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

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\textbf{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.

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 and Ramírez, 2019). In 2015 and 2019, the collapse of two large mine tailing dams in southeastern Brazil killed 289 people and destroyed over 1325 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., 2019; 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 and Dunker, 1983; Gannon, 2021; Atkinson et al., 2006), 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 (Fig. 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 (Subiria et al., 2018). Despite the importance of this biome for biodiversity, extensive habitat destruction 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.

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 and 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 and 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:

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

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).

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.

### 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.

<p>| HOW: Description of the impacts and their consequences for the M&amp;L mammals in the environmental impact reports |</p>
<table>
<thead>
<tr>
<th>Satisfactory detail</th>
<th>Middling Detail</th>
<th>Generic</th>
<th>Very Generic</th>
<th>Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfactory detail</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Middling Detail</td>
<td>3</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Generic</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Very Generic</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Absent</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WHO: Inclusion of M&amp;L mammals in the environmental impact report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfactory detail</td>
</tr>
<tr>
<td>Middling Detail</td>
</tr>
<tr>
<td>Generic</td>
</tr>
<tr>
<td>Very Generic</td>
</tr>
<tr>
<td>Absent</td>
</tr>
</tbody>
</table>
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%) (Fig. 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.

A total of 78 EIIs 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; Fig. 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) (Fig. 2B).

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%) (Fig. 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%) (Fig. 3). Moreover, less than 20% of studies identified relevant ecological processes (Criterion 22) and used appropriate quantitative data analyses (Criterion 23) (Fig. 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 (Fig. 3). Nevertheless, only 30% of the studies highlighted species with special importance, such as endemic, rare, or invasive species (Criterion 21; Fig. 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.

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%) (Fig. 4A and B). 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% (Fig. 4C).

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; $\chi^2 = 16.12, df = 3, p$-value = 0.001; Fig. 5). This direction of this effect was consistent across project types (i.e., the interaction model was not significant; $\chi^2 = 1.52, df = 3, p$-value = 0.676), but the effect size was higher for the mining projects (Fig. 5).

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 (Fig. 6).

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 (Fig. 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
Fig. 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 figs. (A, B, and C), but lined up according to their final classification (C).

Fig. 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.
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 (Fig. 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 (Troweek et al., 1995; 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 (Fig. 2A). We also found poor quality baseline studies were linked to inadequate impact reports (Fig. 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 (Fig. 3), which is a widespread problem for monitoring studies (Beanlands and 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 and 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 (Fig. 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, surveys 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 and Passamani, 2009; Duprat and Andriolo, 2011; Penido and 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 (Fig. 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 and 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 (Fig. 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 (Fig. 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 et al., 2020), failure to identify relevant ecological processes (Thompson et al., 1997; Greig and 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 (Fig. 4C), with no substantial differences in how comprehensively the types of impacts projects might have been described (how) (Fig. 4B) or the types M&L mammal species or groups that might be impacted (who) (Fig. 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 (Genelleti, 2002; Sánchez, 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 – Fig. 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 (Fig. 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; Hugé 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 that at 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.

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 and 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 (Hofmann, 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).

6. 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., 1998; 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.

CRediT authorship contribution statement

Amanda M.S. Dias: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization, Project administration. Carly Cook: Conceptualization, Methodology, Validation, Writing – review & editing, Supervision. Rodrigo Lima Massara: Conceptualization, Methodology, Validation, Formal analysis, Writing – review & editing, Supervision. Adriano Pereira Paglia: Conceptualization, Methodology, Validation, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial, personal, or institutional conflicts of interest with the information and results disclosed through this manuscript.

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Appendix A. Supplementary data

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References

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Further readings
