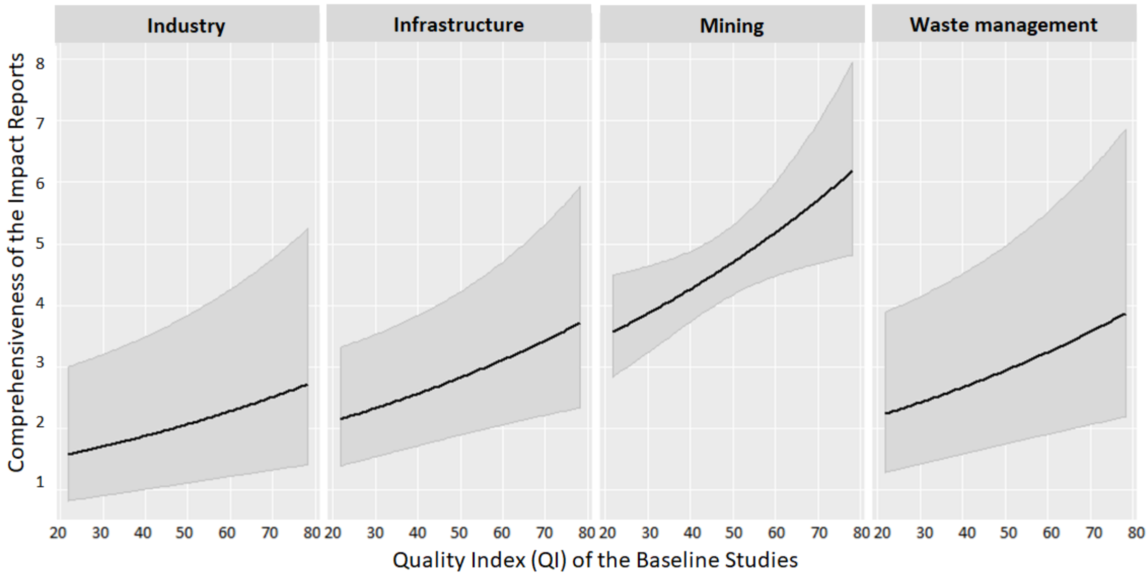


Figure 5. The effect of the baseline studies (Quality Index score) on the comprehensiveness of their respective impact reports (Impact Report score) for each project type. The shaded grey areas are the 95% confidence intervals for each relationship.

3.3 The relevance of the baseline studies and the impact reports on the licensing decision of the environmental agency

We found that 27 (out of 31) TRRs recommended granting the license under some conditions. The remaining four projects were recommended to be rejected and none were recommended to have licenses granted unconditionally. Importantly, none of the reasons why projects were recommended for rejection related explicitly to concerns about biodiversity or the M&L mammals. The four licenses recommended for rejection were justified by: i) a lack of consent from the federal environmental agency (i.e., mining); ii) low production and too many socioeconomic impacts, which were not sufficiently addressed in the baseline studies (i.e., infrastructure); iii) the location being infeasible due to the environmental importance of the requested area, but without specifying the environmental attributes that supported this decision (i.e., mining); and iv) a geological fault that must be better investigated before building the project (i.e., mining). The QI of baseline studies for rejected projects ranged from 34.8 to 39.1, while their impact report comprehensiveness ranged from Poor to Very good (Figure 6).

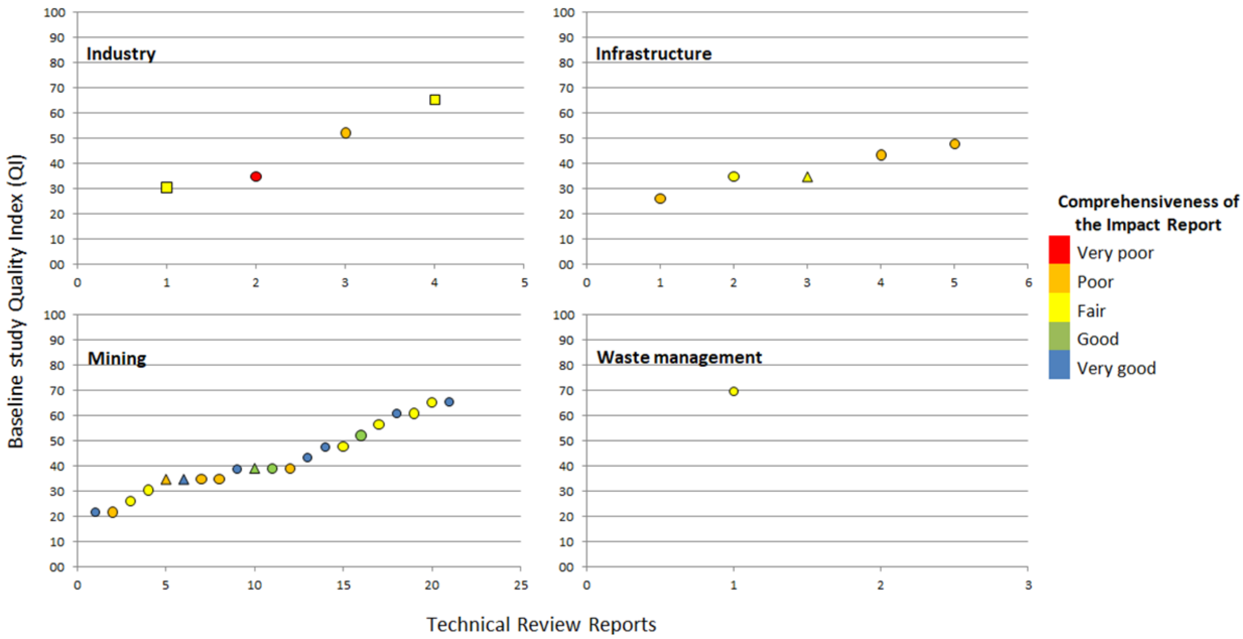


Figure 6. Quality Index scores for 31 projects separated by type, with Technical Review Reports, based on whether the licenses were rejected (triangles) or granted with general conditions (circles) and granted with conditions directly related to M&L mammals (squares). Colors indicate the environmental impact reports comprehensiveness score.

Only two of the 27 TRRs that recommended granting the license under conditions, both related to industry projects, presented justifications directly related to M&L mammals (Figure 6). However, neither justification was directly related to their baseline studies or environmental impact reports, with one condition linked to monitoring roadkill, while the other was to prevent hunting by creating monitoring programs. The environmental impact reports related to these conditions were classified as Fair (scoring Generic & Generic, and Generic & Very Generic for *who* & *how*, respectively) and the QI scores for their baseline studies were 30.4 and 65.2, respectively (Figure 6). Twenty-six of the TRRs had at least one (mean: 3; range: 1-11) condition that did not directly deal with M&L mammals, but could indirectly benefit this group. Most of those required points were about compensation measures and monitoring programs.

Only two TRRs requested reviews in the respective baseline studies of fauna. The first, related to a mining project, from a baseline study with a QI score of 47.8, required the inclusion of a survey period that encompasses rainy and dry seasons when sampling all the studied taxonomic groups, including but not directly citing M&L mammals. This condition met some gaps we found in their respective baseline study, as the aforementioned baseline study did not include rainy and dry seasons in the survey, and neither described in detail how methods were used. It also did not present any statistical analyses. The second, related to an industry project, from a baseline study with a QI score of 65.2, raised some taxonomic uncertainties in species identification, but it does not mention for which group. The use of direct methods to identify species was recommended.

The baseline study associated with this TRR used direct methods, including camera traps and active searches to identify potential species, suggesting the taxonomic inconsistencies may not relate to M&L mammals.

4. DISCUSSION

4.1 Quality assessment of the baseline studies

Our findings support the concerns of many authors that poor baseline studies may harm impact predictions (Treweek et al., 1993; Mandelik et al., 2005). Forecasting impacts on biodiversity requires some baseline information about its current state (Soderman, 2005). In general, we found low scientific rigor in the baseline studies evaluated here, whose average Quality Index (QI) was 45.7, which is well below the minimum desirable threshold we set (QI ≥70) to adequately support impact prediction and decisions in EIAs (Figure 2A). We also found poor quality baseline studies were linked to inadequate impact reports (Figure 5). Using comparable methods and an analogous index, Gannon (2021) found similar results for biodiversity baseline studies in Canadian EIAs (~54 on average). These results suggest that EIA processes in developed countries may face similar limitations in the quality of baseline studies to those observed in developing countries, like Brazil.

The most common limitation we observed in baseline studies was the lack of clear hypotheses and scientific questions (Figure 3), which is a widespread problem for monitoring studies (Beanlands & Duinker, 1983; Legg and Nagy, 2006; Lindenmayer and Likens, 2009; Dias et al., 2019). The most important underlying question to guide an EIA is how biodiversity values will be affected by the proposed project (Westwood et al., 2019). A good quality EIA should explicitly design their baseline study guided by this line of reasoning, yet we did not observe this practice in our evaluation. In addition to guiding questions and hypotheses, data credibility is also a critical element of baseline studies (Westwood et al., 2019). It is well known that the lack of information about the sampling design prevents an assessment of whether data collection was reliable (Barker & Wood 1999; MPU 2004; Gontier et al. 2006; Soderman 2006; Gannon 2021). Likewise, failure to detail methods (e.g., how methods were applied, the sampling effort, a field survey schedule, and the sampling units' description and mapping) compromises the reproducibility of studies.

From the 78 baseline studies evaluated, 18 did not report the survey duration (Figure 3), which is also a common failure of Canadian EIAs (Gannon 2021). Among the 60 remaining studies which did provide these details, 53 studies spent less than 15 days conducting field surveys. We did not evaluate the adequacy of sampling effort in our quality analysis due to the context-specific nature of this information (e.g., the question being addressed, the size of the study area, and the number of researchers conducting the surveys). However, inventories of M&L mammals in the

Atlantic Forest of Minas Gerais usually take much more than 15 days in the field (e.g., in Prado et al., 2008; Silva & Passamani, 2009; Duprat & Andriolo, 2011; Penido & Zanzini, 2012; Costa et al., 2019 the sampling effort ranged from 43 to 792 days). Importantly, guidelines for studies that rely on camera trap data, considered best-practice for detecting M&L mammals, suggest that each site should be sampled for 3-5 weeks (Kays et al., 2020). This duration is necessary to achieve precise estimates of species richness while also accounting for imperfect detection. Particularly for identifying small-scale variation in richness and capturing local covariates, such as seasonal influences which have strong impacts on mammal communities and are required for comparisons across study areas or periods (Kays et al., 2020).

Similar to Gannon (2021) we found most baseline studies did not account for imperfect detection in their analyses (Figure 3). This is important because assuming that a species was not detected during sampling could lead to false conclusions and compromise estimates of potential impacts or the mitigation measures required if the species is present. Many authors have found that the duration of baseline studies surveys is too short (Treweek et al., 1993, MPU, 2004; Soderman, 2006; Hallatt et al., 2015; Dias et al., 2019), some performed in a single day (Gannon, 2021), or using inappropriate survey methods (Silveira et al., 2010). Insufficient survey time and inappropriate methods likely both contribute to false absences of species in baseline studies. Therefore, consultants must take imperfect detection into account to improve the estimates of the parameters of interest and decrease sampling biases (MacKenzie et al., 2018).

The increased cost associated with longer sampling periods and more expensive techniques (e.g., camera traps, the recommended detection method for M&L mammals; Silveira et al., 2003; Wearn & Glover-Kapfer, 2019) may account for the concerning limitations in the studies designs we observed. Most studies searched directly and indirectly for records of M&L mammals in the field and interviewed local people about the occurrence of M&L mammals in the area (Figure 3). While interviews can complement the direct sampling method, using them as the main or only sampling method might distort results due to species misidentification by a non-specialist or through false positives. While we found one study using only interviews as the sampling method, it was the primary method in many other studies, where interviews were used to justify short field surveys for direct and indirect records of mammals (e.g., a single or a couple of days only).

The limitations we identified in most EIAs (Figure 3) are commonly reported by other studies, including a lack of specificity about methods (Treweek et al., 1993; Le Maitre et al., 1998; Khera and Kumar, 2010), only providing a list of species recorded (Le Maitre et al., 1998; Dias et al., 2019; Teixeira, 2020), failure to identify relevant ecological processes (Thompson et al., 1997; Greig & Duinker, 2011; Scherer, 2011) or provide quantitative data (Mandelik et al., 2005) and meaningful statistical analysis (Samarakoon and Rowan, 2008). Providing species lists without considering the ecological relationships between those species is particularly concerning, and risks underestimating the importance of species that play a particularly important role in the ecosystem, such as keystone species (Sánchez 2013). It is critical that baseline studies in EIA go beyond simply counting species, using a targeted approach to evaluating how the project implementation would affect the biodiversity values present (Teixeira et al., 2020). Ideally, EIA should start by outlining the potential preliminary impacts and then design the baseline study to focus on collecting robust data to estimate the magnitude of the effect on biodiversity (Teixeira et al., 2020). Otherwise, time and money may be wasted on irrelevant and useless studies, while biodiversity may be left at risk (Dias et al., 2017).

4.2 Evaluation of the environmental impact reports for impact predictions and their relationship with baseline studies

The level of detail associated with most (~60%) environmental impact reports was classified as Very poor, Poor or Fair (Figure 4C), with no substantial differences in how comprehensively the types of impacts projects might have were described (*how*) (Figure 4B) or the types M&L mammal species or groups that might be impacted (*who*) (Figure 4A). These results suggest that environmental impact reports that fail in one measure tend to have widespread limitations.

Like studies from Finland and Canada, we found unclear and imprecise impact descriptions, with secondary impacts only superficially addressed (Soderman 2005; Gannon 2021). Assessing the impacts of the project is one of the most important parts of the EIA process, and it is from this phase that recommendation and mitigation proposals are derived. Therefore, superficial environmental impact reports might harm the outcomes of the EIA process and consequently, the effectiveness of environmental protection measures (Samarakoon and Rowan, 2008). Unfortunately, there are many examples where the role of the EIA process to protect biodiversity is not being adequately fulfilled, suggesting a widespread problem with the practice (Treweek et al., 1993; Le Maitre et al., 1998; Samarakoon and Rowan, 2008).

One of the most concerning findings from our study was the weak connections between the baseline information and the impacts descriptions. The environmental impact reports should combine the findings of the baseline studies with scenarios of the likely impacts on biodiversity values associated with the project installation (Geneletti, 2002; Sánches, 2013; Teixeira et al., 2020). Despite M&L mammals being chosen as an indicator group in all of the EIAs we analyzed, we found little consideration of impacts developments would have on M&L mammal species or groups and their respective ecosystem services (i.e., only 9 reports scored 4, 'Satisfactory Detail' for *who* – Figure 4a). The poor linkage between the biodiversity identified in baseline studies and the direct consideration of impacts on those species seems to be a recurring problem in EIAs (MPU, 2004; Soderman, 2005). This makes studies such as ours, which evaluate the links between baseline data limitations and recommendations, all the more important (Soderman, 2005).

Good quality baseline information is fundamental to understanding potential impacts on biodiversity (Treweek et al., 1993; Thompson et al., 1997; Mandelik et al., 2005). Indeed, we found that better quality baseline information was linked to more comprehensive impact reports, while poor quality baseline data was associated with more superficial impact reports for all project types (Figure 5). Although the effect size for mining projects was higher than for other project types, this relationship requires further investigation because of the dominance of mining projects in our dataset. The understanding of the environmental impacts on the M&L mammals might be incomplete or unclear for the non-mining projects even with a high-quality index of their baseline studies. Despite this relationship, we found that some good baseline studies linked to superficial impact reports and vice-versa, suggesting that vigilance is needed to ensure both documents provide high-quality information with which to judge likely environmental impact, particularly when potential conflicts of interest can influence the outcomes of the EIA process (Salamanca, 2018). Thus, identifying punctual and systemic limitations is essential to prevent EIA from being a mere formality rather than a robust evaluation.

4.3 The relevance of the baseline studies and the impact reports on the licensing decision of the environmental agency

The TRR process, which generates the recommendations for licensing decisions, should routinely check if baseline studies are appropriate and if potential impacts were properly assessed (Sánchez, 2013). We expected that low-quality baseline studies and/or superficial impact predictions would be reflected in the decision about whether the development should proceed. However, we did not find a relationship between the license requests denied and the gaps we found in the baseline studies for M&L mammals or the environmental impact reports (Section 3.3). Of the 31 TRRs we considered, only one recommended dealing with baseline study failures, and while this did not mention M&L mammals directly, it highlighted gaps we identified in the baseline study (i.e., not accounting for seasonality and no method description). Even so, it is important to highlight how brief and unclear descriptions associated with any conditions were, allowing considerable room for interpretation.

Despite the problems we identified with baseline studies and environmental impact statements in our study, these issues almost universally did not hinder projects from obtaining environmental licenses. This disconnect between problems with EIAs and whether licenses are granted has led some to question whether EIA processes function more like a “mitigation tool” than an evaluation process, simply finding a route to enable the project to proceed (Fonseca and Gibson 2021). Given the role of the EIA process is to identify projects that will have an unacceptable impact on the environment, the failures we observed suggest this process is not being conducted in a way that would enable the environmental agency responsible for the authorization of the projects to make informed judgments. While high-quality EIAs offer the potential for evidence-informed decisions, there is no formal requirement to prevent impacts, and projects can still proceed even when impacts are identified (Morrison-Saunders and Bailey, 2003; Huge et al, 2020).

4.4 Limitations

Documents related to environmental licensing in Brazil are public by law (CONAMA, 1997). However, the organization and accessibility of documentation still face challenges (Fernández, et al., 2018; Dias et al., 2019). Although we made a great effort to identify as many EIAs as possible using the online repository, these issues likely mean there were relevant projects that we were not able to include in our study. Likewise, we were not able to find 47 of the TRRs associated with the 78 projects we identified. By not including a physical search for documents (i.e., requesting formal views in person at the regional units of the environmental agency), we may have missed some reports, limiting our capacity to fully assess the quality of the recommendations made based on the EIS. However, a similar study conducted by Dias et al. (2019) used the formal request process and found the results were similar to using the online repository. The patterns we observed have been identified in other studies in Brazil and elsewhere (e.g., Fonseca and Gibson 2021), suggesting the EIAs we identified are representative of broader patterns.

It is important to recognize that we evaluated documents assuming that the quality of the reports represents the quality of the studies and assessments themselves. Similarly, our study focused only on M&L mammals, and these findings may not fully capture deficiencies in how the EIA processes deal with other taxonomic groups. Also, the qualitative analysis we used to evaluate the quality of baseline studies and the comprehensiveness of the impact predictions will have been influenced by the categories that we chose to assess, and the subjective nature of some of the criteria (e.g., level of detail).

It is also important to note that our study did not account for the number or the severity of the impacts on mammals. Therefore, reports were not penalized for describing generic impacts that could be detrimental to mammals (e.g., pollution) because our classification considered impacts as a whole and not each one individually. We also understand that some projects may have chosen to make a broad assessment of other species or groups, especially because different projects may cause impacts on several groups. However, once M&L mammals were chosen as an indicator group in baseline studies, which was the case for all projects analyzed in this study, the potential impacts on these groups should have been at least described in the impact reports.

Our approach considered a set of elements to provide an important overview of the components included in the environmental impact statements, from baseline data to the rationale provided for impact predictions and highlights the essential elements that should be accounted for in building a robust, transparent evaluation report. However, if poor quality baseline studies and inadequate impact reports failed to note potentially significant adverse effects on M&L mammals, the lack of references to M&L mammals in the decisions would be expected. This highlights a significant shortcoming in the process, whereby the quality of baseline studies and impact reports are not scrutinized before making decisions. Although it was encouraging at that least two decisions cited inadequate baseline studies as a reason for conditional approval (Section 3.3), from the information available, there are major shortcomings that undermine the credibility of the EIA process.

4.5 Recommendations

The limitations our study identified with the EIA process appear to be systemic and will likely require changes at a system level to address. We propose four key changes that could help to ensure greater transparency, efficiency and improve the robustness of the EIA process. First, a culture of evidence-based decision-making could help ensure there is a better link between baseline data and recommendations. Scientific evidence should be a fundamental element in all the steps of the EIA process, especially to determine baseline conditions, to identify potential impacts, to decide what kind of mitigation is the most appropriate, and finally, to decide about the project viability (Westwood et al., 2019).

Second, systems are needed to capture the data from EIAs to ensure these data can be used to inform future assessments or even be considered at the planning level, as in Strategic Environmental Assessments (Therivel & González, 2021). A substantial amount of data is generated through EIAs (Sánchez and Saunders, 2011) and the better management of these data by the environmental agencies, including an easily accessible geospatial database and regular updates, could contribute to a more transparent, reliable EIAs in the future (Sánchez and Saunders, 2011). However, the baseline studies we evaluated here barely explore the information coming from other projects under EIA in the same region. But if EIAs were required to map the occurrence of a species they detect, this information could be used to support future assessments, enabling them to use the records from neighboring projects' baseline studies and monitoring programs. This type of data management system could result in a more robust diagnosis of the study area, allowing time and money to be better spent in more significant impact predictions and assessments.

However, poor evidence management dramatically reduces the possibility of learning from past EIAs, either to support future projects or for other purposes, such as scientific research (King et al., 2012). We notice that the effort spent in new (and often poor quality) field surveys is larger than the evidence management and review efforts in EIA. We think that a targeted approach to baseline studies (Teixeira, et al., 2020) plus strategic use of existing data could not only result in more biodiversity-friendly decisions but also be cheaper and less time-consuming.

In addition to better systems to manage data collected through the SEA and EIA process, improvements are required to make the EIA process more transparent and the documents and outcomes more easily accessible by the public. Improving the management and transparency of the EIA process could also support the assessment of cumulative impacts of developments in a region (Gannon, 2021). Good data management has the potential to improve these processes, which can be a critical weakness of the EIA process (Bigard et al., 2017). Furthermore, transparency, oversight, and peer-review could improve data quality in EIA, enabling weaknesses in study design and impact evaluation to be identified and highlighted. We recognize the many ways stakeholders can influence the decision-making in EIAs (Salamanca, 2018). The production of information lacking scientific rigor, as we found here, leaves too much room for a decision guided by economic or political interests in EIAs (Ferraz, 2012). If stakeholders, civil society, scientists, and conservation decision-makers all have the potential to assess data integrity associated with EIAs, this could help raise the standards of the EIA process (King et al., 2012).

Finally, raising the standard of EIAs will require greater investment in the Brazilian environmental agencies to enable them to promote a more robust process. Poor structure, low investment, insufficient number of staff, limited professional qualifications for staff, and damped labor demand are some of the bottlenecks within these environmental agencies (Hofman, 2015). Brazil is not alone in identifying challenges for environmental agencies, with inexperienced staff reviewing reports also being highlighted as an obstacle to EIA in South Africa (Brownlie et al., 2006).

5. CONCLUDING REMARKS

The problems we identified with EIAs, of significant gaps in baseline biodiversity studies leading to deficiencies in impact reports, and no relationships between these data and the licensing decisions made, seem to be widespread in EIAs across many countries (Buckley, 1995; Le Maitre et al., 1997; Milledge, 1998; Atkinson et al., 2000; Hallatt et al., 2015). Brazilian EIAs in other regions likely also face similar problems (MPU, 2004; Teixeira et al, 2020). Cultural change in EIA is fundamental to improve not only the quality and the credibility of the biodiversity information produced by EIAs, but also to ensure these data are appropriately stored, organized, and made freely available. A greater commitment to evidence-based decision-making through strengthened environmental agencies, supported by good data management systems and quality control processes, could substantially strengthen EIAs. With EIA processes in many countries, more studies, such as ours, that evaluate the strengths and weaknesses of EIAs, would provide an opportunity to identify best-practice and provide new directions to promote EIA as a tool to protect biodiversity rather than being a simple ticking-a-box exercise.

APPENDIX A - SUPPLEMENTARY MATERIAL

Criteria used to assess the quality of baseline surveys of M&L mammals, included within Environmental Impact Statement. ToR = formal Terms of Reference for fauna studies in Environmental Impact Assessments

N	Statement	Source	
		Literature	ToRs
1	The study is guided by the hypothesis-driven method. Questions and hypotheses logically linked to the possible impacts of the project are expressed in the text.	Ferraz (2012); Dias et al (2019)	X
2	The sample design is done aiming to answer the questions previously established.	Ferraz (2012); Dias et al (2019)	X
3	Field survey(s) was (were) performed.	Mandelik et al (2005)	
4	The report presents a survey schedule containing the start and end dates of field expeditions.	Samarakoon and Rowan (2008)	X
5	The report presents a list with the sampled units properly georeferenced.	Dias et al (2019)	
6	The camera-trap method was performed.		X
7	The active search method (search for direct views and/or for clues) was performed.		X
8	The interview with the local community was performed.		X
9	The used methods were explained in detail (e.g., samples were collected at day or night, baits were used or not, etc).	Samarakoon and Rowan (2008); Dias et al (2019)	X
10	The report contains information on the sampling effort (e.g., number of traps per night, a total of kilometers sampled, or hours spent per transects, number of locals interviewed, etc).	Samarakoon and Rowan (2008); Dias et al (2019)	X
11	The report describes the phytophysiognomies of the sampled units.	Treweek et al (1993); Dias et al (2019)	X
12	The sampling approach is designed independently for M&L mammals and not shared among (or availed from) other taxonomic groups.	Tompson (2007)	
13	The report contains information on the number of sampling units.	Dias et al (2019)	
14	The report contains information on the distance between sampling units.	Dias et al (2019)	
15	The report presents a map displaying the sampling units.	Dias et al (2019)	
16	The sampling design takes into account imperfect detection (e.g., capture-mark-recapture, distance data, occupancy/detection models), or at least presents arguments for not considering it.	Ferraz (2012)	
17	The sampling design takes seasonality into account, including at least one field survey during the dry season and another one during the rainy season - safeguard when secondary data meet this need, and this is expressed in the text.	Fraser et al (2003); Tompson (2007); Dias et al (2019)	x
18	The report presents secondary data containing confirmed or potential records in the study area or region.	Fraser et al (2003); Mandelik et al (2005); Tompson (2007)	x
19	The report presents a species list.	Fairweather (1994); Dias et al (2019)	x
20	The report presents the status of threatened species according to official lists.	Thompson et al (1997); Byron et al (2000); Mandelik et al (2005); Tompson (2007); Dias et al (2019)	x
21	The report contains information on which species have special importance (e.g., endemic, rare, key, invasive, hunting, migratory, etc).	Samarakoon and Rowan (2008); Scherer (2011)	x
22	The study identifies ecological or species-environment relationships (e.g., areas of nesting, feeding, reproduction, etc).	Fairweather (1994); Mandelik et al (2005); Scherer (2011)	
23	The data were analyzed using at least one quantitative analysis (e.g., diversity, abundance or similarity indexes, etc).	Fairweather (1994); Dias et al (2019)	

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CAPÍTULO 2 - Imperfect detection of terrestrial mammal species in EIA baseline studies might be compromising decisions and mitigation measures for the group in Brazil

O presente capítulo provavelmente será submetido ao periódico *Ecological Indicators* (Fator de impacto 4.958). Trata-se de uma revista científica focada no campo da avaliação de indicadores ecológicos e ambientais e práticas de manejo, o que inclui a produção de avaliações cientificamente rigorosas e politicamente relevantes usando programas de monitoramento e avaliação baseados em indicadores.

ABSTRACT

The Environmental Impact Assessment (EIA) is an instrument for managing the impacts of human activities. Within EIA, reliable baseline information is essential to understand how those impacts would affect biodiversity. However, EIA baseline studies recording species that do not occupy the studied site or not registering those that truly occupy might conduct to wrong interpretations and ill-informed decisions if imperfect detection is not considered. We investigated how methodological choices (e.g., the sampling methods employed: camera traps, census, sign surveys and interview with locals) may influence the successful species' detection in biodiversity baseline studies of mining projects under EIA and species' inventories carried out for scientific research purposes, both located in the Iron Quadrangle region, in the state of Minas Gerais, southeastern Brazil. We used occupancy models that account for imperfect detections to evaluate the effect of the study type and some of their methodological attributes on false-positive and true detections of medium to large-sized terrestrial mammals. Additionally, we also evaluated the influence of species rarity and habitat quality on the species' true detection. We found uncertainty between two models for false-positive. The additive effect between study type and sampling method was the best-ranked model, followed by the structure containing only the study type. We estimated that, among EIA baseline studies, by sign surveys and interviews they had, respectively, 2.1% and 4.4% of chances of registering species that do not exist, while chances are close to zero in scientific studies. For true detection, the model structure with an interaction effect between the study type and the sampling method was the best ranked. In EIA baseline studies, species were truly detected up until three times less by census, camera traps and sign surveys when compared to scientific studies, but their estimates were higher for interviews. The results we found might indicate that intrinsic characteristics of studies may contribute to their having less chances of correctly detection species, and it is worst in EIA baseline studies. Both false-positive and true detections may be related to the sensitive points that affect the quality of the EIA baseline studies, as a less than appropriate application of methods. This draws attention to the importance of considering imperfect detection estimates on biodiversity surveys. As a rule, most of the work from both consultancy and academia starts from the premise that detection probability is perfect, but it is not. This can produce biased and misleading results and, in the case of baseline studies, encourage unfounded decisions in the EIA.

Keywords: Biodiversity, Environmental Impact Assessment, Fauna survey, True detection, False-positive.

1. INTRODUCTION

The biodiversity loss is globally connected to economic activities, such as the conversion of natural habitats into agricultural systems, logging, power generation, and mining plants (WWF, 2020). If on the one hand, those activities are economically important, on the other hand, they can significantly press natural habits. Mining, for example, has a great role in the Brazilian commodity exports (Pena, *et al*., 2017), but also may cause deforestation, soil removal and it is frequently associated with secondary activities, which also cause cascading impacts (e.g., roads constructions and urbanization; Fernandes, 2016, Sonter *et al*., 2014 apud Pena, *et al*., 2017). Thus, mechanisms to control and find the best alternatives for the economy and environment are essential.

The Environmental Impact Assessment (EIA) is an important tool for controlling human activities which may cause adverse effects (Sánchez, 2013). It aims to assess those potential adverse effects, propose ways to attenuate them, and support decision-makers about the project's environmental viability (Geneletti, 2002; Sánchez, 2013). Nevertheless, assessing any project impacts demands good quality baseline information on how the ecosystem to be potentially affected works and what elements are parts of it (Teixeira *et al*., 2020; Dias *et al*., 2022). Baseline studies must acknowledge the present state of the environment before the establishment of the projects. Thus, it would be possible to predict the future impacts and assess how they may overlap the current environmental conditions (Sánchez, 2013; Teixeira *et al*., 2020). Therefore, the information produced along the EIA process should build the basis for the decision on project approval (Dias *et al*., 2022).

However, many inconsistencies have been previously identified in biodiversity baseline studies in EIAs, including low scientific rigor and inappropriate sampling designs, or even a lack of ecological analyses (Treweek *et al*., 1993; Le Maitre *et al*., 1998; Mandelik *et al*., 2005; Samarakoon and Rowan, 2008; Khera and Kumar, 2010; Hallatt *et al*., 2015; Gannon, 2021; Dias *et al*., 2022). Among the worrying points found, at least in the Canadian and Brazilian EIAs, baseline studies did not account for species imperfect detection (Gannon, 2021; Dias, *et al*., 2022), which can lead to wrong interpretations of the adverse effects, of proposing ways to attenuate them and finally, on the final decision with regard the project's environmental viability. This is concerning because the existing but not accounted species (i.e., false-negative detections) might be easily disregarded in the EIA impact estimations and mitigation measure proposals. At the same time, the species that are accounted for but not existing (i.e., false-positive detections) might generate controversial and non-sense mitigation measure proposals.

Previous reviews also found Brazilian EIA biodiversity baseline studies with too short field surveys (Treweek *et al*., 1993, MPU, 2004; Soderman, 2006; Hallatt *et al*., 2015; Dias *et al*., 2019a), spending less than 15 days in the field to inventory medium to large-sized terrestrial mammals, while scientific (or academic) studies whose the objective was also to inventory this same taxonomic group in the same region, spent much more time in the field (Dias *et al*., 2022). Similarly, there are records of EIA biodiversity baseline studies using unsuitable sampling methods (Silveira *et al*., 2010), as interviews with local people about the occurrence of species as the main sampling method, which are more likely to false-positive detections, instead of direct methods, such as camera traps (Dias *et al*., 2022), which is highly recommended for surveying medium to large-sized terrestrial mammals (Silveira *et al*., 2003; Wearn & Glover-Kapfer, 2019).

Survey duration and sampling methods may be related to how time and money-consuming the study itself can be, which probably influence the choices of the consulting companies when outlining it (Dias *et al*., 2017). However, we expect that choices about the study's sampling design disconnected from its purpose may produce unreliable species detection due to false presences or false absences. Thus, with many decisions on approval of environmental degrading projects based on unreliable baseline information, the consequences for biodiversity can be worrying.

We evaluated the effect of the sampling design of biodiversity studies (i.e., EIA biodiversity baseline studies and species' inventories carried out for scientific research purposes) on false-positive and true detections of medium to large-sized terrestrial mammals using occupancy models that account for imperfect detections. Specifically, we evaluated the influence of the study type (i.e., EIA biodiversity baseline studies *versus* scientific species surveys), as well as the influence of some methodological variables on false-positive and true detections of species, and how it may compromise the impact estimations and mitigation measure proposals. We expected that biodiversity baseline studies from EIAs would have more false-positive detections and lower true detections compared to scientific studies due to more ambiguous methods and smaller sampling efforts used by the former studies, respectively. Additionally, because other variables may influence detection probability, we also evaluated the influence of species rarity and habitat quality on the species' true detection. We focused on medium to large-sized (M&L) terrestrial mammals' surveys from baseline studies of mining projects under EIA and inventories made with scientific proposals, both located in the Iron Quadrangle region, in the state of Minas Gerais, southeastern Brazil.

2. METHODS

2.1 Study area

The Iron Quadrangle (IQ) is a mineral province located in the state of Minas Gerais, southeastern Brazil, that comprises several deposits of minerals such as iron, gold, and manganese over an area of approximately 7,000 km² (Roeser & Roeser, 2010). The history of colonization and development in this region is intertwined with the history of exploration of mineral resources. Mining is the most important economic activity in IQ until nowadays (Castro, 2011). The region has the highest concentration of large mining projects in the state of Minas Gerais, which trades about 1 to 6 billion USD annually (ANM, 2019). On the national stage, the IQ was the main responsible to place the state of Minas Gerais at the second position in mineral production in 2019, representing 40% of Brazilian mineral commercialization (ANM, 2020).

The IQ is mainly under the domain of the Atlantic Forest, but it also connects parts of the Cerrado, which are two Brazilian hotspots for biodiversity conservation (Myers, *et al*., 2000; Drummond *et al*., 2005). Besides it features areas important for conservation, with unique environments (e.g., the rupestrian grassland; Fernandes, *et al* 2014) and important levels of plant and animal diversity and endemism (Drummond *et al*., 2005), the IQ is also important for the preservation of ecosystem services (e.g., underground water reservoir; Duarte, *et al*., 2016).

We choose the IQ region as the study area (**Figure 1**) due to its potentially conflicting economic and conservation importance, in the face of the ongoing mining activities pressures and the relevance of the EIA in this context.

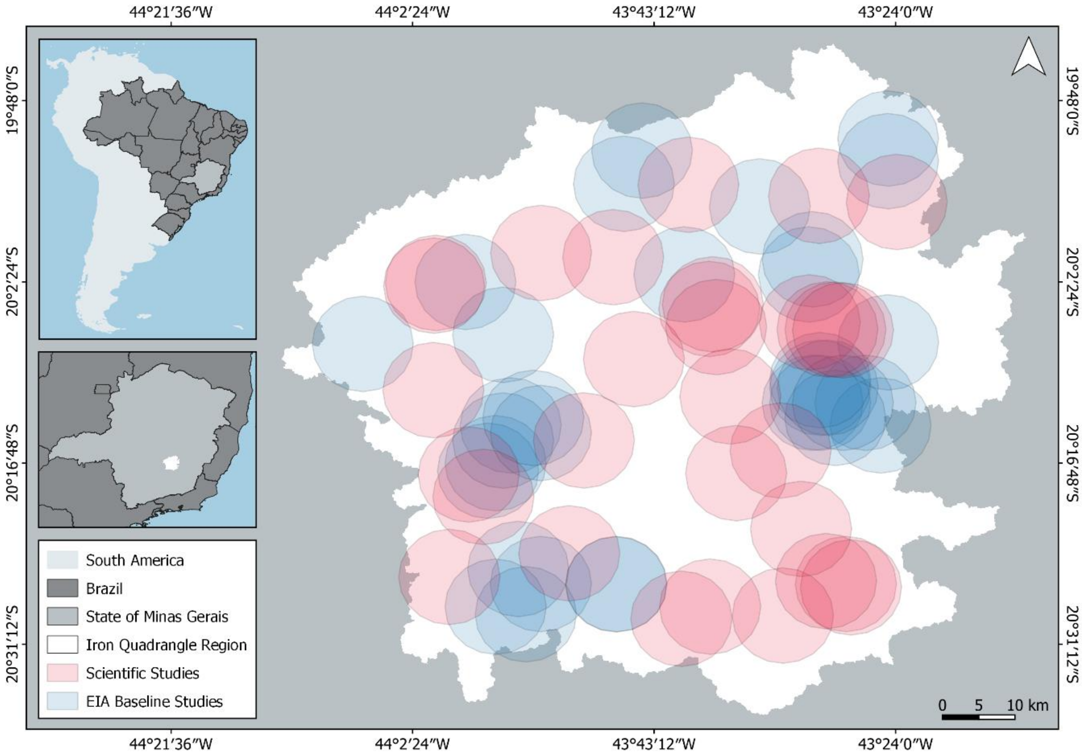

Figure 1: Location of the study area in the Iron Quadrangle region, state of Minas Gerais, southeastern Brazil. The blue circles represent the locations of the 34 projects within the study, where Environmental Impact Assessments (EIAs) were conducted including medium and large-sized mammals. The red circles are where the 31 medium and large-sized mammals' inventories for scientific research purposes were carried out. Circles represent 7km buffers in the study areas (see details in section 2.3)

2.2 Sampling approach

2.2.1 M&L mammals' baseline studies in the EIA of mining projects

We searched for mining projects located in the IQ region, under the state of Minas Gerais jurisdiction, that considered medium and large-sized (M&L) terrestrial mammals in baseline studies when applying for environmental licenses through EIAs. We established a timeframe from 2005 to 2018 (i.e., until the collection of data for this study), assuming that there were no changes in the M&L mammals' species composition during this period. We made this assumption because during this timeframe there was no sudden differences in natural areas in the IQ region (i.e., from 677.870 to 676.784 hectares, considering the 34 municipalities that compose this macro-region; Mapbiomas, 2018; UFOP, 2018). Once the documents linked to the licensing are public in Brazil (CONAMA, 1997), we downloaded the Environmental Impact Statements

(EIS) (i.e., the document where baseline studies can be found) from an online repository of the environmental agency of the state of Minas Gerais (i.e., SIAM - available in siam.mg.gov.br).

Because different projects might have substantial differences in the types and extent of impacts they may cause on biodiversity and in the indicators they use to assess them (Dias *et al*., 2022), we focused only on iron ore mining projects to minimize these differences. Also, we focused on M&L mammals as a model due to their: *i*) well-established taxonomy (Dias, *et al*., 2022); *ii*) representation of the best-studied mammal group (Bogoni, *et al*., 2020); *iii*) utility as a proxy for other biodiversity components (Bogoni, *et al*., 2020); and iv) recurrence in being chosen as an indicator in projects under EIA (Dias *et al*., 2022). To be included in our analyses the baseline study must report the sampling method used in each species detection event. Within the M&L mammals' baseline studies, we tabulated the species they registered, the methods they used, and sample effort spent.

2.2.2 M&L mammals' inventories in scientific studies

We searched for scientific studies (i.e., published scientific papers, technical books, and postgraduate theses and dissertations) whose at least one of the goals was to inventory with primary data the M&L terrestrial mammals in some parts of the IQ region, considering the same timeframe we used for baseline studies (i.e., from 2005 to 2018). We searched for the scientific studies on indexing websites and search engines, such as *Google Scholar* and *Web of Science,* using 2 or more combined keywords (e.g., "inventory" AND "mammals" AND "Minas Gerais"; "species list" AND "Iron Quadrangle" AND "medium and large-sized mammals") and their correspondent in Portuguese. We also consulted the bibliographic references of studies resulting from those searches that presented compilations of secondary data on M&L mammals in the studied region, searching for the studies containing primary data.

Those collected scientific studies whose samplings were distributed in too extensive areas were partitioned into different studies to match the same scale where the EIA baseline studies were conducted. Specifically, using the software QGIS 3.12.3 (QGIS, 2019), we grouped the sampling points of each scientific study that were conducted through a large area in the IQ into 7 km buffers, and considered each buffer as an independent study, counting the sampling effort spent and results obtained apart. We chose this buffer scale because most sampling points from EIA baseline studies, that provided this information (i.e., the overall study area), were distributed up to 7 km from the project under EIA. Each buffer was positioned to accommodate the largest number of sampling points from the same scientific study.

As for the baseline studies, the scientific studies must report the sampling method used for each registered species to be included in our analysis. We tabulated the species list, methods, and sampling effort used in each scientific study.

2.3 Methodological, ecological, and environmental variables

To evaluate whether methodological factors employed by both scientific and EIA baseline studies may influence the detection probability of the mammal species, we considered the following variables: *i*) the type of sampling methods employed; *ii*) the number of complementary sampling methods used, and *iii*) the sampling effort spent on the field survey.

Both study types employed distinct direct (i.e., mammal visualization during the census and mammal photos using camera traps) and/or indirect (searching for mammal clues or signs and interviews) sampling methods for surveying M&L mammals. Census is the most traditional direct sampling method in mammalian surveys (Espartosa *et al*., 2011). It consists of a specialist's active search for the visualization of animals in linear transects or random walks (Reis *et al.*, 2014). Parallel to the census, the searching for clues or signs (e.g., feces, footprints, hair, burrows, etc.) is normally applied, despite its limitations related to species identification (Reis *et al.*, 2014). Camera trapping, in its turn, is highly recommended for the precise identification of large species (Lyra-Jorge *et al*., 2008; Wearn & Glover-Kapfer, 2019), but it used to be also more expensive and complicated to buy, especially at the beginning of its application (Tobler *et al*., 2008). On the other hand, the sampling by interviews (i.e., asking local people about animals they have seen in the study area) is cheaper, but it may carry biases due to species misidentification or false positives (Reis *et al.*, 2014; Kachel *et al*., 2022).

Because sampling methods may vary in efficiency, accuracy, cost-benefits, and biases (e.g., camera traps usually perform better for larger animals) (Espartosa, *et al*., 2011; Lyra-Jorge *et al*., 2008; Reis *et al*., 2014), it may be useful a field protocol that employs complementary sampling methods for surveying M&L mammals communities (Lyra-Jorge *et al*., 2008). Thus, in addition to the type of sampling method employed, we also evaluated the influence of the number of sampling methods used by the studies on the species detection probability. This variable varied from 1 to 4, according to the four sampling methods mentioned above.

We also evaluated the influence of the sampling effort on the species detection probability. Because studies can report the sampling effort using different metrics (e.g., the census can be reported in the number of kilometers or hours sampled, while camera trapping' effort can be reported in traps/night or the number total of hours), may be hard to make comparisons between sampling efforts employed by each method. Also, our purpose here was only to compare the overall sampling effort between studies, independent of the used methods. Thus, to make the sampling effort between studies comparable, we considered the number of days that the researchers and/or cameras were in the field using the formula:

$$SE = DR + DCT \ x \ NCT$$

Where SE = Sampling effort; DR = Number of days the researcher was in the field; DCT = Number of days the camera traps operated in the field; and NCT = Number of camera traps in the field.

Apart from methodological variables, we evaluated whether ecological factors may influence the species detection probability. Specifically, we considered that given a certain species occur in a certain location, the chances of it being detected by a study may be affected by the rarity of the species. Thus, based on Kays and collaborators (2020), we considered rare those species detected in less than 25% of the direct sampling methods (i.e., visual record of animals and photographic recording by camera traps) employed by the collected studies. Species registered by direct methods in 25.1% to 50% of the studies were considered less rare, while those registered by 50.1% to 75% of the studies were considered common, being very common only those species registered in more than 75.1% of the studies. However, because no species was detected in more than 50% of the studies, we considered only rare (1) and less rare (0) species.

Finally, we also evaluated whether an environmental variable may influence the species detection probability. There is a positive relationship between habitat quality and biodiversity (Duarte *et al*., 2016). For instance, landscape features may influence the intensity of habitat use by some M&L mammals (Massara, *et al*., 2018; Dias *et al*., 2019b). Therefore, we evaluated whether the habitat quality may influence the species' habitat use and thus, their detection probability by considering the habitat quality map (i.e., a raster layer) produced by Duarte *et al*., (2016) for the IQ region. The authors calculated the habitat quality in the IQ region considering the classes of land uses and land covers as well as the distances to impacts. The habitat quality score in each pixel varies from 0 to 1, being the higher the score, the higher the quality. Using the software QGis 3.12.3, we overlap the habitat quality raster with each of the 7 km buffers that surrounds the centroids of the study areas of the collected mammals' studies. Then, we calculated the average score of habitat quality in each of the 7 km buffers (ranging from 0 to 1) to represent the habitat quality for each studied area.

2.4 Statistical approach

Considering that species detections by some sampling methods are ambiguous or uncertain (i.e., might be either the species of interest or not), we used the single-season occupancy model that accounts for false-positive-detections for analysis (Miller *et al*., 2011) in Program Mark (White and Burnham, 1999). This model has four parameters that can be modeled in the function of predictor variables: two parameters are related to detection probabilities (*p10* and *p11*), one parameter is related to the probability of certain detection (*b*) and one is related to the occupancy probability parameter (Ψ).

To focus on our hypotheses of interest, we defined our survey occasions as the sampling methods employed by each study, whereas a sampling unit was defined as each M&L mammal species (MacKenzie et al., 2018). Specifically, each study, regardless of the type (i.e., scientific or EIA baseline studies), was considered a group composed of survey occasions, being each survey occasion considered a method that was employed by each study. For example, if a certain study employed three distinct sampling methods, the group of survey occasions referred to this specific study was composed of three survey occasions and so on. Additionally, our sampling unit was each mammal species that could potentially occur in any part of the IQ region according to all M&L mammals' studies collected (list of species available at Appendix A - Supplementary Material). Also, because we aimed to build a comprehensive list of potential species, we included two species (i.e., *Tayassu pecari* and *Priodontes maximus*) that were not registered by the collected studies (potential false absences), but whose geographic range may include the IQ region (IUCN, 2022).

Therefore, the parameter *p11* was defined as the probability of detecting species *i* by a survey method *j* in a study t given species *i* was present in the area sampled by the study and, therefore, this parameter was related to the true detection probability, as it accounts for the false-negative detections (Miller *et al*., 2011). Conversely, the parameter *p10* was defined as the probability that species *i* would be incorrectly detected by a survey method *j* in a study *t*, given species *i* did not occur in the area sampled by the study, thus representing the false-positive detection probability (Miller *et al*., 2011). The parameter *b* was defined as the probability that a detection could be designated as certain given the species *i* was using the area sampled by a study and it was unambiguously detected by the survey method *j*. Contrary, *1-b* is the probability of an uncertain detection. Finally, the parameter Ψ was defined as the occupancy probability of the overall M&L terrestrial mammal community according to the species list considered by us.

Thus, the encounter histories were composed of whether or not a certain species was registered by a certain method within each study conducted in IQ. However, because some sampling methods are prone to false-positive detections, the modeling approach used by us allowed accounting for three detection states: one related to uncertain or ambiguous detections (coded as 1 in the encounter histories); one related to certain or unambiguous detections (coded as 2 in the encounter histories); and one related to non-detections (coded as 0 in the encounter histories) (Miller *et al*., 2011). For example, let's suppose an encounter history for a collected study composed of a sequence of "2010". This sequence means that a certain species is known to be present in a studied area due to unambiguous, certain detection by the first sampling method. Then, the species was not detected by the second and fourth sampling methods, and was detected by the third sampling method, but there was uncertainty about the detection. Alternatively, an encounter history composed of a sequence of "1010" means that species may be present or not in the studied area. Thus, an uncertain detection was obtained by the first and third method, and species was not detected by the second and fourth method during this specific study.

For our study, we assumed that species detected by either visualization during the census or camera traps would not be prone to false-positive and uncertain detections and thus, we fixed the parameters *p10* and *b* for these sampling methods in 0 and 1, respectively. On the other hand, we assumed that sign surveys and interviews always have uncertain detections and thus, we fixed the *b* parameter for these two methods at 0. Therefore, detections made by the direct and indirect sampling methods were always coded as 2 (unambiguous detections) and 1 (ambiguous detections) in the encounter stories, respectively. Although we recognize that either the direct and indirect methods are prone to ambiguous and unambiguous detections, respectively, we did not have access to the raw data to discriminate whether the registers made by each type of method could be classified as ambiguous or not and thus, we had to make this *a priori* assumption. However, because the indirect methods are always more prone to ambiguous detections than the direct methods, we believe this assumption did not prevent us from evaluating our hypotheses of interest.

The parameter *p10,* which relates to the false-positive detection probability, was modeled as a function of sampling method (sign surveys *versus* interviews) and study type (scientific *versus* EIA baseline studies). Because false-positive detections might differ between sampling methods and the method with higher or lower detection might be the same regardless of the study type or not, respectively, we also constructed an additive and an interactive model between these two variables and evaluated their influence on *p10*.

The parameter *p11*, which relates to the true detection probability, was modeled as a function of study type, sampling method (sign surveys, interviews, visualizations through census, and camera traps), sampling effort, number of employed methods, species rarity and habitat quality. We also explored the influence of additive and interactive models between study type and all other variables on *p11*, considering that true detection might differ as a function of them regardless of the study type or not. Specifically, the sampling method used, the sampling effort spent, the number of employed methods, the species rarity and the habitat quality might influence true detection probability, but with different effects between study types or not.

Because our aim was not to evaluate the factors that influence the M&L mammals' occupancy in different areas of the IQ region, we focused on only one estimation of occupancy probability (Ψ) for the entire IQ region, instead of modeling Ψ as a function of predictor variables (i.e., we used only the intercept-model structure).

We used the step-down approach for model selection (Lebreton, 1992). Specifically, using the most parametrized model structure for *p11,* we built different model structures with only one hypothesis at time for *p10*. Thus, we used the Akaike Information Criterion adjusted for small sample sizes (AICc) to determine the most parsimonious model structures (Δ-AICc $\leq$ 2) influencing *p10* (Burnham and Anderson, 2002). Then, we fixed *p10* with the most parsimonious model structures and started modeling *p11* using the same strategy. This process enabled us to identify the variables that influenced the true and false-positive detection probabilities of the species.

3. RESULTS

We collected a total of 65 M&L mammals' studies in IQ, 34 baseline studies linked to EIA of mining projects and 31 inventories linked to scientific research (**Figure 1**). The 31 scientific inventories derived from four articles, two master dissertations, one undergraduate thesis, and one technical book (**Table 1**).

Table 1. Number of species' inventories considered in this study, derived from eight scientific research.

Source	**Type**	**Number of inventories linked to scientific research considered in this study**
Braga, *et al*., 2018	Article	1
Melo, *et al*., 2009	Article	1
Talamoni, *et al*., 2014	Article	1
Morcatty, *et al*., 2013	Article	4
Silva, 2013	Master dissertation	4
Hufnagel, 2017	Master dissertation	18
Hufnagel, 2014	Undergraduate thesis	1
AngloGold Ashanti, 2009	Technical book	1
	Total	**31**

A total of 37 species composed the list of M&L mammals that potentially occur in the IQ region (**Appendix A – Supplementary Material**). EIA baseline studies recorded 11.6 species on average (range from 1 to 22), while scientific inventories recorded 11.8 (ranging from 3 to 27). The most registered species in EIA baseline studies (i.e., considering every record, made by every sampling method, in all EIA baseline studies) were the Crab-eating Fox (*Cerdocyon thous*), the Common Tapeti (*Sylvilagus brasiliensis*) and the Capybara (*Hydrochoerus hydrochaeris*), with 50, 48 and 40 records, respectively. In scientific inventories, the most registered species were the Common Tapeti (*S. brasiliensis*; 31 records), the South American Coati (*Nasua nasua*; 29 records), and the Long-nosed Armadillo (*Dasypus novemcinctus*) and the Lowland Paca (*Cuniculus paca*), with 27 records each.

The Margay (*Leopardus wiedii*) and the Greater Naked-tailed Armadillo (*Cabassous tatouay*) were recorded only by scientific inventories, while the Molina´s Hog-nosed Skunk (*Conepatus chinga*), the Greater Grison (*Galictis vitata*), and the Big-eared Opossum (*Didelphis aurita*) were recorded only by baseline studies. The White-lipped Peccary (*Tayassu pecari*) and the Giant Armadillo (*Priodontes maximus*) were not detected by any of the study types. Most species were considered rare (84%; 31 species) because they were recorded by direct methods in less than 25% of the studies, while only six species (16%) were considered less rare (i.e., recorded by direct methods from 25.1 to 50% of the studies. No species has been recorded by direct methods in more than 50% of the studies to be considered common.

Camera traps were used by most scientific studies (i.e., 87%), but only by few EIA baseline studies (i.e., 18%), while the combination of census and searching for animals' clues were used by most EIA baseline studies (i.e., 97%) and a smaller portion of scientific studies (i.e., 39%). Interviews were used by 74% of EIA baseline studies and 39% of scientific studies. A total of 61% of the scientific studies used a single sampling method, which was camera traps. Among the EIA baseline studies, only one (i.e., 3%) used a single sampling method, which was interviews. All other studies used a combination of two or more.

The sampling effort was very different between both study types. Scientific studies spent on average 625.52 days in the field (ranging from 9 to 4153), while EIA baseline studies spent 13.93 days (ranging from 1 to 54). While all scientific studies reported information enough to calculate the sampling effort in days, five EIA baseline studies did not.

The habitat quality was a bit higher in study areas of scientific studies (i.e., 0.649 on average, ranging from 0.317 to 0.850) than in study areas of EIA baseline studies (i.e., 0.547 on average, ranging from 0.369 to 0.696).

Following the step-down approach for model selection, we first built five models while modeling *p10*. There was uncertainty between two models. The additive effect between study type and sampling method was the best-ranked model (Δ-AICc = 0.00), indicating that both variables influence the false-positive detections. The second best-ranked model was the structure containing only the study type (Δ-AICc = 0.21). Thus, we fixed *p10* with these two model structures at time and started modeling *P11* using a total of 34 model structures (**Table 2**).

The model structure with an interaction effect between the study type and the sampling method was the only that influenced *P11*, which means that the true detection probability was influenced by the sampling methods in different ways in the scientific and EIA baseline studies. Contrary to our expectations, *P11* was not influenced by sampling effort or number of methods applied, neither by rarity of the species or habitat quality (**Table 2**).

Table 2. Model selection results of the probabilities of false-positive (*p10*) and true detection (*p11*) of medium and large-sized (M&L) terrestrial mammals in baseline studies of mining projects under EIA and surveys made with scientific purposes in the Iron Quadrangle region, state of Minas Gerais, southeastern Brazil. See details in section 2.3. Methodological, ecological, and environmental variables.

Model	AICc	Δ-AICc	AICc Weights	Model Likelihood	Number of parameters	Deviance

Modeling *p10*						
p10 (study type + method) *p11* (study type x method) Ψ (.)	4688.975	0.000	0.387	1.000	12	4651.975
p10 (study type) *p11* (study type x method) Ψ (.)	4689.185	0.210	0.348	0.900	11	4656.625
p10 (.) *p11* (study type x method) Ψ (.)	4691.397	2.422	0.115	0.298	10	4662.935
p10 (method) *p11* (study type x method) Ψ (.)	4691.402	2.427	0.115	0.297	11	4658.842
p10 (study type x method) *p11* (study type x method) Ψ (.)	4693.801	4.826	0.035	0.090	13	4651.975
Modeling *p11*						
P10 (study type + method) *P11* (study type x method) Ψ (.)	4688.982	0.000	0.525	1.000	12	4651.982
P10 (study type) *P11* (study type x method) Ψ (.)	4689.180	0.198	0.475	0.906	11	4656.620
p10 (study type + method) *P11* (study type + rarity) Ψ (.)	4745.198	56.216	0.000	0.000	7	4727.336
p10 (study type) *P11* (study type + rarity) Ψ (.)	4746.778	57.796	0.000	0.000	6	4731.978
p10 (study type + method) *P11* (study type x rarity) Ψ (.)	4748.265	59.283	0.000	0.000	8	4727.122
p10 (study type) *P11* (study type x rarity) Ψ (.)	4749.623	60.641	0.000	0.000	7	4731.761
P10 (study type + method) *P11* (study type + method) Ψ (.)	4761.675	72.692	0.000	0.000	9	4737.008
P10 (study type) *P11* (study type + method) Ψ (.)	4762.797	73.815	0.000	0.000	8	4741.655
P10 (study type + method) *P11* (rarity) Ψ (.)	4764.388	75.406	0.000	0.000	6	4749.588
P10 (study type) *P11* (rarity) Ψ (.)	4766.173	77.190	0.000	0.000	5	4754.237
P10 (study type + method) *P11* (method) Ψ (.)	4777.452	88.470	0.000	0.000	8	4756.309
P10 (study type) *P11* (method) Ψ (.)	4778.810	89.828	0.000	0.000	7	4760.948
P10 (study type + method) *P11* (study type x number of methods) Ψ (.)	4980.527	291.545	0.000	0.000	8	4959.384
P10 (study type + method) *P11* (study type + sampling effort) Ψ (.)	4980.801	291.819	0.000	0.000	7	4962.939
P10 (study type) *P11* (study type x number of methods) Ψ (.)	4981.891	292.909	0.000	0.000	7	4964.029
P10 (study type) *P11* (study type + sampling effort) Ψ (.)	4982.390	293.408	0.000	0.000	6	4967.590
P10 (study type + method) *P11* (sampling effort) Ψ (.)	4982.584	293.602	0.000	0.000	6	4967.784
P10 (study type + method) *P11* (study type x sampling effort) Ψ (.)	4983.143	294.161	0.000	0.000	8	4962.001
P10 (study type + method) *P11* (study type + number of methods) Ψ (.)	4983.195	294.213	0.000	0.000	7	4965.333
P10 (study type) *P11* (sampling effort) Ψ (.)	4984.364	295.382	0.000	0.000	5	4972.429
P10 (study type) *P11* (study type x sampling effort) Ψ (.)	4984.507	295.524	0.000	0.000	7	4966.644
P10 (study type) *P11* (study type + number of methods) Ψ (.)	4984.772	295.789	0.000	0.000	6	4969.972
P10 (study type + method) P11 (number of methods) Ψ (.)	4997.866	308.884	0.000	0.000	6	4983.066
P10 (study type + method) *P11* (study type + habitat quality) Ψ (.)	4998.787	309.805	0.000	0.000	7	4980.925
P10 (study type + method) *P11* (study type) Ψ (.)	4999.010	310.027	0.000	0.000	6	4984.210
P10 (study type) P11 (number of methods) Ψ (.)	4999.648	310.666	0.000	0.000	5	4987.713
P10 (study type) *P11* (study type + habitat quality) Ψ (.)	5000.378	311.396	0.000	0.000	6	4985.578
P10 (study type) *P11* (study type) Ψ (.)	5000.791	311.809	0.000	0.000	5	4988.856
p10 (study type + method) *P11* (study type x habitat quality) Ψ (.)	5001.730	312.748	0.000	0.000	8	4980.587
p10 (study type) *P11* (study type x habitat quality) Ψ (.)	5003.089	314.106	0.000	0.000	7	4985.227
P10 (study type + method) *P11* (habitat quality) Ψ (.)	5003.793	314.811	0.000	0.000	6	4988.993
P10 (study type) *P11* (habitat quality) Ψ (.)	5005.570	316.588	0.000	0.000	5	4993.635
P10 (study type + method) *P11* (.) Ψ (.)	5017.108	328.126	0.000	0.000	5	5005.173
P10 (study type) *P11* (.) Ψ (.)	5019.067	330.085	0.000	0.000	4	5009.817

Because of model selection uncertainty, we model-averaged the model parameters to report the final estimates. The false-positive estimations (i.e., *p10*) were higher in EIA baseline studies compared to scientific studies for either sign surveys or interviews, being 0.021 (95%-CI=0.006

- 0.071) and 0.044 (95%-CI=0.017 - 0.108) for each method, respectively. By combining all EIA baseline studies that used each of these methods through the formula $1\text{-}(1\text{-}p)^K$, where p is the false-positive detection probability estimates and K is the number of studies that used each method, the probability of falsely detecting species at least once during EIA baseline studies in the IQ region would be $1\text{-}(1\text{-}0.021)^{33} = 0.50$ for sign surveys and $1\text{-}(1\text{-}0.044)^{25} = 0.67$ for interviews. Conversely, the false-positive estimations were closer to zero for both methods in scientific studies, being 0.8×10^{-5} (95%-CI=0.3×10^{-3} – 0.3×10^{-3}) for sign surveys and 0.3×10^{-4} (95%-CI=0.1×10^{-2} – 0.1×10^{-2}) for interviews.

The true detection estimations (i.e., *p11*) were higher in scientific studies for all methods, except for interviews [i.e., 0.36 (95%-CI=0.32 - 0.39) for EIA baseline studies and 0.23 (95%-CI=0.19 - 0.28) for scientific studies]. True detection probability by camera traps in EIA baseline study was 0.09 (95%-CI=0.05 - 0.14) and 0.20 (95%-CI=0.18 - 0.23) for scientific studies, while census was 0.05 (95%-CI=0.03 - 0.06) and 0.16 (95%-CI=0.13 - 0.21), respectively. Sign surveys estimated 0.14 (95%-CI=0.12 - 0.16) for EIA baseline studies and 0.26 (95%-CI=0.21 - 0.30) for scientific studies (**Figure 2**).

The occupancy probability (ψ) for M&L mammals in the IQ region was 0.86 or 86% (95%-CI=0.71 - 0.94), which corresponds to ~ 32 species among the 37 that composed the list of potential species. Among the species estimated as not present were *Tayassu pecari* and *Priodontes maximus*, included in the list of potential species, but not detected by any study; and *Conepatus chinga*, *Galictis vittata*, and *Didelphis aurita*, were detected only by indirect methods.

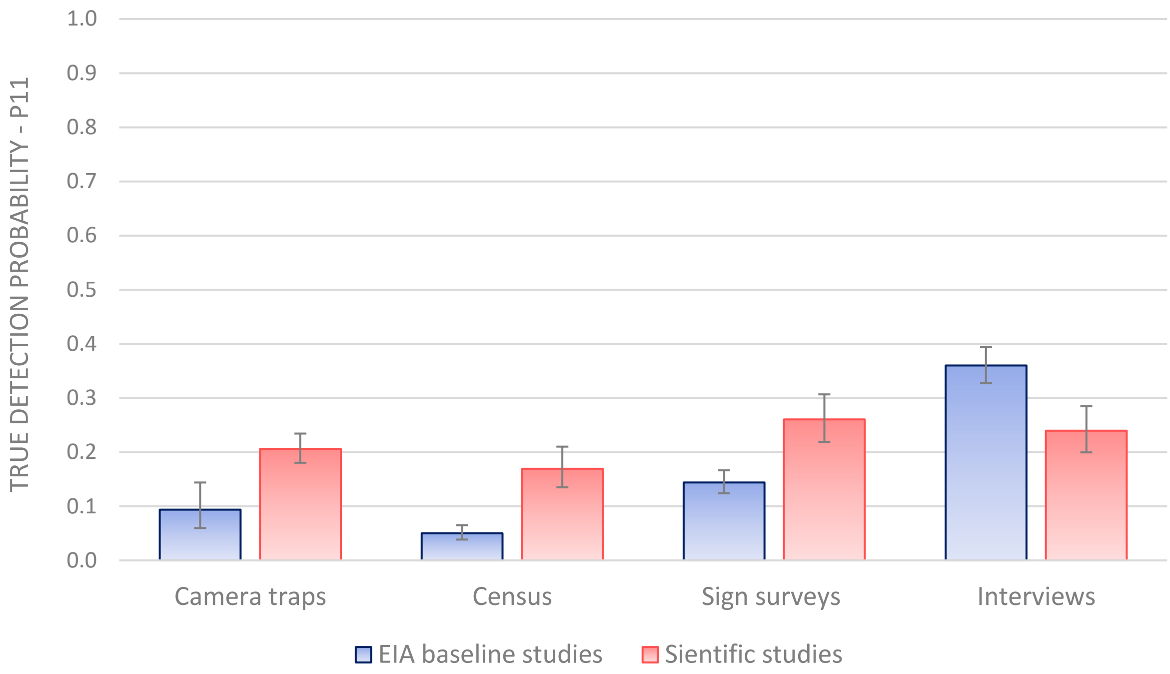

Figure 2. True detection probability (*p11*) of medium and large-sized (M&L) terrestrial mammals according to four types of methods (i.e., camera traps, census, sign surveys and interviews) employed by baseline studies of mining projects under EIA and surveys made with scientific proposals in the Iron Quadrangle region, state of Minas Gerais, southeastern Brazil.

4. DISCUSSION

Many authors demonstrated legitimate concerns about the quality of EIA biodiversity baseline studies. Structural shortcomings previously identified included: 1) low scientific rigor, with no driven questions or impact-oriented hypotheses (Dias, *et al*., 2022); 2) design flaws, such as field surveys neglecting seasonal influence and poor sampling effort (Hallatt *et al*., 2015; Dias *et al*., 2019a; Dias *et al*., 2022); 3) no quantitative data or proper statistical analyses (Mandelik *et al*., 2005; Samarakoon and Rowan, 2008; Dias *et al*., 2019a, Dias *et al*., 2022); 4) studies containing only uninformative lists of species (Treweek *et al*., 1993; Le Maitre *et al*., 1998; Khera and Kumar, 2010; Dias *et al*., 2019a, Dias *et al*., 2022) and failing to report information about sampling (Dias *et al*., 2022). Yet, few authors highlighted the importance of considering imperfect detection in these surveys (Gannon, 2021; Dias *et al*., 2022). The present study is the first one dedicated to modeling the influence of methodological factors of EIA baseline studies on species' detection.

As we expected, false-positive detections were higher in EIA baseline studies, while scientific studies had no false-positive detections. We estimated that in EIA baseline studies, about 4.4% of the detections made by interviews were erroneous, that is, some species were recorded, but did not occur. This means that, a hypothetical EIA baseline study that detected 23 species using interviews, probably about one of them does not actually occur. For sign surveys, erroneous detections were estimated at 2.1%. Considering together all the EIA baseline studies that used one of those methods (i.e., 33 for sign surveys and 25 for interviews), the false-positive estimations increase considerably, being 50% for sign surveys and 67% for interviews. Also as expected, true detection estimates were lower in EIA baseline studies for all methods, except for interviews. Specifically, given a species was present at the study site, we found that an EIA baseline study had 9%, 5% and 14% chances of detecting it by camera traps, census, and sign surveys, respectively. Contrary, using the same methods but in scientific studies, the chances of detecting species increased to 20%, 16% and 26%, respectively (**Figure 2**).

It's worth emphasizing that both study types presented true detection probability estimates quite low, although even lower in studies linked to EIA, which reinforces that mammals' species are naturally elusive (Gálvez *et al*., 2016; Hufnagel, 2017; Kindberg *et al*., 2009). This draws attention to the importance of considering imperfect detection estimates on biodiversity surveys. As a rule, most of the work from both consultancy and academia starts from the premise that detection probability is perfect, but it is not. This can produce biased and misleading results and, in the case of baseline studies, encourage unfounded decisions in the EIA.

Once reliable baseline information is essential to build a comprehension of how potential impacts would affect biodiversity (Treweek *et al*., 1993; Thompson *et al*., 1997; Mandelik *et al*., 2005 Dias *et al*., 2022), registering species that do not occur or not registering those that do occur might conduct to wrong interpretations (Gannon, 2021; Dias *et al*., 2022). Thus, the assessment of impacts and all EIA's subsequent decisions, such as the implementation of effective mitigation measures, may be compromised (Dias *et al*., 2022). If imperfect detection is not considered, species that are present, but were not registered, would be not contemplated by mitigation programs, while resources may be eventually wasted on programs that consider species that are not present.

Although the sampling effort was quite discrepant among the type of studies (i.e., ranging from 9 to 4153 in scientific and from 1 to 54 in EIA baseline studies), counterintuitively and different from previous studies (Dias *et al*., 2019b; Guimarães, 2019), this variable and the number of complementary methods employed did not matter for species true detection. Also different from other studies (Guimarães, 2019; Rios *et al*., 2022) the variables related to species' rarity and habitat quality did not affect species detection probability at occupied sites.

The results we found might indicate that intrinsic characteristics of studies may contribute to their having less chances of detection species, and it is generally worst in EIA baseline studies. Both false-positive and true detections may be related to the sensitive points that affect the quality of the EIA baseline studies or other characteristics of them that we did not model. In a previous study we used a good practices checklist to evaluate the quality of 78 EIA baseline studies with a score from 0 (lowest quality) to 100 (highest quality) (Dias *et al*., 2022). A subset of 34 of those EIA baseline studies composed the present study, scoring 44.8% on average (range from 21.7% to 73.9%). No driving questions or hypotheses, important information about sampling design missing and weak ecological and quantitative analyses were some of the shortcomings identified. These inconsistencies may indirectly contribute to increasing false-positive detections and decreasing true detections in EIA baseline studies (Dias *et al*., 2022).

Moreover, a less than appropriate application of methods in biodiversity baseline studies might be a practice in EIA, once species were truly detected three times less by census and about twice less by camera traps and sign surveys when compared to scientific studies. The higher estimates of true detection through interviews in EIA baseline studies may be due to the overuse of this method by these studies compared to scientific studies (i.e., 74% versus 39%, respectively). Nevertheless, it is important to emphasize that the use of interviews should be considered with caution, as this method was the most vulnerable to false-positive detections (Reis *et al.,* 2014).

False-positive detection estimates also may reflect a need for caution in the application of the indirect sampling methods in EIA baseline studies. Maybe more reliable records would be obtained better by observing the experience of the professionals who identify animal clues in sign surveys or the mechanisms to filter the respondents in interviews. Also, the false-positive detection estimates reinforce the importance of employing direct sampling methods. Camera traps highly recommended for accurate M&L mammals' identification (Silveira *et al*., 2003; Wearn & Glover-Kapfer, 2019). However, this method was barely used by EIA baseline studies we evaluated (i.e., 18%), maybe because of their higher costs (Tobler *et al*., 2008). As suggested by Dias *et al* (2022), costs may be accounted for the consultant companies' decisions concerning methods using, when designing EIA studies.

According to our occupancy probability estimates (i.e., 0.864 or 86.40%), five species might not occur, of which two most likely do not occur in the study areas. The White-lipped Peccary (*Tayassu pecari*) and the Giant Armadillo (*Priodontes maximus*) probably do not actually occur in IQ region. They were not detected by any study we evaluated and fresh evidence of the presence of these species in Brazilian Atlantic Forests are scarce (Srbek-Araujo *et al*., 2009; Silveira and Pacheco, 2018). The other three species probably occur in the macro-region, but it is not possible to be sure whether they occur in the sampled sub-localities. The Molina's Hog-nosed Skunk (*Conepatus chinga*), the Greater Grison (*Galictis vittata*), and the Brazilian Common Opossum (*Didelphis aurita*) were detected only by indirect methods. Thus, their records in the sampled area are uncertain. This, again, highlights the importance of considering imperfect detection in surveys. The Brazilian Common Opossum, for example, might indicate the poor quality of habitats (Cárceres and Monteiro-Filho, 2006). Thus, an eventual false positive can lead to a misinterpretation, encouraging ill-founded decisions (Kache *et al*., 2022). In addition, the non-recording of this species may be related to the methods we focused on, once it is usually detected by the methods dedicated to the sampling small mammals (Reis, et al., 2014).

Finally, we believe that we would add more refinement to the models we built if we had access to the raw data and metadata of both study types, for example, to better decide if each record should be considered ambiguous and or not. Information about the experience of the professionals involved in consultancy work and the budget available for carrying these studies out would be also useful to better respond about their influence on species detectability. This should also be further explored in future studies. Also, we recognize that the 31 scientific studies were partitioned from only eight studies, may have caused lack of independence between the samplings, in terms of study quality and professional experience, for example. However, this was necessary to put them on the same scale of EIA Baseline studies. Yet, the low number of scientific studies available may be a hindrance.

It is known that good baseline information is essential to support decisions in EIA and many studies warn for the necessary improvements in biodiversity baseline studies design. However, few of them draw attention to the imperfect species detection implications in EIA (Gannon, 2021; Dias *et al*., 2022). We focused on estimating false-positive and true detection in EIA based on baseline data. We found worrying estimates for both, indicating that studies results might lead to misinterpretations and, consequently, misguided EIA decisions. We warn that just as urgent as improve the quality of studies in EIA (in terms of methods application, sampling design, ecological analyses, and information reporting; Dias *et al*., 2022), is considering imperfect detection in those studies. Otherwise, species that are present, can be left out mitigation programs, while species that have been erroneously recorded may be allocated on it, for example. Finally, further studies that evaluate raw data and metadata of EIA may contribute to understand how intrinsic characteristics of baseline studies, such as consultants experience, can affect their efficiency in detecting species.

APPENDIX A – SUPPLEMENTARY MATERIAL

List of M&L mammals' species that could potentially occur in the IQ region, including scientific names (according to Abreu *et al.*, 2021) and common names in English (according to IUCN, 2022) and Portuguese (according to Abreu *et al.*, 2021).

Scientific name (Abreu *et al.*, 2021)	**Common name (IUCN, 2022)**	**Portuguese common name (Abreu et al., 2021)**
Mazama americana (Erxleben, 1777)	Red Brocket	Veado-mateiro
Mazama gouazoubira (Fischer, 1814)	Gray Brocket	Veado-catingueiro
Dicotyles tajacu (Linnaeus, 1758)	Collared Peccary	Cateto
Tayassu pecari (Link, 1795)	White-lipped Peccary	Queixada
Cerdocyon thous (Linnaeus, 1766)	Crab-eating Fox	Cachorro-do-mato
Chrysocyon brachyurus (Illiger, 1815)	Maned Wolf	Lobo-guará
Lycalopex vetulus (Lund, 1842)	Hoary Fox	Raposinha
Leopardus guttulus (Hensel, 1872)	Southern Tiger Cat	Gato-do-mato-pequeno
Leopardus pardalis (Linnaeus, 1758)	Ocelot	Jaguatirica
Leopardus wiedii (Schinz, 1821)	Margay	Gato-maracajá
Panthera onca (Linnaeus, 1758)	Jaguar	Onça-pintada
Puma concolor (Linnaeus, 1771)	Puma	Onça-parda
Herpailurus yagouaroundi (É. Geoffroy Saint-Hilaire, 1803)	Jaguarundi	Gato-mourisco
Conepatus chinga (Molina, 1782)	Molina's Hog-nosed Skunk	Cangambá
Conepatus semistriatus (Boddaert, 1785)	Striped Hog-nosed Skunk	Cangambá
Eira barbara (Linnaeus, 1758)	Tayra	Irara
Galictis cuja (Molina, 1782)	Lesser Grison	Furão-pequeno
Galictis vittata (Schreber, 1776)	Greater Grison	Furão-grande
Lontra longicaudis (Olfers, 1818)	Neotropical Otter	Lontra
Nasua nasua (Linnaeus, 1766)	South American Coati	Quati
Procyon cancrivorus (Cuvier, 1798)	Crab-eating Raccoon	Mão-pelada
Cabassous tatouay (Desmarest, 1804)	Greater Naked-tailed Armadillo	Tatu-de-rabo-mole-grande
Cabassous unicinctus (Linnaeus, 1758)	Southern Naked-Tailed Armadillo	Tatu-de-rabo-mole-pequeno
Dasypus novemcinctus (Linnaeus, 1758)	Nine-banded Armadillo	Tatu-galinha
Dasypus septemcinctus (Linnaeus, 1758)	Brazilian Lesser Long-nosed Armadillo	Tatuí
Euphractus sexcinctus (Linnaeus, 1758)	Yellow Armadillo	Tatu-peba
Priodontes maximus (Kerr, 1792)	Giant Armadillo	Tatu-canastra
Didelphis albiventris (Lund, 1840)	White-eared Opossum	Gambá-de-orelha-branca
Didelphis aurita (Wied-Neuwied, 1826)	Brazilian Common Opossum	Gambá-de-orelha-preta
Sylvilagus brasiliensis (Linnaeus, 1758)	Common Tapeti	Tapiti
Tapirus terrestris (Linnaeus, 1758)	Lowland Tapir	Anta
Myrmecophaga tridactyla (Linnaeus, 1758)	Giant Anteater	Tamanduá-bandeira
Tamandua tetradactyla (Linnaeus, 1758)	Southern Tamandua	Tamanduá-mirim
Hydrochoerus hydrochaeris (Linnaeus, 1766)	Capybara	Capivara
Cuniculus paca (Linnaeus, 1766)	Agouti	Paca
Dasyprocta leporina (Linnaeus, 1758)	Red-rumped Agouti	Cutia
Dasyprocta azarae (Lichtenstein, 1823)	Azara's Agouti	Cutia

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OS RUMOS DA BIODIVERSIDADE NO CONTEXTO DA AIA

Parece existir uma dificuldade intrínseca na AIA em estabelecer relações de causa e efeito quanto as atividades de empreendimentos e suas consequências. Em se tratando da biodiversidade, identificar essa relação pode ser ainda mais complexo, seja pela carência de parâmetros bem estabelecidos para seus indicadores, seja pela natureza subjetiva dos resultados das medições (Geneletti, 2006). Por exemplo, diferente de um monitoramento de contaminantes na água ou sedimento, relativamente fáceis de medir, e para os quais existem limites bem estabelecidos na legislação brasileira (e.g., CONAMA 367/2005 e CONAMA 454/2012), responder sobre a influência de ruídos causados pela operação de máquinas sobre a vocalização e reprodução de anfíbios pode ser bem mais complexo. Além das complexidades próprias da abordagem da biodiversidade na AIA, muitas limitações adicionais são apontadas na literatura, principalmente no que diz respeito à obtenção de informações de linha de base. Reconhecer as limitações dos estudos de base da biodiversidade e suas implicações na avaliação de impactos e no processo decisório é fundamental para fomentar as discussões de melhores práticas sobre esse tema que já é, por si só, complexo.

Nós encontramos limitações bastante significativas na abordagem da biodiversidade no contexto da AIA para o licenciamento de empreendimentos. O primeiro capítulo mostrou que a qualidade técnica dos estudos de base avaliados foi comprometida por fatores como a falta de rigor científico, de robustez analítica e de clareza no reporte de informações. Essas falhas limitaram as avaliações de impactos, mas não a obtenção de licenças ambientais. O segundo capítulo mostrou que a efetividade dos estudos de base em detectar corretamente as espécies em campo pode ter sido afetada por fatores ligados à qualidade desses estudos, além dos métodos de coleta utilizados. De maneira geral, a baixa qualidade e a baixa efetividade dos estudos da biodiversidade encontradas neste trabalho evidenciam a provável cultura de realização de estudos para mero cumprimento de protocolos para obtenção das licenças ambientais, ao invés de subsidiar as avaliações, decisões e monitoramentos, de fato. Diante das inúmeras inconsistências técnicas apontadas, entendemos que existem oportunidades de melhorias na abordagem da biodiversidade na AIA em vários níveis e por vários *stakeholders*, especialmente no que diz respeito a definição do escopo dos estudos, em sua elaboração propriamente dita e em seu uso na tomada de decisão. Compilamos aqui, embora sem a pretensão de esgotá-las, cinco dessas oportunidades de melhores práticas:

i. **Elaborar estudos impacto-orientados:** Não é possível (e nem necessário) caracterizar todos os elementos da biodiversidade de uma determinada área para avaliar efetivamente a influência dos impactos de um empreendimento sobre ela. Por vezes, inventários podem ser necessários, mas simples listas de espécies, quando desvinculadas do processo analítico impacto-orientado, contribuem muito pouco para a avaliação de impactos e não costumam fornecer bases robustas para a fase de acompanhamento. Idealmente, deve-se esboçar os (potenciais) impactos prioritários do empreendimento e definir *a priori* o que se espera em termos de resposta para cada indicador escolhido (Teixeira *et al*, 2020). Somente após esse exercício deve-se definir o escopo dos estudos, direcionando os esforços de coleta para os dados que realmente permitem que os efeitos dos impactos sobre a biodiversidade sejam estimados. Nesse sentido, é papel das agências ambientais elaborar Instruções Técnicas e Termos de Referência que guiem essa prática, ao invés pré-definirem escopos rígidos e genéricos. Por outro lado, é papel da consultoria indicar precisamente nos estudos quais perguntas deseja responder e qual raciocínio ou modelo conceitual levou a escolha dos indicadores e seus parâmetros, incluindo bases ecológicas teóricas sobre como eles responderiam ao impacto.

ii. **Construir delineamentos direcionados a responder as perguntas:** Os estudos da AIA deveriam, de maneira geral, buscar responder como a biodiversidade (representada por indicadores em escala espaço-temporal adequada) é afetada pelos impactos do empreendimento. Nesse contexto, a função dos estudos de base não seria necessariamente inventariar todas as espécies que ocorrem na área de estudo, mas sim diagnosticar a situação atual de tudo que se precisa saber a respeito dos indicadores para responder essa pergunta central (Teixeira *et al*, 2020), a partir da reflexão sobre o que, como e por que coletar (Yoccoz *et al*., 2001). A partir daí, perguntas mais específicas sobre a relação indicador-impacto podem ser elaboradas. Assim, é fundamental que os estudos de base sejam delineados somente depois uma intensa reflexão sobre as perguntas que se deseja responder, estabelecidas *a priori*, ou seja, o desenho amostral deve ser elaborado antes do início das atividades de campo. Essa recomendação parece óbvia, mas na prática é possível que muitos consultores se perguntem ao final dos estudos “o que é possível fazer com esses dados?” ou simplesmente reportem a lista de espécies sem nenhum processo analítico. Definir o delineamento *a priori* significa, por exemplo, determinar o esforço, o número de unidades amostrais e de réplicas, determinar os métodos de coleta (inclusive considerando os fatores que afetam a probabilidade de detecção das espécies, quando isso for pertinente, como enfatizado no segundo capítulo deste trabalho) e quais análises são as mais adequadas, sempre considerando as perguntas que se pretende responder.

iii. **Garantir a reprodutibilidade e o reporte adequado das informações:** Tão importante quanto delinear adequadamente os estudos é reportar as informações de maneira a garantir sua reprodutibilidade. Além dos objetivos e de todo o raciocínio percorrido na construção do delineamento, o relatório deve informar de maneira clara como ocorreu a aplicação dos métodos, as datas e períodos de coleta, se a sazonalidade foi considerada, o número de unidades amostrais e esforço empregado, as coordenadas e mapas etc. O reporte adequado de informações aumenta consideravelmente a confiabilidade dos estudos, e, consequentemente, a solidez das decisões neles baseadas, e ainda pode contribuir para futuras comparações ou reutilização dos dados.

iv. **Promover a gestão adequada dos dados:** Apesar de, em linhas gerais, os estudos serem públicos depois de protocolados junto aos órgãos licenciadores, acessar os dados produzidos ao longo dos processos de licenciamento não é tarefa trivial. Em licenciamentos estaduais de Minas Gerais, por exemplo, é possível solicitar vistas aos processos formalmente para ver as cópias físicas dos documentos ou acessá-los digitalmente via plataforma online (o SIAM). Entretanto, percebemos ao coletar os dados para este estudo, que ambos os tipos de acesso têm limitações. O procedimento para pedir vistas pode ser demorado e burocrático. Além disso, os documentos podem estar desorganizados e alguns até desaparecidos. Quanto ao acesso através do repositório online, alguns documentos podem não estar disponíveis ou identificados de maneira inadequada, o que torna mais difícil encontrá-los. Mesmo quando é possível encontrar os estudos, por qualquer das vias, não é possível ter acesso aos dados brutos. Isso reduz muito as possibilidades de (re)uso das informações, seja na pesquisa científica, seja em outros processos de licenciamento, ou mesmo em análises de impactos cumulativos. Nesse contexto, *softwares* que promovessem o adequado armazenamento, gestão e geoespacialização dos dados provenientes dos processos de licenciamento seriam bastante úteis (King *et al.*, 2012). Ademais, as possibilidades de acesso e revisão por pares, além de conferirem transparência aos processos, podem contribuir significativamente para a melhoria da qualidade dos estudos, das avaliações e das decisões. Além disso, esses sistemas poderiam permitir a documentação sistematizada das ações no âmbito do licenciamento (e.g., qual medida de mitigação foi adotada) e seus desdobramentos (e.g., o que funcionou e o que não funcionou), de modo que essas evidências pudessem ser consultadas posteriormente, fomentando decisões futuras.

v. **Decidir com base em evidências:** De maneira geral, as recomendações anteriores tratam da qualidade e da gestão das evidências sobre a biodiversidade, obtidas ao longo dos processos de licenciamento. Mas ter boas evidências disponíveis, não significa necessariamente usá-las para embasar as decisões. É claro que estudos robustos e sistemas de gestão de informações são essenciais, mas isso pode não ser suficiente se não há cultura de tomada de decisões com base em evidências. Por exemplo, é possível que muitas ações ao longo dos processos de licenciamento sejam adotadas por praxe, como programas de monitoramento de determinados grupos taxonômicos que são propostos ou exigidos no licenciamento de quase todos os empreendimentos, sem que necessariamente sejam consideradas as informações de base e avaliações de impactos (Dias *et al.*, 2019); ou medidas de mitigação adotadas com base apenas em convicções pessoais (Sutherland, 2000); e até a decisão sobre a viabilidade do empreendimento, que pode sofrer influência de conflitos de interesse (Salamanca, 2018; Ferraz, 2012). Considerar as evidências disponíveis para então decidir quais são as melhores ações é a lógica que deveria ser aplicada em todos os níveis da AIA, mas isso passa, necessariamente, pelo fortalecimento dos órgãos ambientais.

Na prática, em termos de movimentações para mudanças no processo de licenciamento, é possível notar que existem duas tendências parcialmente antagônicas: de um lado as pressões para flexibilização do processo de licenciamento e de outro o endurecimento das regras para geração de estudos de boa qualidade em áreas de barragens. O Projeto de Lei Federal 3729/04, aprovado na câmara dos deputados em maio de 2021 e aguardando apreciação pelo senado federal, sob o argumento de desburocratização dos processos, pretende dispensar do licenciamento diversas atividades econômicas e restringir a participação de órgãos intervenientes, dentre outras providências que enfraquecem o licenciamento ambiental. Por outro lado, a demanda por estudos ambientais mais rigorosos surgiu como consequência de dois grandes desastres ambientais ocorridos em Minas Gerais: os rompimentos das barragens de mineração de Mariana, em 2015, e Brumadinho, em 2019. Esses eventos possivelmente jogaram luz sobre o problema de não se ter informações adequadas de linha de base que possam ser efetivamente úteis em avaliações *post hoc* e monitoramentos. Assim, a Resolução Conjunta SEMAD/FEAM/IEF/IGAM 3049/2021, estabeleceu diretrizes e procedimentos a serem adotados para o Plano de Ação de Emergência de Barragens de Mineração em Minas Gerais. Dentre eles, a caracterização de linha de base quanto a fauna silvestre e os serviços ecossistêmicos, que segue um Termo de Referência (TR) específico, tem o objetivo de retratar a situação ambiental pré-desastre com a finalidade de permitir futura avaliação de impacto ambiental e para nortear ações de mitigação, reversão e compensação, em caso de indesejável rompimento de barragem.

De um modo geral, o TR para caracterização de barragens traz instruções mais detalhadas (em comparação aos TRs tradicionais do licenciamento) para o delineamento dos estudos de base, de modo que estes sejam mais focados nos potenciais impactos. Nesse sentido, os requerimentos incluem, por exemplo, a caracterização dos processos ecológicos, da bioacumulação e biomagnificação nas teias tróficas e dos serviços ecossistêmicos. Além disso, são exigidas atualizações periódicas dos dados de base, mapeamento geoespacializado das áreas, replicação e independência das amostras etc. Esta pode ser uma oportunidade para mudanças de cultura com potencial de melhorar a qualidade dos estudos de base da biodiversidade e, por fim, das etapas que se seguem na AIA. Lamentavelmente, a oportunidade de melhoria nos procedimentos de AIA deriva de desastres, ressaltando que os avanços na AIA podem ser eminentemente reativos e não proativos. De qualquer forma, há muito o que se avançar, pois os estudos no âmbito de licenciamentos ambientais ainda seguem sendo elaborados sem essa lógica de robustez.

Finalmente, diante da dicotomia existente, e considerando os achados deste trabalho que apontam para falhas graves e sistemáticas, é claro que os esforços não devem ser para uma mera simplificação da estrutura vigente do processo de licenciamento, pois isso pode gerar um cenário ainda mais problemático. A busca deve ser por um processo de licenciamento que, em primeiro lugar, vise ajustar ou atenuar as falhas existentes, para posteriormente buscar por algo menos burocrático. É notável que muitas melhorias precisam acontecer na AIA brasileira, assim como parece haver oportunidade de ser feito com o novo TR para caracterização da linha de base de barragens.

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