

Large and medium-sized mammals in the urban park Cinturão Verde, Cianorte, northwestern Paraná

Thaís de Oliveira Martins¹, Simone Pereira Bunhuolo¹, Henrique Ortêncio Filho¹ and Thomas E. Lacher Jr.^{2*}

1 Grupo de Estudos em Ecologia de Mamíferos e Educação Ambiental (GEEMEA), Universidade Estadual de Maringá, Av. Reitor Zeferino Vaz, s/n, 87360-000, Goioerê, PR, Brazil

2 Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843-2258, United States

* Corresponding author. E-mail: tlacher@tamu.edu

Abstract: We surveyed the composition of large and medium-sized mammals in the urban park Cinturão Verde in the city of Cianorte, Paraná, Brazil. This urban reserve is an important regional corridor for wildlife. Data were collected monthly during seven months for six days with track plots, camera traps, and visual searches for animals and sign. Richness estimates were calculated using Chao 2 and ICE estimators. Nineteen species of mammals in seven orders and 14 families were recorded. Although the area displays a high degree of disturbance, it supports the presence of important species for the fauna of northwestern Paraná, including state, regional and globally threatened species.

Key words: urban wildlife; corridors; fragmentation; species richness; Atlantic Forest

INTRODUCTION

Faunal surveys remain critically important because any project linked to conservation or sustainable use requires a basic knowledge of the species composition and ecology of resident organisms (Scott et al. 1987). The ecological importance and elevated degree of threat of large and medium-sized mammals (Di Marco et al. 2014) make clear the need to include information about this group in inventories and environmental diagnostic studies (Pardini et al. 2003). Terrestrial mammals have a prominent role in the function of Neotropical ecosystems (Terborgh et al. 2001) and are essential to ecosystem processes even in small fragments. Herbivorous and frugivorous species play an important role in maintaining the diversity of forest trees as both seed dispersers and predators of seedlings (Dirzo and Miranda 1990), whereas carnivores regulate populations of herbivores and frugivores (Terborgh 1992; Terborgh et al. 2001). The loss of large and

medium-sized mammals can provoke an entire series of trophic cascades (Estes et al. 2011). The main threats to terrestrial large and medium-sized mammals are habitat destruction, hunting, loss of critical resources and illegal trade (Schipper et al. 2008). Therefore the presence of viable populations of large and medium sized mammals may be excellent indicators of forest health.

There are 701 species mammals described for Brazil and 298 are found in the Atlantic Forest, 30% of them endemic (Paglia et al. 2012). This biome consists of multiple forested ecosystems, including tropical rain forest on the Atlantic slope, mixed Araucaria pine forests in the south, and deciduous and semideciduous forests to the west (Tabarelli et al. 2005). The entire biome has suffered significant deforestation and fragmentation (Ribeiro et al. 2009).

The semideciduous forests of southeastern Brazil, in particular in the state of Paraná, are among the most severely altered of this biome (Di Bitetti et al. 2003). There are few records of studies on mammal inventories in the forested fragments in the northwestern region of Paraná. Urban forest fragments are especially poorly studied; however, in the Atlantic Forest, these fragments may have higher richness and diversity of butterflies than urban parks and can serve as important reservoirs for more disturbance-tolerant species (Rodrigues et al. 1993). Research in temperate regions has shown the persistence of small and mid-body size predators in urban fragments (Crooks, 2002) which can help to maintain important ecosystem processes.

The Cinturão Verde Park in Cianorte, state of Paraná, is an important remnant of semideciduous forest, characterized by the absence of southern conifers and the partial loss of leaves in the dry season (SEMA 2010). In Paraná, this forest occurs in the western, northwestern and northern portions of the state (França and Archela 2008). The present study investigated the

species richness of terrestrial large and medium-sized mammals in the Cinturão Verde Park in Cianorte with intensive sampling to provide data for the conservation and maintenance of the park's natural ecosystems.

MATERIAL AND METHODS

Study site

The Cinturão Verde Park in Cianorte, state of Paraná, southeastern Brazil, is a protected area composed of eight habitat fragments that surround the city of Cianorte, two of which were selected for this study (Figure 1). The park retains important components of regional biodiversity (Baldo and Silveira 2009). The area consists of approximately 312 ha around the coordinates 23°40'S, 052°35'W at 530 m elevation (Cianorte 2010). The park is one of the last regional remnants of typical seasonal submontane semideciduous forest with some influence of the Cerrado biome (Vazzoler et al. 1997). The vegetation has characteristics of modified mature forest in the interior but around the edges of the park there are many areas of highly degraded vegetation. Characteristic plant species in the park reflect a combination of components of the Brazilian Atlantic Forest and vegetation typical of disturbed areas with invasive species. Some typical species include *Aspidosperma polyneuron*, *A. ramiflorum*, *Cedrella* sp., *C. brasiliensis*, *Nectandra puberula*, *Citrus sinensis*, *Tabebuia* sp., *Piper* sp., *Machaerium* sp., *Hymenaea* sp., *Achromia aculeata*, *Solanum* sp., and *Galesia* sp. (Cioffi et al. 1995). The climate is classified as Köppen

Cfa, mesothermal humid subtropical, with hot summers, a concentration of rainfall in the summer months, winters with infrequent frosts, and no marked dry season (Cioffi et al. 1995). Data collection was focused on two modules within the park, the Fantasmilha module which borders Rio Fantasmilha and the Perobas module (Figures 1 and 2). The Perobas module is less disturbed than the Fantasmilha module, however it is bordered and cut by several dirt roads (Figure 2), including one that links the city of São Tomé to Cianorte.

Data collection

In this study we considered as large and medium-sized mammals those weighing over 1 kg as adults, according to the system adopted by Chiarello (2000). To survey mammals and estimate species richness we applied direct methods such as visual encounters and images on camera traps as well as indirect methods via recording tracks (Freitas and Silva 2005; Cullen Jr. et al. 2006; Oliveira et al. 2007; Srbek-Araujo and Chiarello 2007; Borges and Tomás 2008). We also examined specimens from the park deposited during the three years prior to this study in the Laboratory of Zoology, Universidade Paranaense, Campus Cianorte. Data collection for the survey of large and medium-sized mammals was conducted from September to December 2010 and from March to May 2011, with three days of sampling every 15 days, totaling six sample days each month.

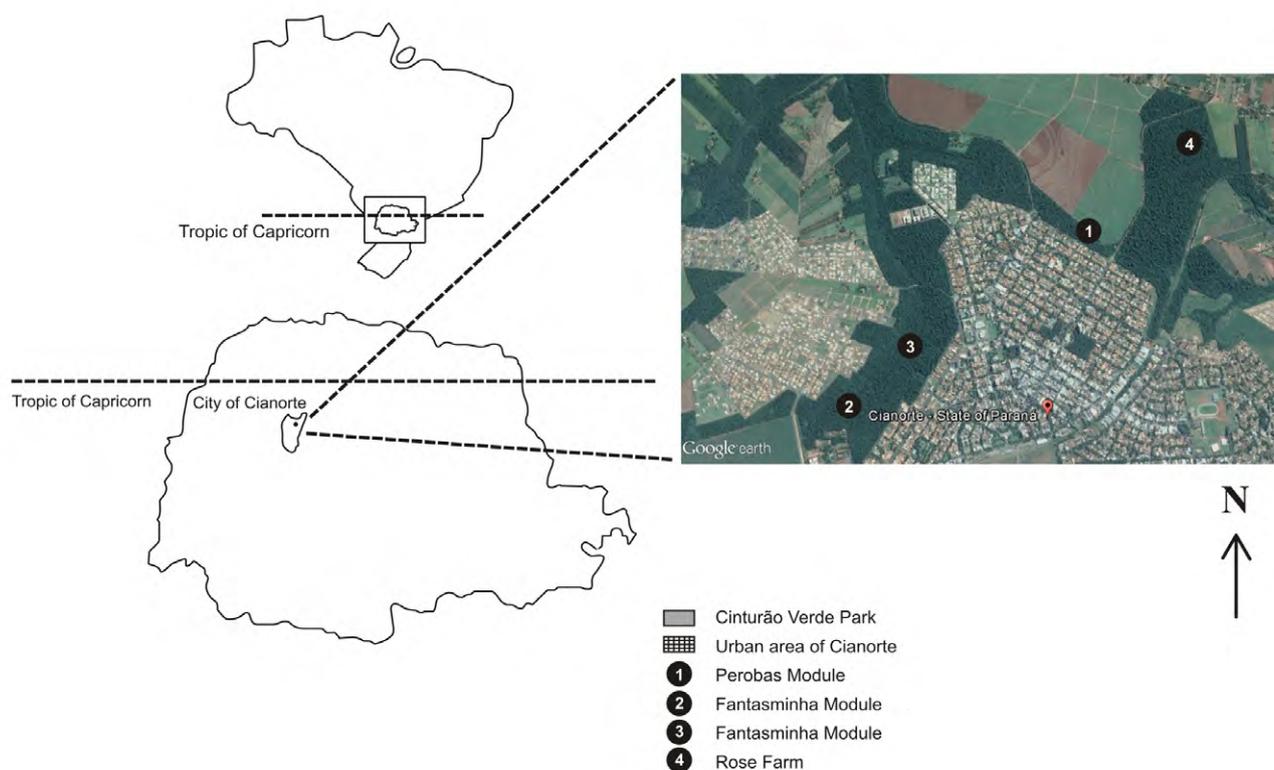


Figure 1. Location of the city of Cianorte in the state of Paraná, with and a satellite image (Google Earth™) of the city of Cianorte, Paraná, Brazil showing the distribution of the units of the Parque Cinturão Verde surrounding the city.

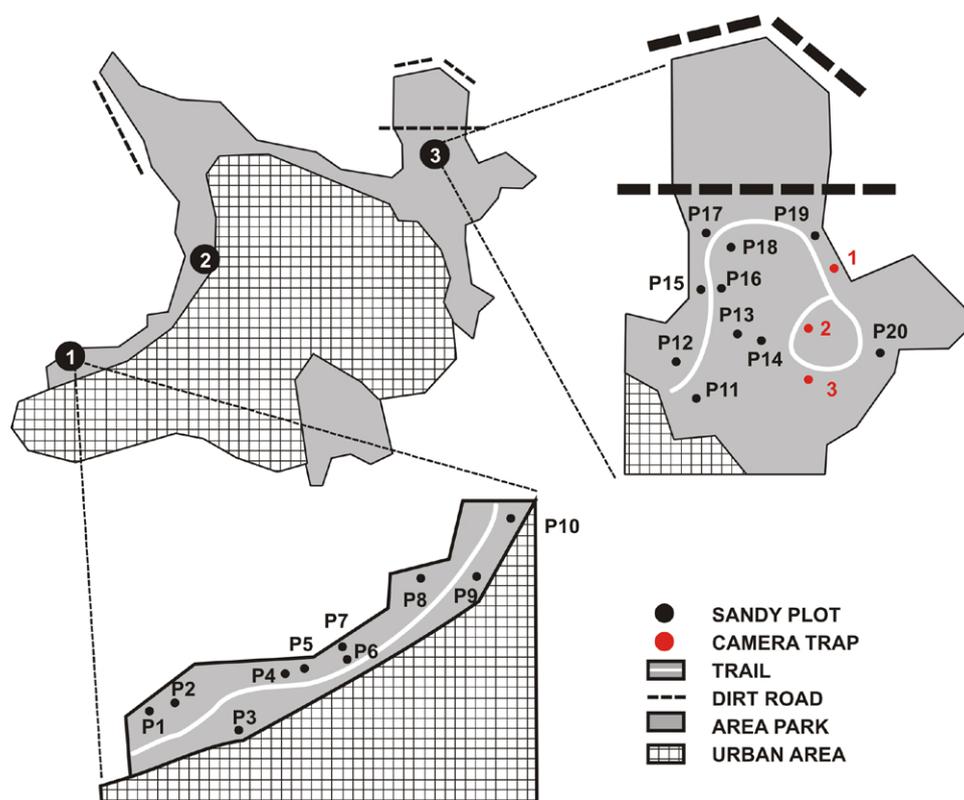


Figure 2. Schematic locations of the collection points, sand traps, and camera traps in the Fantasmilha module and along the Rio Fantasmilha (1), and in the Perobas module (2), both located in the northern sectors of Cinturão Verde Park, Paraná, Brazil. Data were collected between September and December of 2010 and March to May 2011.

Mammal track methods

We established sand plots and sampled the sand banks on the Fantasmilha River and dirt roads within and around the park. We installed 20 sand plots, 10 in the Fantasmilha Module and 10 in the Perobas Module. Each sand plot represented a sample point and was placed approximately 100 m from adjacent plots. All plots were standardized at 60 cm × 60 cm with sand fill 20 cm deep. To prepare the plots, the sand was loosened and moistened with a spray of water. Plots were baited with banana, orange, pineapple and bacon. Sand plots were inspected daily in the morning. Total sample effort was 840 sand plot-nights (20 plots, 6 days/month for 7 months).

Samples on sand banks of the Fantasmilha River and on dirt roads were carried out simultaneously with the sand plots (Rudran et al. 1996; Araújo et al. 2012). We looked for footprints on the river sand banks and the roads during two days each month, totaling 14 days over seven months of sampling.

The tracks were measured with a ruler and photographed. Tracks were identified using field guides (Becker and Dalponte 1991; Oliveira and Cassaro 2006; Borges and Tomás 2008; Carvalho Jr. and Luz 2008; Moro-Rios et al. 2008). Plaster molds of tracks in good condition were prepared for further analysis (Borges and Tomás 2008). Plaster molds were cataloged and deposited in the collection of the Laboratory of Biology,

Study Group in Mammalian Ecology and Environmental Education (GEEMA) from the State University of Maringá, Campus Goioerê.

Camera traps and visual methods

Three Bushnell® camera traps were positioned 300 m apart from each other and 30 cm above ground installed on tree trunks. The equipment was placed only in the Perobas module for security reasons. We baited the camera trapping points (bacon, banana, pineapple and oranges) to lure the animals (Cullen Jr. et al. 2006). Traps were positioned at strategic points, such as near burrows, possible tracks and waterways. Over the study we accumulated 126 camera-days (3 traps × 6 days × 7 months).

The species recorded by the camera traps were easily recognized, however doubts were clarified with the aid of Reis et al. (2011a) and Patrocínio (2009). The photos were also cataloged and deposited in the collection at the Laboratory of Biology, Universidade Paranaense, Campus Cianorte.

Data analysis

Species richness was estimated using program EstimateS version 8.2 (Colwell 2006). Analyses were conducted in classic mode using sampled-based incidence data and the Chao 2 and ICE indices were used for estimation of species richness. We based richness estimates

on eight sampling periods: recently collected specimens followed by the seven additional field sampling periods. Data on frequency of observations by species and sampling method were analyzed using descriptive statistics and represented in percentages. Conservation status was determined globally (IUCN 2015), for Brazil (Chiarello et al. 2008), and for Paraná (Mikich and Bérnils 2004).

RESULTS

We gathered a total of 198 records of 19 species of large and medium-sized native or exotic terrestrial mammals

from seven orders and 14 families (Table 1). Three species were collected in the three years prior to our survey and deposited in the collection at the Laboratory of Biology, Universidade Paranaense, Campus Cianorte (Appendix, Figure A1): *Procyon cancrivorus* (2007), *Leopardus guttulus* (2007), and *Coendou spinosus* (2008). All were killed on roads in or adjacent to the park. Only *C. spinosus* was not recorded during the sampling period. Four other specimens were collected during the study (Appendix, Figure A1): *Eira barbara* (7 November 2010), *Tamandua tetradactyla* (14 December 2010),

Table 1. Medium and large size terrestrial mammals from the Cinturão Verde Park in Cianorte, state of Paraná, southeast of Brazil. Legend – IUCN status: IUCN (2015), Brazil status (Chiarello et al., 2008), Paraná status (Mikich and Bérnils, 2004). Site: Fantasmilha (F), Perobas (P).

Order / family / species	Method of detection	IUCN status	Site
CARNIVORA			
Canidae			
<i>Canis familiaris</i> (Linnaeus, 1758)	All methods	LC (Domestic)	
<i>Cerdocyon thous</i> (Linnaeus, 1766)	Sand, road, camera	LC	P
Felidae			
<i>Leopardus guttulus</i> (Hensel, 1872)	Sand, road, museum (2007)	VU ²	P
<i>Puma yagouaroundi</i> (G. Saint-Hilare, 1803)	Road	LC	P
Mustelidae			
<i>Eira barbara</i> (Linnaeus, 1758)	Sand, river, museum (2010)	LC	P
Procyonidae			
<i>Nasua nasua</i> (Linnaeus, 1766)	Sand, river, camera, visual, museum	LC	F/P
<i>Procyon cancrivorus</i> (Cuvier, 1798)	River, road, museum (2007)	LC	
CINGULATA			
Dasypodidae			
<i>Dasyus novemcinctus</i> (Linnaeus, 1758)	Sand, river, road, camera	LC	F/P
<i>Euphractus sexcinctus</i> (Linnaeus, 1758)	Sand, river, road, visual	LC	P
DIDELPHIMORPHIA			
Didelphidae			
<i>Didelphis albiventris</i> (Lund, 1840)	Sand, river, visual	LC	F
<i>Didelphis aurita</i> (Wied-Neuwied, 1826)	Sand, river, visual	LC	P
LAGOMORPHA			
Leporidae			
<i>Lepus europaeus</i> (Pallas, 1778)	Museum (2011)	LC (Exotic)	
<i>Sylvilagus brasiliensis</i> (Linnaeus, 1758)	Sand, river, visual	LC ³	F/P
PILOSA			
Myrmecophagidae			
<i>Tamandua tetradactyla</i> (Linnaeus, 1758)	Museum (2010)	LC	
PRIMATES			
Cebidae			
<i>Sapajus nigritus</i> (Goldfuss, 1809)	Sand, river, camera, visual, museum	NT ⁴	F/P
RODENTIA			
Caviidae			
<i>Hydrochoerus hydrochaeris</i> (Linnaeus, 1766)	River road	LC	
Cuniculidae			
<i>Cuniculus paca</i> (Linnaeus, 1758)	Sand, river	LC ⁵	P
Dasyproctidae			
<i>Dasyprocta azarae</i> (Lichtenstein, 1823)	Sand, river	DD	P
Erethizontidae			
<i>Coendou spinosus</i> ⁶ (F. Cuvier, 1823)	Museum (2008)	LC	
Echimyidae			
<i>Myocastor coypus</i> (Molina, 1782)	Museum (2011)	LC	

¹ Not included in final calculations of richness estimates.

² As *L. tigrinus*, globally Vulnerable (IUCN 2015) and Vulnerable in Brazil (Chiarello et al. 2008).

³ Vulnerable in the state of Paraná (Mikich and Bérnils 2004).

⁴ Globally Near Threatened (IUCN 2015).

⁵ Endangered in the state of Paraná (Mikich and Bérnils, 2004).

⁶ See Voss et al. 2013.

Lepus europaeus (21 April 2011), and *Myocastor coypus* (10 May 2011). We considered all collected specimens as valid records for the richness estimation. We excluded feral domestic dogs from the richness estimates and from the final species tally. The richest orders were Carnivora (six species, 31.6%) and Rodentia (five species, 26.3%), followed by Cingulata, Lagomorpha, and Didelphimorphia (two species, 10.5% each). Pilosa and Primates were represented by only one species each (5.3%). Richness estimates generated by the Chao 2 method ($n = 26.17$) and the ICE method ($n = 25.56$) were somewhat higher than the observed richness curve for the study area (Figure 3). The observed richness tracked the lower confidence interval closely.

traps obtained a total of 15 records, 7.6% of all records. Cameras documented the occurrence of *S. nigritus* ($n = 4$), *Cerdocyn thous* ($n = 2$), *Dasypus novemcinctus* ($n = 4$) and *N. nasua* ($n = 5$).

DISCUSSION

There are few studies on faunal surveys in northwestern Paraná. Rocha-Mendes et al. (2005) recorded 39 species in three fragments totaling 703 ha in the city of Fênix based only on interviews with local residents. Another survey, using 248 sand plots and yielding 10 species, was conducted during four days in a forest fragment of approximately 382 ha, near the city of Umuarama (Oliveira et al. 2012). According

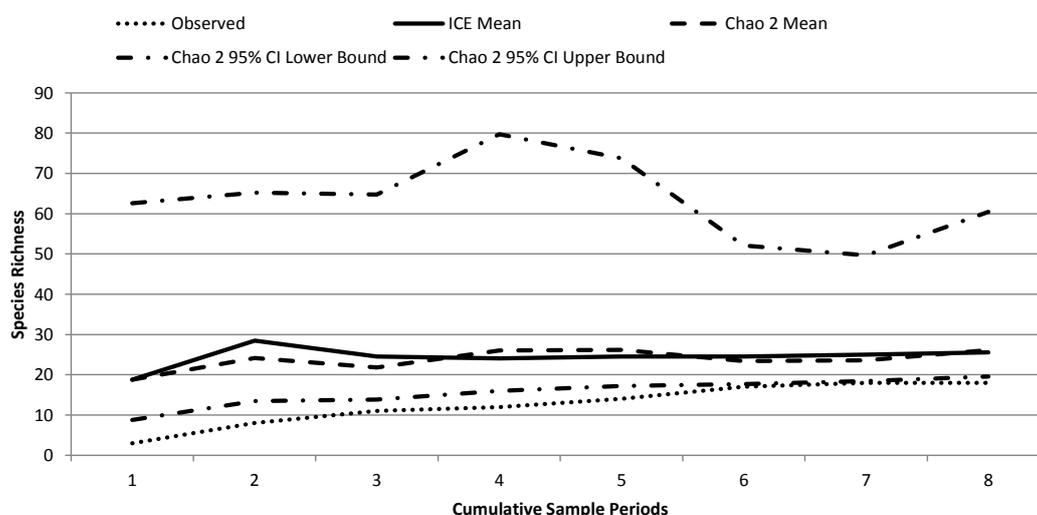


Figure 3. Observed and estimated richness of the large and medium size mammals of the Cinturão Verde Park. Graph presents observed richness against two estimates, ICE and Chao 2. Only the 95% confidence intervals for Chao 2 are shown to minimize clutter.

There were 92 records in all the sand plots representing 46.5% of the total records obtained (Appendix, Figure A2). Of the species identified, the species most frequently recorded were *Didelphis* sp. with 22 occurrences. We recorded tracks of *Leopardus guttulus*, listed as globally vulnerable as *L. tigrinus* (Trigo et al. 2013; IUCN 2015), for which the presence was confirmed by a specimen deposited at the Laboratory of Zoology, Universidade Paranaense, Campus Cianorte, that was collected as roadkill in 2007. Tracks on river sand banks and on the dirt roads accounted for 32.8% of the total records. *Hydrochoerus hydrochaeris* and *Procyon cancrivorus* tracks were observed both along the river and on dirt roads in both modules. *Puma yagouaroundi* was recorded on tracks and on dirt road but only in the Fantasmilha module (Table 2).

We made 16 visual observations representing 8.1% of the total records. Taxa observed most frequently were *Sapajus nigritus* and *Nasua nasua*, observed on both modules and along the river. Two other species sighted were *Sylvilagus brasiliensis* in both modules and *Euphractus sexcinctus* in the Perobas module. The camera

to Rocha-Mendes et al. (2005), the number of species recorded was satisfactory, based upon the sampling effort employed; however, the fragment was in a rural area, much less disturbed than our site. Cinturão Verde Park is located in and around the city of Cianorte, under intense anthropogenic impacts marked by landfills, erosion, sewage, invasive plant species, the presence of domestic animals, and significant edge effects. The more irregular and smaller the fragment, the greater the area of contact with the surrounding matrix of development and associated microclimatic changes (Laurance and Bierregaard 1997), reducing or eliminating sensitive populations of forest species (Hero and Ridgway, 2006).

This makes it all the more surprising that we recorded as many species as we did in our surveys and the richness estimator indicated that the park may support approximately 26 species. The results suggest that the inventory for the park attained 73% of the estimated richness for the area. The 19 species represent 7.6% of total recorded for the Atlantic Forest and 47.5% of the 40 species of large and medium-sized mammals anticipated for the northwestern region of Paraná

Table 2. Number of observations by method of data collection for all species of large and medium-sized mammals recorded in the Cinturão Verde Park in Cianorte, state of Paraná, southeast of Brazil, from September to December 2010 and March to May 2011. Domestic dogs were very abundant everywhere, but their numbers are not included, nor was the roadkill of *Myocastor*. Legend for observations: sand tracks (ST), river tracks (RT), dirt road tracks (DT), camera trap (CT), visual observation (VO), and specimens from collections (MS).

Species	ST	RT	DT	CT	VO	MS	Total
<i>Cerdocoyon thous</i>	2	0	3	2	0	0	7
<i>Coendou spinosus</i>	0	0	0	0	0	1	1
<i>Cuniculus paca</i>	5	3	0	0	0	0	8
<i>Dasyprocta azarae</i>	4	2	0	0	0	0	6
<i>Dasybus novemcinctus</i>	12	7	9	4	0	0	32
<i>Didelphis sp.*</i>	22	6	0	0	2	0	30
<i>Eira barbara</i>	6	3	0	0	0	1	10
<i>Euphractus sexcinctus</i>	2	3	2	0	1	0	8
<i>Hydrochoerus hydrochaeris</i>	0	5	2	0	0	0	7
<i>Leopardus guttulus</i>	2	0	1	0	0	1	4
<i>Lepus europeus</i>	0	0	0	0	0	1	1
<i>Nasua nasua</i>	20	7	0	5	6	2	40
<i>Puma yagouaroundi</i>	0	0	1	0	0	0	1
<i>Procyon cancrivorus</i>	0	3	1	0	0	1	5
<i>Sapajus nigritus</i>	10	5	0	4	5	1	25
<i>Sylvilagus brasiliensis</i>	7	2	0	0	2	0	11
<i>Tamandua tetradactyla</i>	0	0	0	0	0	2	2
Total	92	46	19	15	16	10	198

* The presence of two species was confirmed by visual observation, however they can only be identified to genus by tracks, thus observations are merged.

(Mikich and Oliveira 2003; Instituto Pró-Carnívoros 2011; Reis et al. 2011a). Our study recorded species that had not yet been identified for the area, including one globally threatened species and two threatened at the state level (Table 1).

The Perobas module plots obtained more records than those installed in the Fantasminha module. Perobas is larger and less disturbed; other studies also reveal higher richness in larger and less disturbed Atlantic Forest fragments (Fonseca 1989). There are also several dirt roads that surround and cut through Perobas, but they also connect this fragment with several others and perhaps serve as an “ecological stepping stone” for animals to move between fragments (Reis and Tres 2006). Most species recorded in the Fantasminha module were generalists, indicating that this fragment has a higher degree of degradation. We observed a constant presence of domestic waste and signs of human activity on the trails and in the river, as well as the presence of invasive plant species.

Most commonly recorded species: disturbance-tolerant and invasive species

According to Rossi et al. (2006), two species of opossum, *Didelphis albiventris* and *D. aurita*, occur in the state of Paraná. These species can be distinguished easily by ear pigmentation (Silva 1994) but not by footprints. Therefore, in this study, only the genus is documented

and not species.. The high number of records was expected because marsupials are quite tolerant of human habitation and their tracks and signs can be found in residential areas (Becker and Dalponte 1991). A second abundant species, the diurnal *N. nasua*, was detected by nearly all methods. *Dasybus novemcinctus* also was common, with 12 records in sand traps and 20 additional records via other methods. Although this armadillo is hunted, it remains common and widely distributed in Brazil (Aguar 2004).

Of note is the high number of records of *Canis familiaris* (domestic dog) found in sand plots and camera traps, which were often full of their images. This species can be very destructive by consuming the prey of wild carnivores, transmitting diseases, and hunting and killing many species of wildlife (Negrão and Valladares-Padua 2006).

Most uncommonly recorded species

There were six records of *Eira barbara* prints in the sand traps. There were no previous records of this species in the park. *Hydrochoeris hydrochaeris* is the largest living rodent (Reis et al. 2011a) and its tracks were only observed outside the sand plots, as were *P. cancrivorus* and *P. yagouaroundi*. Of tracks identified outside of the sand plots, most were along the river; this watercourse is the only one within the park, so animals likely use it as a water source. The tracks of small felines are very similar and difficult to identify; however, the record of *P. yagouaroundi* was possible to confirm because the smaller felids occurring in the state of Paraná (excluding *L. pardalis*) are *L. wiedii*, *L. guttulus* and *P. yagouaroundi*. Of these three species *P. yagouaroundi* is most distinctive because the palmar pad has a somewhat triangular ovate shape with three ripples in the heel and the impression of the four fingers is rounded in the form of a semicircle in front of the pad (Moro-Rios et al. 2008).

Species of conservation concern

Leopardus guttulus is the smallest cat species in Brazil, having body proportions similar to the domestic cat (Oliveira and Cassaro 2006). This cat is considered a flagship species that can be used in public relations to rally protection for areas and other animals (Chiarello et al. 2008). *L. guttulus* is also considered an umbrella species (Schonewald-Cox et al. 1991; Roberge and Angelstam 2004) whose conservation can provide protection to a large number of species that naturally occur in the same area (Indrusiak and Eizirik 2003). There might be some question as to the identification of this species; however, there was no other possible match to the tracks other than domestic cats. We discarded the possibility of domestic cats since none were ever seen during the study, either inside or adjacent to the park and never captured in any camera trap images (where many feral domestic dogs were observed). We are also confident in what we

felt was a very careful analysis of the characteristics of the tracks we observed. There is also a 2007 record of a roadkill from the park. This species is threatened due to hunting for their fur, animal trafficking and the loss of habitat (Mikich and Bérnils 2004).

Sylvilagus brasiliensis and *Cuniculus paca*, are listed as vulnerable and endangered, respectively, for the state of Paraná (MMA 2008). The large increase in populations of *L. europaeus*, an introduced species (Reis et al. 2011b), is a major reason for inclusion of *S. brasiliensis* in the vulnerable category. *Cuniculus paca* is threatened and declining due to hunting as a game species and a decrease in the quality and extent of its habitat (Mikich and Bérnils 2004). The only primate observed was (*Sapajus nigritus*), but it was recorded in high numbers with all methods. This species is diurnal (Becker and Dalponte 1991) and has a large population in the park. This primate is listed as globally Near Threatened by the IUCN (2015).

Historical data

We also consulted the collection of specimens deposited at the Laboratory of Zoology, Universidade Paranaense, Campus Cianorte for historical records. Of the 19 taxa identified in this study, three of them (*L. europaeus*, *T. tetradactyla* and *C. spinosus*) were included in the list of species with records in the teaching collection. These animals were roadkilled on the streets and highways surrounding the study area in the three years prior to the study and were collected and archived at the university. Besides these specimens cited, there is a specimen of *Lontra longicaudis* in this collection, but despite many reports of the occurrence of this animal fishing near the Cinturão Verde Park, the record was not considered valid due to an unconfirmed collection locality. It is likely that this species, as well as *Pteronura brasiliensis*, occasionally use nearby locations due to the large populations of fish and ease of hunting in dammed areas of the watershed. Within the conservation area there is only a narrow and shallow waterway so that *L. longicaudis* and *P. brasiliensis* likely rarely traverse the park. The high levels of disturbance and regular human activity also likely explain the absence of *Puma concolor*, *Leopardus pardalis*, *Chrysocyon brachyurus* and other less common larger mammals, which might be found in this region.

These results contribute to the knowledge of the biology of mammals in the northwestern region of Paraná state. The information obtained suggests the need for implementation of improved conservation strategies focusing on the importance of minimizing impacts in the area and eliminating invasive species. Previous research on faunal collapse in forest fragments has shown that a failure to maintain predator populations can result in large population increases of herbivores, resulting in significant plant community impacts (Terborgh et al.

2001; Estes et al. 2011). Recent research has highlighted the equally severe consequences of the depletion of large and medium-sized herbivores (Ripple et al. 2015). The remaining relatively high species richness of large and medium-sized mammals in the region can likely be conserved with improved management of this urban wildlife corridor, which will in turn maintain the ecological processes associated with these forest fragments.

ACKNOWLEDGEMENTS

We thank Paranaense University and the Secretary of Environment of Cianorte for logistical support; Adriano Bunhuolo, Adilson Buschini, Antônio Carlos Franco de Lima, Eliane Oliveira, Elzo Bunhuolo, Ermelindo Bunhuolo, Agnes Bunhuolo, Lily Janke, Matheus Baravieira, Sandra Mara Milani Nishimura and Silvia Regina Ferreira, for their support in collecting the field; Gledson Bianconi for the loan of traps; and Vagner Canuto for his support in data analysis.

LITERATURE CITED

- Aguiar, J.M. 2004. Species summaries and species discussions; pp. 3–26, in: G. Fonseca, J. Aguiar, A. Rylands, A. Paglia, A. Chiarello and W. Sechrest. (orgs.). The 2004 Edentate Species Assessment Workshop. Edentata. Washington, DC: Conservation International.
- Araújo, R.M., M.B. Sousa and C.R. Ruis-Miranda. 2012. Densidade e tamanho populacional de mamíferos cinegéticos em duas Unidades de Conservação do Estado do Rio de Janeiro, Brasil. *Iheringia, Série Zoologia* 98(3): 391–396. doi: [10.1590/S0073-47212012000100001](https://doi.org/10.1590/S0073-47212012000100001)
- Baldo, M.C. and H. Silveira. 2009. A contribuição dos estudos climáticos para o plano de manejo do Parque Municipal Cinturão Verde, Cianorte – PR. Maringá: Universidade Estadual de Maringá. 20 pp.
- Becker, M. and J.C. Dalponte. 1991. Rastros de mamíferos silvestres brasileiros: um guia de campo. Brasília: UnB. 180 pp.
- Borges, P.A.L. and W.M. Tomás. 2008. Guia de rastros e outros vestígios de mamíferos do Pantanal. Corumbá: Embrapa Pantanal. 140 pp.
- Carvalho Jr., O. and N.C. Luz. 2008. Pegadas: série boas práticas. Belém: EDUFPA. 64 pp.
- Chiarello, A. G. 2000. Density and population size of mammals in remnants of Brazilian Atlantic Forest. *Conservation Biology* 14(6):1649–1657. doi: [10.1590/S0073-47212008000300014](https://doi.org/10.1590/S0073-47212008000300014)
- Chiarello, A.G., L.M.S. Aguiar, R. Cerqueira, F.R. Melo, F. H. G. Rodrigues and V.M.F. Silva. 2008. Mamíferos Ameaçados de Extinção no Brasil; pp. 681–874, in: A.B.M. Machado, G.M. Drummond and A.P. Paglia (org.). Livro vermelho da fauna brasileira ameaçada de extinção. Belo Horizonte: Fundação Biodiversitas.
- Cianorte, Secretaria do Meio Ambiente. 2010. Plano de Manejo do Parque Cinturão Verde. Accessed at <http://www.cianorte.pr.gov.br>, 10 April 2011.
- Cioffi, H., I.V. Praxedes, I.A.T. Varella and W.K. Mesquita. 1995. Cianorte: sua história contada pelos pioneiros. Maringá: Gráfica Ideal. 440 pp.
- Colwell, R.K. 2006. EstimateS 8.20: Statistical estimation of species richness and shared species from samples. User's Guide. Accessed at <http://viceroy.eeb.uconn.edu/estimates/>, 1 August 2011.

- Crooks, K.R. 2002. Relative sensitivities of mammalian carnivores to habitat fragmentation. *Conservation Biology* 16(2): 488–502. doi: [10.1046/j.1523-1739.2002.00386.x](https://doi.org/10.1046/j.1523-1739.2002.00386.x)
- Cullen Jr. L., R. Rudran and C. V. Valladares-Padua. 2006. Métodos de estudos em biologia da conservação e manejo da vida silvestre. Curitiba: UFPR. 667pp.
- Di Bitetti, M.S., G. Placi and L.A. Dietz. 2003. Uma visão de biodiversidade para a Ecorregião Florestas do Alto Paraná – Bioma Mata Atlântica: planejando a paisagem de conservação da biodiversidade e estabelecendo prioridades para ações de conservação. Washington, DC: World Wildlife Fund.. 153 pp.
- Di Marco, M., L. Boitani, D. Mallon, M. Hoffmann, A. Iacucci, E. Meijaard, P. Visconyi, J. Schipper and C. Rondinini. 2014. A retrospective evaluation of the global decline of carnivores and ungulates. *Conservation Biology* 28(4): 1109–1118. doi: [10.1111/cobi.12249](https://doi.org/10.1111/cobi.12249)
- Dirzo, R. and A. Miranda. 1990. Contemporary Neotropical defaunation and forest structure, function, and diversity — a sequel to John Terborgh. *Conservation Biology* 4(4): 444–447. doi: [10.1111/j.1523-1739.1990.tb00320.x](https://doi.org/10.1111/j.1523-1739.1990.tb00320.x)
- Estes, J.A., J. Terborgh, J.S. Brashares, M.E. Power, J. Berger, W.J. Bond, S.R. Carpenter, T.E. Essington, R.D. Holt, J.B.C. Jackson, R.J. Marquis, L. Oksanen, T. Oksanen, T.T. Paine, E.K. Pickett, W.J. Ripple, S.A. Sandin, M. Scheffer, T.W. Schoener, J.B. Shurin, A.R.E. Sinclair, M.E. Soulé, R. Virtanen and D.A. Wardle. 2011. Trophic downgrading of Planet Earth. *Science* 333: 301–306. doi: [10.1126/science.1205106](https://doi.org/10.1126/science.1205106)
- Fonseca, G.A.B. 1989. Small mammal species diversity in Brazilian tropical primary and secondary forests of different sizes. *Revista Brasileira de Zoologia* 6(3): 381–422
- Franca, E.T. and R.S. Archela. 2008. Cartografia dos remanescentes florestais do município de Londrina-Pr; pp. 1942–1956, in: Anais do V Seminário Latin-americano / I Seminário Ibero-americano de Geografia Física. Santa Maria, RS: Igne Inteligência Digital.
- Freitas, M.A. and T.F.S. Silva. 2005. Guia ilustrado – Mamíferos na Bahia: espécies continentais. Pelotas: USEB. 132 pp.
- Hero, J.M. and T. Ridgway. 2006. Declínio global de espécies, pp. 53–90, in: C.F.D., Rocha, H.G. Bergallo, M.V. Sluys and M.A.S. Alves. *Biologia da conservação: essências*. São Carlos: RiMA.
- Indrusiak, C. and E. Eizirik. 2003. Carnívoros, pp. 507–533, in: G.A. Fontana and R.E. Reis (org.). *Livro Vermelho da Fauna Ameaçada de Extinção no RS*. Porto Alegre: EDIPUCRS.
- Instituto Pró-Carnívoros. 2011. Carnívoros. Accessed at <http://www.procarnivoros.org.br>, 24 May 2011.
- IUCN (International Union for the Conservation of Nature). 2015. The IUCN Red List of threatened species. Version 2015.2. Accessed at <http://www.iucnredlist.org>, 2 July 2015.
- Laurance, W.E. and R.O. Bierregaard Jr. 1997. Tropical forest remnants: ecology, managements, and conservation of fragmented communities. Chicago: University of Chicago Press. 632 pp.
- Mikich, S. B. and K.L. Oliveira. 2003. Revisão do Plano de Manejo do Parque Estadual de Vila Rica, Fênix – PR. Curitiba: Mater Natura and Ministério do Meio Ambiente. 452 pp.
- Mikich, S.B. and R.S. Bérnils. 2004. Livro vermelho da fauna ameaçada no Estado do Paraná. Curitiba: Instituto Ambiental do Paraná and Mater Natura. 765 pp.
- MMA (Ministério do Meio Ambiente). 2008. Livro vermelho da fauna brasileira ameaçada de extinção. Brasília: MMA. 1420 pp.
- Moro-Rios, R.F., J.E. Silva-Pereira, P.W. Silva, M. Moura-Brito and D.N.M. Patrocínio (eds.). 2008. Manual de rastros da fauna paranaense. Curitiba: Instituto Ambiental do Paraná. 70 pp.
- Negrão, M. F. F. and C. Valladares-Pádua. 2006. Registros de mamíferos de maior porte na Reserva Florestal do Morro Grande, São Paulo. *Biota Neotropica* 6(2): 1–13. doi: [10.1590/S1676-06032006000200006](https://doi.org/10.1590/S1676-06032006000200006)
- Oliveira, G., M. Passipieri, A.L. Altimare and L.G.T. Feba. 2007. Eficiência das armadilhas dos tipos Tomahawk e Pitfall na captura de pequenos mamíferos. Caxambu: VIII Congresso de Zoologia. 2 pp.
- Oliveira, L.P., D. Aguiar, T.C.C. Margarido and J.R. Pachaly. 2012. Caracterização faunística de mamíferos de médio e grande porte de um fragmento florestal do noroeste de médio e grande porte de um fragmento florestal do noroeste do estado do Paraná, Brasil. *Arquivos de Ciências Veterinárias e Zoologia da UNIPAR* 15(2): 109–114. <http://revistas.unipar.br/veterinaria/article/viewFile/4212/2621>
- Oliveira, T.G. and K. Cassaro. 2006. Guia de campo dos felinos do Brasil. São Paulo: Instituto Pró-Carnívoros, Fundação Parque Zoológico de São Paulo, Sociedade de Zoológicos do Brasil and Pró-Vidas Brasil. 80 pp.
- Paglia, A.P., G.A.B. da Fonseca, A.B. Rylands, G. Herrmann, L.M.S. Aguiar, A.G. Chiarello, Y.L.R. Leite, L.P. Costa, S. Siciliano, M.C.M. Kierulff, S.L. Mendes, V. da C. Tavares, R.A. Mittermeier and J.L. Patton. 2012. Lista anotada dos mamíferos do Brasil / Annotated checklist of Brazilian mammals. 2ª Edição / 2nd Edition. *Occasional Papers in Conservation Biology (Conservation International)* 6: 76 pp.
- Pardini, R., E.H. Ditt, L. Cullen Jr., C. Bassi and R. Rudran. 2003. Levantamento rápido de mamíferos terrestres de médio e grande porte; pp. 181–201, in: L. Cullen Jr., R. Rudran and C. Valladares-Padua (org.). Métodos de estudos em biologia da conservação e manejo da vida silvestre. Curitiba: Universidade Federal do Paraná.
- Patrocínio, D.N.M. 2009. Bichos do Paraná. Curitiba: Instituto Ambiental do Paraná. 243 pp.
- Reis, A. and D.R. Tres. 2006. Novos Aspectos de Restauração de Áreas Degradadas. PET Biologia: Universidade Federal de Santa Catarina. 106 pp.
- Reis, N., A. L. Perachi, W.A. Pedro and I.P. Lima. 2011a. Mamíferos do Brasil. Londrina. 439 pp.
- Reis, N., H. Ortêncio Filho and G. Silveira. 2011b. Ordem Lagomorpha; pp. 151–154, in: N. Reis, A.L. Perachi, W.A. Pedro and I.P. Lima (eds.). Mamíferos do Brasil. Londrina: Universidade Estadual de Londrina.
- Ribeiro, M.C., J.P. Metzger, A.C. Martensen, F.J. Ponzoni and M.M. Hirota. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation* 142(6): 1141–1153. doi: [10.1016/j.biocon.2009.02.021](https://doi.org/10.1016/j.biocon.2009.02.021)
- Ripple, W. J., T. M. Newsome, C. Wolf, R. Dirzo, K. T. Everatt, M. Galetti, M.W. Hayward, G.I.H. Kerley, T. Levi, P.A. Lindsey, D.W. Macdonald, Y. Malhi, L.E. Painter, C.J. Sandom, J. Terborgh, and B. Van Valkenburgh. 2015. Collapse of the world's largest herbivores. *Science Advances* 1: e1400103. doi: [10.1126/sciadv.1400103](https://doi.org/10.1126/sciadv.1400103)
- Roberge, J. and P. Angelstam. 2004. Usefulness of the umbrella species concept as a conservation tool. *Conservation Biology* 18(1): 76–85. doi: [10.1111/j.1523-1739.2004.00450.x](https://doi.org/10.1111/j.1523-1739.2004.00450.x)
- Rocha-Mendes, F, S.B. Mikichi, G.V. Bianconi and W.A. Pedro. 2005. Mamíferos do município de Fênix, Paraná, Brasil: etnozoologia e conservação. *Revista Brasileira de Zoologia* 22(4): 991–1002. <http://ojs.c3sl.ufpr.br/ojs/index.php/zoo/article/viewFile/6923/4915>.
- Rodrigues, J.J.S., K.S. Brown, Jr. and A. Ruzsycyk. 1993. Resources and conservation of Neotropical butterflies in urban forest fragments. *Biological Conservation* 64(1):3–9.
- Rossi, R.V., G.V. Bianconi and W.A. Pedro. 2006. Ordem Didelphimorphia; pp. 27–66, in: N.R. Reis, A.L. Perachi, W.A. Pedro and I.P. Lima (eds.). Mamíferos do Brasil. Londrina: Universidade Estadual de Londrina.
- Rudran, R., T.H. Kunz, C. Southwell, P. Jarman and A.P. Smith. 1996. Observational techniques for nonvolant mammals; pp. 81–104, in: Wilson, D.E., R. Cole, J.D. Nickols, R. Rudran and M.S. Foster

- (eds.). Biological diversity handbook series: measuring and monitoring biological diversity: Standard methods for mammals. Washington, DC: Smithsonian Institution Press.
- Schipper, J., J.S. Chanson, F. Chiozza, N.A. Cox, M. Hoffmann, V. Katariya, J. Lamoreux, A.S.L. Rodrigues, S.N. Stuart, H.J. Temple, J. Baillie, L. Boitani, T.E. Lacher Jr., R.A. Mittermeier, A.T. Smith, D. Absolon, J.M. Aguiar, G. Amori, N. Bakkour, R. Baldi, R.J. Berridge, J. Bielby, P.A. Black, J.J. Blanc, T.M. Brooks, J.A. Burton, T.M. Butynski, G. Catullo, R. Chapman, Z. Cokeliss, B. Collen, J. Conroy, J.G. Cooke, G.A.B. Fonseca, A.E. Derocher, H.T. Dublin, J.W. Duckworth, L. Emmons, R.H. Emslie, M. Festa-Bianchet, M. Foster, S. Foster, D.L. Garshelis, C. Gates, M. Gimenez-Dixon, S. Gonzalez, J.F. Gonzalez-Maya, T.C. Good, G. Hammerson, P.S. Hammond, D. Happold, M. Happold, J. Hare, R.B. Harris, C.E. Hawkins, M. Hayward, L.R. Heaney, S. Hedges, K.M. Helgen, C. Hilton-Taylor, S.A. Hussain, N. Ishii, T.A. Jefferson, R.K.B. Jenkins, C.H. Johnston, M. Keith, J. Kingdon, D.H. Knox, K.M. Kovacs, P. Langhammer, K. Leus, R. Lewison, G. Lichtenstein, L.F. Lowry, Z. Macavoy, G.M. Mace, D.P. Mallon, M. Masi, M.W. McKnight, R.A. Medellín, P. Medici, G. Mills, P.D. Moehlman, S. Molur, A. Mora, K. Nowell, J.F. Oates, W. Olech, W.R.L. Oliver, M. Oprea, B.D. Patterson, W.F. Perrin, B.A. Polidoro, C. Pollock, A. Powel, Y. Protas, P. Racey, J. Ragle, P. Ramani, G. Rathbun, R.R. Reeves, S.B. Reilly, J.E. Reynolds, C. Rondinini, R.G. Rosell-Ambal, M. Rulli, A.B. Rylands, S. Savini, C.J. Schank, W. Sechrest, C. Self-Sullivan, A. Shoemaker, C. Sillero-Zubiri, N. Silva, D.E. Smith, C. Srinivasulu, P.J. Stephenson, N. Van Strien, B.K. Talukdar, B.L. Taylor, R. Timmins, D.G. Tirira, M.F. Tognelli, K. Tsytulina, L.M. Veiga, J.C. Vié, E.A. Williamson, S.A. Wyatt, Y. Xie and B.E. Young. 2008. The status of the world's land and marine mammals: diversity, threat, and knowledge. *Science* 322: 225–230. doi: [10.1126/science.1165115](https://doi.org/10.1126/science.1165115)
- Schonewald-Cox, C., R. Azari and S. Blume. 1991. Scale, variable density, and conservation planning for mammalian carnivores. *Conservation Biology* 5(4): 491–495. doi: [10.1111/j.1523-1739.1991.tb00356.x](https://doi.org/10.1111/j.1523-1739.1991.tb00356.x)
- Scott, J.M., B. Csuti, J.D. Jacobi and J.E. Estes. 1987. Species richness — a geographical approach to protecting future biological diversity. *BioScience* 37 (11): 782–788. [http://www.jstor.org/stable/1310544](https://www.jstor.org/stable/1310544)
- SEMA (Secretaria do Meio Ambiente). 2010. Série Ecossistemas Paranaenses: Floresta Estacional Semidecidual. Curitiba: Instituto Ambiental do Paraná. 14 pp.
- Silva, F. 1994. Mamíferos silvestres: Rio Grande do Sul. Porto Alegre: Fundação Zoobotânica do Rio Grande do Sul. 246 pp.
- Srbek-Araujo, A. C. and A.G. Chiarello. 2007. Armadilhas fotográficas na amostragem de mamíferos: considerações e metodológicas e comparação de equipamentos. *Revista Brasileira de Zoologia* 24(3): 647–656. doi: [10.1590/S0101-81752007000300016](https://doi.org/10.1590/S0101-81752007000300016)
- Tabarelli, M., L.P. Pinto, J.M.C. Silva, M. Hirota and L. Bede. 2005. Challenges and opportunities for biodiversity conservation in the Brazilian Atlantic Forest. *Conservation Biology* 19(3): 695–700. http://tropicalconservationscience.mongabay.com/content/v4/11-09-25_267-275_Bernard_et_al.pdf
- Terborgh, J. 1992. Maintenance of diversity in tropical forests. *Biotropica* 24 (2): 283–292. <http://www.jstor.org/stable/2388523>
- Terborgh, J., L. Lopez, P. V. Nuñez, M. Rao, G. Shahabuddin, G. Orihuela, M. Riveros, R. Ascanio, G.H. Adler, T.D. Lambert and L. Balbas. 2001. Ecological meltdown in predator-free forest fragments. *Science* 294 (5548): 1923–1926. doi: [10.1126/science.1064397](https://doi.org/10.1126/science.1064397)
- Trigo, T.C., A. Schneider, T.G. de Oliveira, L.M. Lehuguer, L. Silveira, T.R.O. Freitas and E. Eizirik. 2013. Molecular data reveal complex hybridization and a cryptic species of Neotropical wild cat. *Current Biology* 23(24): 2528–2533. doi: [10.1016/j.cub.2013.10.046](https://doi.org/10.1016/j.cub.2013.10.046)
- Vazzoler, A.E.A.M., A.A. Agostinho and N.S. Hahn (eds.). 1997. A planície de inundação do alto rio Paraná: aspectos físicos, biológicos e socioeconômicos. Maringá: EDUEM and Nupélia. 460 pp.
- Voss, R.S., C. Hubbard and S.A. Jansa. 2013. Phylogenetic relationships of New World porcupines (Rodentia, Erithizontidae): Implications for taxonomy, morphological evolution and biogeography. *American Museum Novitates* 3769: 1–36. <http://hdl.handle.net/2246/6417>

Author contributions: TOM, SPB and HOF conducted the field work and data collection. HOF collated the data and ran the richness estimators. TEL assisted in data collection and organization and literature review, and TEL and HOF wrote the manuscript.

Received: 3 October 2014

Accepted: 2 February 2016

Academic editor: Maria Luisa Jorge

APPENDIX



Figure A1. Images of species collected as road kill within the borders of the Parque Cinturão Verde in Cianorte. **A:** *Procyon cancrivorus*. **B:** *Myocastor coypus*. **C:** *Leopardus guttulus*. **D:** *Tamandua tetradactyla*. **E:** *Coendou spinosus*. **F:** *Lepus europaeus*

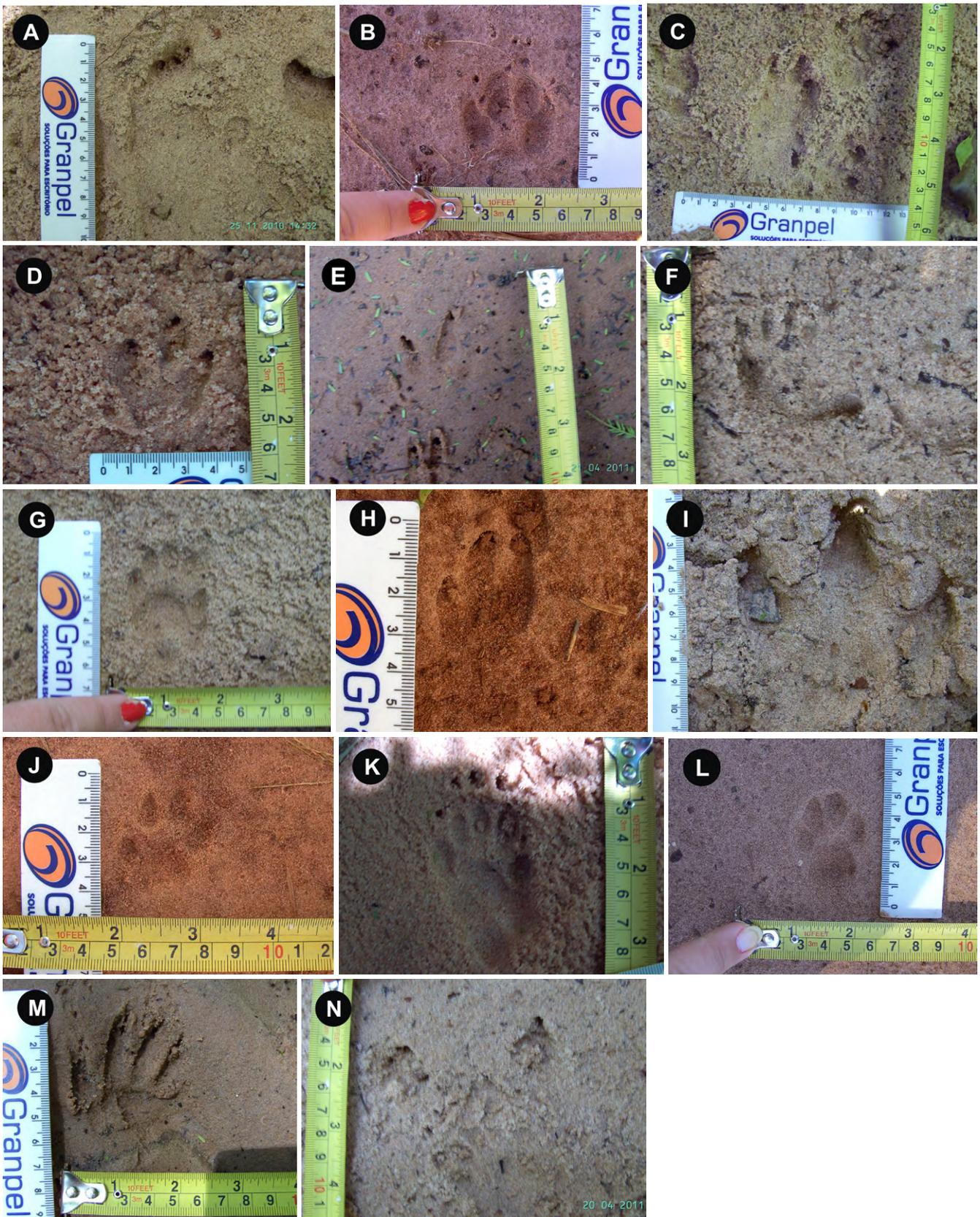


Figure A2. Tracks in sand plots. **A:** *Cebus nigritus*. **B:** *Cerdocyon thous*. **C:** *Cuniculus paca*. **D:** *Dasyprocta azarae*. **E:** *Dasybus novemcinctus*. **F:** *Didelphis* sp. **G:** *Eira barbara*. **H:** *Euphractus sexcinctus*. **I:** *Hydrochoerus hydrochaeris*. **J:** *Leopardus guttulus*. **K:** *Nasua nasua*. **L:** *Puma yagouaroundi*. **M:** *Procyon cancrivorus*. **N:** *Sylvilagus brasiliensis*.