Opinion Article

The need to improve and integrate science and environmental licensing to mitigate wildlife mortality on roads in Brazil

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Abstract
The ongoing expansion of the transportation network is one of the most important threats to tropical ecosystems. In recent years, the Brazilian government is making huge investments in paving and upgrading of the existing road network. It is therefore crucial time to consider how to achieve mitigation of two main road impacts: wildlife mortality and isolation. We discuss the improvement of road ecology research and environmental impact assessments, and recommend the integration of both as a way to achieve effective mitigation. Research oriented toward practical needs is likely to increase use of road ecology in decisions about the impacts of roads and traffic, including the environmental licensing of roads. Well-planned, focused assessments can effectively influence road planning. However, merely improving environmental assessments and research will not be enough to make environmental licensing more effective: there is a need for integration among professions involved in road construction, biodiversity management and conservation for better regulations and enforcement.

Key words Applied research; environmental impact assessment; study design; road ecology; capacity building

Resumo
A atual expansão da rede viária é uma grande ameaça aos ecossistemas tropicais. Nos últimos anos, o governo brasileiro tem feito enormes investimentos na pavimentação, manutenção e duplicação de estradas, impactando grandes extensões de ecossistemas remanescentes. É de fundamental importância avaliar como mitigar dois importantes impactos das estradas: mortalidade por atropelamento e isolamento das populações. Nós discutimos a qualificação da pesquisa em ecologia de estradas, a qualificação do licenciamento e recomendamos a integração entre ambos como uma maneira de atingir uma mitigação efetiva. Pesquisa orientada a responder questões relevantes e bem formuladas tem maior potencial de influenciar a tomada de decisão relacionada à mitigação dos impactos de rodovias. Avaliações de impacto ambiental bem planejadas e executadas aumentam a influência destes estudos no planejamento das estradas, especialmente quando são executados estudos com forte poder de inferência. Entretanto, somente a qualificação da pesquisa e do licenciamento isoladamente não são suficientes para que a mitigação seja mais eficiente: é preciso integrar os profissionais envolvidos na construção de estradas, manejo da biodiversidade e conservação para melhorar os instrumentos de regulação e sua aplicação. As recomendações apresentadas neste artigo para aumentar a efetividade da mitigação dos impactos de estradas demandam o envolvimento e contribuição de diferentes profissionais.

Palavras-chave Pesquisa aplicada; avaliação de impacto ambiental; desenho amostral; ecologia de estradas; formação de recursos humanos

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Introduction

An opportunity to mitigate road impacts on wildlife

Large investments in transportation are occurring worldwide, but are more pronounced in developing nations and tropical regions, such as in the Amazon basin in South America, Congo basin in Africa, and in Southeast Asia [1]. The expansion of road networks to previously roadless areas opens up regions for deforestation, illegal hunting, and human occupation [2]. While new road construction is one of the most important threats to the tropics, Brazil is also experiencing huge investments in road paving and upgrading of the existing transportation network, further impacting large areas of the remaining ecosystems in the whole country.

Roads are the main way of transportation in Brazil, bearing almost 60% of cargo and 96% of passenger transportation. In 2010, the Brazilian road network was around 1.6 million kilometers long, about 86% of which were unpaved roads [3]. The major expansion of the road network in the country happened between 1960 and 1980 [4], before the 1986 requirement of environmental impact assessments. Since 2007, the federal government has invested in 11,565 km of roads (and investments in more 7,002 km are still in progress) through the Growing Acceleration Program (Programa de Aceleração do Crescimento, PAC) for improvement and construction of roads [5, 6]. The number of vehicles in Brazil grew enormously from 29 million in 2000 (one vehicle for each 5.88 inhabitants) to 85 million in 2014 (one vehicle for each 2.38 inhabitants) [7, 8], an increase enhanced by government subsidies to the auto industry and tax reductions for purchase of new vehicles.

We have now an urgent need to take action on mitigating road impacts on wildlife in Brazil and other tropical countries that are expanding their road networks. In Brazil, during the time that the number of vehicles has more than doubled and the government invested more than 70 billion dollars on transportation, road ecology has become a consolidated research field. New laws were created both to require evaluation of the impacts of existing roads, and to regulate environmental impact assessments on the network expansion. This scenario creates an opportunity to rethink and improve ways to mitigate road impacts on wildlife.

Laurance et al. [9] recommend reducing the global environmental impacts of road expansion by avoiding the first cut of forests, enhancing the environmental responsibility of financial institutions, using better decision tools, and improving engagement. In this paper we focus on the existing road network and its impacts on wildlife mortality and isolation. To improve and increase the integration of science and environmental licensing in Brazil, we highlight three recommendations for effective

mitigation of road mortality and isolation: improvement of research, improvement of environmental impact assessments, and the integration of both.

Priority research questions about wildlife mortality and isolation by roads

Research on road ecology and related subjects can improve decision-making and reduce road mortality and isolation through the environmental licensing of roads. We explore three priority subjects related to wildlife mortality and isolation: cumulative effects of mortality on populations, spatial and temporal scales of road effects, and the effectiveness of mitigation measures.

The first Brazilian studies of wildlife mortality on roads described species richness and road-kill numbers without much attention to study design and methodology [10]. Recent studies are more robust in data collection and in inferences about road mortality (e.g. [11, 12]), and explore methodological issues [13, 14]. However, Brazilian studies usually assess road mortality only at the individual level and little is known about effects of road mortality on population persistence. For example, if road mortality is compensated by a decrease in other sources of mortality in the population, road mortality may not affect population persistence. On the other hand, if road mortality is additive, the population effect may be much more intense than predicted only by road-kill numbers. Demographic bias was demonstrated for some groups, such as turtles, that suffer higher mortality of reproductive females in North America, changing population structure [15]. Also, looking at the effects on populations and on per capita mortality may indicate cases in which higher road mortality is not the best indicator of where mitigation is needed (e.g. [16]). Another methodological approach is estimating the probability of an individual being killed when crossing the road [17] and evaluating whether this is a good indicator of effects at the population level. Effects on the population level may be explored and predicted by developing individual-based models (e.g. [18]) and population models (e.g. [19]).

The second priority subject is the effect of roads at different spatial and temporal scales. Road ecology studies are usually restricted to local effects of road segments during the study period (e.g. [11, 12, 16]) or effects from the past (e.g. [20]). However, cumulative mortality and connectivity loss along the regional road network is likely to affect population persistence at both local and regional scales. An evaluation of the whole transportation system can identify priority zones for mitigation, as done by The Netherlands [21] and Switzerland [22] to restoring landscape connectivity based on regional or national road network assessments. Considering climate and human land use changes, the temporal scales for evaluation of the effects of mortality and isolation must include future scenarios, addressing both changes in species distributions and land/road use changes. Identifying factors related to road-kill in space (e.g. [11, 23, 24]) and time (e.g.[11, 24]) will allow us to build predictive models that can be validated and applied to different road networks to plan mitigation measures in advance.

The third priority subject for investigation is that of mitigation measures: are the measures effective? This requires assessment of how road mortality may be mitigated [25], how to improve knowledge about mitigation measures, and how to examine the effectiveness of mitigation programs already implemented, given the aims of each measure (mortality reduction and/or connectivity restoration, for example) [26]. Experimentally manipulating the characteristics of mitigation measures (such as wildlife passages) is an example of how scientific research may inform decision making on what is the best option for mitigation and which attributes are important for enhancing mitigation effectiveness [27, 28].

Improving environmental impact assessments and monitoring of road impacts

Environmental impact assessments are one of the best ways to identify, predict, mitigate, and compensate the negative effects of roads on biodiversity [29]. However, academics have criticized environmental licensing in Brazil for its lack of clear objectives and poor methodological quality [30, 31]. For example, Gonçalves [32] observed that EIAs for road upgrading usually do not explore road mortality data to help define mitigation measures. Environmental licensing is also criticized by government sectors and construction companies. Usually there are delays in road construction due to poor financial planning and execution of road projects, and also cases of fraud. However, some stakeholders and companies blame these delays on unjustifiable environmental requirements, as a clear strategy to reduce licensing obligations. Ineffective environmental impact assessments may cause people to perceive these studies as a barrier to development [33], when they should be an instrument for prevention of environmental degradation.

In Brazil, road construction, paving, and widening can only be carried out after environmental licenses are issued (Complementary Law 6938/1981 and CONAMA Resolutions 001/1986 and 237/1997). Since the major expansion of roads in the country occurred before that law [4], the federal government recently issued a new law requiring environmental impact assessments of 55,000 kilometers of existing national paved roads that were constructed before 1986 (Program of Environmentally Sustainable Federal Roads, created by Interministerial Regulation 423/ 2011, revoked and substituted by Interministerial Regulation 288/2013 with licensing procedures defined by MMA Regulations 420/2011 and 289/2013).

Many Brazilian environmental impact assessments of roads have poor study designs and focus only on lists of species present, including road-killed species or those using wildlife passages. To assess the impacts of roads on wildlife, these assessments should explore variations on mortality rates or population isolation in space and time [10] and the consequences of these changes to population persistence, for example, through population viability analysis (e.g. [19]). Many different study designs may be implemented for environmental impact assessments [34] and before-after-control-impact is one of the options (recommended by [25]) to evaluate impacts and the effectiveness of mitigation. Increasing the quality of environmental impact assessments enhance their influence on decision-making.

Increasing the quality of environmental impact assessments depends on stronger regulations like clear terms of reference to guide studies and specifying the questions that should be addressed. According to Landim and Sánchez [30], new laws ruling environmental licensing have increased the quality of studies, followed by an increase in regulation by environmental agencies.

Recently, the federal licensing agency (Brazilian Institute of the Environment and Renewable Natural Resources - IBAMA) issued a new requirement to define a protocol for data collection during environmental impact assessments of roads (Normative Instruction - IN 13/2013). Although this new legal instruction is an important step in improving study design for environmental impact assessments, it has been criticized by scientists and managers for its excessive requirements, its lack of clarity about which questions should be answered, and its focus on biodiversity inventory instead of on actual impact assessment.

Yoccoz et al. [35] point out three questions that should be considered during the planning of monitoring programs, which are valid also for environmental impact assessments: why collect data, what type of data should be collected, and how data should be collected and analyzed. Ferraz [31] argues that data collection during environmental impact assessments should be guided by a list of

possible impacts and clearly stated questions, and data should only be collected after justifying such collection. The collection of large amounts of data without well thought-out questions to be answered may generate information about biodiversity, but cannot serve as a basis for qualified decisions [36] about road impacts and how to mitigate them.

Although mitigation measures have been installed in many Brazilian roads, both the planning of measures and the monitoring of their effectiveness are usually carried out with inadequate sampling and analysis [32]. The lack of information on the best locations and types of mitigation may reduce their effectiveness, waste money, and lose credibility before stakeholders. Mitigation measures should be supported by studies related to mitigation goals, which will indicate the best type and location for management actions. Mitigation goals should be linked to the types of road impacts assessed, such as reducing mortality and/or increasing connectivity. Some northern hemisphere best practices guides suggest issues that should be addressed in planning and choosing among different mitigation options (e.g. [37, 38]) and they should be adapted to the economic, social, and biodiversity context of tropical regions.

Mitigation implementation should be followed by systematic monitoring to evaluate its effectiveness, with a robust study design, appropriate selection of target species, and good evaluation criteria [26]. Evaluation criteria for mitigation effectiveness need to be directly related to mitigation goals and assess whether road impacts identified were actually mitigated. This can only be achieved through clearly defined questions and collection of appropriate data. For example, well-designed monitoring programs can determine whether mitigation measures developed for other countries are ideal for Brazilian wildlife. Most wildlife passages and fences are designed for large animals, and the majority of Brazilian wildlife is small to medium sized. Brazil has a huge diversity of anurans, including many species of tree frogs that may be impacted by roads [11]. As these species are able to climb, fences may need some adaptations to be effective in preventing these animals from reaching the road.

Mechanisms to promote integration among institutions and professional skill upgrade

Merely improving research and environmental assessments will not be enough to make environmental licensing more effective: there is a need for integration among all stakeholders. Individual qualification must be accompanied by integration among professionals involved in road construction, biodiversity research, management, and conservation. Road ecology researchers should address questions relevant for reducing road impacts on wildlife, while consultants and decision makers from environmental agencies should be familiar with these studies and raise new questions to be addressed by researchers. Transportation agencies and road builders should interact with other professionals involved, exchanging information about the feasibility of the proposed actions and the need to integrate concerns about environmental impacts with concerns about traffic efficiency and safety. A step in this direction is creation of the National Action Plan (PAN – Plano de Ação Nacional, in Portuguese) for the conservation of wildlife affected by roads, involving environmental and road managers, consultants, and researchers who established several goals related to public policies, research and capacity building.

Improvement of both research and environmental licensing needs investments in all fields. Professional researchers, consultants, and environmental managers should all be integrated, as they are directly involved in research and licensing. The amelioration of study designs (both requested by environmental agencies and applied by consultants and researchers) requires better academic training of these professionals. Limitations in scientific thinking of professionals result in ecological knowledge not being applied to environmental problem solving. Lewinsohn et al. [39] argue that universities should teach ecological problem solving, rather than ecological concepts. Resolving

environmental problems and narrowing the gap between academic knowledge and decision-making demands multi- and inter-disciplinary involvement [39]. These professionals could be integrated through short courses or workshops focused on environmental problem solving, offered by experienced researchers, managers, and consultants.

Integration of the different professionals involved is fundamental to the success of mitigation and prevention of road impacts on wildlife. Permanent forums with frequent discussions about knowledge gaps and proposed actions can increase integration at the planning level. Centralized databases should be adopted by researchers, environmental agencies, and consultants as repositories of their data. Researchers and managers should evaluate which questions can be answered with data already collected and what further data are needed.

Funding is also important for adequate research and integration among professions. Since investments in transportation infrastructure are a priority for the Brazilian national government, financial resources to improve environmental decision-making also should be a priority. The companies responsible for Brazilian toll roads should invest part of their profit in research and development (R&D) instead of limiting such funding to engineering and road technology projects. Including environmental research as an additional funding priority is an example of ways to increase financial support for sound decision-making in road planning and operation.

Final considerations

The goals presented here to increase the effectiveness of the mitigation of road impacts on wildlife call for the involvement of different professionals related to this subject. In recent years, environmental agencies have been discussing their procedures for environmental impact assessments and some improvements have already occurred, such as new regulations and changes in reference terms for licensing studies, but there is still a lot to be done. Also, research groups investigating road ecology issues in Brazil are already responsible for important integration initiatives, such as the creation of an online guide to mitigation measures for consultants [40], the development of free software for analysis of road mortality to be used in environmental impact assessments [41], and a mobile app for citizen science collection of road-kill data (http://cbee.ufla.br/portal/sistema_urubu/).

We focused our discussion here on the need to mitigate road mortality and isolation of wildlife populations, but similar recommendations could also apply to the assessment and mitigation of other road impacts (such as pollution) or even to the impact of other human structures (such as power lines and dams). For example, the impacts of railroads on wildlife are poorly investigated, not only in Brazil, and many questions presented here are also of great relevance to environmental impact assessments of railroads.

Brazil, a country known for its megadiversity, is undergoing an expansion of the road network and, unlike previous decades, has now the legal obligation to mitigate road impacts. The recent requirement to mitigate impacts of roads already constructed is the best moment we have to improve research and put scientific knowledge into practice by integrating ecological issues with socioeconomic and traffic safety issues. We believe that putting these goals in practice will be an enormous step in the development of an environmentally friendly transportation system in Brazil.

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