

Road Mortality of Snakes at the Parque Estadual da Fonte Grande, an Urban Forest of Southeastern Brazil

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ABSTRACT: The Atlantic rainforest harbors a high number of species despite of the dramatic reduction on forested area due to unsustainable-anthropogenic exploitation. A consequence of urbanization enlargement is the increase of road–killed animals. We collected road–killed snakes for two years at the Parque Estadual da Fonte Grande, an urban forest, aiming to assess road effects on the local community of snakes. In total, 25 individuals from 12 species were encountered and are distributed into the families: Boidae (N = 1 species), Colubridae (4 spp.), Dipsadidae (4), Elapidae (1), Leptotyphlopidae (1), and Viperidae (1). Rarefaction curve predicts another 12 snakes for this area. The higher mortality rate of diurnal snakes may have been determined by the apparent higher intensity of diurnal car traffic. We provide some suggestions for reducing the deleterious impact of this road on the local community of snakes.

Key words: Atlantic rainforest; road–killed; reptile; snakes; urban forest.

RESUMO: *Serpentes atropeladas em uma floresta urbana no Sudeste do Brasil.* A Mata Atlântica abriga um elevado número de espécies, embora esse bioma tenha sofrido redução drástica da área florestada devido à insustentável exploração antropogênica. Uma consequência do crescimento da urbanização é o aumento da taxa de atropelamento de fauna. Durante dois anos coletamos serpentes atropeladas no Parque Estadual da Fonte Grande, uma floresta urbana, com o objetivo de avaliar os efeitos da estrada sobre a comunidade de serpentes local. No total, 25 indivíduos de 12 espécies foram encontrados e distribuem-se nas famílias: Boidae (N = 1 espécie); Colubridae (4 spp.), Dipsadidae (4), Elapidae (1), Leptotyphlopidae (1), e Viperidae (1). A curva de rarefação prevê que mais 12 espécies podem ser encontradas nesta área. A alta taxa de

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mortalidade de serpentes diurnas pode ser determinada aparentemente pela maior intensidade de tráfego de veículos durante o dia. Oferecemos algumas sugestões para reduzir o impacto deletério dessa estrada na comunidade de serpentes da região.

Palavras-chave: Mata Atlântica; atropelamento; répteis; serpentes; floresta urbana.

Introduction

Snakes are particularly vulnerable to mortality on roads due to their slow locomotion, propensity to use road surfaces to warm up themselves, and because they are intentionally killed by drivers when encountered on roads (Rudolph *et al.*, 1999). Globally, mortality of fauna along the roads has increased due to car collision (Trombulak & Frissell, 2000). For instance, road mortality was the main cause of population decline of the timber rattlesnake (*Caudisona horrida*) in United States (Rudolph & Burgdorf, 1997).

Road cruising and collecting have been considered a valuable research tool used to study biology, ecology and conservation of snakes (Gibson & Merkle, 2004). In Brazil, however, few studies have taken advantage of this common available–research resource. In southern Brazil, Rosa & Mauhs (2004) and Silva *et al.* (2007) carried out the first assessments of road–killed snakes in Brazil. Moreover, Castro & Teixeira (2007) carried out a similar study, pointing out the situation of road–killed amphibians and reptiles in southeastern Brazil; while Turci & Bernarde (2009) reported road–killed vertebrates in northern Brazil.

This study reports the richness and relative abundance of road-killed snakes at Parque Estadual da Fonte Grande, Southeastern Brazil, aiming to understand the impact of a road on the local snakes community. It also provides suggestions regarding mechanisms that the park administration could adopt to mitigate the road's negative effects.

Material and Methods

Study area

The Parque Estadual da Fonte Grande (PEFG; 20°18'S, 40°20'W) has an area of ca. 216 ha and is located in the municipality of Vitória, state of Espírito Santo (ES), in Southeastern Brazil (Fig. 1). PEFG has a five–meters–wide cobblestone road with two kilometers long, and with no side path. Small

and large vehicles pass along this road; most of them are related to tourism activities, PEFG's employees, and television or cellphone stations' employees.

The PEFG has a rugged topography, forming valleys and mountains, and ranging in altitude from 50 to 308 m above sea level (SEMMAN *et al.*, 1996). It is located in the Atlantic Forest morphoclimatic domain, being classified as Ombrophilous Forest (Ab'Saber, 1977). However, after a long historical process of deforestation, this protected area is mostly composed of secondary forest (*ca.* 30 years of regeneration), exotic vegetation, natural fields, and human-living areas (SEMMAM *et al.*, 1996; Simon *et al.*, 2007). The studied road that crosses PEFG is bordered in most of its extension by secondary forest in advanced regeneration stage.

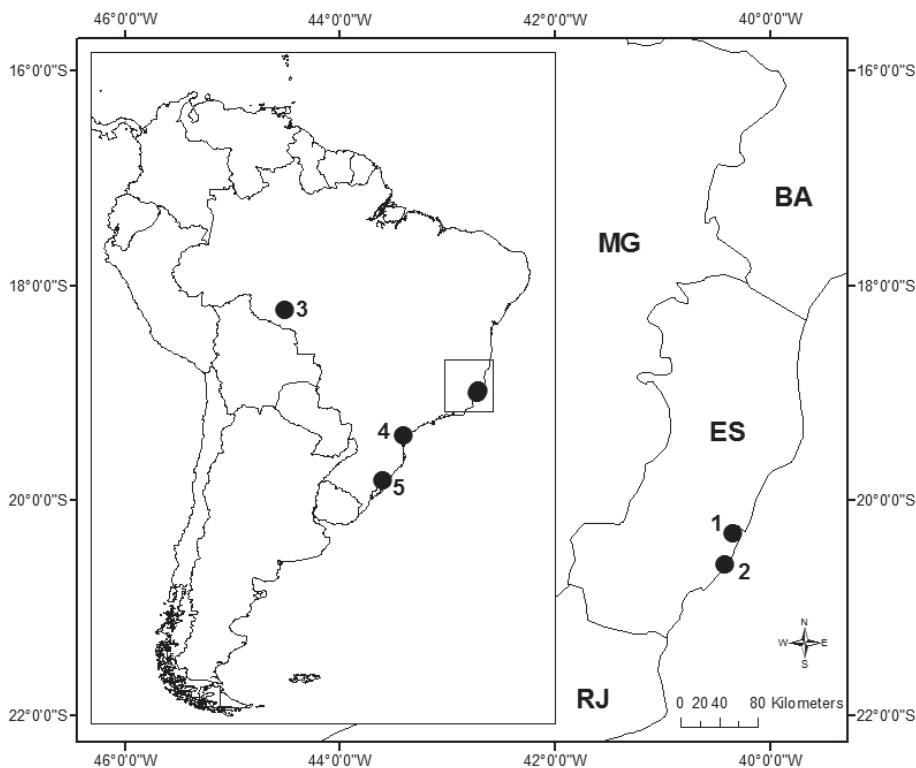


Figure 1. Locations of the studies on road-killed snakes in Brazil: 1) PEFG's road, present study; 2) ES-060 in Castro and Teixeira (2007); 3) RO-383 in Turci and Bernarde (2009); 4) PR-040 in Silva *et al.* (2007); 5) RS-040 in Rosa and Mauhs (2004).

According to Köppen's Climate Classification, the area is categorized as *AW Tropical*, with little rain during winter (June, July, August and, September) and heavy rain during summer (December, January, February and, March). Both seasons are greatly influenced by maritime air currents due to the proximity to Atlantic ocean (SEMMAM *et al.*, 1996). During a 29 years (1976 to 2005) assessment, the Weather Station of Vitória recorded an average annual rainfall of 1,239 mm/year and an annual average temperature of 23.5° C.

Field methods and Data analysis

The Parque Estadual da Fonte Grande's road was monitored daily in its entire length from April 2006 to April 2008. According to Langen *et al.* (2007), surveying methods based on walking are the most effective for collecting small road-killed individuals. Thus, PEEG's employees conducted walking surveys twice a day along the PEEG's road, both at early morning and evening. Dead snakes were collected, fixed in 10% formalin, and kept in plastic containers with 10% formalin for seven days. After this period, they were preserved in 70% ethanol.

Accumulation curve was performed to demonstrate the total number of species observed during the process of data collection. The expected richness was demonstrated by rarefaction curves, using Chao 2 estimator, which have performed well for low samples sizes (Chazdon *et al.*, 1998). These analyses were randomized 1000 times using the software Primer 6.0 (Clarke & Gorley, 2006). Due to the low abundance of snakes, daily samples were grouped by months. Chi-square (X^2) was used to test for differences in seasonal variation and activity time of collected snakes.

Voucher specimens are housed in the Zoology collection of: a) Museu de Biologia Mello Leitão (MBML), Santa Teresa, Espírito Santo; b) Museu de Zoologia João Mojen (MZUFV), Viçosa, Minas Gerais; and c) Museu de Ciências Naturais (MCNR), Belo Horizonte, Minas Gerais (see Appendix 1). Taxonomical terminology follows Bérnills (2012).

Results

A total of 25 road-killed snakes from 12 species were collected at Parque Estadual da Fonte Grande. The species rarefaction curve indicates a high probability of finding additional 12 species with increasing sampling effort (Fig. 2). The collected snakes were distributed among five families and 11 genera. The most common families were Colubridae (N = 4 species) and Dipsadidae (N = 4 species), representing 66.7% of the total species richness. Boidae, Elapidae,

Leptotyphlopidae and Viperidae were each represented by one species (Table 1). Most specimens were heavily damaged by car collision. One carcass could not be identified because of the severe damage. According to the list of reptile species Threatened of Extinction in the state of Espírito Santo (Almeida *et al.*, 2007), all the species recorded in the present study are currently categorized as Not Threatened.

The species *Boa constrictor* had the highest road–mortality rate (N = 5; N% = 20.7). *Oxybelis aeneus*, *Bothropoides jararaca*, and *Micrurus corallinus* had three individuals road-killed each (N% = 12.5 each), followed by *Oxyrhopus petola* and *Pseudoboa nigra* with two individuals each. The remaining species had one road–killed specimen each (Table 1). The semiarboreal snakes (*B. constrictor*, *C. multiventris*, *D. albifrons*, *P. olfersii*, and *B. jararaca*) represented 48.0% of the total capture, while the fossorial (*M. corallinus* and *L.*

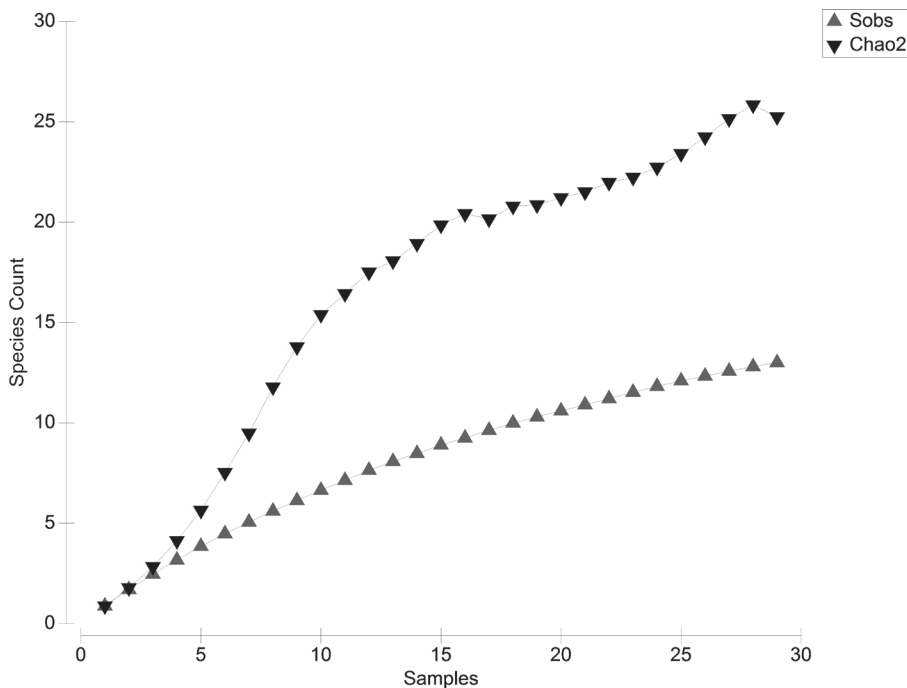


Figure 2. Accumulation curve representing the observed richness (Sobs), and Rarefaction curve estimating richness, generated by the estimators Chao 2 for road–killed snakes at Parque Estadual da Fonte Grande, Vitória, Southeastern Brazil.

salgueiroi) snakes represented 16.7%. *Oxybelis aeneus* was the only strictly arboreal species found and no aquatic species was observed.

By the end of this study, PEFG's staff had not evaluated the road's traffic intensity between the seasons. Seasonal variation on the number of road-killed snakes was not different ($\chi^2 = 0.417$, $df = 1$, $P < 0.5$), although traffic impact was strongly bias to diurnal snakes ($\chi^2 = 0.485$, $df = 1$, $P < 0.05$).

Discussion

In comparison to other studies on road-killed snakes, the Parque Estadual da Fonte Grande has the second highest number of road-killed snakes recorded in Brazil despite of having the shortest road (Table 2). Castro &

Table 1. Road-killed snakes from April 2006 to April 2008 at the Parque Estadual da Fonte Grande, southeastern Brazil. Activity time: D = diurnal, C = crepuscular, and N = nocturnal; Seasons: Winter = W (May to October), and Summer = S (November to April); Habitat: A = arboreal, F = fossorial, T = terrestrial, and SA = semiarboreal (arboreal + terrestrial).

Taxon	Activity time	Seasons				N	N%	Habitat
		1 w	1 s	2 w	2 s			
Family Boidae								
<i>Boa constrictor</i> (Linnaeus, 1758)	D, C, N	4		1		5	21	SA
Family Colubridae								
<i>Chironius exoletus</i> (Linnaeus, 1758)	D				1	1	4.2	SA
<i>Chironius multiventris</i> (Schmidt and Walker, 1943)	D	1				1	4.2	SA
<i>Mastigodryas bifossatus</i> (Raddi, 1820)	D	1				1	4.2	T
<i>Oxybelis aeneus</i> (Wagler, 1824)	D	1		1	1	3	13	SA
Family Dipsadidae								
<i>Dipsas albifrons</i> (Sauvage, 1884)	N			1		1	4.2	SA
<i>Oxyrhopus petola</i> (Linnaeus, 1758)	C, N		2			2	8.3	T
<i>Philodryas offerstii</i> (Lichtenstein, 1823)	D		1			1	4.2	SA
<i>Pseudoboa nigra</i> (Duméril, Bibron and Duméril, 1854)	N				2	2	8.3	T
Family Elapidae								
<i>Micrurus corallinus</i> (Merrem, 1820)	D		2	1		3	13	F
Family Leptotyphlopidae								
<i>Trilepida salgueiroi</i> (Amaral, 1955)	N			1		1	4.2	F
Family Viperidae								
<i>Bothropoides jararaca</i> (Wied, 1824)	C, N	1		1	1	3	13	SA
Unidentified specimen					1	1		
Total individuals (Richness)		8 (5)	5 (3)	6 (6)	6 (5)	25	100	

Teixeira (2007), also in Espírito Santo, reported the highest richness with 19 species. Nevertheless, Castro & Teixeira (2007) conducted a daily sampling study for a longer period (6 years) and in a longer road (67.5 km; in comparison to our study). Rosa & Mauhs (2004) found three species in 52 kilometers of road in the state of Rio Grande do Sul, Silva *et al.* (2007) found eight species in 8 kilometers in the state of Paraná, and Turci & Bernarde (2009) found 10 road-killed snakes in 110 kilometers of the Amazonian biome in the state of Rondônia.

Although the number of individuals found per kilometer was lower than in some other studies, the PEFG’s road is the narrowest one and is likely to have the lowest traffic intensity. The low number of road killing events along PEFG’ road may also be attributed to the activity of necrophagous. These animals could remove the carcasses before they become research data (Silva *et al.*, 2007). All these factors supracited are likely enhanced by the proximity to the forest that favors the presence of animals. Additionally, PEFG’s road is surrounded by forest, which may underestimate the number of dead snakes because some injured animals may die inside the forest, thus not visible for the collectors.

Three individuals of *O. aeneus* were road-killed despite of their arboreal habitat and agile nature. The same number of individuals was recorded to *M. corallinus*. This is a highly fossorial species that occurs in the litter and undergrowth of forested areas. Castro & Teixeira (2007) also reported *O. aeneus* and *M. corallinus* as road-killed snakes in ES. Our study recorded for the first time as road-killed, the fossorial species *Trilepida salgueiroi*. This potential rarity is attributed to the secretive habits of the species (Passos *et al.*, 2005).

Despite of being reported to occur in the municipality of Vitória (Silva-Soares *et al.*, 2011), the aquatic species *Liophis miliaris* was not found killed on this road. In other supracited studies on road-killed animals, *L. miliaris* had the greatest abundance (see Rosa & Mauhs, 2004; Castro & Teixeira, 2007). The absence of this snake in our study could be justified by the scarcity and

Table 2. Comparison among studies on road-killed snakes in Brazil. Km = Total studied traversed extension in kilometers; N = Number of specimens encountered; N / Km = Number of road-killed specimens per kilometers.

Studied site	State	Km	Richness	N	N / Km	Source
RS-040	RS	1,092	3	5	0,004	Rosa and Mauhs (2004)
PR-340	PR	1,044	10	41	0,039	Silva et al. (2007)
RO-383	RO	3,300	10	40	0,012	Turci and Bernarde (2009)
ES-060	ES	no def.	19	317	no def.	Castro and Teixeira (2007)
PEFG	ES	2,920	12	25	0,009	Present study

long distance of ponds or streams from PEFG's road.

Boa constrictor had the highest percentage of death ($N\% = 20.7$), which is a prediction of its high local abundance. *Boa constrictor* and *Bothropoides jaracara* commonly occur in anthropogenic areas (Sazima & Haddad, 1992). Reinert (1993) stated that the abundance of available prey dictates the habitat use by snakes. We found a dead specimen of *B. jaracara* ingesting an urban rodent *Rattus rattus*, and other two individuals were found road-killed with rats in their stomach. Besides the use of the road for thermal regulation, we suggest *B. jaracara* uses the road to prey on urban rodents since it seems to be common therein due to human occupation at PEFG's vicinity.

The statistically similar number of death during different seasons at PEFG's road might apparently be related to constant car traffic throughout the year. It is noteworthy that, during winter, the PEFG hosts field lectures for students of Vitória municipality's schools, which may be balancing the car traffic observed during the summer derived mainly by tourism vehicles (pers. obs.). Therefore, most of the traffic on PEFG's road is diurnal, which consequently explains the significant impact on diurnal and crepuscular snakes. Nevertheless, snakes mortality is not limited to daytime. As we observed, daytime car traffic is made basically by the staff responsible for the operation of radio, cell phone, and TV towers, which are installed on top of the park. Another explanation for the mortality of nocturnal individuals is the unusual behavior of this species group in activity during daytime, as already observed by other authors (Marques & Sazima, 2004).

The present work provides the first species list of snakes for PEFG and also constitutes the first collected specimen/vouchers of some species for Vitória such as *Chironius multiventris*, *C. exoletus*, *Dipsas albifrons*, *Philodryas olfersii*, and *Trilepida salgueiroi*. The municipality of Vitória harbors 27 snake species (Silva-Soares *et al.*, 2011); in this context and considering the rarefaction curve (Fig. 2), the PEFG may harbor almost all snake species listed for this municipality. Inventories of species have extensively been used by ecologists and professionals who are ahead of conservational proposals and decisions (Droege *et al.*, 1998). Our study provides local data that demonstrates the importance of preserving the remnants of PEFG. It is possible that this urban forest is the least natural environment where some species of snakes might be encountered in Vitória.

Although some snakes are intentionally killed on roads, most of them are killed accidentally (Rudolph *et al.*, 1999; Turci & Bernarde, 2009). In accordance, reptile mortality could be reduced by adopting some simple measures, such as (i) warning signs of crossing animals, (ii) speed bumps along the road. We strongly recommend PEFG's administration, and other conserva-

tion agencies, to implement these strategies, which could contribute to reduce road-killed animals.

Several countries have already included ecological principles in environmental transportation policy (Forman & Alexander, 1998). The information gathered here could be used as a starting point for environmental management and conservation programs for the local fauna. Further studies on population dynamics should be carry out on different groups in order to understand the deleterious human effects of road traffic.

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Appendix 1: Snakes from Parque Estadual da Fonte Grande, municipality of Vitória, state of Espírito Santo, Southeastern Brazil. Boidae: *Boa constrictor* MBML 2207, 2210, 2217–19; **Colubridae:** *Chironius exoletus* MCNR 2758; *Chironius multiventris* MCNR 2754; *Mastigodryas bifossatus* MCNR 2755; *Oxybelis aeneus* MBML 2212–14; **Dipsadidae:** *Dipsas albifrons* MZUFV 1575; *Oxyrhopus petola* MCNR 2756, MBML 2211; *Philodryas olfersii* MCNR 2757; *Pseudoboa nigra* MZUFV 1572–73; **Elapidae:** *Micrurus corallinus* MBML 2208–10; **Leptotyphlopidae:** *Trilepida salgueiroi* MZUFV 1574; **Viperidae:** *Bothropoides jararaca* MBML 2206, 2215–16.

References

- AB'SABER, A. N. 1977. Os domínios morfoclimáticos na América do Sul. Primeira aproximação. *Geomorfologia. Instituto Geografia da Universidade de São Paulo*, 52: 1–21.
- ALMEIDA, A. P., GASPARINI, J. L., ABE, A. S., ARGOLO, A. J. S., BAPTISTOTTE, C., FERNADES, R., ROCHA, C. F. D. & VAN-SLUYS, M. 2007. Espécies Ameaçadas de Extinção no Espírito Santo.

- In* Instituto de Pesquisas da Mata Atlântica. *Os Répteis Ameaçados de Extinção no Estado do Espírito Santo*. Vitória, p. 65–74.
- BÉRNILS, R. S. (ORG.). 2012. Brazilian Reptiles – List of Species. Sociedade brasileira de Herpetologia. Disponível em <<http://www.sbherpetologia.org.br>>. Acesso em 20 de julho de 2012.
- CASTRO, T. M. & TEIXEIRA, R. L. 2007. Straßenverkehr als Bedrohung für die Amphibien und Reptilien des Atlantischen Regenwalds in Südost–Brasilien. Eine Fallstudie. *Sauria*, 29(2): 35–42.
- CHAZDON, R. L., COLWELL, R. K., DENSLOW, J. S. & GUARIGUATA, M. R. 1998. Statistical Methods for Estimating Species Richness of Woody Regeneration in Primary and Secondary Rain Forests of NE Costa Rica. *In* F. DALLMEIER & J. A. COMISKEY (eds.). *Forest Biodiversity Research, Monitoring and Modeling: Conceptual Background and Old World Case Studies*. Parthenon Publishing, Paris, p. 285–309.
- CLARKE, K. R. & WARWICK, R. M. 2006. Primer-6 computer program. Plymouth Natural Research Council.
- DROEGE, S., CYR, A. & LARIVÉE, J. 1998. Checklists: an under–used tool for the inventory and monitoring of plants and animals. *Conservation Biology*, 12(5):1134–1138.
- FORMAN, R. T. T. & ALEXANDER, L. E. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics*, 29: 207–231.
- GIBSON, J. D. & MERKLE, D. A. 2004. Road Mortality of Snakes in Central Virginia. *Banisteria*, 24: 8–14.
- LANGEN, T. A., MACHNIAK, A., CROWE, E., MANGAN, C., MARKER, D., LIDDLE N. & RODEN, B. 2007. Methodologies for surveying herpetofauna mortality on rural highways. *Journal of Wildlife Management*, 71: 1361–1368.
- MARQUES, O. A. V. & SAZIMA, I. 2004. História natural dos répteis da Estação Ecológica Juréia–Itatins. *In* O. A. V. Marques & W. Duleba (eds.). *Estação Ecológica Juréia–Itatins: Ambiente físico, flora e fauna*. Holos editora, Ribeirão Preto, 1: 257–277.
- OXLEY, D. J., FENTON, M. B. & CARMODY, G. R. 1974. The effects of roads on populations of small mammals. *Journal Applied Ecology*, 11: 51–59.
- PASSOS, P., CARAMASCHI, U. & PINTO, R. R. 2005. Rediscovery and redescription of *Leptotyphlops salgueiroi* Amaral, 1954 (Squamata, Serpentes, Leptotyphlopidae). *Boletim Museu Nacional do Rio de Janeiro*, 520: 1–10.
- REINERT, H. K. 1993. Habitat selection in snakes. *In* R. A. Seigel & J. T. Collins (ed.). *Snakes: Ecology and Behavior*. McGraw–Hill, 201–240.
- ROSA, A. O. & MAUHS, J. 2004. Atropelamento de animais silvestres na

- rodovia RS-040. *Caderno de Pesquisa Série Biológica de Santa Cruz do Sul*, 16(1): 35–42.
- RUDOLPH, D. C. & BURGDORF, S. J. 1997. Timber Rattlesnakes and Louisiana Pine Snakes of the West Gulf Coastal Plain: Hypotheses of Decline. *Texas Journal Science*, 49(3): 111–122.
- RUDOLPH, D. C., BURGDORF, S. J., CONNER, R. N. & SCHAEFER, R. R. 1999. Preliminary evaluation of the impact of roads and associated vehicular traffic on snake populations in eastern Texas. *In Proceedings of Third International Conference on Wildlife Ecology and Transportation*. Tallahassee, p. 129–136.
- SAZIMA, I. & HADDAD, C. F. B. 1992. Répteis da Serra do Japi: notas sobre história natural. *In* H. F. Leitão-Filho & L. P. C. Morellato (orgs.). *História natural da Serra do Japi – ecologia e preservação de uma área florestal no sudeste do Brasil*. Editora Unicamp, Campinas, 212–236.
- SECRETARIA MUNICIPAL DO MEIO AMBIENTE, INSTITUTO DE DEFESA AGROPECUÁRIA E FLORESTAL AND CEPEMAR ENGENHARIA E MEIO AMBIENTE. 1996. *Plano de Manejo: Parque Estadual da Fonte Grande*. CEPEMAR, Vitória, Espírito Santo, 66 p.
- SILVA-SOARES, T., FERREIRA, R.B., SALLES, R.O.L., ROCHA, C.F.D. 2011. Continental, insular, and coastal marine reptiles from the municipality of Vitória, state of Espírito Santo, southeastern Brazil. *Check List*, 7: 290–298.
- SILVA, M. O., OLIVEIRA, I. S., CARDOSO M. W. & GRAF, V. 2007. Road kills impact over the herpetofauna of Atlantic Forest (PR-340, Antonina, Paraná). *Acta Biologica Paranaense*, 36(1–2): 103–112.
- SIMON, J. E., LIMA, S. R. & CARDINALI, T. 2007. Comunidade de Aves no Parque Estadual da Fonte Grande, Vitória, Espírito Santo, Brasil. *Revista Brasileira de Zoologia*, 24(1): 121–132.
- TROMBULAK, S. C. & FRISSEL, C. A. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology*, 14: 18–30.
- TURCI, L. C. B. & BERNARDE P. S. 2009. Vertebrados atropelados na Rodovia Estadual 383 em Rondônia, Brasil. *Biotemas*, 22(1): 121–127..