

Medium and large-sized mammals of an isolated Atlantic Forest remnant, southeast São Paulo State, Brazil

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ABSTRACT: The Area of Ecological Interest “Matão de Cosmópolis” is one of the few forest remnants larger than 100 hectares in the metropolitan region of Campinas, São Paulo State, Brazil. Medium and large-sized mammals were surveyed in this forest remnant using natural signs and active search between September 2008 and April 2009. Eighteen species belonging to seven different orders were recorded. Seven species of Order Carnivora were identified, two of which are listed as endangered in São Paulo State (*Leopardus pardalis* and *Puma concolor*). *Cerdocyon thous*, *Sapajus nigritus* and *Canis familiaris* had the highest frequency of occurrence. Results show the importance of AEIMC in regional context for mammal conservation. However, immediate actions for its conservation are required due to anthropogenic activities in the area.

DOI: 10.15560/10.4.850

INTRODUCTION

Mammals are one of the groups most affected by habitat fragmentation and reduction (Chiarello 1999; Michalski and Peres 2005; Galetti *et al.* 2009; Dotta and Verdade 2011), especially by modifications in landscape matrix, which act as a selective filter for fauna (Ceballos and Ehrlich 2002; Fahrig 2003). Adaptation to modified environments determines species survival or extinction (Gascon *et al.* 1999; Pardini *et al.* 2009; Prevedello and Vieira 2010) and their population trends (Michalski and Peres 2007).

Forest remnant size affects abundance and diversity of mammal species (August 1983) depending on the amount of available resources and habitat (Robinson and Redford 1986). Therefore, mammal communities in small forest patches are simplified, mainly due to the absence of sensitive species (Silva Jr. and Mendes-Pontes 2008).

In the countryside of São Paulo State, remnants of Atlantic Forest are mostly small, with little or no connectivity, and inserted in agricultural matrices (Ribeiro *et al.* 2009). Scarcity of information on mammals' occurrence and distribution in some regions of São Paulo State (Vivo *et al.* 2011) justify the need to obtain information about species inhabiting fragmented and agricultural areas of this biome (Pardini *et al.* 2003). Thus, this study aims to provide information on mammalian fauna in a highly modified and fragmented region of the Atlantic Forest biome, dominated by sugarcane crops and strong human interference.

MATERIALS AND METHODS

Study site

The study was carried out in Area of Ecological Interest “Matão de Cosmópolis” (AEIMC), which was the first Conservation Unit (CU) classified as Area of Ecological

Interest established in Brazil under decree n. 90,791 from 9 January 1985. This forest remnant is located between Cosmópolis and Artur Nogueira municipalities (22°36'30" S, 47°08'05" W) in the metropolitan region of Campinas (MRC), São Paulo State, Brazil (Figure 1). The area was created to protect local biota and covers 173.05 ha with predominant semideciduous forest vegetation (IBGE 2004b), in a transition area between the Atlantic Forest and Cerrado biomes (IBGE 2004a).

Landscape matrix is mainly composed by sugarcane crops, a predominant mosaic in southeastern Brazil (Silva and Tabarelli 2000). The MRC has approximately 10% of its area covered with native forests, divided into almost 35,000 forest fragments. Only 19 forest fragments have more than 100 ha extension (Matias *et al.* 2012), including AEIMC.

Mammals' survey

Survey was conducted between September 2008 and April 2009, using active search method (Voss and Emmons 1996), which consisted of walking at an average speed of 1 km/h, on trails and dirt roads, searching for direct (*e.g.*, sightings, vocalizations) and indirect (*e.g.*, footprints, burrows, feces) evidence of mammalian activity. Surveys were weekly, starting at 8:00 h and lasting for 4–6 hours, depending on the number of records. Mammals weighting over 1 kg were considered medium-sized (Chiarello 2000a). Although we have been able to identify small-sized species, these were used only for local species list, not for analysis. Voss (2011) and Paglia *et al.* (2012) were used for species nomenclature.

All registered footprints were carefully measured and photographed, and in some cases we made quick-drying plaster molds for subsequent comparisons. Footprints measures and photographs were compared with material

from specialized bibliography (Becker and Dalponte 1999; Borges and Tomás 2008). Records of footprints and sightings for each species were considered as a single record for each sampling day. Caves, feces, food leftovers and other natural signs were considered only to indicate mammalian activity, and identified using specialized literature (Emmons and Feer 1997; Chame 2003; Borges and Tomás 2008).

Data Analysis

For data analysis species richness was estimated (1st order Jackknife and Bootstrap), species' frequency of occurrence, which consisted in dividing the number of individual records (footprints and sightings per day) by the total number of records, and species diversity (Shannon-Wiener diversity index). All analyses were carried out in R 3.1.0 (R Core Team 2014). Extinction threat degree for species was determined according to Machado *et al.* (2008) and Percequillo and Kierulff (2009).

RESULTS AND DISCUSSION

In 32 days of field work, we covered 192 km, and recorded 21 mammal species, 18 of medium- and large-sized native, one small-sized and two exotic (Table 1, Figure 2), resulting in 207 records of footprints and sightings. Species recorded represent 40% of medium- and large-sized mammal species in whole São Paulo State (Vivo *et al.* 2011). Carnivores were the most representative Order in the study area (seven species). We did not record *Dasyprocta* sp., *Nasua nasua* or *Lontra longicaudis*, which

are usually found in Atlantic Forest remnants (Modesto *et al.* 2008; Dotta and Verdade 2011; Penido and Zanzini 2012). Nor did we record *Chrysocyon brachyurus* or *Conepatus semistriatus*, which are common species in Cerrado remnants (Rocha and Dalponte 2006; Lessa *et al.* 2012).

Rodrigues (2009) reported the occurrence of *C. brachyurus* and *L. longicaudis* in “Mata da Meia Lua”, a forest remnant adjacent to AIEMC (8 km in a straight line). In “Horto de Tupi”, Piracicaba, São Paulo State, near the study site, Saciloto (2009) registered the occurrence of *Dasyprocta azarae*, *C. semistriatus* and *N. nasua*.

Most species recorded at AIEMC were present in other Atlantic Forest remnants with similar structure and landscape configuration found in study area (Figure 3), which reinforces the hypothesis of those species being habitat and diet generalists. When compared to surveys carried out in larger and preserved areas, AIEMC lacks more sensitive species such as *Tapirus terrestris*, *Tayassu peccari* and *Panthera onca*. Tapir and white-lipped peccary can be considered extinct in MRC due to hunting pressure (Cullen Jr. *et al.* 2000; Peres 2001), and jaguar due to retaliation for livestock predation (Palmeira *et al.* 2008). Despite the lower sampling effort in this study compared to other inventories, results showed high species richness (Figure 3).

It was not possible to differentiate small felids (*Leopardus tigrinus*, *Leopardus wiedii* and *Puma yagouaroundi*) and species of *Mazama* genus (*Mazama americana* and *Mazama gouazoubira*) by footprint

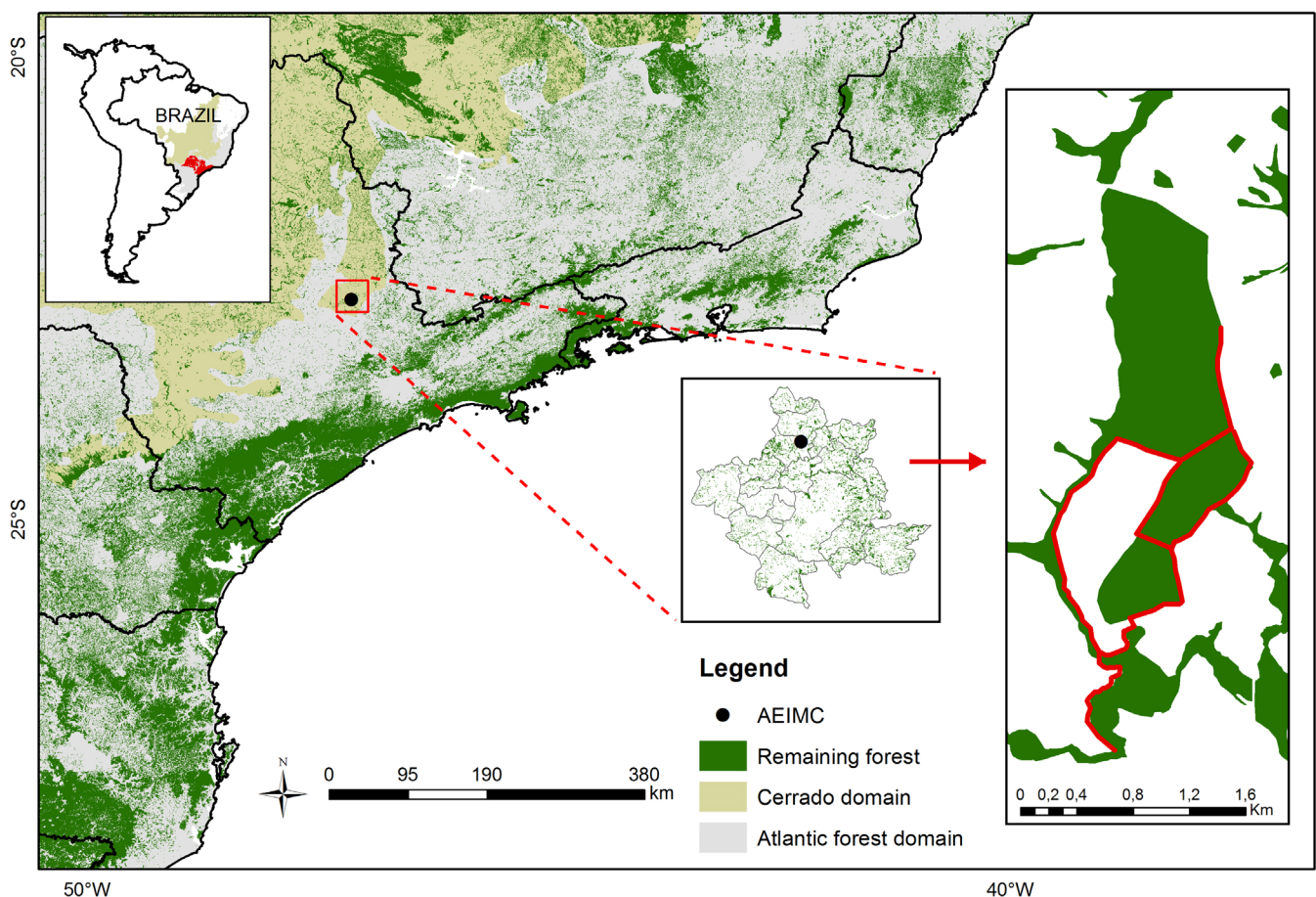


FIGURE 1. Location of AIEMC, São Paulo State, Brazil. Red lines indicate the paths traversed during sampling.

identification. However, *L. tigrinus* and *P. yagouaroundi* were registered in Area of Ecological Interest “Mata de Santa Genebra”, Campinas, São Paulo State (MMA 2010); in “Mata da Meia Lua”, *L. tigrinus* was recorded by camera trapping (Rodrigues 2009); and a *L. wiedii* individual was found bowled over in a secondary road between Cosmópolis and Limeira municipalities (Magioli, M., pers. obs.). According to distribution of *M. americana* and *M. gouazoubira*, both species could occur in AIEMC. However, *M. americana* has essentially forest habits and anthropogenic influence has reduced its populations and

distribution in southeastern Brazil, while *M. gouazoubira* is more tolerant to modified and agricultural areas (Duarte and Reis 2012).

We observed a slight levelling-off in species accumulation curve (Figure 4). Richness estimators 1st order Jackknife and Bootstrap, suggest 22 and 20 species respectively, i.e., 20% and 10% greater than samples recorded. Combining use of sampling methods could have contributed to the record of other species, as suggested by richness estimators. However, the region lacks security to use camera trapping, because cameras are constantly



FIGURE 2. Photographic records of mammals' footprints. A) *Didelphis albiventris*; B) *Dasybus novemcinctus*; C) *Dasybus septemcinctus*; D) *Euphractus sexcinctus*; E) *Cabassous tatouay*; F) *Sapajus nigritus*; G) *Lepus europaeus*; H) *Silvylagus brasiliensis*; I) *Leopardus pardalis*; J) *Leopardus* sp.; K) *Puma concolor*; L) *Cerdocyon thous*; M) *Galictis cuja*; N) *Eira barbara*; O) *Procyon cancrivorus*; P) *Mazama* sp.; Q) *Guerlinguetus ingrani*; R) *Hydrochoerus hydrochaeris*; S) *Cuniculus paca*; T) *Sphiggurus villosus*.

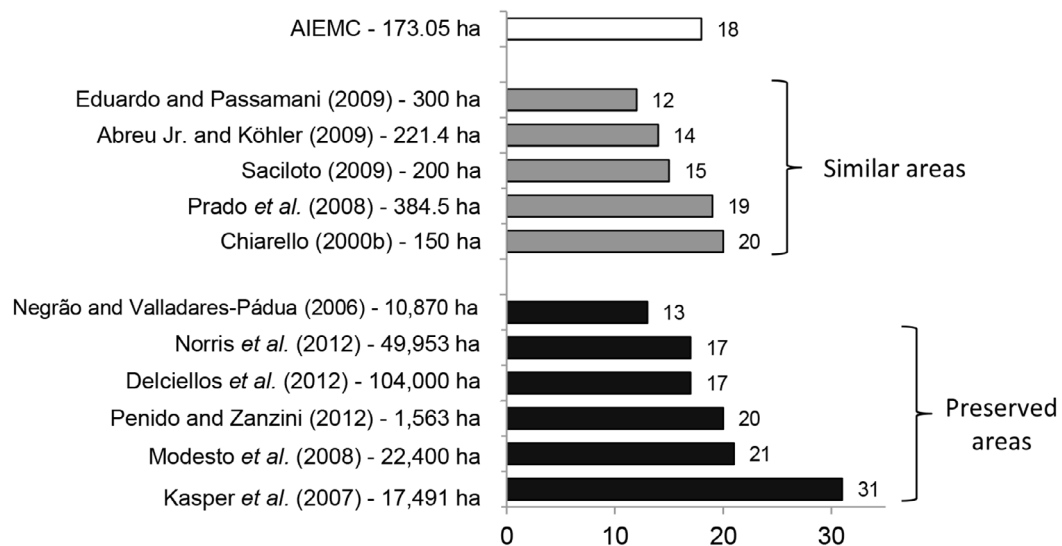


FIGURE 3. Species richness of medium and large-sized mammals at AIEMC compared to other mammal assemblages.

subject to theft. The limited period of time to perform this study, prevented using line transects sampling inside the forest remnant. Despite using a single sampling method, the record of footprints and natural signs proved suitable for the study area, considering the objectives (to detect cursorial medium and large-sized mammals) and the high number of species detected when compared to other similar and protected areas (Figure 3).

Species classified as habitat and diet generalists were more frequently recorded (Figure 5). The crab-eating fox (*Cerdocyon thous*) was also frequently recorded in other studies (Prado et al. 2008; Dotta and Verdade 2011; Lessa et al. 2012), which may be related to its tolerance to modified environments (Ferraz et al. 2010) with an opportunistic and generalist diet (Rocha et al. 2008). The black-horned capuchin (*Sapajus nigritus*) shows great diet flexibility and tolerance to small-sized and modified forest remnants (Auricchio 1995). Some recorded species are more tolerant to anthropogenic environments, such as *Dasyus novemcinctus* (Aguar and Fonseca 2008), *Procyon cancrivorus* (Siviero 2012) and *Hydrochoerus hydrochaeris* (Ferraz et al. 2007).

Domestic dogs (*Canis familiaris*) had the third highest occurrence (Figure 5), and because they are exotic and may

be considered invasive, they may exert a negative effect on wild species, as a potential disease vector, predator, and even competing for resources with wild carnivores (Campos et al. 2007; Oliveira et al. 2008b). The European hare (*Lepus europaeus*), also an exotic and invasive species, seems to be well adapted to virtually all Brazilian biomes. Its populations are increasing, occupying many areas of Brazil, expanding its geographic distribution (Reis et al. 2010).

Species with few occurrences may have been subsampled, possibly due to their preferences for more riparian habitats (such as paca, *Cuniculus paca*, and lesser grisson, *Galictis cuja*; [Emmons and Feer 1997]) or more scansorial habits (such as orange-spined hairy dwarf porcupine, *Sphiggurus villosus*, and white-eared-opossum, *Didelphis albiventris*), which reduces the chances to detect their tracks. Although present in agricultural and disturbed areas the tayra (*Eira barbara*), was recorded only once, which may indicate a low population density or even local rarity (Emmons and Feer 1997). Also *Sylvilagus brasiliensis*, *Euphractus sexcinctus*, *Dasyus septemcinctus* and *Cabassous tatouay* had only a few records, although they are considered common species that tolerate disturbed and agricultural areas (Emmons and Feer 1997; Aguiar 2004; Aguiar and Fonseca 2008).

Species listed with some level of conservation threat comprise two felines (Table 1), which shows that, despite high degree of disturbance, AIEMC hosts species with relevant conservation value. We recorded only one footprint trail of ocelot (*Leopardus pardalis*), despite it being considered a cosmopolitan species with occurrences in a wide variety of habitats, including agricultural and disturbed areas (Oliveira et al., 2010).

Puma concolor was the largest mammal registered in AIEMC, with a relatively high frequency of occurrence (Figure 4). Considered opportunistic (Sunquist and Sunquist 2002), *P. concolor* preys on a wide variety of animals (Emmons 1987; Foster et al. 2010), and can feed on resource originated from highly fragmented and agricultural areas (Magioli et al. 2014).

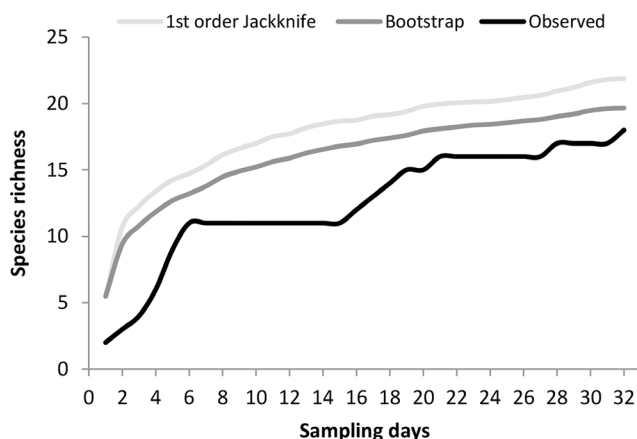
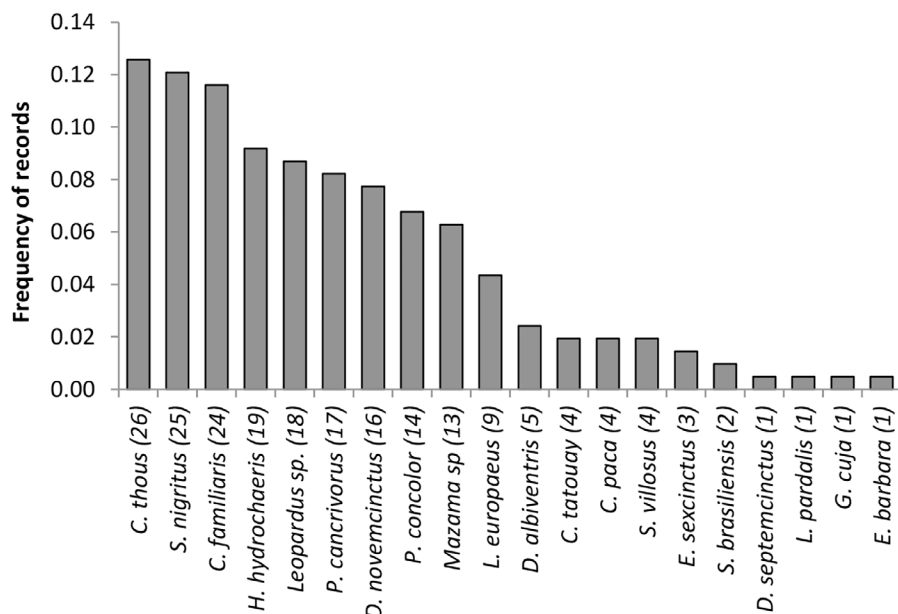


FIGURE 4. Species accumulation curve and estimated richness (1st order Jackknife and Bootstrap).

TABLE 1. Medium and large-sized mammals registered at AIEMC. Legend: F=footprints; S=sighting; V=vocalization; O=other signs (caves, feces, food leftovers, carcasses); Vu = vulnerable; En = endangered.

TAXON	COMMON NAME	RECORD METHOD	CONSERVATION STATUS	
			Machado <i>et al.</i> 2008	Percequillo and Kierulff 2009
DIDELPHIMORPHIA				
Didelphidae				
<i>Didelphis albiventris</i> Lund, 1840	White-eared Opossum	F,O		
CINGULATA				
Dasypodidae				
<i>Dasypus novemcinctus</i> Linnaeus, 1758	Nine-banded Armadillo	F,O		
<i>Dasypus septemcinctus</i> Linnaeus, 1758	Brazilian Lesser Long-nosed Armadillo	F		
<i>Euphractus sexcinctus</i> (Linnaeus, 1758)	Yellow Armadillo	F,O		
<i>Cabassous tatouay</i> (Desmarest, 1804)	Greater Naked-tailed Armadillo	F,O		
PRIMATES				
Cebidae				
<i>Sapajus nigritus</i> (Goldfuss, 1809)	Black-horned Capuchin	F,S,V,O		
LAGOMORPHA				
Leporidae				
<i>Lepus europaeus</i> (Pallas, 1778)	European hare	F,O		
<i>Sylvilagus brasiliensis</i> (Linnaeus, 1778)	Brazilian rabbit	F		
CARNIVORA				
Felidae				
<i>Leopardus pardalis</i> (Linnaeus, 1758)	Ocelot	F	Vu	Vu
<i>Leopardus</i> sp. (Schreber, 1775)	Small wild cats	F		
<i>Puma concolor</i> (Linnaeus, 1771)	Puma	F,V,O	Vu	Vu
Canidae				
<i>Canis familiaris</i> (Linnaeus, 1753)	Domestic dog	F,S,V,O		
<i>Cerdocyon thous</i> (Linnaeus, 1766)	Crab-eating Fox	F		
Mustelidae				
<i>Galictis cuja</i> (Molina, 1782)	Lesser Grison	F		
<i>Eira barbara</i> (Linnaeus, 1758)	Tayara	F		
Procyonidae				
<i>Procyon cancrivorus</i> (G. [Baron] Cuvier, 1798)	Crab-eating Raccoon	F		
ARTIODACTYLA				
Cervidae				
<i>Mazama</i> sp. (Erxleben, 1777)	Deer	F		
RODENTIA				
Sciuridae				
<i>Guerlinguetus ingrami</i> (Thomas, 1901)	Brazilian Squirrel	F		
Caviidae				
<i>Hydrochoerus hydrochaeris</i> (Linnaeus, 1766)	Capybara	F,O		
Cuniculidae				
<i>Cuniculus paca</i> (Linnaeus, 1758)	Paca	F		
Erethizontidae				
<i>Sphiggurus villosus</i> (F. Cuvier, 1823)	Orange-spined Hairy Dwarf Porcupine	F,O		

**FIGURE 5.** Occurrence of species at AIEMC. Values in parentheses represent the number of records of each species during sampling period.

Compared to other areas, AIEMC showed high species diversity ($H'_{10} = 2.62$). Rocha and Dalponte (2006) found similar value ($H'_{10} = 2.40$) in Municipal Biological Reserve “Mario Vianna”, Nova Xavantina, Mato Grosso State, a forest fragment with similar characteristics. Lopes and Ferrari (2000) found that H' values of a mammal community in eastern Brazilian Amazonia varied according to intensity of disturbance in environment ($H'_{10} = 0.98$ to 2.16).

This was the first mammalian inventory carried out at AIEMC, which showed high species diversity despite its insertion in an agricultural environment with strong anthropogenic pressure. Our study highlights the importance of preserving this Atlantic forest remnant for conservation and maintenance of regional and local mammalian fauna. Moreover, the area provides opportunity for further studies on population dynamics, wildlife conservation and management, as well as for inventorying other animal groups, such small non-volant mammals, bats, birds and reptiles.

The presence of two endangered species reinforces the need of investments and actions to better conserve this small forest remnant as well as to study other fragments in MRC. Among priority actions necessary to improve the quality of this remnant, we suggest an increase in connectivity, management of its surroundings (solid waste disposal) and control of exotic species, such as domestic dogs.

ACKNOWLEDGMENTS: We thank the Forest Science Department (“Luiz de Queiroz” College of Agriculture, University of São Paulo) and the Postgraduate Program in Forest Resources (PPGRF). We also thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the scholarship granted for M. Magioli. We thank Maria Luisa Jorge, Julio Cesar Dalponte and one anonymous reviewer for comments and suggestions that significantly improved the quality of an earlier version of this manuscript.

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RECEIVED: March 2013

ACCEPTED: July 2014

PUBLISHED ONLINE: September 2014

EDITORIAL RESPONSIBILITY: Maria Luisa Jorge