Oecologia Australis
21(3): 350-360, 2017
10.4257/oeco.2017.2103.11

CUMULATIVE ENVIRONMENTAL IMPACTS AND EXTINCTION RISK OF BRAZILIAN CARNIVORES

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ABSTRACT
Mammalian carnivores are crucial bioindicators of environmental impacts. Threats to the Brazilian carnivores identified by the national evaluation of extinction risk were reviewed in this article. Native vegetation suppression, road and hydroelectric dam building, mining and petrol extraction are the main threats and are all subjected to laws that require environmental licensing, which should be a safeguard that measures would be adopted to mitigate their negative impacts; however, almost half of the carnivore species are under some degree of extinction threat. This evidences the need for effective enforcement of environmental legislations and for considering cumulative and indirect effects of human activities on carnivore populations. Therefore, the current trends of changes in Brazilian environmental legislation should be reversed in order to avoid biodiversity loss.
Keywords: Carnivora; cumulative environmental impacts; Mammalia.

Mammalian carnivores are crucial as bioindicators of environmental impacts because it would be a challenge to find any human impact on the environment that does not represent a threat to these animals. The characteristics of most of these species make them highly vulnerable to environmental changes: they have large home ranges, which are easily reached by some human activity or other (Ripple *et al.* 2014); they are phylogenetically close to domestic dogs and cats (Agnarsson *et al*. 2010, Thalmann *et al.* 2013), being thus sensitive to many of their diseases (Deem *et al.* 2000, Whiteman *et al.* 2007, Curi *et al.* 2010, Megid *et al.* 2013); they can be attracted by resources offered by human settlements, such as cattle, domestic fowl and garbage (Graham *et al.* 2005, Penteriani *et al.* 2016); and they may be hunted for fear, retaliation, or sport (Packer *et al.* 2011, Swanepoel *et al.* 2015) even in remote areas. Finally, they have typically high positions in the food chains; therefore, they are indirectly affected by all threats that reach their prey, beyond those on themselves (Ripple *et al.* 2014).

Native vegetation suppression, road and hydroelectric dam building, mining and petrol extraction cause most of the impacts on carnivore populations. According to the current Brazilian legislation, Federal Law 6.938/81 (Brasil 1981) and CONAMA Resolutions 1/86, 237/97, 357/2005 and 430/2011 (CONAMA 1986, 1997, 2005, 2011), these activities require environmental licenses by the developers. Thus, the licensing process should be a safeguard that measures would be adopted to mitigate the threats identified in previous studies of environmental impact (EIAs), as indicated by these laws and regulations.

One of the instruments of the National Environment Policy is the national official evaluation of extinction risk. This evaluation was conducted for the Brazilian carnivores in 2011, and published in the form of full assessments in an issue of the journal 'Biodiversidade Brasileira' (Beisiegel *et al.* 2013b). The Brazilian official list with the fauna species in danger of extinction was published in 2014 according to the document "Portaria n° 444, de 17 de dezembro de 2014" (MMA 2014). Based on the threats to the Brazilian carnivores described in this evaluation, the goal of this paper was to discuss the necessity of the enforcement of environmental legislations, the additional need of evaluating and considering the cumulative and indirect effects of human activities and thus reinforce the risks that the current trends of changes in Brazilian environmental legislation present to these species.

All the main threats faced by Brazilian carnivores (Table 1) were resumed from the full Brazilian extinction risk assessments and from the global Red List assessments published by the International Union for the Conservation of Nature (IUCN). Most of these threats (N = 11; Table 1) are subjected to some licensing process under the current Brazilian law. Therefore, why are they still threatening a large number of important species?

In the last decades of the 20th century, Brazil developed an advanced environmental legislation, which enforcement, however, is still weak (Drummond & Barros-Platiau 2006). This implies the idea that, should the environmental legislation be strictly followed, biodiversity would be sufficiently protected to, at least, warrant a sustainable development, which would afford the species protection against the risk of extinction.

This idea could be particularly true to the aspect of environmental legislation which refers to indirect and cumulative impacts. A large number of threats is identified for almost all species of Brazilian carnivores, with the exception of the most unknown Amazonian species, for which habitat loss is the main known threat (Table 1). The species classified as threatened are, each, subjected to five to twelve individual kinds of impacts. None of these impacts is isolated and uni-dimensional in its effects. All licensed impacts, and many of the consequent impacts, have the effect of generating or increasing other impacts that also are identified as threats to Brazilian carnivores. Therefore, all of these are cumulative impacts, which can be defined as "the synergistic, interactive, or unpredictable outcomes of multiple land-use practices or developments that aggregate over time and space" (Ross 1998, Johnson 2011).

Habitat loss and fragmentation, the most important threat affecting most of the species, has also an incremental effect in almost all of the other identified threats. The effects of cumulative impact of habitat loss for carnivores are well exemplified by the Population Viability Analyses (PVAs) developed for the jaguar, *Panthera onca* (Desbiez *et al.* 2012). These analyses concluded that population size and habitat carrying capacity are the main determinants of extinction risk for jaguars. The driver of these variables is mainly habitat fragmentation, which reduces the sizes of jaguar populations. All the impacts that result in decreased carrying capacity of the habitat, such as poaching of jaguar prey species, fire, and introduction of domestic animals that may prey on the same species as jaguars, are also increased by habitat loss and fragmentation. Although eolic energy plants is cited only in the assessment of *Puma concolor* (Azevedo *et al.* 2013), this is also one of the major threats to the jaguar *P. onca* at the Caatinga, where eolic plants are being planned at the best area of one of the very few remaining subpopulations of the species (Paula *et al.* 2012).

Bush dogs (*Speothos venaticus*) also exemplify clearly the effects of cumulative impacts of habitat loss and fragmentation. Although the animals are able to survive in fragmented landscapes, they forage and rest almost only in native vegetation fragments, using the cultivated matrix mainly for traveling among them (Lima *et al.* 2014). Their home range in this situation is much larger than in a landscape composed mainly of natural vegetation, which possibly reflects depletion of prey base due to fragmentation and hunting of bush dog preys by humans. The most important causes of death for the groups studied by Lima *et al.* (2012, 2014) were predation by domestic dogs, killing by humans and probably mange. The loss and fragmentation of the habitat enlarges the necessary home range for one bush dog group, probably decreasing the number of individuals that a region can support; additionally, these supported bush dog groups risk more contact with other threats, due both to the larger area used and the increased penetration of these threats into the dogs' area. The latter are cumulative and indirect impacts of fragmentation.

Although cumulative impacts occur for all Brazilian carnivore species, they are explicitly stated only in the Pampas fox (*Lycalopex gymnocercus*) IUCN assessment: "However, due to the species' adaptability, the Pampas Fox seems able to withstand the loss and degradation of its natural habitat, as well as hunting pressure. Since no studies are available on its population dynamics in rural ecosystems, caution is required, since the sum of these threats may eventually promote the depletion of fox populations" (Jiménez *et al.* 2008).

Table 1. Conservation status and threats to Brazilian carnivores described in the most recent national and global assessments. Threats marked with an asterisk are subjected to environmental licensing (CONAMA 1986, 2011).

Threats	***Atelocynus microtis***	***Cerdocyon thous***	***Chrysocyon brachyurus***	***Lycalopex gymnocercus***	***Lycalopex vetulus***	***Speothos venaticus***	***Bassaricyon alleni***	***Bassaricyon beddardi***
BR	VU	LC	VU	LC	VU	VU	DD	LC
IUCN	NT	LC	NT	LC	LC	NT	LC	LC
Habitat loss frag*	BR, IUCN		BR, IUCN	BR	BR	BR, IUCN	BR, IUCN	BR, IUCN
Road*	BR	BR	BR, IUCN	BR	BR	BR		
Hunting	BR	BR		BR			BR	BR
Domestic	BR, IUCN	BR, IUCN	BR, IUCN	BR	BR	BR, IUCN		
Retaliatory	BR	BR	BR, IUCN	BR, IUCN	BR			
Use	BR	BR	IUCN					
Habitat degr*	BR		BR					
Fire*								
Prey-base depl						BR, IUCN		
Min / Petrol*								
Hydreletric dams*								
Urbanization*			BR		BR, IUCN	BR, IUCN		
Hybridization								
Water pollution*								
Bioacumulation								
Pesticides*								
Eolic energy*								
Tourism*								
Government				IUCN				
Number of threats	7	5	7	6	5	5	2	2
Sources	Leite-Pitman & Williams 2011, Leite-Pitman & Beisiegel 2013	Beisiegel *et al.* 2013a, Lucherini 2015	Paula *et al.* 2013, Paula & DeMatteo 2015	Jimenéz *et al.* 2008, Queirolo *et al.* 2013c	Dalponte & Courtenay 2008, Lemos *et al.* 2013	DeMatteo *et al.* 2011, Jorge *et al.* 2013	Reid & Helgen 2008a, Sampaio 2013	Reid & Helgen 2008b, Mendes Pontes & Beisiegel 2013

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Threats	***Potos flavus***	***Nasua nasua***	***Procyon cancrivorus***	***Conepatus chinga***	***Conepatus semistriatus***	***Leopardus pardalis***	***Leopardus wiedii***
BR	LC	LC	LC	LC	LC	LC	VU
IUCN	LC	LC	LC	LC	LC	LC	NT
Habitat loss frag**	BR, IUCN	IUCN	BR, IUCN	BR	BR	BR, IUCN	BR, IUCN
Road*		BR	BR	BR	BR	BR	BR, IUCN
Hunting	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN	IUCN	
Domestic	BR	BR	BR	BR	BR	BR	BR
Retaliatory		BR		BR		BR, IUCN	BR, IUCN
Use	BR, IUCN	BR	BR, IUCN			IUCN	BR, IUCN
Habitat degr*				BR, IUCN	BR		
Fire*				BR	BR		
Prey base depl							
Min / Petrol*							
Hydreletric dams*							
Urbanization*			IUCN				
Hybridization							
Water pollution*							
Bioacumulation							
Pesticides*					IUCN		
Eolic energy*							
Tourism*							
Government							
Number of threats	4	6	6	7	7	6	5
Sources	Kays *et al.* 2008, Sampaio *et al.* 2013	Emmons & Helgen 2008c, Beisiegel & Campos 2013	Reid & Helgen 2008d, Cheida *et al.* 2013	Emmons & Helgen 2008a, Kasper *et al.* 2013b	Cuarón *et al.* 2008a, Cavalcanti *et al*. 2013	Oliveira *et al.* 2013a, Paviolo *et al.* 2015	Tortato *et al.* 2013, Oliveira *et al.* 2015

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Threats	***Leopardus guttulus***	***Leopardus tigrinus***	***Leopardus geoffroyi***	***Leopardus colocolo***	***Puma yagouaroundi***	***Puma concolor***	***Panthera onca***
BR	VU	EN	VU	VU	VU	VU	VU
IUCN		VU	LC	NT	LC	LC	NT
Habitat loss frag*	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN
Road*	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN	BR	BR, IUCN	BR
Hunting	IUCN	IUCN	BR		BR, IUCN	BR, IUCN	BR
Domestic	BR	BR	BR, IUCN	BR, IUCN		BR	
Retaliatory	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN	BR, IUCN
Use	BR	IUCN	BR				IUCN
Habitat degr*						BR	IUCN
Fire*				BR	BR	BR	
Prey base depl			BR	IUCN		BR, IUCN	IUCN
Min / Petrol*				IUCN			BR
Hydreletric dams*						BR	BR
Urbanization*						BR	
Hybridization	BR		BR	BR			
Water pollution*							
Bioacumulation							
Pesticides*							
Eolic energy*						BR	
Tourism*							
Government control programs							
Number of threats	7	6	8	8	5	11	9
Sources	ICMBio in press	Oliveira *et al.* 2008, Oliveira *et al.* 2013b	Almeida *et al.* 2013, Pereira *et al.* 2015	Queirolo *et al.* 2013a, Lucherini *et al.* 2015	Queirolo *et al.* 2013b, Caso *et al.* 2015	Azevedo *et al.* 2013, Nielsen *et al.* 2015	Caso *et al.* 2008, Morato *et al.* 2013

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Threats	***Lontra longicaudis***	***Pteronura brasiliensis***	***Galictis cuja***	***Galictis vittata***	***Eira barbara***	***Mustela africana***	**Species threatened**
BR	NT	VU	LC	LC	LC	DD	
IUCN	NT	EN	LC	LC	LC	LC	
Habitat loss frag*	BR, IUCN	BR, IUCN	BR	BR	BR, IUCN	BR, IUCN	27
Road*	IUCN		BR, IUCN	BR	BR		23
Hunting	IUCN	BR, IUCN	BR, IUCN	BR, IUCN			22
Domestic	BR	BR, IUCN	BR, IUCN		BR		22
Retaliatory	BR, IUCN	BR, IUCN	BR, IUCN		BR		20
Use	BR	BR	IUCN	BR, IUCN			15
Habitat degr*	BR			BR			7
Fire*			BR		BR		7
Prey base depl		BR, IUCN					7
Min / Petrol*	IUCN	IUCN		BR			5
Hydreletric dams*	BR	BR, IUCN		BR			5
Urbanization*							5
Hybridization							3
Water pollution*	BR, IUCN	BR, IUCN					2
Bioacumulation	BR, IUCN	BR, IUCN					2
Pesticides*		BR, IUCN					2
Eolic energy*							2
Tourism*		BR, IUCN					1
Government control programs							1
Number of threats	11	12	7	7	5	1	
Sources	Rodrigues *et al.* 2013a, Rheingantz & Trinca 2015	Rodrigues *et al.* 2013b, Groenendijk *et al.* 2015	Reid & Helgen 2008c, Kasper *et al.* 2013c	Cuarón *et al.* 2008c, Kasper *et al.* 2013a	Cuarón *et al.* 2008b, Rodrigues *et al.* 2013c	Emmons & Helgen 2008b, Rodrigues 2013	

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BR - extinction risk category in the last National evaluation; IUCN - extinction risk category in the last global IUCN evaluation; Habitat loss frag - Habitat loss includes deforestation and conversion of open areas to croplands and pastures; Road - mainly roadkills, but also road infrastructure expansion; Hunting - includes hunting for sport, food and fear, which can be real (*e.g.*, fear of big cats) or superstition (*e.g.*, fear that olingos or kincajous will attack a person's neck at night to drink blood); Domestic - domestic animal-related impacts: diseases from domestic animals, killing by domestic dogs and cats and competition with domestic animals; Retaliatory - Retaliatory killing; Use - animals taken for pets, either by local communities or by traffic, or killed for pelts or other body parts; Habitat degr - Loss of habitat carrying capacity and habitat degradation, applying to legal or illegal selective extrativism, overgrazing and soil compactation and, for some species, including depletion of prey base; Fire - legal fire used to clear agricultural areas and accidental or criminal large scale fires. Beyond its risks to the animals, fire causes habitat suppression and depletion of prey base; Prey base depl - Prey base depletion; Min/Petrol - mining and petrol extraction; Bioacumulation refers to mercury and other heavy metals along the food chain; Pesticides - carnivores that feed in or near agricultural areas can be directly killed by pesticides used in this cultures; Eolic energy plants - although they represent a renewable energy source, their implantation represents a large-scale impact; Tourism - poorly planned tourism may cause animals to abandon their home ranges and may create or enhance conflicts between carnivores and people. Threat categories: LC – Least Concern; NT – Near Threatened; DD – Data Deficient; VU – Vulnerable; EN – Endangered.

Analysis of indirect and cumulative effects is required by the CONAMA resolution 1/86 (CONAMA 1986), but according to Glasson & Salvador (2000) "secondary, indirect, and cumulative impacts are also not well identified or properly assessed" in Brazilian EIAs. These analyses are already implemented in some countries such as in the European Union, Canada and United States, and in all countries there is recognition that they are a complex issue and in most cases are only perfunctorily performed (CEQ 1997, Walker & Johnston 1999, Glasson *et al.* 2005, Gunn *et al.* 2011). However, the importance and magnitude of the cumulative impacts, despite the difficulty in its assessment, led to the elaboration of guidelines (CEQ 1997, Walker & Johnston 1999) and a book on cumulative impact mitigation (Krausman & Harris 2011).

Building and paving of roads are the best demonstration that the isolated assessment of environmental impacts of a development may be almost irrelevant on the context of all changes promoted by it. Roads are the second most important threat to Brazilian carnivores, considering the number of species affected (22 species, see Table 1), and one of the most important drivers of biodiversity loss around the world. However, assessments of impacts of roads are frequently limited in scope, focusing only on the direct effects of road building (Laurance *et al.* 2014). Other effects, such as promoting habitat loss and facilitating human access with consequent increases of hunting, prey base depletion, urbanization, human-wildlife conflicts and consequent retaliatory hunting, fires, and loss of carnivore lives due to predation by or diseases acquired from domestic carnivores, which are indirect and cumulative effects of roads, may be even more important as threats than the habitat lost or disrupted by the road. Of the 23 carnivore species threatened by roads, 17 are also affected by hunting, 20 by domestic animals, 19 by retaliatory killing, seven by fire, six by prey base depletion and five by urbanization. One species, the cougar *P. concolor*, is even threatened by all of these impacts, so an analysis of the impact of road building or enlarging in a population of these species should clearly contemplate all these effects.

The advancements made on the last century by Brazil environmental legislation (Drummond & Barros-Platiau 2006) are currently being challenged by economic interests, with the recent example of replacement of the 1965 Forest Code (Brasil 1965) by the Law 12.651/2012 (Brasil 2012), which weakens considerably the protection to native vegetation. One of these challenges is the Proposal of Constitutional Amendment (PEC) 65/2012, which eliminates the process of environmental licensing, substituting it by the simple presentation of the Environmental Impact Assessment, when, in contrast, the example of the Brazilian carnivores is just one of many cases in which environmental protection laws should be strengthened and more rigorously observed in order to avoid risks of biodiversity loss.

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Submitted: 31 May 2016
Accepted: 24 February 2017