Oecologia Australis
21(3): 280-291, 2017
10.4257/oeco.2017.2103.05

ROAD EFFECTS ON WILDLIFE IN BRAZILIAN ENVIRONMENTAL LICENSING

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ABSTRACT
Environmental licensing is a political tool to protect the environment and encourage sustainable development. Environmental Impact Assessments (EIAs) are the important document for impact assessment of activities during environmental licensing, and all decision-making process and effectiveness depend on its quality. Road construction, paving and widening require the approval of an EIA, since these activities are responsible for a large number of environmental impacts. Here we present an analysis of 16 EIAs of Brazilian roads, considering the impacts on terrestrial and aquatic fauna. We discuss if the impacts recognized in road ecology literature are identified and assessed in these studies, if mitigation actions are based on information presented on the EIA, and the quality of road mortality assessment. We based the analysis on a checklist of road impacts and on scores calculated based on a set of criteria. We calculated relative scores for each EIA and for each type of impact across all studies. EIA quality was low (more than half EIAs had relative equal score or less than 50%); the studies analyzed poorly addressed the impacts recognized in the academic literature. The presence of impacts was not coherent along different sections of the EIA (baseline studies, impact matrix and proposition of mitigation measures). In 27.63% of cases the impacts were not present in any section of the EIA. In some situations, the impact was present in the baseline studies, but not in impact matrix or mitigation propositions, and in half of the situations analyzed the relative score of EIAs was lower than 30% for the quality of road mortality impact assessment. We recommend the improvement of the terms of reference should be a priority to enforce the elaboration of enhanced quality studies. A Portuguese version of this manuscript is available on request.
Keywords: environmental impact assessment; environmental permits; road ecology; road impacts; scoping.

INTRODUCTION

Environmental licensing is an important tool for management and conservation, since it has a preventive approach by assessing the occurrence, magnitude and persistence of potential impacts of human interventions before they occur. The aim of environmental licensing is to protect the environment and encourage sustainable development by imposing restrictions and measures of environmental control that developers should follow to locate, install and operate enterprises or activities that may affect the environment (TCU 2004).

Environmental Impact Assessments (EIAs) are the main licensing tool (Braga *et al.* 2005), with critical importance for decision-making. Environmental studies should assess direct and indirect impacts of different activities, considering the potential effects at the landscape level, how different organisms may react to these changes, and the cumulative impacts (Jaeger 2015). Data obtained in these environmental assessments should inform environmental agencies about the environmental viability of an activity and, when viable, they should indicate measures and actions to avoid, minimize, mitigate or compensate potential impacts, respecting mitigation hierarchy (Chee 2015).

Due to the importance of environmental licensing, managers should give special concern to the quality and effectiveness of such studies. In Brazil, such analyses are not common (*e.g.* Landim & Sánchez 2012), although in other countries they have been carried out for a long time (Lawrence 1997a, Jay *et al*. 2007, Chang *et al*. 2013, Badr *et al*. 2011). According to Lawrence (1997a), the goal of EIA quality analysis is to assess its execution (*e.g.* quality of data). EIA effectiveness analysis focuses on the direct and indirect consequences of the EIA process, that is, it considers how the information presented is in fact applied in decision-making (Lawrence 1997a).

EIAs have been criticized for their low quality, for not assessing impacts properly, presenting only descriptive information, and for not including analytical or predictive approaches (Karlson *et al*. 2014, Jaeger 2015). The main critiques are not answering the fundamental questions in these studies, or even not framing the questions related to the potential impacts. Often these environmental studies repeat the same errors of previous EIAs, applying inadequate methods for data collection and analysis (Silveira *et al.* 2010). Some authors argue that the theoretical basis of EIAs is poorly defined and there is a lack of integration between theory and practice (Lawrence 1997b), since EIA emerged from a political and not a scientific demand (Cashmore *et al.* 2004).

Road construction, paving or widening depend on EIA approval since these activities cause significant environmental impacts, such as habitat loss and fragmentation, population isolation, and introduction of invasive species (Trombulak & Frissell 2000), besides being recognized as the main factor driving landscape degradation (Laurance *et al.* 2002). Road mortality due to animal-vehicle collision is among direct road impacts, and it may be responsible for decreasing populations' abundance and persistence for different species (Forman *et al.* 2003). Removing individuals from wildlife populations through road-kill may decrease genetic diversity, which can also affect population persistence (Jackson & Fahrig 2011).

Considering the importance of road impacts on wildlife and the relevance of environmental licensing in avoiding or minimizing such impacts, here we present an analysis of 16 EIAs of Brazilian roads. We analyzed how studies presented road impacts on terrestrial and aquatic fauna and, more detailed, how studies evaluated road mortality. The first question is related to the general study scope and we expected that all EIAs have evaluated the full known road impact spectrum with sufficient quality: (1) Are impacts known from road ecology literature identified and assessed in EIAs? With the second question, we were interested on the relevance and consistency of the environmental studies, whether questions answered were connected to demanded decisions, mainly impact avoidance or mitigation: (2) Are mitigation measures proposed based on information presented in the EIA? Finally, the third question was focused on a single and largely studied impact, wildlife road-kills, and we were curious if the main answers needed to plan mortality mitigation are minimally evaluated: (3) What is the quality of road mortality assessments?

MATERIAL AND METHODS

We consulted road ecology literature (Forman & Alexander 1998, Spellerberg 1998, Trombulak & Frissel 2000, Seiler 2001, Coffin 2007, Fahrig & Ritwinski 2009, Laurance *et al*. 2009, Daigle 2010, Taylor & Goldingay 2010, Sánchez & André 2013, van der Ree *et al*. 2015) to build a checklist of the main environmental impacts of roads on wildlife (terrestrial and aquatic fauna). We used a checklist approach due to its practicality, since this tool can be modified according to the goals of the study (Glasson *et al.* 2005, Sánchez & André 2013).

We listed below the impacts considered in the checklist, including different nomenclatures, mechanisms or factors presented in the EIAs that were recognized in each category of the checklist:

a) Habitat loss: vegetation suppression or deforestation;
b) Habitat modification: noise pollution, hydrological changes, artificial light, change in soil quality and structure, decreased air quality, changes in temperature, changes in moisture, changes in solar radiation, increased wind, traffic effects;
c) Road mortality from animal-vehicle collisions;
d) Barrier and filter: fragmentation, connectivity loss and isolation, reduced access to habitat;
e) Changes in animal behavior: avoidance and attraction;
f) Creation of new habitats;

g) Introduction of exotic species: domestic and wild species;
h) Direct anthropogenic pressure: hunting, fishing, zoonoses, increased fire and accidents with hazardous material.

We carried out EIAs' quality analyses in three steps, representing a gradient of detail. Each step represented one of the study questions stated previously: (1) analysis of the quality of EIAs baseline studies following the checklist; (2) analysis of the coherence among baseline studies, impact matrix and mitigation measures proposition regarding the impacts checklist; and (3) detailed analysis of how EIAs assessed road mortality. We selected 16 EIAs of Brazilian roads (Appendix 1), eight of road widening and eight of road construction/paving, obtained from federal and state environmental agencies websites.

To analyze if and how EIAs' baseline studies assessed the impacts recognized in road ecology literature, we created a list of criteria and scores. We calculated scores for each EIA and for each impact from the checklist according to the criteria presented in Table 1. We calculated a total relative score for each EIA by summing all scores obtained for the different impacts in that study and dividing it by the maximum possible sum of scores. We calculated a total relative score for each impact from the checklist, by summing all scores obtained for that impact in different studies and dividing it by the maximum possible sum of scores. In both cases, we transformed the total relative scores in percentages.

We verified the coherence within EIAs' sections by comparing the presence of the impacts among baseline studies, impact matrix and proposed mitigation measures. We used an expanded version of the checklist, listing the different factors related to each impact (for example, we divided the impact of habitat modification in noise pollution, artificial light, increased temperature, etc.). We only analyzed presence/absence of each impact in each EIA section.

To answer the third question, we created criteria and scores to analyze how EIAs assessed road mortality impact (Table 2). In this analysis, we included detailed criteria related to the fundamental questions for decision-making about mitigation measures of this impact.

RESULTS

EIAs quality was low concerning the general road impacts on wildlife listed on the checklist (Table 3). No EIA had a total final score higher than 75%, and the average score for EIAs was 44.01% (±17.68). More than half EIAs (62.5%) had relative score equal or less than 50%. No impact from the checklist had a total relative score higher than 60.42%, with half of impacts obtaining 50% or less. Average score was similar between EIAs of road widening (47.40% ±21.36) or road construction/paving (40.63% ±13.68) in relation to the checklist impacts.

Even when analyzing EIA quality using a detailed checklist and comparing the coherence among the different sections of EIA (baseline studies, impact matrix and proposition of mitigation measures), studies' quality was low. Considering the results of coherence among these three EIA sections (Table 4), in only 32.24% of cases an impact present in the baseline studies was also present in the impact matrix and in proposition of mitigation measures. In 16.78% of cases, an impact present in baseline studies was not present in the impact matrix or in proposition of mitigation measures and, surprisingly, in 2.63% cases an impact was present in proposition of mitigation measures without being present on baseline studies. In 27.63% of cases the impacts were not present in any section of the EIA (Table 4).

Table 1. Scores framing used to analyze baseline studies in EIAs considering the checklist of impacts. For each impact we established one score. Impacts considered were habitat loss; habitat modification; road mortality from animal-vehicle collisions; barrier and filter; changes in animal behavior; creation of new habitats; introduction of exotic species; direct anthropogenic pressure.

Evaluation criteria	Possible scores	Framing
Impacts from the checklist	0	The impact was not mentioned in baseline studies
	1	The impact was only superficially mentioned in relation to wildlife
	2	A characterization of the impact was presented
	3	The assessment included quantitative future predictions regarding the impact

Table 2. Evaluation criteria, scores and respective framing used for evaluation of how road mortality impact was assessed in EIAs.

Evaluation criteria	Possible scores	Framing
The methods used to assess road mortality are described in the study	0	Methods were not described or road mortality was not assessed
	1	Methods were briefly described
	2	Methods described, but data collection or analysis was not very clear
	3	Detailed description of methods, with all information needed for comprehension
Road mortality magnitude	0	Estimates of road mortality magnitude were not presented
	1	Estimates of road mortality magnitude were based on other studies or expressed qualitatively (high/low)
	2	Estimates of road mortality magnitude were based on data collection
	3	Estimates of road mortality magnitude were based on data collection corrected by searcher bias and carcass removal
Road mortality species	0	Species list was not presented
	1	Species list of potential impacted species was presented
	2	Species list was based on previous surveys on the same road
	3	Impact on species population was estimated
Spatial patterns of road mortality (modelling approaches were also considered)	0	No spatial data or no spatial pattern analysis
	1	Spatial data without spatial analysis (ex. number of road-kills per km)
	2	Spatial pattern analysis with confidence interval or evaluation of significance
	3	Spatial pattern analysis and explanatory models
Temporal patterns of road mortality (modelling approaches were also considered)	0	No temporal data or no temporal pattern analysis
	1	Temporal data without temporal analysis (*e.g.* number of road-kills per month)
	2	Temporal pattern analysis with confidence interval or evaluation of significance
	3	Temporal pattern analysis and explanatory models
Proposition of mitigation measures	0	No indication of mitigation types or locations
	1	Indication of types or locations for mitigation with no justification based on the assessment
	2	Indication of types and locations for mitigation with no justification based on the assessment
	3	Indication of types and locations for mitigation with justification based on the assessment

EIA quality, concerning impacts of road mortality, scored 28.82% (±21) for EIAs and 28.82% (±20.22) for impacts, lower than obtained in the general checklist analysis (44.01% ±19.75 and 44.01% ±17.68, respectively) for all impacts. Half of the EIAs analyzed had a relative score lower than 30%, indicating lower EIA quality when evaluation criteria were detailed. Only one EIA presented analyses of temporal patterns of road mortality, consequently this was the criteria with lower quality (Table 5). There was no difference between the average relative score between EIAs of road widening (36.11% ±18.78) and road building/paving (21.53% ±21.71). All criteria had similar values of quality in studies for road widening and construction/paving, except for the criteria related to temporal pattern of road mortality, which only an EIA of road widening did not score zero (Table 5).

DISCUSSION

Although there are many papers published in scientific journals reviewing and listing impacts in road ecology literature (*e.g.* Forman & Alexander 1998, Spellerberg 1998, Trombulak & Frissell 2000, Seiler 2001, Coffin 2007, Fahrig & Ritwinski 2009, Laurance *et al.* 2009, Daigle 2010, Taylor & Goldingay 2010, van der Ree *et al.* 2015), EIAs analyzed in our study poorly addressed the impacts on our checklist based on that literature. Road ecology synthesis literature has almost 20 years and is still growing (*e.g.* Forman *et al.* 2003, Beckman *et al.* 2010, van der Ree *et al.* 2015). There are also many studies that developed explanatory and predictive models (*e.g.* Gunson *et al.* 2011, Langen *et al.* 2012, Litvaitis *et al.* 2015) that could be used in EIAs to assess potential impacts, as well as many different methodological approaches to prioritize locations for mitigation (Beckman *et al.* 2010) or to evaluate mitigation effectiveness (van der Grift *et al.* 2013, 2015). The lack of connection between the impacts discussed in road ecology literature and the ones presented in EIAs may be due to the absence of integration among researchers, environmental managers, technicians and environmental consultants, or even due to not understanding what should be presented in an EIA.

Table 3. Results of the analysis of how impacts were assessed in EIAs baseline studies. Scores are in ascending order by study and by criterion. Gray scale indicates low quality studies (darker represents worse scores). Wid. = Widening; Cons. = Construction; Pav. = Paving.

Road	**BR 104**	**ES 080**	**BR 158**	**SP 300**	**Rodoanel Oeste**	**BR 290**	**Rodoanel Norte**	**BR 285**	**BR 135**	**BR 101**	**BR 319**	**BR 116**	**BR 317**	**BR 386**	**BR-040 DF/GO/MG**	**BR 040 RJ**	**Final relative score %**
Type	Wid	Cons Pav	Wid	Wid	Cons	Wid	Cons	Cons Pav	Cons Pav	Wid	Cons Pav	Wid	Cons Pav	Wid	Wid	Wid	
Year	2009	2006	2007	2002	1997	2010	2010	2010	2013	2012	2005	2009	2008	2009	2015	2010	
Road length (km)	51.4	15.02	268.8	76.95	31.7	115.7	42.8	30.3	48.7	155.7	418.2	219.4	110.7	35.2	557.2	25	
Creation of new habitats	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	6.25
Changes in animal behavior	0	0	0	0	1	0	0	1	2	2	2	2	2	2	2	2	29.17
Introduction of exotic species	0	0	0	0	0	0	1	1	1	0	0	0	2	2	2	2	31.25
Habitat loss	0	0	2	2	2	2	0	1	0	2	3	2	2	2	2	2	50.00
Barrier and filter	0	1	1	1	2	2	2	2	2	2	2	2	2	2	3	2	58.33
Road mortality from animal-vehicle collisions	1	1	2	1	0	2	2	2	2	2	2	2	2	2	2	3	58.33
Direct anthropogenic pressures	0	2	1	2	1	2	2	2	2	2	2	2	2	2	2	3	58.33
Habitat modification	1	0	1	2	2	0	2	2	2	2	2	3	2	2	2	3	60.42
Final relative score %	8.33	16.67	29.17	33.33	33.33	33.33	41.67	45.83	45.83	50.00	54.17	54.17	58.33	62.50	62.50	75.00	-

Table 4. Presence of each impact in different sections of EIAs (baseline studies, impact matrix and proposition of mitigation measures). Gray boxes represent in low consistency between different sections of EIAs: dark gray = present only in baseline studies; medium gray = present in the impact matrix and mitigation measures; dark gray = present in baseline studies and in the impact matrix; X in bold and underlined = only in impact matrix. B = Baseline studies; I = Impact Matrix; M = Mitigation Measures.

Road	**Rodoanel Oeste**			**SP 300**			**BR 319**			**ES 080**			**BR 158**			**BR 317**			**BR 104**			**BR 116**		
Year	1997			2002			2005			2006			2007			2008			2009			2009		
EIA chapters	B	I	M	B	I	M	B	I	M	B	I	M	B	I	M	B	I	M	B	I	M	B	I	M
Noise pollution	x	x	x	x	x		x							x	x	x				x		x		
Changes in temperature, moisture, solar radiation, wind				x			x															x		x
Traffic effects				x	x		x							x		x						x	x	
Behavioral changes (avoidance, attraction)		**x**		x	x		x	x	x					x	x	x	x	x				x	x	x
Changes in soil structure and quality			x											x	x	x				x		x		
Artificial light			x	x	x									x		x			x					
Decreased air quality	x												x	x	x	x			x	x	x	x		
Hidrological changes	x	x	x	x				x	x							x			x	x	x	x	x	x
Introduction of exotic species	x							x	x	x		x				x								
New habitats																								
Increased fishing													x	x	x	x		x	x			x		x
Increased fires	x	x	x	x			x	x	x	x			x	x	x	x	x	x				x		x
Deforestation/logging	x	x	x	x	x		x	x	x				x	x	x	x					x	x	x	x
Increased hunting	x	x	x			x	x	x	x				x	x	x	x	x	x	x			x		x
Zoonoses							x	x	x			x				x	x	x				x	x	x
Habitat loss	x	x	x	x	x		x	x	x		x		x	x	x	x						x		x
Accidents with hazardous material		**x**		x									x		x							x	x	x
Filter and barrier	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x				x	x	x
Road mortality		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x				x	x	x

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Road	BR 386			BR 040 RJ			Rodoanel Norte			BR 285			BR 290			BR 101			BR 135			BR-040 DF/GO/MG		
Year	2009			2010			2010			2010			2010			2012			2013			2015		
EIA chapters	B	I	M	B	I	M	B	I	M	B	I	M	B	I	M	B	I	M	B	I	M	B	I	M
Noise pollution	x	x	x	x	x		x						x	x	x		x	x	x	x	x	x	x	x
Changes in temperature, moisture, solar radiation, wind	x			x	x		x			x						x			x			x		
Traffic effects	x		x	x	x		x			x		x							x		x	x		
Behavioral changes (avoidance, attraction)	x		x	x	x	x	x	x	x	x		x			x		x		x	x	x	x	x	x
Changes in soil structure and quality	x	x	x	x	x		x									x	x	x	x	x	x	x		
Artificial light							x																	
Decreased air quality	x	x	x	x	x		x						x	x	x	x	x	x	x		x	x		
Hidrological changes	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
Introduction of exotic species	x	x		x	x	x	x	x	x	x						x	x	x	x			x		
New habitats	x			x			x																	
Increased fishing							x			x							x	x	x	x		x	x	x
Increased fires	x	x	x	x												x	x	x		x	x	x	x	x
Deforestation/logging	x	x	x	x	x	x				x		x				x	x	x	x	x	x	x	x	x
Increased hunting	x		x	x	x	x	x	x	x	x	x		x			x	x	x	x	x		x	x	x
Zoonoses	x	x	x	x	x		x	x	x	x						x	x	x	x	x	x	x		
Habitat loss	x		x	x	x	x				x		x	x	x	x	x	x	x		x	x	x	x	x
Accidents with hazardous material	x	x	x	x	x		x	x	x					x	x			x			x			
Filter and barrier	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x	x		x	x	x	x
Road mortality	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 5. Scores of each criterion of how road mortality impact was assessed in EIAs. Scores are presented in crescent order by study and by criterion. Scale of gray was used to emphasize the low quality of studies (darker represents worse scores).

Evaluation Criteria	BR 104	ES 080	BR 319	Rodoanel Oeste-SP	BR2 85	Rodoanel Norte-SP	BR 58	SP 300	BR 116	BR 040 RJ	BR 317	BR 101	BR 386	BR 290	BR 135	BR 040 DF/GO/MG	Final relative score %
Type	Wid	Cons Pav	Cons Pav	Cons	Cons Pav	Cons Pav	Pav	Wid	Wid	Wid	Cons Pav	Wid	Wid	Wid	Cons Pav	Wid	
The methods used to assess road mortality are described in the study	0	0	0	0	0	0	0	0	1	1	1	1	2	2	3	3	29.17
Road mortality magnitude	0	0	0	0	0	0	0	0	0	1	0	0	2	2	2	3	20.83
Road mortality species	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	41.67
Spatial pattern of road mortality	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	18.75
Temporal pattern of road mortality	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2.08
Proposition of mitigation measures	0	0	1	2	2	3	1	2	3	1	3	3	1	1	3	3	60.42
Final relative score %	0	0	5.56	11.1	11.1	16.67	22.2	27.8	33.3	33.3	38.9	38.9	44.4	44.4	66.7	66.7	-

Quality and effectiveness of environmental licensing process have been discussed in several countries from analyses of technical studies and proposition of methodological alternatives (Söderman 2005, Sandham *et al.* 2013, Karlson *et al.* 2014). Some examples of critiques about technical studies are: absence of quantitative analyses, lack of spatial and temporal assessment of environmental impacts, the use of inadequate methods (Karlson *et al.* 2014), weak specialized knowledge with low specific information about species (Karjalainen *et al.* 2013), failure on approach of potential ecological impacts, superficiality in the treatment of local impacts, negligence of effects on landscape scale, and lack of knowledge of cumulative effects of landscape fragmentation and habitat loss on the viability of wildlife populations (Jaeger 2015).

The baseline studies of an EIA should present data that support the environmental licensing decision-making process. Information on impacts described in baseline studies were usually not used in the proposition of mitigation measures, and these were proposed based on impacts not even mentioned in the baseline studies or impact matrix. In general, baseline studies analyzed are not achieving the aim of an EIA. Studies are being carried out recurrently without stating the questions related to the potential effects of the activity being licensed, a basic principle for an effective study (Yoccoz *et al*. 2001, Ferraz 2012) long stated in scoping guidelines to account for biodiversity in environmental impact assessments (CBD 2006). Our results indicated that, different from what is expected and determined by legal regulations (CONAMA 1986, 1997 - Resolutions 01/86 and 297/97, respectively), mitigation measures are proposed without support in baseline studies that could justify their need or better actions.

Road impacts on wildlife were only superficially assessed in EIAs analyzed. Quantitative analyses to predict intensity, extension or duration of the impacts were missing, and there was a predominance of expectations based only on the opinion of consultants. In only half of the cases, EIAs included analytical approaches, and in only one EIA included predictive approaches. According to Santos (2010), there are two types of approaches in an EIA: the exhaustive and the focused. The first one, which is the most used in Brazil (as reinforced by our results), describes in detail all different components of the landscape that will be potentially affected, considering that more information is more quality. Alternatively, in the focused approach, which we agree is the best, only potential impacts variables are assessed, and this allows the description of the future landscape conditions considering the situation in which the proposed activity is implemented, but also the situation in which the activity is not implemented.

The EIAs analyzed in this study did not assess properly the potential impacts of roads probably because the licensing process is just considered a legal pre-requisite for project approval by many of the involved stakeholders, and not as a fundamental step in decision-making to minimize impacts and promote sustainability (Jaeger 2015). Landim & Sánchez (2012) indicate that new legislation and enhanced regulation were the main drivers of increased EIA quality in environmental licensing of mining activities. We recommend, though, that terms of reference (TORs), which guide environmental studies, clearly state which information should be presented in baseline studies, recommending how this information should be obtained, considering costs, deadlines and, specially, the relevance of each information for decision-making. Understanding the questions of the studies, it is easier to know where to search for answers, and this can reverse the low EIA quality identified in our study. The effectiveness of the changes we suggest could be tested by comparing the results of EIA quality in association with TORs quality.

As important as systematically analyzing the studies produced, new strategies and criteria to qualify future studies are needed as well. Researchers and environmental consultants can produce information that, if integrated, will enforce the proposition of focused and strong inference approaches to assess the impacts with higher quality. Environmental licensing process needs an approximation between academia and environmental managers. Sandham *et al.* (2013) demonstrated that only changes in legislation are not enough to achieve better quality, and that building capacity of the professionals involved and integration are needed, combined with stronger requirements.

Another step to increase quality and effectiveness of environmental licensing is to invest in capacity building of technicians and environmental consultants. Universities and other research institutions can play a fundamental role in this approximation and qualification strategy and effectively act in environmental licensing process, reviewing studies structure as a whole and the potential impacts of each type of project, communicating new knowledge for planning studies and collecting relevant data to estimate the magnitude of impacts, and to avoid and mitigate them.

Our study showed an inability of EIAs to assess properly impacts of roads on wildlife and, consequently, to provide the best information for decision-making and mitigation planning. Our findings are apparently independent of the degree of detail, the criteria of analysis and the type of the project (road widening or construction/paving). To reverse this scenario, we list three actions that reinforce what other authors have already pointed out (Ferraz 2012): 1) studies should be structured from a checklist of potential impacts; 2) clear questions to address the estimation of magnitude of those potential impacts should be formulated, and 3) variables and general sampling guidelines that support available decisions in each licensing stage should be indicated. These modifications can be stimulated and achieved through the review and qualification of TORs. To make these changes, which depend on the mobilization and qualification of the professionals involved, greater integration between academic and technical practitioners involved in the environmental licensing will be essential.

ACKNOWLEDGEMENTS

We thank Simone Freitas for contributions in the beginning of the Project. We thank Fernando Ascensão, Mozart Lauxen, and two anonymous reviewers for comments in a previous version of the manuscript. Larissa Oliveira Gonçalves received a graduate scholarship from CAPES during the development of this study.

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Submitted: 01 May 2016
Accepted: 28 November 2016

Appendix 1. Environmental Impact Studies (EIA) assessed in this study. The EIA are temporarily available on the website of the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA - http://www.ibama.gov.br/) and can be obtained upon request.

Estudo de Impacto Ambiental. 1997. Implantação Trecho Oeste do Rodoanel Metropolitano de São Paulo entre a interseção com a Rodovia Régis Bittencourt, no Município de Embu, e a interseção com a Estrada Velha de Campinas (Avenida Raimundo Pereira de Magalhães), no Município de São Paulo – SP – 31,7 km de extensão.

Estudo de Impacto Ambiental. 2002. Duplicação da Rodovia SP-300 entre os Municípios de Jundiaí e Tietê – km 72+200 ao km 103+000 e km 113+000 ao km 158+650, incluindo o contorno do Município de Itú – SP – 76,95 km de extensão.

Estudo de Impacto Ambiental. 2005. Reconstrução e Pavimentação da Rodovia BR-319, no segmento entre o km 250 ao km 655,7 (entroncamento BR-230(A)), no Estado do Amazonas – AM – 418,2 km de extensão.

Estudo de Impacto Ambiental. 2006. Implantação da Rodovia ES – 080 (Variante de Colatina); Trecho: Entr. BR-259 (Contorno) – Entr. ES-080 (Ponte do Pancas) – ES – 15,02 km de extensão.

Estudo de Impacto Ambiental. 2007. Construção e Pavimentação – Div. GO/MT – Entr. BR-158, incluindo ponte sobre o Rio das Mortes – MT – 268,8 km de extensão.

Estudo de Impacto Ambiental. 2008. Construção e Pavimentação da Rodovia BR-117, Subtrecho entre a cidade de Boca do Acre/AM e a divisa entre AM/AC – entre o km 416 ao km 526,7 – AM – 110,7 km de extensão.

Estudo de Impacto Ambiental. 2009. Adequação de Capacidade da Rodovia BR-104. Trecho: Entroncamento PE-160 (Pão de Açúcar) e entroncamento da PE-149 (Agrestina) – PE – 51,4 km de extensão.

Estudo de Impacto Ambiental. 2009. Duplicação da Rodovia BR-386/RS. Trecho: Entr. BR-158(A) (Div SC/RS) – Entr. BR-116(B)/290 (Porto Alegre), Subtrecho: Entr. BR-453/RS-130 (p/ Lajeado) – Entr. BR-287(A) (Tabaí), segmento: km 350,8 – km 386,0 – RS – 35,2 km de extensão.

Estudo de Impacto Ambiental. 2009. Adequação da Capacidade e Duplicação da Rodovia BR 116. Trecho: Guaíba – Pelotas Divisa SC/RS (Rio Pelotas) – (p/ arroio dos Ratos) – Acesso a Pelotas Segmento: km 291,2 ao km 510,6 – RS – 219,4 km de extensão.

Estudo de Impacto Ambiental. 2010. Duplicação da Subida da Serra do Mar entre Xerém (Distrito do Município de Duque de Caxias) – RJ – 25,0 km de extensão.

Estudo de Impacto Ambiental. 2010. Implantação e Pavimentação da Rodovia BR-285. Subtrecho entre os Municípios de São José dos Ausentes (Pedreira)/RS e Timbé do Sul/SC – RS/SC – 30,3 km de extensão.

Estudo de Impacto Ambiental. 2010. Implantação Trecho Norte do Rodoanel Mario Covas – SP – 42,8 km de extensão.

Estudo de Impacto Ambiental. 2010. Duplicação da Rodovia BR-290/RS. Trecho: Entr. BR-101 (Osório_ - Entr. BR-293(B) (fronteira Brasil/Argentina) (Ponte Internacional), Subtrecho: Entr. BR-116(B) (p/ Guaíba) – Entr. BR-153(A) (Cachoeira do Sul), segmento: km 112,3 – km 228,0 – RS – 115,7 km de extensão.

Estudo de Impacto Ambiental. 2012. Duplicação da Rodovia BR-101/ES. Trecho entre a Divisa da BA/ES e a Divisa ES/RJ, Subtrecho Entr. BR-262(B) – Divisa no segmento km 302,7 – km 458,4 – ES/RJ – 155,7 km de extensão.

Estudo de Impacto Ambiental. 2013. Implantação, Pavimentação e Melhorias da Rodovia BR-135/MG. Trecho: Div. BA/MG – Fim Contorno Curvelo, Subtrecho: Manga – Itacarambi, segmento: km 88,7 – km 137,4 – MG – 48,7 km de extensão.

Estudo de Impacto Ambiental. 2015. Duplicação da Rodovia BR-040 – DF/GO/MG – 557,2 km de extensão.