

## HUMAN TRANSPORTATION NETWORK AS ECOLOGICAL BARRIER FOR WILDLIFE ON BRAZILIAN PANTANAL-CERRADO CORRIDORS

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**Abstract:** Highway impacts on terrestrial fauna are known as a serious mortality source for several species around the world. Despite the international concerns about this issue, only recently has this question been included in Brazilian policies of transportation.

Brazilian Pantanal and Cerrado biomes and corridors are known as two of the broadest wildlife sanctuaries in South America, and their fauna movements has been drastically affected by road development. The last 13 years of road fauna-monitoring databases at Pantanal and Cerrado highways has shown a fast evolution of wildlife mortality caused by vehicle traffic.

Pantanal and Cerrado road fauna has been represented by more than 140 species; 16 of them are considered endangered by Brazilian Government as *Chrysocyon brachyurus*, *Speothos venaticus*, *Leopardus pardalis*, *Oncifelis colocolo*, *Panthera onca*, *Puma concolor*, *Pteronura brasiliensis*, *Blastocerus dichotomus*, and *Myrmecophaga tridactyla*, one of the most vulnerable species, reaching more than 200 road kills per year.

In Pantanal, highway mortality of wildlife multiplied eight times in the last 10 years. Along 1,350km of federal roads around Pantanal (from Cáceres/MT to Corumbá/MS) road kill estimate escalated from 1,120 deaths/year in 1992 to 8,090 deaths/year in 2002. In Cerrado areas, road kill rate evolution takes the same pattern. On 310km of roads around Emas National Park, highway mortality of fauna was close to 405 deaths/year in 1999, and it reached 540 deaths/year at the end of 2002, that is, an increase of 33 percent in three years.

We mapped the most relevant wildlife corridors for applying road fauna management and landscape design technologies to allow safe crossings between animal and human corridors (under or over passages).

### Introduction

Road impacts on terrestrial vertebrates are one of the most serious mortality causes for several animal species around the world (ICOET 2001, KERLEY *et al.* 2002). Mammal species such as large carnivores are known for their natural low population densities, and are often considered rare and endangered in many Brazilian regions. Besides the Amazon in the northern South America continent, Central Brazil also has two other biomes that broadly help to support large mammal species in healthy populations, such as Cerrado and Pantanal (fig. 1).

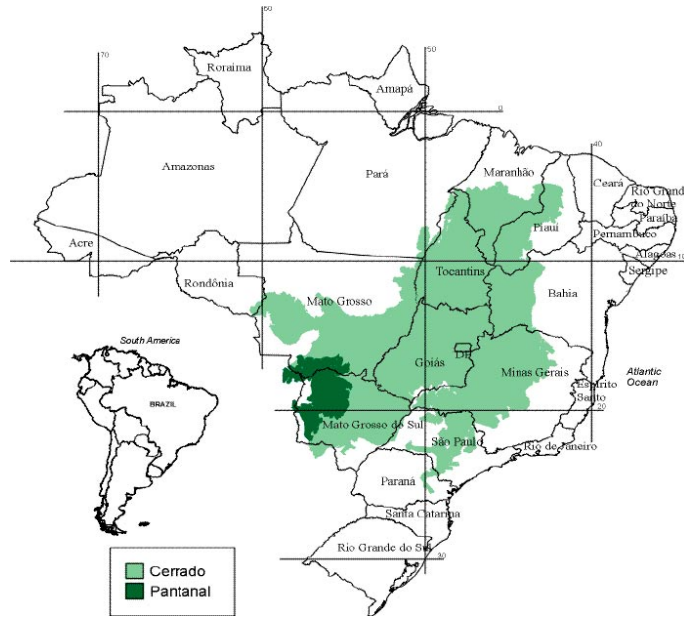


Fig. 1. South America and Brazilian map showing Cerrado and Pantanal area.

Cerrado is the Brazilian name for the Neotropical Savanna located in Central Brazil, occupying 2,064,676 square kilometers (= 800,000 miles<sup>2</sup>). It corresponds to approximately 15 times the Florida State area. Brazilian law officially protects only 3.1 percent of Cerrado core area.

Pantanal is known as the world's largest wetland, also located in western Brazil at the middle of South America. Its area corresponds to 154,884 square kilometers (= 60,000 miles<sup>2</sup>), nearly the size of Florida State and it also represents four times the Everglades biome area (Florida wetland). Legally protected areas in Pantanal correspond only to 1.6% percent of all this biome.

As seen in figure 1, both biomes occupy strategic positions in South America, showing the highest Neotropical diversity of fauna. Principally Cerrado is a convergence area for large animal species. Cerrado makes the natural connection among other important biomes such as Amazon, Caatinga, Atlantic Forest, Pantanal and other wetlands like South American Chacos in Bolivia and Paraguay (Redford and Fonseca 1986).

Despite their importance, Pantanal and Cerrado are threatened by human activities and movements (urbanization, farming and transportation). The few existing conservation units are in progressive isolation, and several wild animal species have been endangered by environmental disturbances and losses. Road building and development increasing these impacts, essentially because they promote habitat fragmentation and animal mortality by vehicle traffic (ICOET 2001).

Public and private organizations in Brazil (coordinated by Conservation International Institute) have developed a broad and long-term project called Cerrado-Pantanal Ecological Corridors (CPEC). Its main objective involves many environmental research works and institutional policy actions to establish huge land reconnection as a continuous corridor. This proposal intends to link natural fragments and reserves from different sizes and preservation conditions and to guarantee their protection and conservation, and also their connectivity restoration (see figure 2).

Road kills of terrestrial wildlife are one of the key questions to be included in the conservation equation for Cerrado-Pantanal Corridor success (Fischer 2003). Figure 3 shows the Brazilian transportation network (rail and highways) along Cerrado and Pantanal areas. Traditional roads and railways may easily interrupt all habitat reconnections proposed by CPEC. So, road fauna management is a primary issue to be discussed, and it is the greatest CPEC challenge for biodiversity conservation in Central Brazil (see Sullivan 1996).

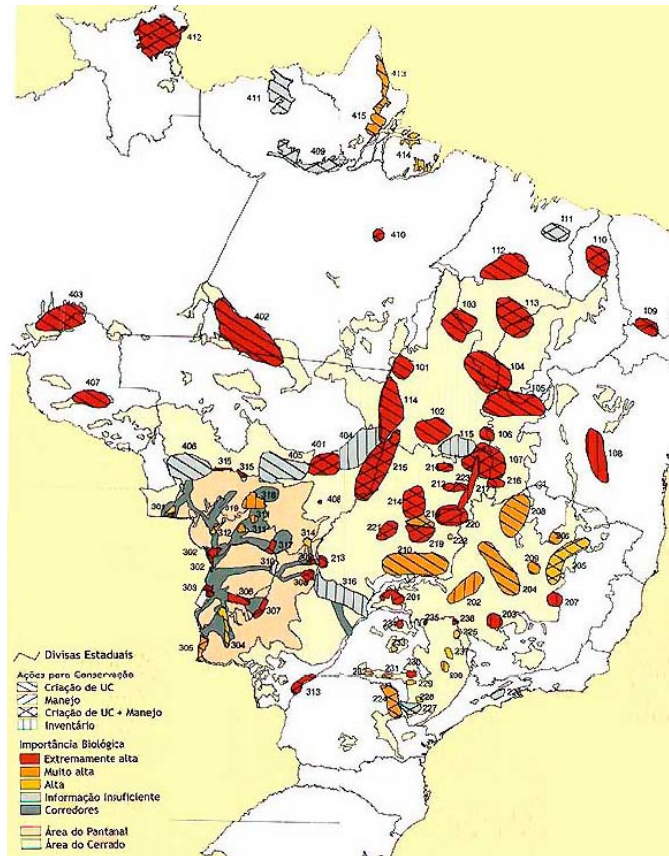


Fig. 2. Brazilian priorities for conservation that must be reconnected by Cerrado-Pantanal Ecological Corridors Project. (Source: Conservation International.)



Fig. 3. Brazilian transportation network that represents ecological barriers for CPEC Project. (Source: Transportation Ministry, Federal Government, Brazil.)

## **Objectives**

Our objectives in this paper are:

- 1) To give a general overview of fauna road kills at Pantanal and Cerrado biomes.
- 2) To define critical road spots for wildlife movements as pilot-areas for monitoring and testing fauna management technologies.
- 3) To establish environmental indicators for reconnecting and protecting natural fauna corridors.
- 4) To recommend effective mitigation actions and technologies for existing roads on Cerrado and Pantanal ecosystems.

In addition, we have developed a specific proposal to complement two running project statements presented in this paper. Our priority is to allow safe animal crossings over some specific South Pantanal and Emas National Park (Cerrado) road spots. Also, we must extend our investigation to every relevant road on the CPEC area, as part of the global project. The estimated costs to execute a preliminary project for wildlife management at CPEC roadspots must reach approximately USD \$200,000.

## **Methods**

During the last eight years, we have consolidated a consistent road fauna-monitoring database at Pantanal and Cerrado highways. We have conducted two specific monitoring projects that show a fast evolution of wildlife mortality caused by vehicle traffic.

The first running project cited above has been executed in the Cerrado biome since 1996, involving fauna ecology and management in all human transportation routes around Emas National Park, Goiás State, and its border limits with Mato Grosso and Mato Grosso do Sul States (Jácomo et al. 1996, Ramos-Neto 1998, Silveira 1999; Fischer 2003). The second running project takes place in South Pantanal at its federal main road (BR-262), between Campo Grande and Corumba cities (FISCHER, 1996, 1997, and 1999). This work also started in 1996; however, we used historical data from BR-262 road fauna collected since 1989 by other researchers in Pantanal (R. Herrera, pers. comm.).

In both, South Pantanal and Emas National Park roads, our methods consist of fortnightly monitoring animal activities and mortalities on all lanes. When possible, local driver interviews and historical data about road fauna are useful to help estimate highway mortality index increasing. Databases were overlaid on satellite images for landscape analysis, dividing roads in segments, according to their environmental characteristics (geomorphology, biogeography, conservation status, etc).

We use rare, endemic and/or endangered animal species occurrences to detect wildlife corridors and critical road spots of animal-vehicle collisions. Also, we define structures, equipments and strategic actions to integrate roads and railways to the natural environment, including public and private reserves around them.

## **Results**

Pantanal and Cerrado road fauna has been represented by more than 140 species of mammals, avian, reptiles and amphibians (Fischer 1999, 2003). From the road fauna list (tables 1, 2 and 3), sixteen species are officially considered endangered (MMA 2003): *Penelope obscura* (dusky-legged-guan), *Crax fasciolata* (curassow), *Chrysocyon brachyurus* (manned-wolf), *Pseudalopex vetulus* (short-eared-fox), *Speothos venaticus* (bush-dog), *Leopardus* spp. (ocelot and margay), *Oncifelis colocolo* (wild-cat), *Panthera onca* (jaguar), *Puma concolor* (puma), *Pteronura brasiliensis* (giant-otter), *Blastocerus dichotomus* (marsh-deer), *Priodontes maximus* (giant-armadillo), and *Myrmecophaga tridactyla* (giant-anteater). Also, the giant anteater and short-eared-fox are two of the most threatened species commonly found on Pantanal and Cerrado roads (see figures 4, 5 and 6).

Besides the giant anteater and short-eared-fox, other common road kill species are *Bufo marinus* (marine-toad), *Ameiva ameiva* (common-ameiva), *Caiman crocodylus yacare* (yacare-caiman), *Eunectes notaeus* (yellow-anaconda), *Rhea americana* (greater-rhea), *Cariama cristata* (red-legged-seriema), *Poliborus plancus* (crested-caracara), *Cerdocyon thous* (crab-eating-fox), *Procyon cancrivorus* (crab-eating-raccoon), *Dasyurus novencinctus* (nine-banded-armadillo), *Euphractus sexcinctus* (yellow-armadillo), *Tamandua tetradactyla* (collared-anteater), field-deer (*Ozotocerus bezoarticus*) and *Hydrochaeris hydrochaeris* (capybara). In general, mammal occurrences represent more than 70 percent of all animal road kills, followed by avian, reptiles and amphibians, respectively.

Also, the highway mortality rate on Pantanal and Cerrado routes has significantly increased. In Pantanal, highway mortality of wildlife multiplied eight times in the last 10 years. Along 1,350km of federal roads from Cáceres (MT) to Corumba (MS), road kill estimates escalated from 1,120 deaths/year in 1992 to 8,090

deaths/year in 2002. In Emas National Park, road kill rate evolution takes the same pattern. On 310km of roads around Emas, highway mortality of fauna was close to 405 deaths/year in 1999, and it reached 540 deaths/year at the end of 2002, that is, an increase of 33 percent in three years (Fischer 2003).

Our global estimate for animal-vehicle collisions on all Cerrado-Pantanal corridors is more than 15,000 wild animals killed this year (2003), 10,000 of them representing mammal species.

Table 1.

Herpetofauna road killed species in Cerrado and Pantanal transportation network, Brazil. (+)=rarely road killed; (++)=eventually road killed; (+++)=frequently road killed.

TAXA	Family	Species	Vulgar Name	Cerrado	Pantanal
AMPHIBIA					
Anura	Bufonidae	<b>Bufo spp.</b>	<b>Toad</b>	<b>+++</b>	<b>+++</b>
	Hylidae	<i>Hyla spp.</i>	Tree-frog		<b>+++</b>
	Leptodactylidae	<i>Leptodactylus spp.</i>	Rana	<b>+</b>	<b>+</b>
		<i>Physalaemus sp.</i>	Rana	<b>+</b>	
	Pseudidae	<i>Pseudis paradoxa</i>	Paradox-frog		<b>++</b>
REPTILE					
Chelonia	Chelidae	<i>Phrynops sp.</i>	Toad-headed-turtle		<b>+</b>
		<i>Acanthochelis sp.</i>	Turtle		<b>+</b>
	Testudinidae	<i>Geochelone carbonaria</i>	Red-foot-tortoise		
Crocodylia	Alligatoridae	<b>Caiman crocodilus yacare</b>	<b>Yacare-caiman</b>	<b>+</b>	<b>+++</b>
		<i>Caiman latirostris</i>	Broad-nosed-yacare		
Squamata					
Sauria	Iguanidae	<i>Iguana iguana</i>	Green-iguana		<b>+</b>
	Teiidae	<b>Ameiva ameiva</b>	<b>Green-ameiva</b>	<b>+++</b>	<b>+++</b>
		<b>Tupinambis spp.</b>	<b>Tegu</b>	<b>++</b>	<b>+++</b>
		<i>Dracaena paraguayensis</i>	Paraguay-caiman-lizard		<b>+</b>
	Tropiduridae	<b>Tropidurus spp.</b>	<b>Lizard</b>	<b>++</b>	<b>++</b>
Ofidia	Boidae	<b>Boa constrictor</b>	<b>Common-boa</b>	<b>+</b>	<b>++</b>
		<b>Eunectes spp.</b>	<b>Anaconda</b>		<b>+++</b>
	Colubridae	<i>Apostolepis sp.</i>	Ground-snake		
		<i>Chironius spp.</i>	Tree-snake		<b>+</b>
		<i>Clelia occipitolutea</i>	Musuranna	<b>+</b>	<b>+</b>
		<i>Dipsas sp.</i>	Slug-eating-snake		
		<i>Drymarchon corais</i>	Indigo-snake		<b>++</b>
		<i>Erythrolamprus sp.</i>	False-coral	<b>+</b>	
		<i>Helicops leopardinus</i>	False-water-snake		<b>++</b>
		<b>Hydrodynastes gigas</b>	<b>False-water-cobra</b>		<b>+++</b>
		<i>Leptodeira annulata</i>	Cat-eyed-snake		<b>+</b>
		<i>Liophis spp.</i>	Liophis		<b>++</b>
		<b>Mastigodrias bifossatus</b>	<b>Water-snake</b>	<b>+</b>	<b>+++</b>
		<i>Oxyrhopus sp.</i>	False-coral	<b>+</b>	<b>+</b>
		<i>Philodryas spp.</i>	Mato-grosso-racer		<b>++</b>
		<i>Pseudoboa sp.</i>	False-coral	<b>+</b>	
		<b>Spilotes pullatus</b>	<b>Tiger-ratsnake</b>	<b>++</b>	<b>++</b>
		<i>Thamnodynastes strigilis</i>	Brazilian-snake		<b>+</b>
		<b>Waglaerophis merremi</b>	<b>Brazilian-boipeva</b>	<b>++</b>	<b>+++</b>
	Elapidae	<i>Micrurus sp.</i>	Coral-snake		
	Leptotyphlopidae	<i>Leptotyphlops sp.</i>	Blindsnake		<b>+</b>
	Viperidae	<b>Bothrops spp.</b>	<b>Viper</b>	<b>++</b>	<b>++</b>
		<i>Crotalus durissus</i>	Rattlesnake	<b>+</b>	

\*In bold, the most threatened species in both biomes.

Table 2.

Avifauna road-killed species in the Cerrado and Pantanal transportation network, Brazil. (+)=rarely road killed; (++)=eventually road killed; (+++)=frequently road killed; @=Brazilian red list species (MMA 2003).

Order	Family	Species	Vulgar Name	Cerrado	Pantanal
Rheiformes	Rheidae	<b>Rhea americana</b>	<b>Greater-rhea</b>	+++	++
Tinamiformes	Tinamidae	<b>Nothura spp.</b>	<b>Nothura @</b>	+++	++
		<i>Tinamus spp.</i>	Tinamou		+
		<b>Crypturellus spp.</b>	<b>Tinamou @</b>	+	+
		<i>Rhynchotus rufescens</i>	Red-winged-tinamou	++	
Pelicaniformes	Phalacrocoracidae	<i>Phalacrocorax olivaceus</i>	Neotropic-cormorant		
Ciconiiformes	Ardeidae	<i>Ardea cocoi</i>	White-necked-heron		+
		<i>Botaurus pinnatus</i>	Pinnated-bittern		+
		<i>Bubulcus ibis</i>	Cattle-egret		+
		<i>Butorides striatus</i>	Striated-heron		+
		<i>Casmerodius albus</i>	Great-egret		+
		<i>Egretta thula</i>	Snowy-egret		+
		<i>Tigrisoma lineatum</i>	Rufescent-tiger-heron		+
	Ciconiidae	<i>Euxenura maguari</i>	Maguari-stork		+
		<i>Jabiru mycteria</i>	Jabiru		++
	Threskionithidae	<i>Ajaia ajaja</i>	Roseate-spoonbill		+
		<i>Phimosus infuscatus</i>	Bare-faced-ibis		+
		<i>Theristicus caudatus</i>	Buff-necked-ibis	++	+
Falconiformes	Accipitridae	<i>Accipiter striatus</i>	Sharp-shinned-hawk		
		<i>Bursarellus nigricollis</i>	Black-collared-hawk		+
		<i>Buteo albicaudatus</i>	White-tailed-hawk		
		<i>Buteo brachyurus</i>	Short-tailed-hawk		
		<i>Buteo magnirostris</i>	Roadside-hawk		+
		<i>Buteogallus urubitinga</i>	Great-black-hawk		+
		<i>Elanus leucurus</i>	White-tailed-kite		
		<i>Harpyaliaetus coronatus</i>	Crowned-eagle @		
		<b>Heterospizias meridionalis</b>	<b>Savanna-hawk</b>	++	++
		<i>Milvago chimachima</i>	Yellow-head-caracara		++
		<i>Parabuteo unicinctus</i>	Harri´s-hawk		
	Cathartidae	<i>Cathartes aura</i>	Turkey-vulture		++
		<i>Cathartes burrovianus</i>	Yellow-headed-vulture		+
		<b>Coragyps atratus</b>	<b>Black-vulture</b>	+++	+++
		<i>Sarcoramphus papa</i>	King-vulture		+
	Falconidae	<i>Falco sparverius</i>	Sparrow-hawk		++
		<i>Micrastur gilvicollis</i>	Lined-forest-falcon		
		<i>Micrastur ruficollis</i>	Barred-forest-falcon		
		<b>Polyborus plancus</b>	<b>Crested-caracara</b>	+++	+++
Anseriformes	Anatidae	<i>Anas spp.</i>	Pintail		
		<i>Mergus octosetaceus</i>	Brazilian-merganser @		
		<i>Netta erythrophthalma</i>	Pochard		
		<i>Sarkidiornis melanotos</i>	Comb-duck		
Galliformes	Cracidae	<b>Crax fasciolata</b>	<b>Curassow @</b>	+	+
		<b>Penelope spp.</b>	<b>Guan @</b>	++	++
Charadriiformes	Charadriidae	<i>Charadrius collaris</i>	Plover		
		<i>Vanellus cayanus</i>	Lapwing		
		<i>Vanellus chilensis</i>	Lapwing		
	Jacaniidae	<i>Jacana jacana</i>	Jaçanã		+
Gruiformes	Aramidae	<i>Aramus guarauna</i>	Limpkin		+
	Cariamidae	<b>Cariama cristata</b>	<b>Seriema</b>	+++	+++
	Rallidae	<i>Aramides sp.</i>	Rail		++
		<i>Rallus sp.</i>	Rail		++
Columbiformes	Columbidae	<i>Columba spp.</i>	Pigeon		++
		<i>Columbina spp.</i>	Dove		++
		<i>Geotrygon sp.</i>	Dove		
		<i>Scardafella squammata</i>	Scaled-dove		
		<i>Zenaida auriculata</i>	Eared-dove	+	+

\*In bold, the most threatened species in both biomes.

Table 2.  
Continuation.

Order	Family	Species	Vulgar Name	Cerrado	Pantanal	
Psittaciformes	Psittacidae	<i>Amazona sp.</i>	Parrot		+	
		<i>Anodorhincus hyacinthinus</i>	Blue-macaw @		+	
		<i>Ara ararauna</i>	Blue-and-yellow-macaw			
		<i>Ara maracana</i>	Blue-winged-macaw			
		<i>Aratinga sp.</i>	Parakeet		++	
		<i>Brotogeris chiriri</i>	Parakeet			
		<i>Nandayus nenday</i>	Black-hooded-parakeet		++	
		<i>Pionus maximiliani</i>	Parrot		+	
		<i>Pyrrhura sp.</i>	Parakeet		+	
Cuculiformes	Cuculidae	<b><i>Crotophaga ani</i></b>	<b>Smooth-billed-ani</b>	+++	+++	
		<i>Crotophaga major</i>	Greater-ani			
		<b><i>Guira guira</i></b>	<b>Guira-cuckoo</b>	+++	+++	
		<i>Piaya cayana</i>	Squirrel-cuckoo			
Strigiformes	Strigidae	<b><i>Athene cunicularia</i></b>	<b>Burrowing-owl</b>	++	+++	
		<i>Bubo virginianus</i>	Great-horned-owl		+	
		<i>Glaucidium brasilianum</i>	Ferruginous-pigmy-owl			
		<i>Glaucidium minutissimum</i>	Least-pigmy-owl			
		<b><i>Rhinoptynx clamator</i></b>	<b>Striped-owl</b>	+	++	
		<b><i>Pulsatrix perspicillata</i></b>	<b>Spectacled-owl</b>	+	++	
		<i>Tyto alba</i>	Barn-owl	+		
Caprimulgiforme	Caprimulgidae	<b><i>Caprimulgus spp.</i></b>	<b>Nightjar</b>	++	++	
		<i>Nyctibius spp.</i>	Potoo	+		
Apodiformes	Apodidae	<i>Cypseloides senex</i>	Great-dusky-swift			
		<i>Reinarda squamata</i>	Palm-swift			
	Trochilidae	<i>Colibri semirrostris</i>	Violetear			
		<i>Glaucis hirsuta</i>	Hermit			
		<i>Heliophryx aurita</i>	Fairy			
		<i>Phaetornis spp.</i>	Hermit			
Coraciiformes	Alcedinidae	<i>Ceryle torquata</i>	Ringed-kingfisher			
		<i>Chloroceryle americana</i>	Green-kingfisher			
		<i>Trogon sp.</i>	Trogon			
Trogoniformes	Trogonidae					
Piciformes	Bucconidae	<i>Nonnula sp.</i>	Nunlet			
		<i>Galbula sp.</i>	Jacamar			
	Picidae	<i>Celeus flavescens</i>	Blond-crest-woodpecker			
		<i>Colaptes campestris</i>	Campo-flicker	++		
		<i>Picoides mixtus</i>	Checkered-woodpecker			
			<i>Veniliornis sp.</i>	Woodpecker		
		Ramphastidae	<b><i>Ramphastos toco</i></b>	<b>Toco-toucan</b>	++	++
Passeriformes	Corvidae	<i>Cyanocorax spp.</i>	Jay		+	
	Fringilidae	<b><i>Paroaria spp.</i></b>	<b>Cardinal</b>	++	++	
	Furnariidae	<i>Furnarius rufus</i>	Rufous-hornero			
	Hirundinidae	<i>Notiochelidon cyanoleuca</i>	Blue-white-swallow		+	
		<i>Riparia riparia</i>	Bank-swallow			
		<i>Tachycineta albiventer</i>	White-winged-swallow			
	Icteridae	<b><i>Gnorimopsar chopi</i></b>	<b>Blackbird</b>	++	++	
	Mimidae	<i>Mimus saturninus</i>	Mocking-bird	++		
	Ploceidae	<i>Passer domesticus</i>	House-sparrow			
	Thraupidae	<i>Ammodramus humeralis</i>	Grassland-sparrow	+		
		<i>Sporophila spp.</i>	Seedeater			
		<i>Thraupis sayaca</i>	Tanager		+	
		<i>Volatinia jacarina</i>	Grassquit	++		
			<i>Zonotrichia capensis</i>	Rufous-collared-sparrow		
	Trogloditidae	<i>Cistophorus platensis</i>	Grass-wren			
	Turdidae	<i>Turdus rufiventris</i>	Rufous-bellied-trush			
		<i>Turdus amaurochalinus</i>	Creamy-bellied-trush			
Tyrannidae	<i>Myiozetetes cayanensis</i>	Flycatcher				
	<i>Pitangus sulphuratus</i>	Great-kiskadee				

Table 3.

Mastofauna road-killed species in the Cerrado and Pantanal transportation network, Brazil. (+)=rarely road killed; (++)=eventually road killed; (+++)=frequently road killed; @=Brazilian red list species (MMA 2003).

Order	Family	Species	Vulgar Name	Cerrado	
Rodentia	Agoutidae	<i>Agouti paca</i>	Paca		
	Caviidae	<b><i>Cavia aperea</i></b>	<b>Preá</b>	++	++
	Dasyproctidae	<i>Dasyprocta azarae</i>	Agouti		
	Erethizontidae	<i>Coendou prehensilis</i>	Porcupine	+	+
	Hydrochaeridae	<b><i>Hydrochaeris hydrochaeris</i></b>	<b>Capybara</b>	++	+++
	Muridae	<i>Holochilus brasiliensis</i>	Marsh-rat		
		<i>Nectomys sp.</i>	Water-rat	+	+
		<i>Oecomys spp.</i>	Rice-rat	+	+
		<i>Oryzomys spp.</i>	Rice-rat	+	+
Marsupialia	Didelphidae	<i>Caluromys philander</i>	Wooly opossum	+	+
		<b><i>Didelphis spp.</i></b>	<b>Common-opossum</b>	++	+++
		<i>Micoureus cinereus</i>	Mouse-opossum	+	+
Artiodactyla	Cervidae	<b><i>Blastocerus dichotomus</i></b>	<b>Marsh-deer @</b>		++
		<b><i>Mazama americana</i></b>	<b>Red-deer</b>	+	++
		<b><i>Mazama goazoubira</i></b>	<b>Gray-deer</b>	++	++
		<b><i>Ozotocerus bezoarticus</i></b>	<b>Field-deer</b>	++	+
	Tayassuidae	<b><i>Tayassu pecari</i></b>	<b>White-lipped-peccary</b>	++	+
		<b><i>Tayassu tajacu</i></b>	<b>Collared-peccary</b>	++	+
		<i>Sus scropha</i>	Wild pig		+
Perissodactyla	Tapiridae	<b><i>Tapirus terrestris</i></b>	<b>Tapir</b>	++	++
Edentata	Bradypodidae	<i>Bradypus variegatus</i>	Sloth	+	
	Dasypodidae	<b><i>Cabassous unicinctus</i></b>	<b>Naked-tailed-armadillo</b>	+	++
		<b><i>Dasybus novencinctus</i></b>	<b>Common-armadillo</b>	++	+++
		<b><i>Euphractus sexcinctus</i></b>	<b>Yellow-armadillo</b>	+++	+++
		<b><i>Priodontes maximus</i></b>	<b>Giant-armadillo @</b>	++	
	Myrmecophagidae	<b><i>Myrmecophaga tridactyla</i></b>	<b>Giant-anteater @</b>	+++	+++
		<b><i>Tamandua tetradactyla</i></b>	<b>Collared-anteater</b>	+++	+++
Lagomorpha	Leporidae	<b><i>Sylvilagus brasiliensis</i></b>	<b>Brazilian-rabbit</b>	+	++
Primata	Atelidae	<b><i>Alouatta caraya</i></b>	<b>Black-howler-monkey</b>	+	+
		<i>Alouatta fusca</i>	Red-howler-monkey		
	Callitrichidae	<i>Callithrix penicillata</i>	Marmoset	+	
	Cebidae	<b><i>Cebus apella</i></b>	<b>Brown-capuchin-monkey</b>	+	++
Carnivora	Canidae	<b><i>Cerdocyon thous</i></b>	<b>Crab-eating-fox</b>	+++	+++
		<b><i>Chrysocyon brachyurus</i></b>	<b>Manned-wolf @</b>	++	++
		<b><i>Pseudalopex vetulus</i></b>	<b>Brazilian-field-fox @</b>	+++	+++
		<b><i>Speothos venaticus</i></b>	<b>Bush-dog @</b>	+	+
	Felidae	<b><i>Herpailurus yagouaroundi</i></b>	<b>Jaguarundi</b>	++	++
		<b><i>Leopardus pardalis</i></b>	<b>Ocelot @</b>	+	++
		<b><i>Leopardus tigrina</i></b>	<b>Oncilla @</b>	+	+
		<b><i>Leopardus wiedii</i></b>	<b>Margay @</b>	+	+
		<b><i>Oncifelis colocolo</i></b>	<b>Grass-wild-cat @</b>	++	++
		<b><i>Panthera onca</i></b>	<b>Jaguar @</b>	+	+
		<b><i>Puma concolor</i></b>	<b>Puma @</b>	++	++
	Mustelidae	<i>Conepatus semistriatus</i>	Skunk	+++	
		<b><i>Eira bárbara</i></b>	<b>Tayra</b>	++	+
		<i>Galictis cuja</i>	Grison	++	
		<b><i>Lutra longicaudis</i></b>	<b>Common-otter</b>	++	++
		<b><i>Pteronura brasiliensis</i></b>	<b>Giant-otter @</b>		+
	Procyonidae	<b><i>Nasua nasua</i></b>	<b>Coati</b>	++	++
		<b><i>Procyon cancrivorus</i></b>	<b>Crab-eating-raccoon</b>	+++	+++
Chiroptera	Molossidae	<i>Molossus spp.</i>	Mastiff-bat	+	+
	Noctilionidae	<b><i>Noctilio leporinus</i></b>	<b>Fishing-bat</b>		++
	Phyllostomidae	<i>Anoura spp.</i>	Long-tonged-bat		
		<i>Artibeus spp.</i>	Fruit-eating-bat		
		<i>Carollia spp.</i>	Short-tailed-bat		
		<i>Desmodus rotundus</i>	Common-vampire		
	Vespertilionidae	<i>Myotis spp.</i>	Little-brown-bat	+	+

\*In bold, the most threatened species in both biomes.



Fig. 4. Avian road-killed in CPEC (top-bottom; left-right): Gray-egret; Nightjar; Seriema; Striped-owl; Toco-toucan; Spectacled-owl; Crested-caracara; Sparrow-hawk; Savanna-hawk; Jabiru.



Fig. 5. Mammal road-killed species in CPEC (top-bottom; left-right): Capybara (adult); Capybara (offspring); Crab-eating-raccoon; Giant-anteater (female and offspring); Capybara and Black vulture; Coati; Yellow-armadillo; Common-armadillo; Naked-tailed-armadillo; Collared-anteater.



Fig. 6. Mammal and reptile road-killed species in CPEC (top-bottom; left-right): Field-deer; Jaguar; Grass-wild-cat; Common-otter; Brown-capuchin-monkey; Ocelot; Yellow-anaconda; Crab-eating-fox; Tegulizard; Yacare-caiman.

## **Conclusions**

Human terrestrial ways cause ecological impacts throughout natural ecosystems. Railways are less aggressive to wildlife than highways through relevant ecosystems (lower traffic, lower rail side disturbance, lower pollution, more economic, etc). See Fischer (2002).

In relevant biomes such as Brazilian Cerrado and Pantanal, traditional roads promote pollution (sonorous, atmospheric, environmental); irregular roadside occupation; environment degradation and fragmentation; border effects on native vegetation; and new environmental features like roadside corridors (secondary vegetation and artificial water ponds) that attracts animals close to the road lanes, increasing animal-vehicle collisions (Fischer 1997; Fischer et al. 2000).

Habitat fragmentation and highway mortality are the most visible impacts produced by roads. Meanwhile, other indirect and invisible effects of roads must strongly concern conservationist policies about terrestrial transportation systems, such as the break of wild animal metapopulation structure. As ecological barriers, roads promote animal population isolation that in turn promotes local extinctions, then regional extinctions, and, finally, general extinctions.

In relevant biomes with a high diversity and density of wild animal populations, wildlife passages under or over roads must be implemented. Riparian and gallery forests in Cerrado areas may be a useful indicator for animal corridors along road landscape (Redford and Fonseca 1986, Naiman et al. 1993). Also, animal movements monitoring may help to determine mitigation efforts (Romin and Bissonette 1996).

Where human and animal corridors intersect, under and overpasses are among the best ways to avoid animal-vehicle collisions. Specific wildlife passages or some adaptations of non-wildlife structures like bridges and culverts, may be used successfully for safe animal crossings on railways and roads (Foster and Humphrey 1995, Rodriguez and Delibes 1996).

Road fauna management is the primary step to guarantee CPEC project viability for protecting animal species, especially those endangered. Serious and ambitious projects like CPEC passes will be successful only to the extent that wildlife mortality on transportation corridors can be drastically reduced. It is urgent and imperative that policies reflect the true value of our fauna and promote their destiny.

## **Recommendations**

- In the case of traditional roads, mitigation efforts must be applied to allow suitable reconnection of ecological corridors, including safe and fauna passages at crossing points.
- Regional study of forest reserves and fauna corridors; characterization and census of local and regional fauna; survey of agricultural production in the neighborhood region; hierarchic definition of vital zones for local fauna — all these investigations must be carried out for establishing road management and mitigation.
- Fauna passages must prioritize areas with continuous natural ecosystems, still preserved or in good condition of conservation;
- Dimension, location and vegetation corridor recovery definitions for fauna passages implementation and a research program for monitoring animal passages, fauna diversity and frequency of use must always be conducted by fauna specialists, principally in tropical areas with high diversity of competitors and prey-predator relationships.
- Permanent environmental education for drivers and permanent control of speed limits and vehicle traffic for human and wildlife safety must be applied along the roads, specially on road spots for fauna.
- Partnerships must be celebrated with local communities, associations of nature protection, NGOs, universities and other research institutions to support and to legitimize all actions.

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In 1998 he started as a coordinator of "Estrada Viva: BR-262," a road and environmental managing plan for South Pantanal roads (BR-262 highway, park roads and secondary roads), by Convenio of Ministry of Transportation, UFMS and NGO "Estrada Viva." In 1999 he became President of the NGO "Estrada Viva." Some projects that Wagner has been involved with include: Road fauna management at Belem road project, Amazon (Belem-PA); Ecological corridor management at Ferronorte Railway in Central Brazil (MS-GO); Road fauna management around Emas National Park, Central Brazil (GO). Consultant in, Management Plans of several Conservation Units (National and State Parks, Biological Reserves, Ecological Station, Environmental Protection Areas) in Brazil at Cerrado (Jalapão and Chapada dos Veadeiros), Caatinga (Seridó) and Atlantic Forest (Guaribas and Saltinho); Environmental studies of several waterways, hydro-electric and termo-electric energy projects in Brazil; and a conservation biology consultant.

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