Carlos Eduardo Ribas Tameirão Benfica

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Diversity and habitat use by a diurnal raptor assemblage in a Cerrado protected area, southeastern Brazil

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Dissertação apresentada ao Instituto de Biociências da Universidade de São Paulo, para obtenção do Título de Mestre em Ciências, na Área de Ecologia.

Orientador: Prof. Dr. José Carlos Motta-Junior

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Orientador

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Família e amigos, meus sinceros agradecimentos.

“Mestre não é quem sempre ensina, mas quem de repente aprende.”

“Vivendo, se aprende; mas o que se aprende, mais, é só fazer outras maiores perguntas.”

João Guimarães Rosa

(trechos retirados de *O Grande Sertão Veredas*)

“I have deep faith that the principle of the universe will be beautiful and simple.”

Albert Einstein

“Es gibt keine ewigen Tatsachen so wie es keine absoluten Wahrheiten gibt”

(não há fatos eternos, como não há verdades absolutas)

Friedrich Nietzsche

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Índice

INTRODUÇÃO

Segundo Ferguson-Lees & Christie (2002) encontram-se descritas 338 espécies de aves de rapina em todo o mundo, sendo que, grande parte desta diversidade está representada nos Neotrópicos. A riqueza encontrada nas Américas do Sul e Central representa 28% do total (95 espécies) e está classificada em duas ordens taxonômicas: Accipitriformes e Falconiformes (Ferguson-Lees & Christie, 2002; Hackett et al., 2008; AOU, 2011; CBRO, 2011), sendo a primeira com o maior número de representantes nos Neotrópicos, aproximadamente 70, restando aproximadamente 25 espécies para a ordem Falconiformes.

No Brasil podem ser regularmente encontradas 66 espécies de aves de rapina diurnas (Sick, 1997; Ferguson-Lees & Christie, 2002; CBRO, 2011), entretanto, nem todas elas ocorrem no domínio do Cerrado (del Hoyo *et al.*, 1994; Ferguson-Lees & Christie, 2002; Gwynne *et al.,* 2010). No Cerrado, um *hotspot* da biodiversidade mundial (Myers *et al.,* 2000), podem ser encontradas aproximadamente 46 espécies de rapinantes diurnos (del Hoyo *et al.*, 1994; Sick, 1997; Ferguson-Lees & Christie, 2002; Gwynne *et al.,* 2010) o que representa 48% da riqueza Neotropical (Ferguson-Lees & Christie, 2002). A riqueza passível de ser encontrada no Cerrado, se comparada, é ainda maior que a riqueza regularmente encontrada na América do Norte (por volta de 32 espécies), demonstrando o quão diversa uma savana Neotropical pode ser (Alderfer, 2006; AOU, 2011). Contudo, apesar da considerável diversidade, estudos voltados à ecologia das assembleias de rapinantes diurnos no Brasil somente começaram a ser realizados nos últimos 10-15 anos e, portanto, ainda são escassos considerando a área ocupada pelo território do país (Baumgarten, 1998, 2007; Azevedo *et al.*, 2003; Manosa *et al.*, 2003; Loures-Ribeiro & Anjos, 2006; Carvalho & Marini 2007; Canuto, 2009; Granzinolli, 2009; Zorzin, 2011; Zilio, 2012).

Devido à sua biodiversidade e à elevada porcentagem de habitats naturais perdidos nas últimas décadas, o Cerrado se tornou um dos ecossistemas mais ameaçados do mundo (Myers *et al.,* 2000) e de acordo com Machado *et al.* (2004) e Klink & Machado (2005), mais de 55% da área natural de vegetação do Cerrado foram perdidas. Atualmente, segundo os mesmos autores, a destruição dos habitats é explicada, em sua maioria, pela expansão de áreas para a agricultura, impacto que afeta diretamente a maioria das espécies de aves, incluindo as de rapina (Bierregaard, 1995; Stotz *et al*., 1996; Marini & Garcia, 2005; Carrete *et al.,* 2009). Apesar das ameaças e de sua grande representatividade, mais de 20% do território nacional (Klink & Machado, 2005), poucos foram os estudos focaram descrever as assembleias das aves de rapina diurnas no Cerrado ou em seus ecótonos (Baumgarten, 1998, 2007; Carvalho & Marini, 2007; Granzinolli, 2009; Zorzin *et al. in prep.*). Por outro lado, diversos são os trabalhos que inventariaram as assembleias de aves, em geral, de determinadas localidades do Cerrado. Contudo, apesar destes levantamentos apresentarem listagens extensas de aves de rapina, os predadores não foram o foco das observações (Silveira, 1998; Willis, 2004; Straube *et al*., 2005; Marques, 2008, Rego *et al.*, 2011) e isto torna estes estudos pouco comparáveis (quantitativamente), uma vez que os métodos e os objetivos diferem substancialmente.

Transecções lineares ou "rotas por veículos" (Fuller & Mosher, 1981, 1987) são frequentemente utilizadas para que sejam coletadas informações sobre a riqueza, abundâncias relativas (Ellis *et. al*., 1990; Donázar *et al.*, 1993; Marin & Schmitt, 1996; Meunier *et* al., 2000; Pearlstine *et al.,* 2006; Granzinolli, 2009), densidades estimativas populacionais (Andersen *et al.*, 1985; Viñuela, 1997; Baumgarten, 1998, 2007, Boano & Toffoli, 2002; Nikolov *et al.,* 2006, Piana & Marsden, 2012), período de atividade (Bunn *et al.*, 1995), uso e seleçãoo do habitat (Garner & Bednarz, 2000; Thiollay & Rahman, 2002; Nikolov *et al.,* 2006; Granzinolli, 2009) e para avaliar a resposta das espécies à diferentes níveis de degradação do ambiente (Carrete *et al.,* 2009).

Índices de abundância obtidos ao longo de rotas por veículos podem ser, em certas ocasiões, limitados ou até mesmo enviesados, uma vez que a visibilidade e outras variáveis podem se alterar ao longo das rotas (ver Verner, 1985; Millsap & Lefranc, 1988). Entretanto, estudos que envolvem este método são frequentes, uma vez que pode cobrir uma área considerável em um só dia, e os dados coletados podem ser analisados quanto aos mais variados objetivos, como compreender padrões nos deslocamentos temporais ou sazonais, um aspecto pouco conhecido (Fuller &

Mosher, 1981, 1987; del Hoyo *et al.*, 1994; Ferguson-Lees & Christie 2001, Bildstein, 2004, Granzinolli & Motta-Junior, 2010). Portanto, apesar das limitações em determinadas ocasiões se cuidados não forem tomados, amostragens ao longo de estradas podem ser um dos melhores métodos para se obter informações sobre as assembleias de aves de rapina em diversos tipos de habitats, tais como savanas e outros ambientes abertos ou semiabertos.

Rotas por veículos podem fornecer informações sobre uso do habitat por parte da assembleia, uma vez que diversos habitats podem ser amostrados em um único dia ou período. O uso do habitat é uma informação básica sobre os requerimentos da espécie e, ao mesmo tempo, fornece importantes informações sobre o que deve ser, ou o que não pode ser alterado em determinada região para que a abundância local da espécie não seja afetada (Garshelis, 2000). Aves de rapina, assim como outras aves, podem ocorrem em determinado habitat tanto de maneira uniforme quanto de maneira agregada, de acordo com a distribuição de recursos e outras variáveis do habitat (Cody 1985; Janes, 1985; Cornulier & Bretagnolle, 2006). Consequentemente, com o aumento do conhecimento sobre uso do habitat e outros aspectos associados com estes habitats, prioridades podem ser elencadas e planejadas visando a conservação do grupo ou da região estudada (Sutherland & Green, 2010). Rapinantes podem ser utilizados como indicadores da diversidade de aves ou, até mesmo, da diversidade geral, fato que os tornam bons organismos para se basear quando planejando a criação ou o aumento de áreas protegidas (Thiollay, 1999, 2007; Sergio *et al.*, 2006).

Neste estudo, objetivou-se descrever a assembleia das aves de rapina diurnas no Parque Estadual Veredas do Peruaçu (PEVP), norte de Minas Gerais, Sudeste do Brasil, baseado em: (1) diversidade alfa, (2) equabilidade/dominância e (3) abundância relativa das espécies. Não obstante, também são apresentadas informações sobre (4) abundância temporal, (5) efeitos do horário na atividade/detectabilidade e (6) uso do habitat por parte das espécies detectadas na área de estudo. Para isso, foram levantadas as seguintes perguntas:

i) A diversidade alfa e a composição da assembleia de aves de rapina diurnas é similar a outras localidades estudadas no Brasil?

ii) o período do dia influencia a detectabilidade dos rapinantes no PEVP?

iii) Qual habitat possui maior riqueza e abundância de espécies no PEVP?

Riqueza, abundância, uso do habitat e efeitos do horário na detecção das aves de rapina diurnas no Parque Estadual Veredas do Peruaçu, Minas Gerais

RESUMO

Rotas por veículos foram realizadas para que a riqueza, a abundância e o uso do habitat por rapinantes diurnos no Parque Estadual Veredas do Peruaçu (30.702 ha), Minas Gerais, fosse estudada. Onze rotas foram selecionadas e distribuídas em dois habitats: cerrado (n=6) e uma associação entre vereda e cerrado (n=5). O estudo foi realizado entre setembro de 2010 e julho de 2011 por três observadores na carroceria de um veículo 4x4 dirigido a uma velocidade média de 20km/h, totalizando 2772 km percorridos. Ao longo das transecções foram obtidos 681 registros (0,24 rapinantes/km), referentes à 20 espécies, contudo, *Falco peregrinus* foi registrado ao longo das amostragens *ad libitum* e elevou a riqueza. As cinco espécies mais comuns foram *Heterospizias meridionalis, Caracara plancus, Milvago chimachima, Rupornis magnirostris* e *Falco femoralis*, as quais totalizaram aproximadamente 20% da riqueza local e 80% de todos os registros. As cinco espécies mais raras (*Leptodon cayanensis, Elanus leucurus, Accipiter bicolor, Micrastur semitorquatus* e *Falco sparverius*), juntas, representaram menos de 1% das detecções. As aves de rapina foram mais abundantes ao longo da estação chuvosa (n=438), se comparada à seca (n=243). As veredas apresentaram maior riqueza (19 contra 10 *taxa*) e quase três vezes mais registros (n=466; 0,36 rapinantes/km) que o cerrado (n=215; 0,14 rapinantes/km). O número de detecções computadas para as manhãs foi maior do que as anotadas para as tardes. Baseado no ΔAICc, os modelos que melhor explicaram a riqueza e abundância dos rapinantes continham todas as três variáveis independentes (habitat, estação e período do dia). Rotas por veículos aparentaram ser indicadas para estudos com rapinantes em habitats similares a savanas. O cerrado local apresentou menor riqueza e abundância se comparado às veredas, entretanto, o habitat ocupa grandes proporções e deve possuir importante papel na conservação dos rapinantes. A vereda delimita o parque ao norte e nela foram registradas espécies restritas ao ambiente, como a águia-cinzenta (*Urubitinga coronata*), *taxon* mundialmente ameaçado de extinção. Tal fato eleva a importância do habitat para o grupo e, consequentemente, para toda a comunidade. Sugere-se que o parque tenha sua área aumentada em sua porção norte, considerando que, adicionalmente, grande parte da água corrente provém desta porção.

ABSTRACT

Raptors were surveyed by road transects in order to assess local species richness, abundance and habitat use in Parque Estadual Veredas do Peruaçu (30,702 ha), a reserve that lies in the Cerrado Region of southeastern Brazil. Eleven road transects of 7km each were delimited in two different habitats: *cerrado* (n=6) and an associated *vereda-cerrado* (n=5). Transects were sampled between September 2010 and July 2011 by three observers on the back of a 4WD pickup truck, driven at an average speed of 20km/h – total of 2772 km. There were computed 681 records along road transects (0.24 raptors/km), belonging to 20 species. One other species (*Falco peregrinus*) was recorded exclusively along *ad libitum* sampling. The five most common raptors were *Heterospizias meridionalis*, *Caracara plancus*, *Milvago chimachima, Rupornis magnirostris* and *Falco femoralis*, which totalized approximately 20% of local richness and 80% of all records. The five rarest raptors in the study area (*Leptodon cayanensis, Elanus leucurus, Accipiter bicolor, Micrastur semitorquatus* and *Falco sparverius*), together, represented less than 1% of all records. Raptors were more abundant during rainy season (n=438) than during dry season (n=243). The *veredas* presented higher species richness (19 against 10 *taxa*) and almost three times more records (n=466; 0.36 raptors/km) than the *cerrado* (n=215; 0.14 raptors/km). Mornings held higher number of records when compared to afternoons. Based on ΔAICc the models that better explained species richness and raptors' abundance had all three explanatory variables (habitat, season and day period) considered. Road transects seemed to be recommended for surveys in savannah like habitats. The local *cerrado* presented lower raptor richness and abundance when compared to the *vereda*, however it occupies most of the region and it should have an important role on raptors' conservation. The *vereda* delimit the reserve northern boundaries and it holds some locally restricted *taxa,* like the Crowned Eagle (*Urubitinga coronata*) a species globally threatened of extinction. This makes the habitat even more important for these species and, consequently, to local ecological community. The fact that the *vereda* is protected only by one margin is a worrying issue and it is suggested that the reserve boundaries augment northwards, once important water supply also comes from there.

1 INTRODUCTION

The Neotropics hold great part of diurnal raptors diversity, represented by approximately 95 species (28% of worldwide richness, 338 species), which are classified into two taxonomic Orders: Accipitriformes and Falconiformes (Ferguson-Lees & Christie, 2002; Hackett et al., 2008; AOU, 2011; CBRO, 2011). Accipitriformes is the largest Order with approximately 70 species in the Neotropics, consisting of kites, hawks and eagles. The Falconiformes are represented in South and Central America by approximately 25 species of falcons, caracaras and their allies (Ferguson-Lees & Christie, 2002).

In Brazil, there can be regularly found 66 diurnal raptor species (Sick, 1997; Ferguson-Lees & Christie, 2002; CBRO, 2011), however, not all 66 species occur in the *Cerrado* Region (del Hoyo *et al.*, 1994; Ferguson-Lees & Christie, 2002; Gwynne *et al.,* 2010). In the *Cerrado*, a biodiversity hotspot (Myers *et al.,* 2000), there can be found approximately 46 diurnal raptor species (del Hoyo *et al.*, 1994; Sick, 1997; Ferguson-Lees & Christie, 2002; Gwynne *et al.,* 2010), which represents 48% of the Neotropical raptors diversity (Ferguson-Lees & Christie, 2002). This number of species is even higher than the richness regularly found in North America, (around 32 species), showing how diverse a tropical savannah can be (Alderfer, 2006; AOU, 2011). Despite this considerable diversity, studies aiming to better understand the ecology of diurnal raptors assemblages in Brazil only started in the past ten years and so, are still scarce, considering the size of the Brazilian territory (Baumgarten, 1998, 2007; Azevedo *et al.*, 2003; Manosa *et al.*, 2003; Loures-Ribeiro & Anjos, 2006; Carvalho & Marini 2007; Canuto, 2009; Granzinolli, 2009; Zorzin, 2011; Zilio, 2012).

Due to its biodiversity and to the high percentages of habitat loss in the past decades, the *Cerrado* has become one of the most threatened ecosystems worldwide (Myers *et al.,* 2000) and, according to Machado *et al.* (2004) and Klink & Machado (2005), more than 55% of native *Cerrado* vegetation were already lost. Currently, according to the mentioned authors, the loss continues mostly by agriculture expansions, which affects several bird species, including raptors (Bierregaard, 1995; Stotz *et al*., 1996; Marini & Garcia, 2005; Carrete *et al.,* 2009). Despite its threats and its large original representativeness, more than 20% of the

Brazilian territory (Klink & Machado, 2005), few studies focused on diurnal birds of prey assemblages were conducted within the *Cerrado* region or its transition zones (Baumgarten, 1998, 2007; Carvalho & Marini, 2007; Granzinolli, 2009; Zorzin *et al. unpublished data*). In the other hand, several other studies on *Cerrado's* bird assemblages do present extensive raptor species lists, although birds of prey were not their main focus (Silveira, 1998; Willis, 2004; Straube *et al.*, 2005; Marques, 2008, Rego *et al.*, 2011), and so, specific methods were not applied. This fact makes these results not adequately comparable (quantitatively) with those formerly mentioned, once they had different focuses.

Roadside surveys, or line transects (Fuller & Mosher, 1981, 1987), are frequently used to asses species richness, to obtain relative abundance (Ellis *et. al.*, 1990; Donázar *et al.*, 1993; Marin & Schmitt, 1996; Meunier *et* a*l.*, 2000; Granzinolli, 2009), density and populations estimates (Andersen *et al.*, 1985; Viñuela, 1997; Baumgarten, 1998, 2007, Boano & Toffoli, 2002; Nikolov *et al.,* 2006, Piana & Marsden, 2012), to determine daily activity (Bunn *et al.*, 1995), habitat use and selection (Garner & Bednarz, 2000; Thiollay & Rahman 2002, Nikolov *et al.,* 2006; Granzinolli, 2009) and to measure the response to environmental degradation (Carrete *et al.,* 2009).

Abundance indexes obtained by roadside surveys can be limited and biased, once visibility and other variables might change along routes (see Verner, 1985; and Millsap & Lefranc, 1988). However, the data collected by such method is widely used, it can be applied to a large area and could provide important information to better understand raptor's local and regular temporal movements, a really poor know natural history trait (Fuller & Mosher, 1981, 1987; del Hoyo *et al.*, 1994; Ferguson-Lees & Christie 2001, Bildstein, 2004, Granzinolli & Motta-Junior, 2010). So, despite its probable bias if some cautions are not taken, sampling along roads can be one of the best methods to assess raptors assemblages' information in several types of habitat, such as savannahs and others open and semi open habitats.

Road surveys can easily provide information on habitat use by raptor assemblages, once many habitats can be sampled during a single period. Habitat use is a basic study of species' requirements and it provides reliable information on what should be, or should not be, changed in determined region in order to not affect the species presence or abundance (Garshelis, 2000). Raptors, like other birds, might occur in determined habitat, or mosaic, in uniform or aggregated pattern, according to the distribution of resources and also the consequences of other variables on the habitat (Cody 1985; Janes, 1985; Cornulier & Bretagnolle, 2006). Consequently, by improving knowledge on habitat use and population's demographic rates associated with those habitats, conservation priorities can be better planed for the group and region studied (Sutherland & Green, 2010). As a matter of fact, raptors can be used as indicators of bird, or even total, diversity, what makes them even better organisms to base on when proposing nature reserves creation or augment (Thiollay, 1999; 2007; Sergio *et al*., 2006).

In this study, we aimed to describe birds of prey assemblage in the Parque Estadual Veredas do Peruaçu (PEVP), northern Minas Gerais, southeastern Brazil, accounting for: (1) alpha diversity, (2) equitability/dominance and (3) abundance index. Furthermore, it is also provided information on (4) temporal abundance variations and possible local movements, (5) time-of-day effects on activity/detectability and (6) habitat use by the raptors. In order to do that, some questions were raised:

i) Is the alpha diversity and species composition similar to other sites surveyed in a similar way within the Brazilian territory?

ii) Does the time-of-day influence the detectability of raptors in the PEVP?

iii) Which habitat holds higher abundance and species richness within the PEVP?

2 METHODS

2.1 Study area

The Parque Estadual Veredas do Peruaçu (PEVP) is an integral protected reserve created in September 1994 and located within the municipalities of Januária and Cônego Marinho, northern Minas Gerais State (IEF, 2013). The reserve is part of a regional conservation unit mosaic (with almost 2million hectares) named Mosaico Sertão Veredas – Peruaçu, created in April 2009. The mosaic extends upon eleven municipalities and it shelters 12 conservation units, upon which are under federal, state, private or indigenous management (see Funatura, 2008; ICMBio, 2013).

The PEVP comprises 30,702 ha of protected area (between 14°44' - 14°42'S and 44°44' - 44°42'W), which is distributed between 650 e 830 m above sea level. The main vegetation types found in the conservation unit are: i) *savana arbórea* (*cerrado*), in different successional stages; ii) *vereda* and iii) *floresta paludosa*, in its turn, associated with certain portions of *vereda* (Vianna & Amado, 2003). A brief description of each one of these is given (also, see Figure 1):

i) The *savana arbórea*: presents a thin structure composed mainly by small trees and gramineous soil cover is continuous (Figures 1, 2). It occupies a major portion of the park.

ii) The *vereda*: a high concentration of the palm *Mauritia flexuosa* (buriti) is typical of this physiognomy (Figure 3). The *vereda* play an important role for the region, once it shelters the Peruaçu River stream (one of the few sources of running water in the park), and also marks the northern boundary of the PEVP.

iii) The *floresta paludosa*: frequently associated with the *vereda*, possesses a greater tree density, which are broadly characterized by small breast height diameter (DBH) and an approximate height of 15m (Figures 4, 5). One of the main species is *Xylopia emarginata* (pindaíba-do-brejo). This formation is only found, like the *vereda*, along Peruaçu River margins.

Figure 1. Line transect 01, situated in a *cerrado* portion of the Parque Estadual Veredas do Peruaçu (PEVP), MG.

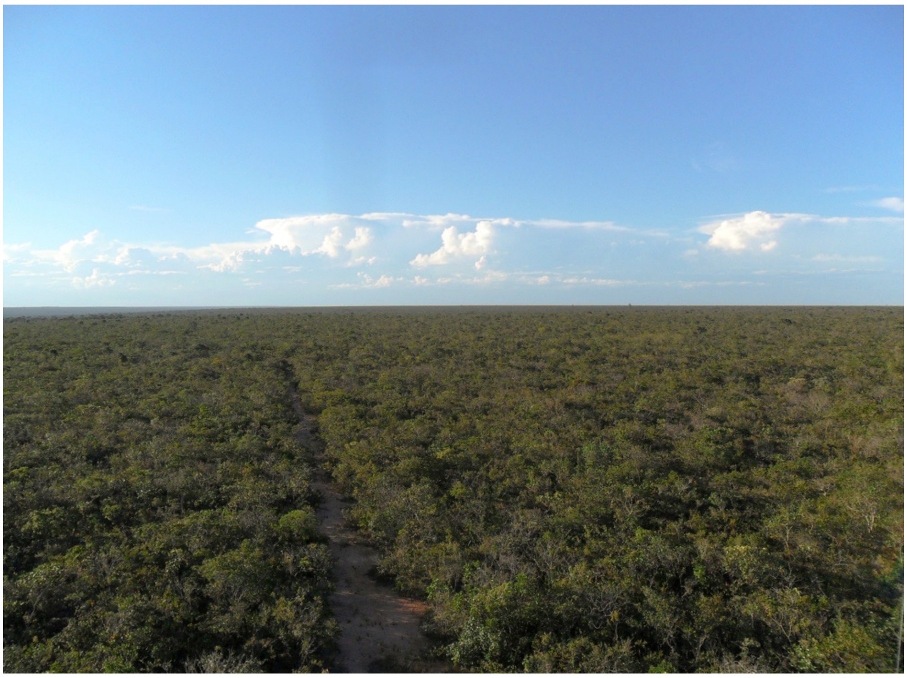

Figure 2. Line transect 02 and the *cerrado* that surrounds it in Parque Estadual Veredas do Peruaçu (PEVP), MG. Photo taken from a fire tower.

Figure 3. Line transect 07, situated in a *vereda* portion of the Parque Estadual Veredas do Peruaçu (PEVP), MG. Créditos: Guilherme Braga Ferreira.

Figure 4. Line transect 08, situated along a *floresta paludosa* in the northern boundary of the Parque Estadual Veredas do Peruaçu (PEVP), MG. Créditos: Guilherme Braga Ferreira.

Figure 5. Line transect 09, situated along a *floresta paludosa* in the northern boundary of the Parque Estadual Veredas do Peruaçu (PEVP), MG. Créditos: Guilherme Braga Ferreira.

According to Koeppen's climate classification system, the climate of the studied region is described as Tropical Wet and Dry (*Aw*), defined by two clearly different seasons, being one dry (April to October/November) and other rainy (October/November to March). During the period this study was conducted, total rainfall was 1,386.01 mm and mean lower and higher temperatures varied between 12.59° C (July/2011) and 35.39° C (October/2010). Region's mean annual rainfall for the last 30 years is 954.5 mm (INMET, 2013), being one of the driest portions of the whole state of Minas Gerais (Figure 6).

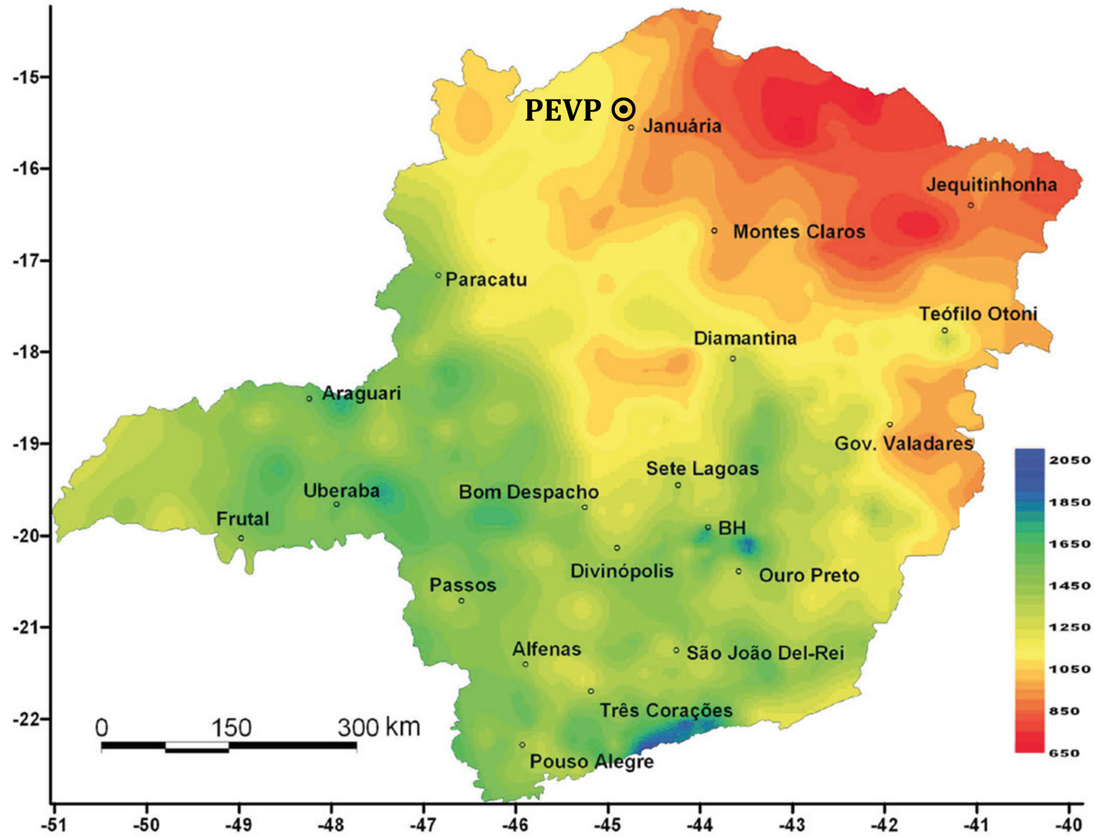

Figure 6. Precipitation (mm) map for the State of Minas Gerais, southeastern Brazil and the location of the study site. Adapted from Guimarães *et al.* (2010).

Despite being inserted within the *Cerrado* Region, according to IBGE (2004), the biogeographic region where the reserve is situated is also under influence of the *Caatinga*. This fact could be easily observed not only based on vegetation, but also in some *Caatinga* endemic or typical bird species, such as: *Megaxenops parnaguae* (Great Xenops), *Myrmochilus s. strigilatus* (Stripe-backed Antbird) and *Gyalophylax hellmayri* (Red-shouldered Spinetail) (Olmos *et al*., 2005, Lopes *et al.,* 2010), common at some PEVP vegetation typologies.

The protected area here mentioned is located within the Peruaçu River basin, an affluent of the São Francisco River, one of the largest rivers in Brazil and detainer of many bird endemism, such as *Hydropsalis vielliardi* (Bahian Nighthawk), and *Xiphocolaptes falcirostris franciscanus* (Moustached Woodcreeper) (Pacheco, 2004). This region is classified by Drummond *et al.* (2005) as a "*specially important area for conservation*" and also as a "*priority area for scientific investigation and management*".

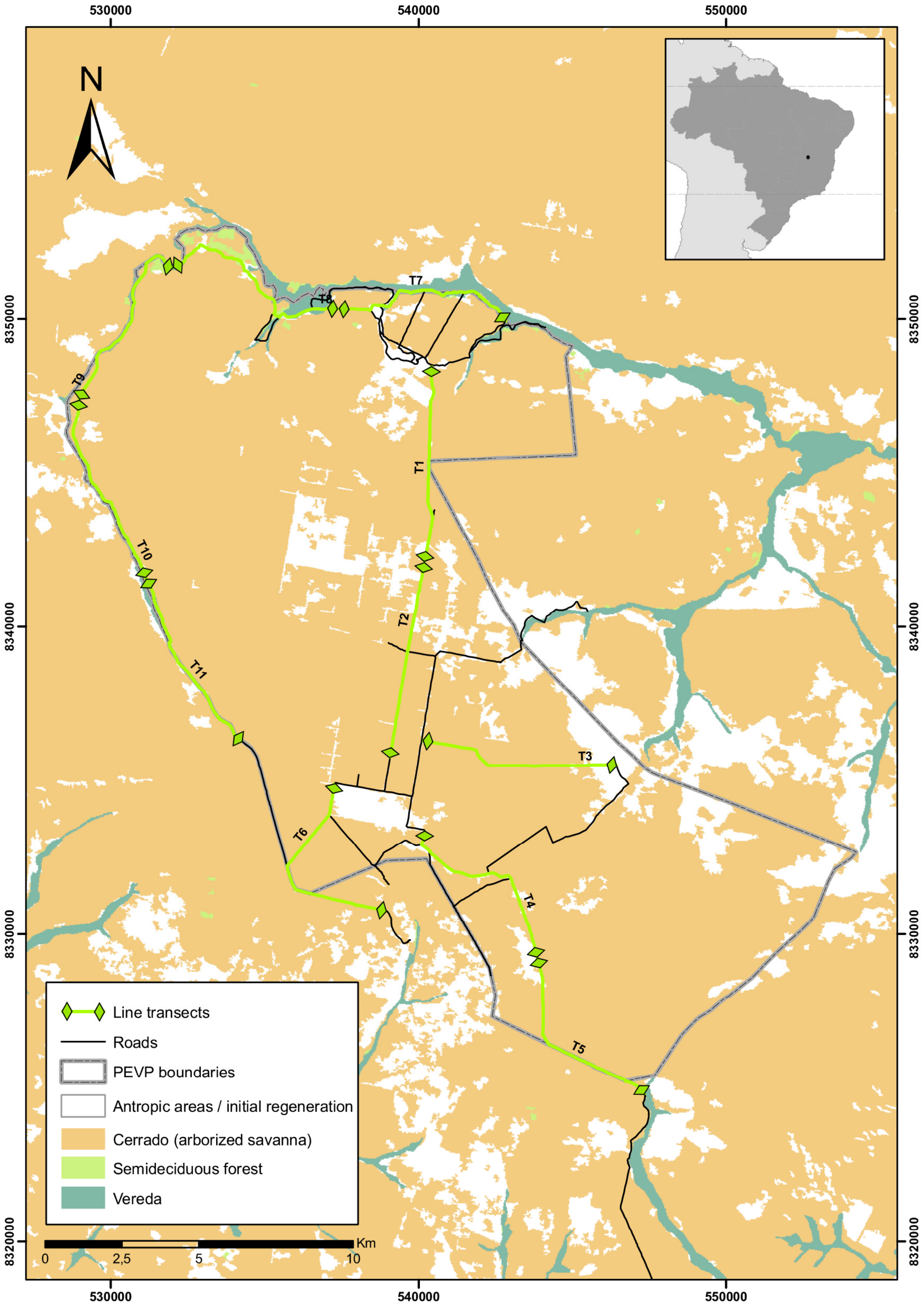

Figure 7. Land use and line transects disposal in the Parque Estadual Veredas do Peruaçu (PEVP), MG (see item 3.3).

This study was conducted between May 2010 and July 2011 yielding 34 days of effective sampling (~10h-12h/day). The total effort was divided into nine field trips carried out by, approximately, each two months, in order to avoid any influence on species detectability due to behavioural and activity levels changes along the year (*e. g.,* dispersal, temporal movements, migration) (Fuller and Mosher 1981, 1987; Bibby *et al.,* 2000; British Columbia, 2001; Andersen, 2006; Bildstein, 2006; Sinclair *et al.,* 2006; Granzinolli & Motta-Junior, 2010).

The first three surveys, which totalized a 10 days field effort, are here accounted only as a qualitative approach, once it was considered part of the pilot study where many methods were tested. Line transect sampling was realized between the fourth and ninth surveys and is the basis of the quantitative analyses. The methods used during the whole study are described below.

2.2 Pilot study

During the pilot study, the surveys were realized with several others methods, such as: point counts, playbacks and *ad libitum* surveys (Fuller and Mosher 1981, 1987; Bibby *et al.,* 2000; British Columbia, 2001; Granzinolli & Motta-Junior, 2010). These worked as complementary methods and were applied to recognize the area and to look out for inconspicuous forest dwelling species, such as *Micrastur* spp. and *Accipiter* spp.. Thus, the results obtained by these complementary efforts are here used only as a qualitative data

2.3 Road surveys (line transects)

Along six field trips, 24 sampling days were applied between September 2010 and July 2011 and once fixing and covering the same sample of transects at each visit provide a greater precision to monitor abundance over time (Buckland *et al*., 2001), the same transects were sampled during this study. Additionally, in an effort to cover a large environmental heterogeneity and, at the same time, the largest portion of the PEVP, 11 line transects of 7 km each were selected based on accessibility, habitat type, line configuration and terrain quality (Figure 7) (Bibby *et al.,* 2000; Buckland *et al.*, 2001; Sinclair *et al.,* 2006). Despite knowing that line transects should go across, rather than along a specific habitat (Buckland *et al.,* 2001; Sinclair *et al.,* 2006, L. Cullen-Junior *pers. com*.), this was not possible due to the existing road configuration. In this way, line transects were positioned along roads already existent, which were not used by any vehicles except by park rangers. These cuts of 7 km were arbitrarily defined due to the logistics and the consequence of it was that some transects were spatially isolated from others and others were not.

The road surveys were always carried out by three observers on the back of a 4WD pickup truck at an average speed of 20 km/h (Granzinolli & Motta-Junior, 2010), in order to avoid undetected individuals. The observers varied along sampled months, but at least one experienced observer was always present. The observations were carried out with binoculars Nikon Monarch (10x36) and a Vortex spotting scope (20-60x80).

Morning and afternoon surveys were performed during 6:00h - 12:00h and 14:00h – 18:00h, respectively, in order to detect alterations between periods of day on assemblage composition and number of individuals. To pass by the same route during different day times and, consequently, to avoid any bias due to that, the routes had pre-defined sequences to be followed, which were chosen by coin flipping in the beginning of each day. There were always sampled 11 routes along mornings and five or six during afternoons, and the last route sampled during the morning was never the first of the afternoon sampling.

✓ Combination 1: Morning surveys order: *1, 2, 3 (6), 4 (5), 5(4), 6(3), 11, 10, 9, 8, 7*; and afternoon surveys order: *1, 2, 3 (6), 4 (5), 5(4)*;

✓ Combination 2: Morning surveys order: *7, 8, 9, 10, 11, 6(3), 4(5), 5(4), 3(6), 2, 1;* and afternoon surveys order: *7, 8, 9, 10, 11, 6(3)*.

Each one of the routes was sampled six times during each field trip, totalizing 36 times by the end of the study (24 during the mornings and 12 during the afternoons). These distances totalized 252 km/route and 2772 km travelled, if gathered. To compare the number of observations between time-of-day periods, in order to detect any variation, five time periods were pre-defined: 06:00 – 8:00; 08:00 – 10:00; 10:00 –12:00; 14:00 –16:00; and 16:00 – 18:00. The total number of detections used to analyse time of day effects was slightly reduced (n = 565), once many records did not fit into these arbitrary selected periods.

During road surveys (Figure 8), every detected raptor (visualized or heard) was computed and the information on its first detection moment was written down on a standardized worksheet. The records were divided into: i) perched individuals; ii) flying/soaring individuals; and iii) vocalization records. All types of records were accounted to obtain the abundance index and other analyses (see item 2.6). Once no visitors are allowed inside the park area without permission, people and car traffic inside it do not occur and, consequently, external influence on population studies of some organisms, like raptors, are minimum.

Figure 8. Road survey in Parque Estadual Veredas do Peruaçu (PEVP) at a line transect inserted in a *cerrado* typology (arborized savannah).

2.4 Species natural history and taxonomic information

All species had information on its natural history traits gathered from available literature, such as Stotz *et al.* (1996), which conceived information about species sensitivity to habitat disturbance; Brown and Amadon (1989) and Ferguson-Lees and Christie (2001), which provided information about species habitats, diets and movements; and del Hoyo *et al.* (1994) compiled available information on several ecological features, such as migrations and local movements. The systematic order and scientific names follow the Brazilian Committee of Ornithological Records (CBRO, 2011).

2.5 Analyses

2.5.1 Similarity and assemblage composition compared to other localities

In order to compare the local raptor assemblage with others studies, there were selected 10 descriptive works conducted specifically with raptors. The objective of selecting only raptor studies for comparison, instead of studies encompassing all birds, is to reduce a possible bias, once specific methods are needed to detect adequately the local raptor assemblage and some bird studies might not have focused on these organisms. The locality of each study is described below:

Cerrado:

PNE-GO. Parque Nacional das Emas, GO (Baumgarten, 1998, 2007): National park with approximately 132,000 ha of protected area, mostly isolated from other *Cerrado* remnants. Main typologies found are *campo limpo* and *campo sujo*, but *veredas* are also found.

EEI-SP. Estação Ecológica Itirapina and surroundings, SP (Granzinolli 2009): The park comprises 2,400 ha of protected area, although the study was realized in an imaginary circle with a diameter of 44km (151,900 ha), considering the EEI at the centre of the delimited circle and neighbouring disturbed sites. Main *Cerrado* physiognomies are *campo sujo*, *campo limpo* and *campo cerrado.*

Atlantic Forest:

FLRNP-SC. Florianópolis, SC (Azevedo *et al.,* 2003): The study was carried out in the whole island, which has approximately 42300 ha and it is distanced approximately 500m away from the continent. The habitats found in the island are *Floresta Ombrófila Densa, Floresta de Planície, restingas,* mangroves and wetlands.

Se.PARANAP-SP. Serra do Paranapiacapa (Manosa *et al.,* 2003): Conducted within two legally protected state reserves boundaries, Parque Estadual Intervales and Parque Estadual Turístico do Alto Ribeira. The main vegetation types found are mature forests, late and young-secondary forests and shrublands. Surrounding and marginal areas present planted *Araucaria angustifolia*, *Pinus* sp. and *Eucalyptus* sp. forest, banana plantations and pastures.

PARANAR-PR. (Loures-Ribeiro & Anjos, 2006): Sites were surveyed mostly along Paraná and Paranapanema rivers, the frontier of Paraná and Mato Grosso do Sul States. The area includes riparian vegetation, such as seasonal, submountain, alluvial semi-deciduous forests and grasslands with large areas of wetland and pastures.

PERD-MG. Parque Estadual do Rio Doce and surroundings, MG (Canuto, 2009): The largest Atlantic Forest reserve in the State, comprising 36,970 ha of forested habitats, although, the study was also conducted along the edges and on its surroundings.

R.DOCE-MG. (Salvador-Jr. & Lima, 2009): This study was realized in Rio Doce and Santa Cruz do Escalvado municipalities, MG, both within Rio Doce river basin, highly impacted region in a macro scale (CERTB pers. obs.). The area presents several habitats, such as secondary forests, shrublands, riparian forests, pastures and slightly urbanized areas.

VICOSA-MG. Viçosa and its surroundings, MG (Zorzin, 2011): This study was realized in a 10,000 ha area of fragmented forests landscape, where pastures figure as the matrix.

Ecotone Cerrado - Atlantic Forest

BH-MG. Belo Horizonte and its surroundings, MG (Carvalho & Marini, 2007): Forest patches immersed in a *Cerrado* (*sensu latu*) matrix were sampled. Areas varied in anthropogenic levels of impact, but a proximity to a large urban centre, in this case, the state capital, is always present.

LGSANTA-MG. Área de Proteção Ambiental do Carste de Lagoa Santa, MG (Zorzin *et al*. (*in prep.*)). The area comprises 359 km^2 of legally protected area, although this reserve category allows human occupation, land use and management, inclusively, some districts are within its boundaries. There is a considerable area of semideciduous vegetation, mainly limestone-associated, protected by it.

Sorensen index was chosen to analyse the similarity between localities and, for that, only presence/ absence data of each study was considered (Wolda, 1981). The specific index was chosen due to the heavier weight it gives for species found in both areas, withdrawing the weight of singular locality species occurrence. To run the mentioned analyses, R software was used (Comprehensive R Archive Network: http://www.r-project.org/).

2.5.2 Species accumulation curve

A species accumulation curve and its Jackknife 1 were elaborated to evaluate the field effort in relation to area's species richness. Both results were obtained by rarefaction, randomized 1000 times using the software *EstimateS 8.2* (Colwell, 2009). The error bars are confidence intervals (95%).

2.5.3 Abundance index

Closely related to a census is an index, which, despite not being considered a total population estimate, it should present proportional relationship to it (Sinclair *et al.* 2006). Following this and aiming a closest comparison with most studies, once it is easier to realize than a census, an abundance index was calculated. This relative abundance of each species was based on the formula presented below:

$$\frac{N\ x\ 100}{n}$$

N= number of occasions a species was detected;

n= total number of detections (all species).

2.5.4 Frequency

Species were classified in categories according to their frequency of occurrence along each round of 11 line transects (77 km). Each one of these rounds was conducted during one morning or two afternoons. This way, a species only marks its presence, or absence, along each 11 line transects cycle. During each field trip, these 11 road transects rounds were repeated for six times, leaving 36 samples to calculate the species frequency along the whole study.

$$\frac{Y\ x\ 100}{36}$$

Y= how many times a species was detected along the 36 repetitions of the 11 line transects cycle.

According to the results of the formula presented above, the species were classified into five categories, adapted from Zorzin (2011):

i) Very Common (VC), present in 70% - 100% of the 11 line transects round;

ii) Common (C), present in 45% - 69.9% of 11 the line transects round;

iii) Uncommon (UC), present in 20% - 44.9% of the 11 line transects round;

iv) Rare (R), present in 5% - 19.9% of 11 the line transects round;

v) Very Rare (VR), present in less than 5% of 11 the line transects round.

2.5.5 Habitat Use

The term *habitat use* will here follow the definition given by Garshelis (2000): "the extent to which different vegetative associations are used", being use measured by species simple presence or absence (Sutherland & Green, 2010). All line transects between 1 and 6 were located in a *cerrado* (*arborized savannah*) typology, whereas the five remaining line transects (7 to 11) followed along a *vereda*/*cerrado* (arborized savannah) associated habitat. So, in order to better analyse future data, once distinguishing the real habitat used by raptors could be dubious, the previously mentioned and described habitats (item 2.1) were gathered into these two categories.

2.5.6 Modelling procedures and selection

Biological inferences on data were made using model selection, which is based on likelihood theory. The method permits several hypotheses to be simultaneously confronted, avoiding the traditional null hypothesis testing, where significance is measured. The initiate analyses, biological hypotheses were formulated and then translated to mathematical equations (models) where the parameters should have biological interpretation (Johnson & Omland, 2004).

To select best model, or models, which is (are) the hypothesis that is (are) best supported by observations, Akaike Information Criterion corrected for small samples (AICc) was used (Burnham & Anderson, 2004; Burnham *et al.,* 2011).

Between the competing models, the one with lowest AICc was considered the best model, although if models presented Δ<2, they were all selected.

$$AICc = AIC + \frac{\left(2K(K+1)\right)}{n-K-1}$$

In a pre-selection, Zero Inflated models (when the count data contains more zeros than expected), also called mixture models, fitted better the data and so, were selected for further analyses. Considering that zeros may come from different sources, ZIP (Zero Inflated Poisson) and ZINB (Zero Inflated Negative Binomial) were selected in order to avoid treating all types of zeros as the same. Zeros in count data may come from different sources, such as: the habitat may not be suitable for several species and, therefore, not used; the habitat may be suitable, but the species can be absent; the area surveyed (one sample) may not be large enough; and observer experience of difficulty to observe the target *taxa* (Zuur *et al.,* 2009). When analysing zero inflated data without accounting for it, the estimated parameters and standard errors may be biased and the excessive number of zeros can cause overdispersion (Zuur *et al.,* 2009). Models were elaborated in order to find out which explanatory variables (habitat, season and day period) better explained species richness and abundance (response variables).

For abundance models, where overdispersion was confirmed, ZINB was chosen and the independent variables habitat, season and day period were used as a possible explanation of too many zeros. Habitat, season and day period may directly influence abundance results, once local raptors could present higher activity during one specific period (influencing daily abundance) (Bunn *et al.* 1995), perform local movements (influencing temporal abundance) (del Hoyo, 1994; Fergusson-Lees & Christie, 2001) and might use or select a determined habitat (Granzinolli, 2009). However, models accounting for season as the probability of false zeros were not presented, once they did not perform better than those models with other variables. Overdispersion was not confirmed for species richness data and, consequently, ZIP was chosen and the independent variables habitat (Granzinolli, 2009) and season (del Hoyo, 1994; Baumgarten, 1998; Fergusson-Lees & Christie, 2001; Granzinolli, 2009) were used as a possible explanation of too many zeros. Model selection analyses were run in R Software (R development Core Team, 2011).

3 RESULTS

3.1 Qualitative results

Twenty-one diurnal raptor species were detected during this study, which represents 45% and 35% of all species that could possible be recorded in the state and in Brazil, respectively (Sick, 1997; Ferguson-Lees & Christie 2001; CRBO, 2011). The alpha diversity is divided into two taxonomic Orders: Accipitriformes (Accipitridae) (n=14), the most representative, and Falconiformes (Falconidae) (n=7), with one third of the species richness.

Within the whole assemblage detected along this study, only one species is considered threatened with extinction, the Crowned Eagle (*Urubitinga coronata*). This species is globally listed as "endangered" by IUCN (2012), nationally as "vulnerable" by MMA (2008) and, again, regionally as "endangered" by COPAM (2010), which is the Minas Gerais state red list. The species was recorded for five times along four field trips. For twice (February and May 2011) the same three individuals (based on male's plumage) were seen together, being two adults and one juvenile. Again, for twice, this adult pair was seen without its juvenile (12th and 13th of July 2011) and only for once, a lonely female was seen (October 2010). The detections were concentrated at the northern portion of the park, along, or just near by (550m away) the *vereda*, and the largest distance between localities where sightings took place was 9 km. The male, just like the juvenile, was easily recognized due to its plumage, not yet 100% adult characterized. These details strongly suggest that all these 11 records remit to the same three individuals.

The *taxa* detected had their sensitivity to habitat disturbance evaluated according to Stotz *et al.* (1996) and their behavioural description followed del Hoyo *et al.* (2004). According to former authors the species were classified into: high sensitivity (n=1 species), medium sensitivity (n=8 species) and low sensitivity (n=12 species); and according to latter authors, they were classified as: presumably sedentary (n=9 species); sedentary (n=5 species); sedentary, although possibly performing local movements (n=2 species); no information available (n=2 species); migratory or nomadic (n=2 species); and migratory (n=1 species) (Table 1).

Table 1. Raptor species detected in Parque Estadual Veredas do Peruaçu (PEVP), MG. It is also presented their sensibility to habitat disturbance (Stotz *et al*. 1996), their local frequency and probable temporal movements realized. Frequency: VR: very rare; R: rare; UC: uncommon; C: common; VC: very common.

Species	English name	Sensibility	Frequency	Migration / Movements
ACCIPITRIFORMES				
Accipitridae				
Leptodon cayanensis	Grey-headed Kite	Medium	VR	Presumably sedentary
Chondrohierax uncinatus	Hook-billed Kite	Low	R	Presumably sedentary
Elanus leucurus	White-tailed Kite	Low	VR	Migratory or Nomadic
Accipiter striatus	Sharp-shinned Hawk	Medium	R	No information
Accipiter bicolor	Bicolored Hawk	High	VR	Presumably sedentary
Rostrhamus sociabilis	Snail Kite	Low	UC	Migratory or Nomadic
Geranospiza caerulescens	Crane Hawk	Medium	UC	Presumably sedentary
Heterospizias meridionalis	Savannah Hawk	Low	VC	Sedentary
Urubitinga coronata *	Crowned Eagle	Medium	R	Sedentary
Rupornis magnirostris	Roadside Hawk	Low	VC	Presumably sedentary
Parabuteo unicinctus	Harris's Hawk	Low	UC	Sedentary; possibly local movements
Geranoaetus albicaudatus	White-tailed Hawk	Low	C	Presumably sedentary
Buteo nitidus	Grey-lined Hawk	Medium	C	Sedentary
Buteo brachyurus	Short-tailed Hawk	Medium	UC	Presumably sedentary
FALCONIFORMES				
Falconidae				
Caracara plancus	Southern Caracara	Low	VC	Sedentary; possibly local movements
Milvago chimachima	Yellow-headed Caracara	Low	VC	Presumably sedentary
Herpetotheres cachinnans	Laughing Falcon	Low	UC	Presumably sedentary
Micrastur semitorquatus	Collared Forest-Falcon	Medium	VR	Sedentary
Falco sparverius	American Kestrel	Low	R	Sedentary
Falco femoralis	Aplomado Falcon	Low	VC	No information
Falco peregrinus	Peregrine Falcon	Medium	-	Migratory

* Species locally, nationally and globally threatened with extinction (MMA, 2008; COPAM, 2010; IUCN, 2012). Information about migration and local movements were taken from del Hoyo *et al.* (2004).

3.1.1 Similarity

Compared to other localities (Table 2), the assemblage found at PEVP is more closely related to the one described by Carvalho & Marini (2007) for Belo Horizonte municipality and surroundings (MG), which is located at an ecotone of *Cerrado*/Atlantic Forest, 530 km southwards of PEVP (Figure 9). Four sites located within the political boundaries of Minas Gerais State compose the other group of localities with higher assemblage similarity, independently if they are within the Atlantic Forest region (PERD, Rio Doce and Viçosa) or within the *Cerrado/*Atlantic forest ecotone (Lagoa Santa). All these four localities are spread apart from PEVP by distances between 500 (Lagoa Santa) and 650 km (Viçosa). Three localities form other clustered group with higher similarity, which are all located within 900 and 1300 km range from PEVP. Out of this specific group, the assemblage closest related to PEVP is PARANAR-PR (Loures-Ribeiro & Anjos, 2006), followed by EEI-SP (Granzinolli, 2009), and PNE-GO (Baumgarten, 1998, 2007), being the former site inserted within the Atlantic Forest region and the other two within the *Cerrado* region, like PEVP. The most distantly related assemblages are those described by Manosa *et al.* (2003) for Serra do Paranapiacaba (SP), and Azevedo *et al*. (2003) for Florianópolis island (SC). These localities are situated approximately 950 and 1400 km apart from PEVP, respectively.

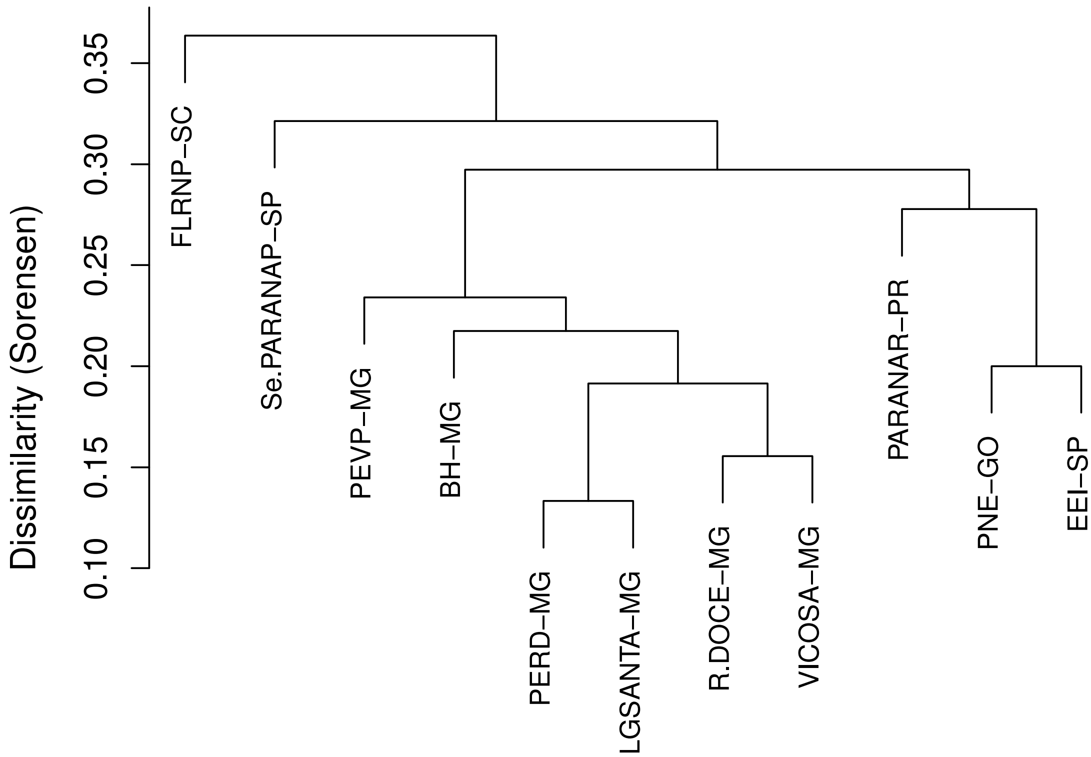

Figure 9: Similarity between the present study and other studies carried out with diurnal birds of prey's assemblages in Brazil.

Table 2. Studies realized with raptor assemblages in Brazil and qualitatively compared with the present study.

Locality	**Abbreviation**	**Species richness**	**Effort (hours)**	**Region**	**Reference**
Parque Estadual Veredas do Peruaçu - MG	PEVP-MG	21	~ 370	*Cerrado*	Present Study
Parque Nacional das Emas - GO	PNE-GO	16	~ 1500	*Cerrado*	Baumgarten, 1998, 2007
Estação Ecológica Itirapina - SP	EEI-SP	19	~ 3240	*Cerrado*	Granzinolli, 2009
Belo Horizonte - MG	BH-MG	21	320	*Cerrado* - Atlantic Forest	Carvalho & Marini, 2007
Lagoa Santa - MG	LGSANTA-MG	26	~ 320	*Cerrado* - Atlantic Forest	Zorzin *et al.* (*in prep*)
Florianópolis island - SC	FLRNP-SC	20	350	Atlantic Forest	Azevedo *et al.,* 2003
Serra do Paranapiacaba - SP	Se.PARANAP-SP	22	88	Atlantic Forest	Manosa *et al.,* 2003
Rio Paraná region - PR	PARANAR-PR	19	~ 160	Atlantic Forest	Loures-Ribeiro & Anjos, 2006
Parque Estadual do Rio Doce - MG	PERD-MG	34	~ 570	Atlantic Forest	Canuto, 2009
Rio Doce region - MG	R.DOCE-MG	21	490	Atlantic Forest	Salvador-Jr & Lima, 2009
Viçosa - MG	VICOSA	25	325	Atlantic Forest	Zorzin, 2011

3.2 Quantitative results (obtained only along road surveys)

3.2.1 Species richness

During the 396 transect samples there were computed 684 records (of which only three of these records were unidentified raptors, not accounted in future analyses), totalizing 20 diurnal raptors species. Raptors were observed in 254 samples (64.1%), leaving 142 samples (35.9%) with no raptor records, at all. Despite being easier to detect a flying/soaring raptor, compared to a perched one (Andersen, 2007), the number of perched birds of prey (*n*=609, 89%) detected along this study was much higher than the number of flying/soaring individuals (*n*=72, 11%). The species accumulation curve did not show a complete stabilization and Jackknife 1 estimated 25.45 ± 5.52 (CI 95%) species for the area. Nevertheless, based on Jackknife 1 results, approximately 84% of the probable alpha diversity was recorded during this study (Figure 10).

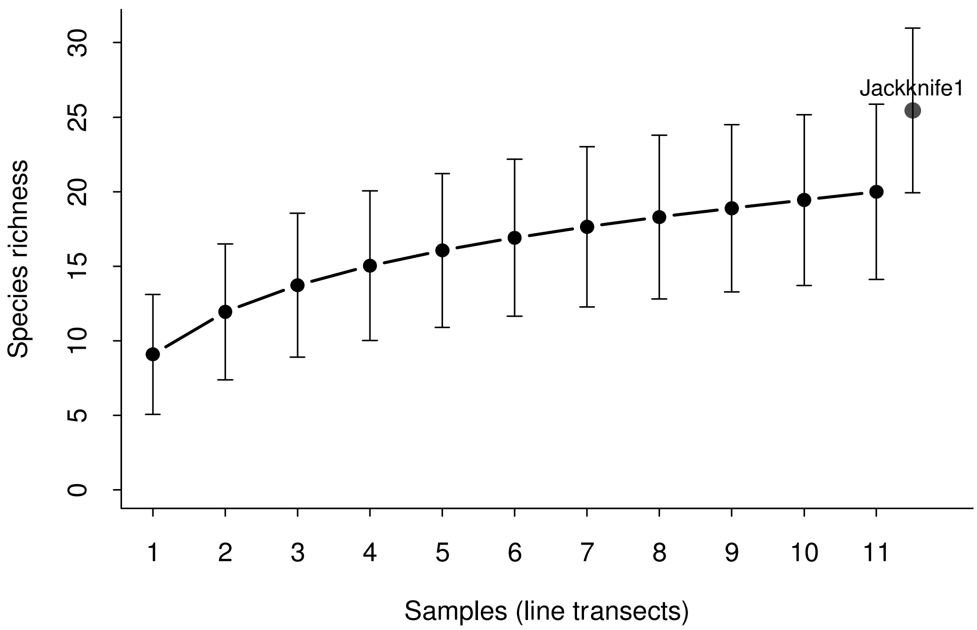

Figure 10. Sample-based species accumulation curve randomized 1000 times and Jackknife 1 of the diurnal birds of prey assemblage of 11 road transects (repeated 36 times each) carried out in savannah protected area, southeastern Brazil. Error bars show confidence interval (95%). EstimateS 8.2 software.

3.2.2 Temporal abundance

November comprised the month with the highest number of records, followed by March, September and January (Table 5). With those high numbers along these months, raptors were more abundant during rainy season (*n*=438) when compared to dry season (*n*=243), once May and July held lowest abundance results (Figure 11). However, three species that were observed only once during the study were detected during these months (*Leptodon cayanensis*, *Elanus leucurus* and *Falco sparverius*). Also, despite the field trips conducted in September, March and May have shown highest species richness, 14 each, the number of species detected during other months did not vary much, being the lowest one observed during July, 11 species.

The highest variations in each species number of observations/field trip were observed for *Heterospizias meridionalis* and *Caracara plancus.* The former had 57 records in November and only one in May, while the latter had 49 detections in November and seven in January. Other species, such as *Milvago chimachima* showed no variation between September and March, although it was barely recorded during the last two field trips (May and July; Figure 11).

Three raptors (*H. meridionalis, M. chimachima* and *C. plancus*) had their temporal abundance analysed more cautiously, once the patterns observed were obvious. A high variation in number of detections along different field trips was computed for *H. meridionalis*, which had number of detections varying, from September to March, between *n*=31 and n=57. However, the months of May and July (dry season), together, were responsible for only four records. Despite observed at constant abundance during four field trips (September to March), *M. chimachima* occurred at extreme low abundance during May and July surveys (dry season's peak). November was an unusual month for *C. plancus* local abundance, being 42% (*n*= 49) of its total number of detections (*n*= 117) computed along this sample (see Figure 11).

Table 3. Species recorded along line transects in Parque Estadual Veredas do Peruaçu (PEVP) and the number of records (detections) during each field trip.

Species	Sep	Nov	Jan	Mar	May	Jul	Total
Heterospizias meridionalis	31	57	40	46	1	3	**178**
Caracara plancus	14	49	7	19	11	17	**117**
Milvago chimachima	23	21	22	25	1	4	**96**
Rupornis magnirostris	15	11	12	20	15	9	**82**
Falco femoralis	7	21	10	5	10	13	**66**
Buteo nitidus	2	10	4	5	8	6	**35**
Geranoaetus albicaudatus	4	5	3	5	5	4	**26**
Geranospiza caerulescens	5	5	--	2	--	--	**12**
Buteo brachyurus	4	1	2	1	2	1	**11**
Herpetotheres cachinnans	1	4	4	--	2	--	**11**
Rostrhamus sociabilis	--	1	1	9	--	--	**11**
Urubitinga coronata *	1	--	--	3	3	4	**11**
Parabuteo unicinctus	--	--	2	1	1	6	**10**
Accipiter striatus	3	1	--	1	1	--	**6**
Chondrohierax uncinatus	1	--	--	2	--	--	**3**
Falco sparverius	--	--	--	--	--	2	**2**
Accipiter bicolor	1	--	--	--	--	--	**1**
Elanus leucurus	--	--	--	--	1	--	**1**
Leptodon cayanensis	--	--	--	--	1	--	**1**
Micrastur semitorquatus	--	--	1	--	--	--	**1**
Unidentified raptors	1	--	2	--	--	--	**3**
Number of detections	**113**	**186**	**110**	**144**	**62**	**69**	**684**
Species richness along line transects	**14**	**12**	**12**	**14**	**14**	**11**	**20**

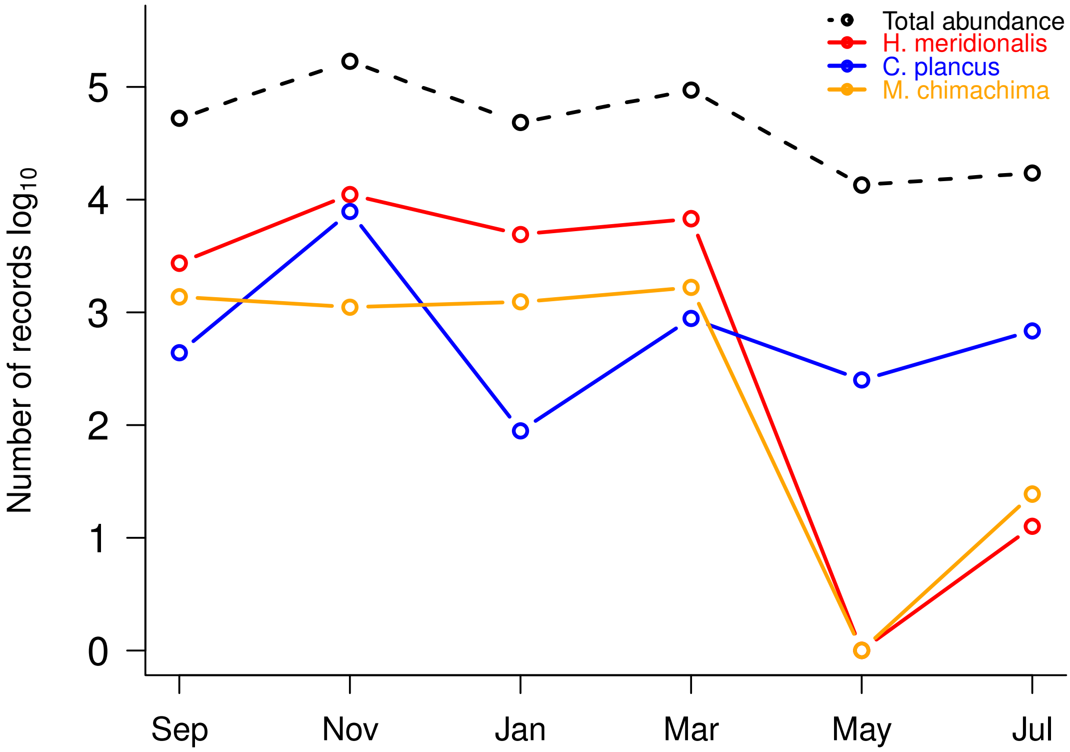

Figure 11. Temporal abundance of the three more commonly recorded raptor species, described as total number of records for each field trip.

3.2.3 Abundance index

Species abundances along road surveys were calculated. The five most common raptors were *H. meridionalis* (26.3%), *C. plancus* (16.9%), *M. chimachima* (13.9%), *Rupornis magnirostris* (12%) and *Falco femoralis* (9.7%), which totalized approximately 20% of local species richness and 79% of all records. Although, in a matter of abundance, *Buteo nitidus* and *Geranoaetus albicaudatus* were also distinguished from others, as can be seen in Whittaker's diagram (Figure 12). According to abundance index, the five rarest raptors in the study site, together, represented only 0.88% of all records (*L. cayanensis, E. leucurus, Accipiter bicolor, Micrastur semitorquatus* and *F. sparverius*). The only species not detected along line transect surveys was the Northern Hemisphere migratory *Falco peregrinus*, which was observed only during the pilot project. Due to that, the species was excluded of most quantitative analyses, leaving only 20 *taxa* to that. The former mentioned species segregate from the others as the most abundant in the studied assemblage. These seven *taxa* were detected along every field trip, just like *Buteo brachyurus*, although, the latter did not hold a high number of records/field trip.

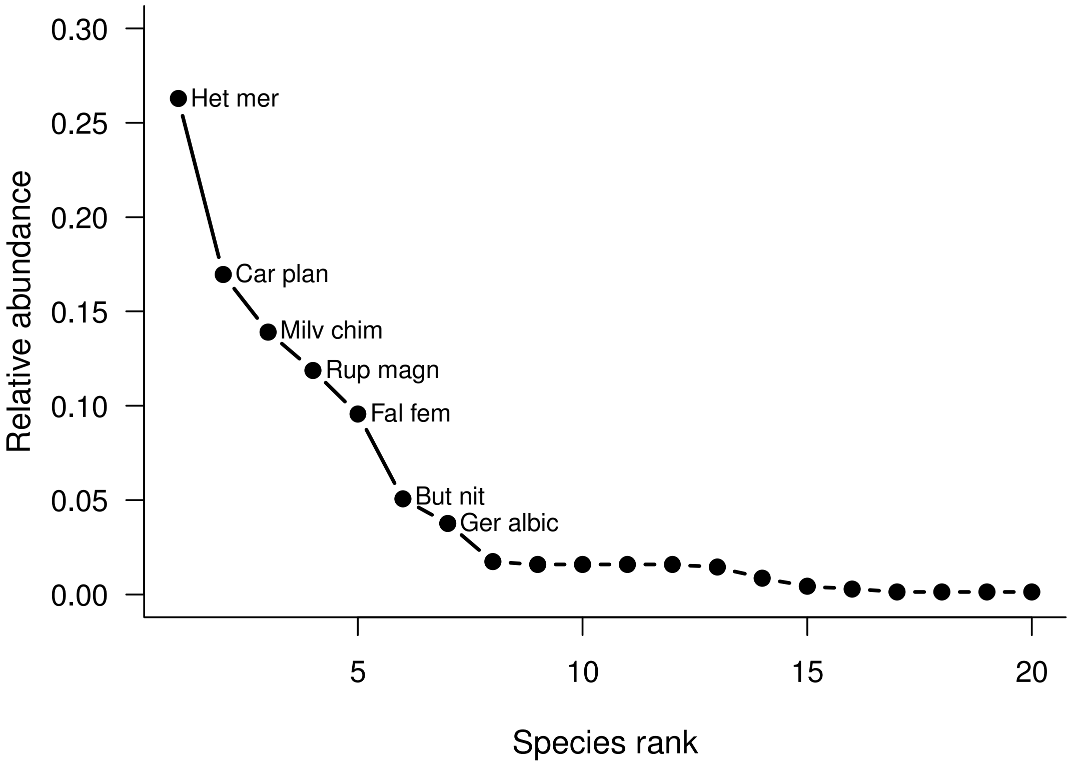

Figure 12. Species' richness and relative abundance along road surveys in PEVP-MG. Het mer = *Heterospizias meridionalis*, Car plan = *Caracara plancus*, Milv chim = *Milvago chimachima*, Rup magn = *Rupornis magnirostris*, Fal femor = *Falco femoralis*, But nit = *Buteo nitidus*, Ger albic = *Geranoaetus albicaudatus*.

The mean number of detections was 1.7 raptors/line transect or 0.24 raptors/km, considering all 681 records obtained along the 396 repetitions of the eleven line transects selected. When divided by habitat types, the *vereda* presents almost three times more records (0.36 raptors/km) than the *cerrado* (0.14 raptors/km). In order to fit into a better scale, species records are presented as individuals/100 km. The abundance results for each species are presented in Table 6.

Table 4. Species detected along road surveys carried in PEVP-MG, their total number of records, abundance index (AI) and relative abundance (individuals/100km).

Species	**Numbers of detections (*n* = 681)**	**AI (%)**	**Individuals/100 km of road transects**
Heterospizias meridionalis	178	26.30	6.42
Caracara plancus	117	16.96	4.22
Milvago chimachima	96	13.91	3.46
Rupornis magnirostris	82	11.88	2.96
Falco femoralis	66	9.57	2.38
Buteo nitidus	35	5.07	1.26
Geranoaetus albicaudatus	26	3.77	0.94
Geranospiza caerulescens	12	1.74	0.43
Buteo brachyurus	11	1.59	0.40
Urubitinga coronata	11	1.59	0.40
Herpetotheres cachinnans	11	1.59	0.40
Rostrhamus sociabilis	11	1.59	0.40
Parabuteo unicinctus	10	1.45	0.36
Accipiter striatus	6	0.87	0.22
Chondrohierax uncinatus	3	0.43	0.11
Falco sparverius	2	0.29	0.07
Accipiter bicolor	1	0.14	0.04
Elanus leucurus	1	0.14	0.04
Leptodon cayanensis	1	0.14	0.04
Micrastur semitorquatus	1	0.14	0.04

3.2.4 Time-of-day effects

Every morning two-hour time period (06:00–8:00; 08:00–10:00; 10:00–12:00) held higher number of records if compared to any afternoon's two-hour periods (14:00–16:00; 16:00–18:00), although when comparing within mornings or afternoons, none of them presented abundance shifts. Species richness did not vary much between two hour periods, although higher results were reached during three time periods, being one at the end of the morning, from 10:00 to 12:00h, and the other two during afternoon, from 14:00 to 18:00h. The lowest richness detected was between 08:00h – 10:00h (Table 7).

Eight species were detected along every two-hours time period, being them the eight species with greater number of records. Not all species had their daily activity patterns analysed due to their low number of records, although, for few which had, slightly different patterns were observed. The species with earlier activity peaks were *R. magnirostris* and *F. femoralis*, both holding higher number of detections between 06:00-08:00. *Caracara plancus* presented its activity peak period between 06:00-10:00, with a difference of one record between each two-hours period. *Milvago chimachima* held almost constant number of records during the whole morning (06:00-12:00). *Heterospizias meridionalis* and *B. nitidus* were recorded enough times for this comparison, although they did not present a clear pattern, may be due to a large concentration of records at some portions of the *vereda*, biasing results.

Table 5. Number of records divided into intervals (02 hours) along morning and afternoon road transects realized in PEVP-MG:

Species	06:00h 08:00h	08:00h 10:00h	10:00h 12:00h	14:00h 16:00h	16:00h 18:00h	Number of records
H. meridionalis	21	39	35	28	30	**153**
C. plancus	29	30	20	12	17	**108**
M. chimachima	18	16	18	11	10	**73**
R. magnirostris	21	12	10	10	10	**63**
F. femoralis	21	13	11	7	9	**61**
B. nitidus	2	6	12	9	1	**30**
G. albicaudatus	4	8	1	1	1	**15**
G. caerulescens	3	2	2	1	2	**10**
P. unicinctus	2	5	3	--	--	**10**
U. coronata	5	--	4	--	--	**9**
R. sociabilis	1	--	4	2	2	**9**
A. striatus	--	1	2	1	2	**6**
H. cachinnans	3	--	--	2	1	**6**
B. brachyurus	1	--	1	1	1	**4**
C. uncinatus	--	--	3	--	--	**3**
F. sparverius	--	1	--	1	--	**2**
A. bicolor	--	--	--	--	1	**1**
E. leucurus	--	--	--	--	1	**1**
L. cayanensis	--	--	--	1	--	**1**
Species richness	**13**	**11**	**14**	**14**	**14**	**19**
Grand Total	**131**	**133**	**126**	**87**	**88**	**565**

3.2.5 Habitat use

The raptor assemblage found in the associated *cerrado* (*savana arbórea)/ vereda* zone presented higher species richness (*n*=19) than the one found in the *cerrado* (*n*=10) and, despite that, all species detected in the *cerrado* were also detected in the *cerrado/vereda.* Considering only species with more than ten records, in both habitats, seven *taxa* demonstrated distinctly higher abundance (>85%) towards one of the two habitats, whereas the remaining species held lower abundances percentages in both habitats. Despite both habitats have presented the same number of most abundant species, their rank differed in species composition and richness.

According to Whittaker's diagram, which was drawn considering species abundance index for each habitat, three species did not present high abundance indexes variation (Figure 13). *Heterospizias meridionalis* held higher species abundance in both habitats, just like *F. femoralis* was the forth one on both ranks. The other species with lower abundance variance between habitats was *C. plancus*. Despite these, the four remaining varied their rank position when compared to the other habitat. *Rupornis magnirostris* was the second species holding higher abundance in the *cerrado*, although, it was only the fifth species with higher abundance in the *cerrado/vereda*, and so, it was almost three times more abundant in the former habitat. In the other hand, *M. chimachima* was considerably more abundant in the *cerrado/vereda* habitat if compared to the *cerrado*. The only switch occurred with *G. albicaudatus* and *B. nitidus*, being the former more common in the *cerrado* and the latter in the *cerrado/vereda*.

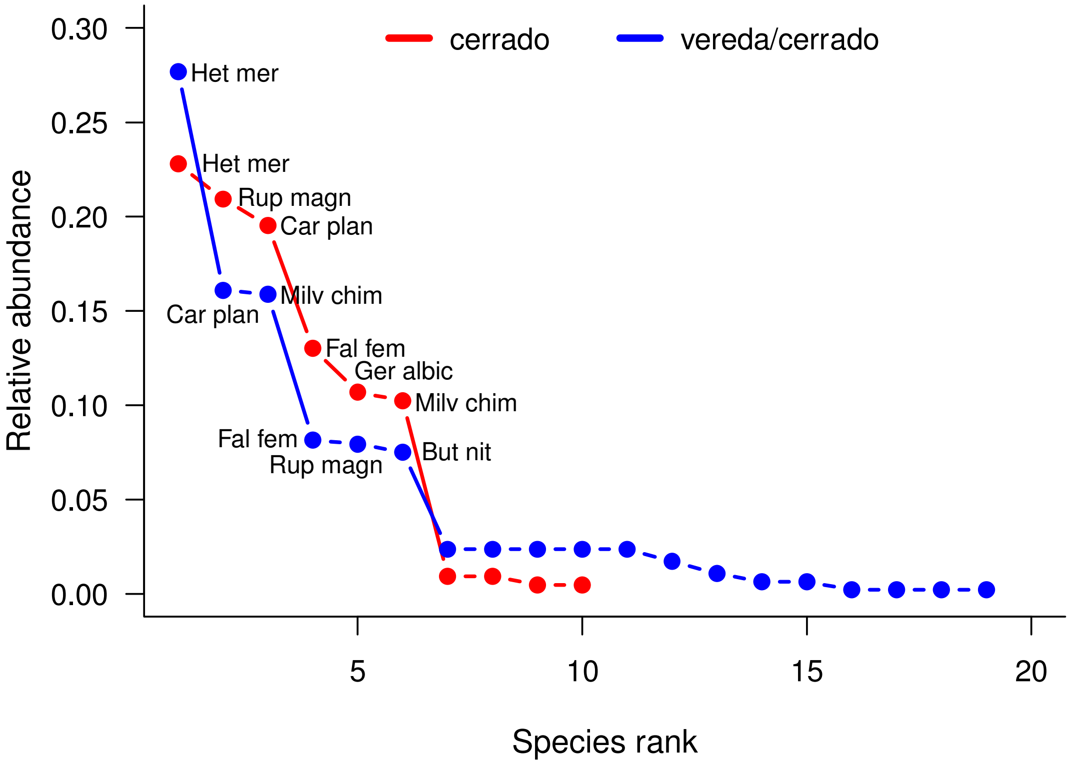

Figure 13. Species' richness and relative abundance along road surveys in each one of the two habitats studied in PEVP-MG. Het mer = *Heterospizias meridionalis*, Rup magn = *Rupornis magnirostris*, Car plan = *Caracara plancus*, Milv chim = *Milvago chimachima*, Fal femor = *Falco femoralis*, Ger albic = *Geranoaetus albicaudatus,* But nit = *Buteo nitidus*.

However, when absolute number of records per species are analysed, some patterns can be detected, suggesting habitat preference, or selection, for determined taxa (Table 8). Considering species with more than ten records (n = 13), it is possible to see that eleven of them held more than 60% of their records in a determined habitat, which was, for ten of them, the *vereda/cerrado* associated portion. The only species with enough number of records (n > 10) that presented more than 60% of its records in the *cerrado* was *G. albicaudatus.*

Table 8. Species detected along road surveys in PEVP-MG and their absolute number of records per habitat.

Species	*cerrado* (1512 km)		vereda/*cerrado* (1260 km)		Total number of records
	Records	(%)	Records	(%)	
H. meridionalis	49	27.5	129	72.5	**178**
C. plancus	42	35.9	75	64.1	**117**
M. chimachima	22	22.9	74	77.1	**96**
R. magnirostris	45	54.9	37	45.1	**82**
F. femoralis	28	42.4	38	57.6	**66**
B. nitidus	0	0	35	100	**35**
G. albicaudatus	23	88.5	3	11.5	**26**
G. caerulescens	1	8.3	11	91.7	**12**
B. brachyurus	0	0	11	100	**11**
U. coronata	0	0	11	100	**11**
H. cachinnans	0	0	11	100	**11**
R. sociabilis	0	0	11	100	**11**
P. unicincitus	2	20	8	80	**10**
A. striatus	1	16.7	5	83.3	**6**
C. uncinatus	0	0	3	100	**3**
F. sparverius	2	100	0	0	**2**
A. bicolor	0	0	1	100	**1**
E. leucurus	0	0	1	100	**1**
L. cayanensis	0	0	1	100	**1**
M. semitorquatus	0	0	1	100	**1**
Grand Total	**215**	31.6	**466**	68.4	**681**

When analysing absolute number of records per habitat, although segregated by line transects, it is possible to observe that every line transect inserted in the *vereda/cerrado* habitat (line transects 7 to 11) presented higher abundance if compared to any transect inserted in the *cerrado* (line transects 01 to 06) (Figure 14). Specifically, considering the *vereda/cerrado* line transects, two showed distinctly higher number of detections, the road transects 07 and 10. The climatic annual shift did not affect much the number of records obtained in the *cerrado*, once line transects inserted in the habitat presented lower encounter variation between field trips (detections varied from 22 to 43). However, line transects inserted in the *vereda/cerrado* presented much higher variation between field trips, ranging from 52 to 148 records, mainly line transects 8 and 10.

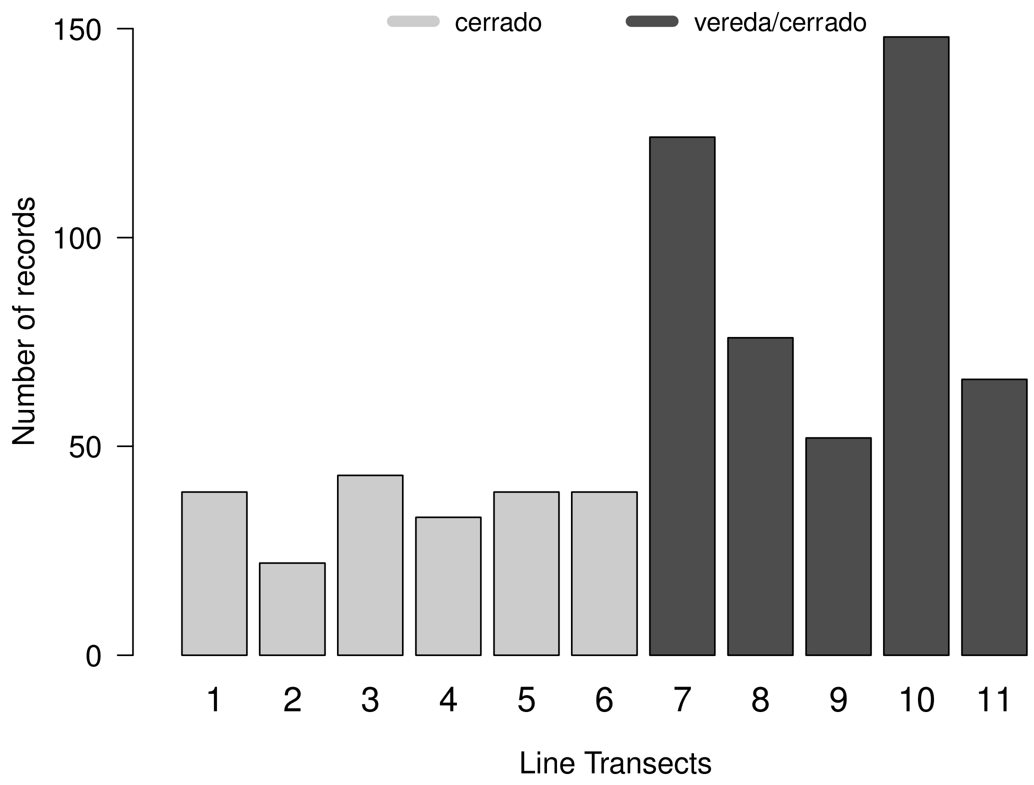

Figure 14. Number of diurnal raptors detections obtained along each line transect realized in PEVP-MG.

3.2.6 Model selection

Based on ΔAICc the model that better explained species richness had all three explanatory variables (habitat, season and day period) considered. In this model, habitat was the variable that explained the false zeros in the count data. Corroborating the importance of all these explanatory variables, the two other models selected (ΔAICc <2) also accounted for the effects of all these variables on species richness. Additionally, the relative weight of these three models to explain the data reached 0.93.

The model that best fitted abundance data was also the one that contained all three explanatory variables and habitat as a variable explaining false zeros (Table 4). The second model ranked in the set also had all three explanatory variables in its formulae, although, habitat and day period explained false zeros. The relative weight of the first model in the rank is 0.68, which means that this model, by itself, explains almost 70% of the data, considering all fitted models. Accounting also with the second model on the rank, the relative weight to explain data raises to 0.85. The null model was the last one in both ranks.

Table 6. Models of the relation between habitat, season (dry or wet) and day period (morning or afternoon) on species richness in PEVP-MG.

Model description - *Species richness*	**ΔAICc**	**DF**	**Weight**
Species richness~habitat+season+day.period | habitat	0.0**	6	0.392
Species richness~habitat+season+day.period	0.2**	8	0.349
Species richness~habitat+season+day.period | habitat + season	1.4**	7	0.193
Species richness~habitat+season | habitat	5.6	5	0.023
Species richness~habitat+season	6.8	6	0.013
Species richness~habitat+season | habitat + season	6.8	6	0.013
Species richness~habitat+day.period | habitat + season	7.1	6	0.011
Species richness~habitat | habitat + season	10.4	5	0.002
Species richness~habitat+day.period | habitat	13.5	5	<0.001
Species richness~habitat+day.period	14.4	6	<0.001
Species richness~habitat | habitat	17.9	4	<0.001
Species richness~habitat	17.9	4	<0.001
Species richness~season+day.period | habitat + season	36.8	6	<0.001
Species richness~season+day.period | habitat	37.1	5	<0.001
Species richness~day.period| habitat + season	41.7	5	<0.001
Species richness~season | habitat + season	42.0	5	<0.001
Species richness~season | habitat	42.1	4	<0.001
Species richness~day.period | habitat	46.0	4	<0.001
Species richness~season+day.period	76.4	6	<0.001
Species richness~season	78.9	4	<0.001
Species richness~day.period	86.8	4	<0.001
Species richness~1	88.1	2	<0.001

** Models selected (ΔAIC<2). The symbol ~ indicates statistical dependence (Species richness ~ "independent variable" means that the expected value for the dependent variable is a linear function of the independent variable; the symbol "+" indicates additive effects of the independent variables listed; variables after symbol "| " try to explain the probability of false zeros.

Table 7. Models of the relation between habitat, season (dry or wet) and day period (morning or afternoon) on diurnal raptors abundance in PEVP-MG.

Model description - *Abundance*	**ΔAICc**	**DF**	**Wheights**
Abundance~habitat+season+day.period | habitat	0.0**	7	0.608
Abundance~habitat+season+day.period | habitat + day.period	1.8**	8	0.251
Abundance~habitat+season+day.period	3.7	9	0.096
Abundance~habitat+season | habitat	6.6	6	0.022
Abundance~habitat+season | habitat + day.period	7.8	7	0.012
Abundance~habitat+season	8.6	7	0.008
Abundance~habitat+day.period | habitat	30.3	6	<0.001
Abundance~habitat+day.period	32.0	7	<0.001
Abundance~habitat+day.period | habitat + day.period	32.0	7	<0.001
Abundance~season+day.period | habitat	33.8	6	<0.001
Abundance~habitat | habitat	34.1	5	<0.001
Abundance~habitat	34.1	5	<0.001
Abundance~habitat | habitat + day.period	35.1	6	<0.001
Abundance~season+day.period | habitat + day.period	35.9	7	<0.001
Abundance~season | habitat	40.5	5	<0.001
Abundance~season | habitat + day.period	42.3	6	<0.001
Abundance~day.period | habitat	58.8	5	<0.001
Abundance~day.period | habitat + day.period	60.8	6	<0.001
Abundance~season+day.period	77.9	7	<0.001
Abundance~season	81.3	5	<0.001
Abundance~day.period	100.4	5	<0.001
Abundance~1	101.5	3	<0.001

** Models selected (ΔAIC<2). The symbol ~ indicates statistical dependence (Species richness ~ "independent variable" means that the expected value for the dependent variable is a linear function of the independent variable; the symbol "+" indicates additive effects of the independent variables listed; variables after symbol "| " try to explain the probability of false zeros.

4 DISCUSSION

4.1 Species richness, composition and similarity

Based on species richness results obtained in this study, and also in similar ones (Baumgarten 1998, 2007 and Granzinolli, 2009), line transects by car appear to be really recommended for surveys carried out in savannah like habitats, once only one, out of 21 *taxa*, was not detected by the method during the present study. The mentioned studies presented lower percentage of total richness recorded along road transects, however the results were also considerable. To support that, Jackknife 1 estimator suggested that the study area should harbour approximately 25 species, pointing out that 80% of the estimated richness was recorded during the 2772 km of line transect sampling.

As expected, due to its evolutionary diversification and, consequently, its higher species richness in the Neotropics (Brown & Amadon, 1989; Sick, 1997; Fergusson-Lees & Christie, 2001), the family Accipitridae held greater percentage of local species richness, when compared to Falconidae. This is a clear pattern and it can be observed, probably, in every raptor inventory carried out in South America (e.g., Thiollay 1989, 2007; Baumgarten, 1998, 2007; Azevedo *et al.*, 2003; Manosa *et al.*, 2003; Loures-Ribeiro & Anjos, 2006; Carvalho & Marini 2007; Canuto, 2009; Carrete *et al.*, 2009; Granzinolli, 2009; Zorzin, 2011; Piana & Marsden, 2012; Zilio, 2012; Zorzin *et al.* (*in prep.*)).

Compared to other studies carried out in *Cerrado* reserves, the present one showed higher diversity. Baumgarten (1998) recorded 16 species for a conservation unit within the *Cerrado* (Parque Nacional das Emas, Goiás State | PNE-GO), being 14 of these (87.5%) detected along 7033 km of road surveys and the other two along other methods. Granzinolli (2009) found similar results for another conservation unit within the *Cerrado* (Estação Ecológica de Itirapina, São Paulo State | EEI-SP), detecting 15 species along 5292km of road surveys. The author detected four other species with different methods, rising local species richness to 19. Therefore, even applying a considerable smaller effort and having, consequently, a smaller number of detections (*n*= 681) compared to Baumgarten (1998) (*n*= 3162) and Granzinolli (2009) (*n*= 2131), the species richness detected along road surveys in this study was in absolute numbers higher than those found in both. This could be due to a probable higher local diversity and/or, could also be a result of the three observers plus driver methodology definition, leaving more persons focused only on detections, reducing the chances of not seeing a locally rare species.

Considering other studies carried out in PEVP's surroundings (specially at Parque Nacional Cavernas do Peruaçu - Kirwan *et al.*, 2001, 2004; Buzzeti, 2003), and accounting all species detected along those, eight other diurnal raptors are listed for the region, although, in a much larger scale: *Pandion haliaetus* (Osprey), *Gampsonyx swainsonii* (Pearl Kite), *Ictinia plumbea* (Plumbeous Kite), *Urubitinga urubitinga* (Great Black-Hawk), *Spizaetus ornatus* (Ornate Hawk-Eagle), *S. tyrannus* (Black Hawk-Eagle), *Micrastur ruficollis* (Barred Forest-Falcon) and *Falco rufigularis* (Bat Falcon). Although, despite presenting distribution to the region, in a macro scale, at least four of these species might not occur within PEVP boundaries, such as *S. ornatus*, *S. tyrannus*, *M. ruficollis* and *F. rufigularis*, once the habitats where they can be found at do not occur in this particularly protected area. However, *P. haliaetus*, *G. swainsonii*, *I. plumbea* and *U. urubitinga* might, occasionally, occur at the study site and could be recorded in future efforts. It is important to mention that *P. haliaetus* and *I. plumbea* populations migrate (Bildstein, 2004), a fact that reduces the odds of recording these species during short period field trips few days.

Comparing to all selected birds of prey studies carried out in different regions of Brazil (Baumgarten, 1998, 2007; Azevedo *et al.*, 2003; Manosa *et al.*, 2003; Loures-Ribeiro & Anjos, 2006; Carvalho & Marini 2007; Canuto, 2009; Granzinolli, 2009; Zorzin, 2011; Zilio, 2012; and Zorzin *et al.* (*in prep.*)), the species richness found in PEVP did not diverge much from the majority, although, the assemblage composition varied substantially, specially when compared to further locations.

Due to vegetation characteristics found in PEVP-MG, it was expected to obtain higher assemblage similarity with other *Cerrado* localities sampled, especially protected areas with high habitat quality, such as PNE-GO or EEI-SP. This expectation was mainly driven by the results obtained by Granzinolli (2009), who compared several assemblages in Brazil and found the one described by Baumgarten (1998, 2007), for Parque Nacional de Emas (PNE-GO), as the most similar to the one studied by him at Estação Ecológica Itirapina (EEI-SP). Once this was the result obtained by the mentioned author, it was expected that the assemblage described here would present higher similarity with those areas, once they all lie within the *Cerrado* and, at least PNE-GO, shelter similar vegetation typologies, such as *vereda* and *cerrado*. However, the site with higher species similarity with the area here studied is the one described by Carvalho & Marini (2007), which lies in a *Cerrado* – Atlantic Forest ecotone and is characterized by different geography and physiognomies (CERTB pers. obs.). Notwithstanding, areas like Parque Estadual do Rio Doce (Canuto, 2009), Rio Doce municipality (Salvador-Junior & Lima, 2009) and Viçosa region (Zorzin, 2011), all immersed within the Atlantic Forest, showed higher similarity with PEVP than both *Cerrado* reserves. Apparently, the distances between sites, as well as other variables, were more important to affect assemblage similarity than several other features, such as the phytogeographic region where each locality belongs.

4.2 Relative abundance

Species were not equally represented in the assemblage, as expected, confirming a well-known ecological pattern for species abundance distribution (Magurran, 2004). The assemblage was characterized by few very abundant *taxa* (*e.g. H. meridionalis*, *R. magnirostris, C. plancus, M. chimachima* and *F. femoralis*), some moderately common (*e.g. Geranospiza caerulescens, G. albicaudatus*, *B. nitidus* and *B. brachyurus*) and others, often the majority, locally rare species (*e.g. L. cayanensis, E. leucurus, A. bicolor, M. semitorquatus*, *F. sparverius* and *F. peregrinus*).

The five most common species recorded at the study area are widespread *taxa* and common along most of their range and, as a matter of fact, all of them can be frequently found in disturbed habitats, even at great urban centres, demonstrating their opportunistic adaptation and low sensitiveness to habitat disturbance (Stotz *et al.*, 1996; Sick, 1997; Fergusson-Lees & Christie, 2001).

Comparing with other Cerrado localities, the selective group of most abundant species did not diverge much from that found by Granzinolli (2009) at EEI-SP. Although, when comparing the results obtained by this study with those found by Baumgarten (1998, 2007), a notable shift was detected. Three, out of the five most abundant species diverge; *H. meridionalis*, *R.* magnirostris and *M. chimachima*, which were substituted at PNE-GO by *E. leucurus*, *G. albicaudatus* and *F. sparverius*, demonstrating a considerable difference on assemblage composition between these two localities. The only species found at a high abundance level by Granzinolli (2009), but not listed as very abundant in PEVP-MG, was *F. sparverius*. The extremely low abundance of *F. sparverius* at PEVP, especially when compared to other localities within the Cerrado, should be due to habitat characteristics and, probably, also because low abundance of resources needed for the species. The same features might also have affected the extremely low abundance of *E. leucurus* in the area. Both species were not expected to present such low abundance, once they are common at several types of open and semi open habitats (Ferguson-Lees & Christie, 2001 and *pers. obs.*).

Total number of raptors/km found in this study (0.24 raptors/km) was lower than the ones found by Baumgarten (1998) (0.34 raptors/km) and Granzinolli (2009) (0.40 raptors/km). Although, the number of raptors/km found in the *vereda* (0.36 raptors/km) is compatible with the results found by these two authors, which suggests that the local *cerrado*, which held 0.14 raptors/km, might not have enough resources to offer, which would affect fitness and, consequently, abundance (Garshelis, 2000).

4.3 Temporal variations

Species richness did not change much along different field trips and this should be the consequence of the sedentary, or presumably sedentary habits of most species. However, Neotropical temporal abundance is a known matter among raptors and it may vary due to several ecological features (Newton, 1979; Brown & Amadon, 1989; Fergusson-Lees & Christie, 2001; Bildstein, 2006) but also due to detectability (Andersen, 2007). Despite many Neotropical raptors are considered largely sedentary, they can realize relatively short movements in response to climatic changes and some might also become nomadic when not breeding, which could also directly affect abundance estimates (Fergusson-Lees & Christie, 2001; Bildstein, 2004, 2006).

Raptors were more numerous during wet than during dry season, although, this was probably a consequence of a clear reduction in numbers of some really abundant species during the rainy period, such as *H. meridionalis* and *M. chimachima*. The record numbers of both species varied substantially and directly influenced the assemblage counts. Other species smoothly varied in abundance and none of them had a great influence on the final results, although, together, this became a clear pattern. The last two field trips (May and July, dry season's peak) held the lowest number of raptors records at all, may be due to the consequences of the lack of rain, which could have affected prey availability and consequently, birds of prey abundance.

Zilio (2012) also found higher raptor abundance during rainy season along road surveys carried out by him in open fields in southern Brazil and Uruguay. In the other hand, Baumgarten (1998) did not find a similar result for PNE-GO, a site within the Cerrado region. The latter author detected higher raptor abundance between March and July, exactly the months with lower number of detections along the present study. When comparing data collected from only one year of his study, the results obtained by Granzinolli (2009) at another *Cerrado* locality (EEI-SP) were similar for rainy (*n*= 644 detections) and dry (*n*= 666 detections) season abundances, which also differ from PEVP results. This suggests that *Cerrado* raptor assemblages may vary differently in abundance along seasons, once populations might present different habits, realizing more, or less, movements according to food availability and other resources.

In order to try to explain this temporal abundance variation, focus will be given to three species, which revealed distinct abundance patterns, *H. meridionalis*, *C. plancus* and *M. chimachima*. The abundance of *H. meridionalis* at PEVP dropped nearly to zero during a certain period of the dry season (May and July), which could be a consequence of low resource availability at a specific portion of the line transects 10 and 11 during a specific period (Janes, 1985; Garshelis, 2000), both along the *vereda*, which held most species records during other field trips. Several individuals, both adults and juveniles, were frequently seen foraging in the area and, for once, eight individuals were counted in a short distance of approximately 200m. This high concentration might be due to an instant increase of food resources and the high availability of perches (burnt *Mauritia flexuosa* trees), allowing the presence of several individuals at good hunting spots. The species is known to be a fire follower (Fergusson-Lees & Christie, 2001), although remaining at such high concentration during so long at not so recently burnt localities is not commonly observed. Despite unexpected, this high concentration of individuals could be also explained by the hypothesis mentioned above, once this occurred during rainy season, which present abundance peaks for some insect Orders at the Cerrado (Pinheiro *et al*., 2008).

Zilio (2012) also found higher abundance for *H. meridionalis* during rainy season (October-March), although not such low results for dry season. Along the other sampled year, the latter mentioned author encountered no significant temporal abundance variation. Baumgarten (1998) found lower abundance for *H. meridionalis* during August and September, corroborating, in a certain way, to the findings of the present study, once these months are considered dry months. In contrast, Granzinolli (2009) attested higher abundance for the species at EEI-SP during dry season (April-September). These variations among studies might be a consequence of different populations responses to different situations found along years, or seasons, like food availability (Hayes, 1991), higher number of non-territorialist juveniles during certain periods (Zilio, 2012).

Though observed at constant abundance during four field trips (September to March) at PEVP, *M. chimachima* was recorded at extremely low numbers during May and July surveys (dry season's peak), just like *H. meridionalis*. According to Fergusson-Lees & Christie (2001), this raptor might be sedentary and also nomadic, which could not be suggested by this study due to its sampling effort (one year). Nevertheless, this pattern observed for both species might have to do with the same issues, like a probable decrease in food resources. If this is assumed, their diets at PEVP might either suffer a considerable overlapping, or the resources consumed might be subordinate to the same annual cycles, decreasing its offer during the same period.

Granzinolli (2009) also obtained results pointing higher *M. chimachima* abundance during rainy season. Conversely, July, August and September (driest months) were the sampled months with lower abundances. This corroborates the results found at PEVP. However, he didn't observe such strong abundance shift. Confronting the data of the present study, corroborated by Granzinolli (2009), Zilio (2012) found that the species was more abundant during wet season in Southern Brazil and Uruguay and Baumgarten (1998) did not detect any temporal abundance variation for the species in PNE-GO. This variation among different studies could be explained as specific responses to local environmental conditions. This would mean that different *M. chimachima* populations might present different responses to each year cycles (seasons).

Other species that presented notable quantitative variation along the period studied was *C. plancus*, however with a distinct pattern. The species was recorded in November at an extremely high abundance, when compared to other sampled months. This abundance peak might be due either to greater resource offer or to an increasing of activity, which could indicate breeding season. Fergusson-Lees & Christie (2001) mention that *C. plancus* could be a seasonally common species in South America, and this could be driven by resources availability, explaining its suggested nomadic behaviour. Del Hoyo *et al.* (1994) classifies the species as "…possible realizes local movements. It is, generally, a scavenger species, although it feeds on slow moving, injured, incapacitated young birds, rodents, reptiles amphibians and fish, as well as invertebrates…" (Fergusson-Lees & Christie, 2001). Studies carried out in South America confirmed its high predation upon invertebrates (Travaini *et al.,* 2001; Vargas *et al.,* 2007) and the offer of some of these prey items during November's survey might have been the main cause of this abundance peak. Due to rain volume, a lot of invertebrates, fossorial species and amphibians were more active, and consequently, easily seen and captured. Besides, it is a time where there is a high abundance of young birds, due to early breeding species (Sick, 1997). For once, an adult individual of *C. plancus* was seen capturing a recently fledged *Gnorimopsar chopi* (Chopi Blackbird).

Baumgarten (1998) observed higher abundance of *C. plancus* during the same period (October-November), corroborating the results at PEVP. Conversely, for the localities studied by Granzinolli (2009) and Zilio (2012) the dry season presented the higher number of records for the species. This variation demonstrates that temporal abundance patterns might vary for different populations.

4.4 Time of day effects

The greater number of records held by morning samples demonstrates higher activity during this period, however, higher results for species richness were obtained during late morning (10:00 – 12:00 h) and afternoon. These results raise the importance of realizing surveys during both periods for studies carried on assemblages' diversity. At some regions, sampling between 12:00 and 14:00 might be reasonable, however, the temperature during this time of day at the study area is very high and the pilot study did not attest numerous results, fact that influenced the decision to not survey the mentioned period. Despite some authors have realized mornings and afternoons surveys, daily activity patterns are not frequently analysed for South American diurnal raptors, what makes comparisons difficult. For North America, Bunn *et al*. (1995) compared mornings and afternoon surveys in northeastern United States and found no difference on raptors abundance between them, contrasting the results obtained by the present study.

The early activity peak detected for *R. magnirostris* and *F. femoralis* may suggest a relation with its prey activity. Despite feeding upon many organisms, these species are known to also feed on birds (Brown & Amadon, 1989; Sick, 1997; Fergusson-Lees & Christie, 2001), which are more active/conspicuous during this time of day, fact that could facilitate opportunistic records.

More opportunistic predators, such as *C. plancus* and *M. chimachima*, presented longer activity periods. The fact that *C. plancus* had almost constant number of records during two morning periods (four hours) and *M. chimachima* during all morning could also be the consequence of the prey they feed on. Both raptors frequently feed upon invertebrates and, sometimes, even fruits (Travaini *et al*., 2001; Galleti & Guimarães-Junior, 2004; Vargas *et al.,* 2007; Sazima, 2007). These can be considered low energy items for both species and could directly affect time spent foraging, once all species should efficiently exploit available resources (Emlen, 1966).

4.5 Habitat use

The higher abundance and species richness found in the *vereda/cerrado* associated habitat demonstrates the importance of this portion of PEVP for local raptors assemblage composition and regional conservation. Regionally, the *veredas* occupy a small area and, consequently, a small percentage of available natural habitats, although this study demonstrated its importance for raptors, once 68% of the records were taken in particular habitat and ten species were detected only in the *veredas*. Raptors are known to occur in several neighbour habitats at different abundances, reflecting habitat quality and selection (Garshelis, 2000; Thiollay, 2007, Granzinolli, 2009).

Tubelis (2009) recently reviewed 25 bird studies carried out in *veredas* along several Brazilian regions and listed 17 raptors species for this typology, whereas this study recorded 19 species for this particular habitat type, what demonstrates the high local richness of the *veredas* present in PEVP. Raptors are known to be associated with certain habitats (Cornulier & Bretagnolle, 2006; Carrete *et al.*, 2009) and, at a local scale, this assemblage is highly aggregated. However, once raptors have large home ranges (Newton, 1979; Brown & Amadon, 1989; Bierregaard, 1995, 1998) and local *veredas* are linear and immersed into a great *cerrado* matrix, the species detected only in the veredas should also depend on this habitat matrix, in a certain way, even not being recorded in them. Thiollay (2007) confirmed that many raptor species in French Guiana were dependent on a combination of two or more habitats, like forest and a neighbour habitat not as preserved as the forest.

The only species with more than ten records and 85% of them concentrated in one habitat (being this habitat the *cerrado*) was *G. albicaudatus*, an open and semi-open habitats typical species, and so, not expected at high numbers in semi-forested habitats, as the *veredas* found in PEVP (Brown & Amadon, 1989; Fergusson-Lees & Christie, 2001). According to Granzinolli & Motta-Junior (2006, 2007) the species consumes mostly small mammals (most important biomass consumed) and invertebrates (most numerous prey consumed), which can be easily detected and, consequently, hunted in open areas.

4.6 Species Conservation

Urubitinga coronata is the only raptor globally threatened with extinction recorded in the study area (IUCN, 2012). The Crowned Eagle is one of the largest raptors in South America and it presents an extensive range in the continent, occurring in open lowland, savannah, bushy steppe, dry scrub and lightly wooded foothills along Bolivia, Argentina, Paraguay and Brazil (Fergusson-Lees & Christie 2001; del Hoyo *et al.* 1994). Despite its wide geographical range, the species holds a low density and its total population is currently estimated at <1000 individuals (IUCN, 2012). Considering its medium sensitivity (Stotz *et al.,* 1996) to habitat disturbance, two of the main threats the species face are habitat destruction and persecution (Sarasola & Maceda 2006; Sarasola *et al.* 2010; IUCN, 2012), which, along with others might have been the cause of the species extinction in Uruguay in the 1930's (Collar *et al.* 1992). Just like several other predators with low population densities and wide geographical ranges, it is hard to effectively preserve the species due its mentioned biological features and to threats they face along its range (Trinca *et al*., 2007; Dickman, 2010; Sarasola *et al.* 2010), fact that gives higher importance for local conservation acts.

The juvenile presence in the area confirms the reproductive activeness of the adult pair, and assuming the species present a low productivity, once it may not breed every year, this can be seen as important information for its conservation (Fergusson-Lees & Christie, 2001; Sarasola & Maceda, 2006). However, all the records were taken along the *vereda*, which is exactly the northern boundary that divide into protected (southern) and unprotected (northern) terrain (see Figure 1). This makes those individuals more vulnerable to the species main threats (like hunting and/or persecution), which are least controlled outside PEVP boundaries. This should be a concern for species regional conservation, once the Crowned Eagles may also use PEVP's surroundings for activities, such as hunting and, may be, even breeding. The presence of large raptors in farmland surroundings disturbs most landowners, who treat the species as a threat to livestock and persecute it, commonly shooting or trapping individuals (Sarasola & Maceda 2006; Dickman, 2010; Sarasola *et al.* 2010, *pers. observation*). To avoid undesirable records and possible criminal acts against the Crowned Eagle and other raptors in the region, it is suggested that information about the species ecological importance should be given to local communities and regional landowners, turning park management more integrated with its regional and social economic context (Sergio *et al.* 2005a).

Like the Crowned Eagle, other species presenting medium (*n*= 7 species) or high sensitivity (*n*= 1 species) to disturbance were also detected in the study area, especially in the *vereda.* This suggests a high importance of the mentioned habitat to raptors local diversity and also that PEVP, specially the *vereda*, presents a good environmental health, once nine *taxa* (43%) of the assemblage depends, in a certain way, on habitat quality (Stotz *et al*. 1996). Raptors can be used as good environmental quality indicators due to their many ecological requirements (Thiollay 1989), being able to select sites with better ecosystem productivity, (fact that directly affects food availability in a bottom-up manner), which could be the case of the mentioned habitat (Sergio *et al.* 2006; Thiollay 2007). Thus, conserving the *veredas*, should reflect directly in the conservation of whole group of organisms associated with it.

Once the six most abundant species for each habitat do not diverge much (only one *taxa*), in order to maintain local diversity, it is important to focus on the moderately common and locally rare species. To obtain success on that, attention should be given to habitat protection and, once records are aggregated in the *veredas*, the northern boundary of the reserve, a greater effort should be directed to this portion. Once limited funding requires prioritising habitats for conservation (Johnson, 2007), the results obtained with this focal group indicates the *veredas* as the portion that should receive greater attention, at this moment. Local *veredas* frequently face human-set fires during dry seasons (April - September) (Lopes *et al*., 2010; *pers. obs.*) and to better protect this habitat from anthropic threats it is suggested an increase of the reserve area towards north, specifically the left margin of Peruaçu River.

As a complementary action, which would favour biodiversity at all, an expansion of the parks' area towards north should be considered, once the *veredas* are located there. Thiollay (1989) proposed raptors as important biological indicators and preferable organisms to take into account during the design of an optimal nature reserve and Estes *et al.* (2011) showed the importance of top predators for species diversity conservation in protected areas. The same author and colleagues proposed that predators' absence could directly affect biological processes, which could, due to different interaction pathways, cause relevant ecosystem changes. Additionally, areas occupied by some raptors are also known to harbour high biodiversity (Sergio *et al*. 2005b, 2006, Thiollay, 2007), justifying its conservation and the umbrella role played by these top predators.

These arguments should be considered in any future decision-making regarding regional conservation. Hence, all the *vereda* would be located inside PEVP's boundaries, protecting the Peruaçu River stream and all its diversity associated, once it harbours high raptor diversity and it is one of the few sources of running water within the park's 30.702 ha.

5 CONCLUSIONS

The study area presented considerable species richness when compared to other localities where sampling accounted only for raptors, especially when confronted with surveys conducted within the Cerrado Region. Despite the species accumulation curve did not present stabilization, the assemblage seemed to be well surveyed and species not detected should present really low regional abundance or may occur occasionally in the study area.

The assemblage composition might be considered moderately sensitive to habitat disturbance, according to Stotz *et al.* (1996), once nine species present medium or high sensitiveness to habitat alteration. This reinforces that the local abundant species (which are the ones with low sensitiveness) do not necessitate higher attention. However, some species once common were already extinguished, fact that could never be ignored. At species level, the most important record was that of the Crowned Eagle, a large-sized and threatened with extinction raptor that occurs in open and semi-open landscapes in South America.

The raptor assemblage found at PEVP is more closely related to the one described for an ecotone region also situated in southeastern Brazil. Apparently, when comparing between sites, the habitats of both areas are not similar and greater similarity was expected with other Cerrado reserves (*e.g.* EEI-SP and PNE-GO). However, geographical distance might have been one of the most important variable (along with others) to determine similarity.

The number of records during road surveys was significant when compared to other studies, especially the ones realized within the Cerrado region. Once none of the studies realized in the Cerrado Region used several short length road transects, a minimum length was not yet well defined. With the realization of this study, which presented areas with really low raptor abundance, such as the *cerrado,* a minimum length for road sampling might be estimated for other localities inserted in the Cerrado Region. However, a high number of zeros in the count data might be expected with such design, once raptors present low densities and large home ranges.

The models selected, both for species richness and abundance, seemed reliable according to experience obtained during data gathering *in situ*. All three independent variables seemed to affect the two response variables and, together, they explained the variations on data upon species richness and abundance. Zero inflated models (ZIP and ZINB) were those that best fitted the data, once GLM did not reached expectations. These types of models are really useful for ecological count data, where zeros can be frequent. The results obtained by the models show that habitat, season and day period, together, have strong effects on species' local richness and abundance.

Species richness did not suffer abrupt changes along field trips, what corroborates with the hypothesis that most species of the local assemblage are residents or only do local movements. These local movements occurred and seasonal patterns were observed, once the wet season held great part of total records. Such movements might have been mostly performed due to resource availability related to breeding or feeding. *Heterospizias meridionalis* was the most abundant species, in both habitats studied, although its abundance highly varied in the *veredas* among field trips. The other most abundant species were also common and widespread *taxa*, however, many species were considered rare or uncommon and should receive attention in future management or conservation acts. According to the results obtained by other authors, no temporal abundance pattern was detected for raptor assemblages in the Cerrado Region, once many species varied differently according to the locality they were studied.

Mornings held more records than afternoons. Some species, such as *R. magnirostris, C. plancus, M. chimachima* and *F. femoralis* presented a concentrated activity peak, although this was always during morning periods. Despite lower, the results found during afternoons were considerable in a matter of richness and abundance. Considering the results obtained by the present study for road sampling, surveys should be also carried during afternoons, if possible logistically and financially.

The species richness and abundance detected in the *cerrado* highly differed from those described for the *vereda-cerrado*. The *cerrado* demonstrated to hold lower raptor richness and abundance, although it occupies most of the region and it should have an important role on raptor conservation. Natural history features (*e.g.* large home ranges, low densities) should force these individuals to use, at some level, habitats only found at considerable distances, at least occasionally. The *veredas*, which are located at the northern portion of the park, delimit the reserve boundaries and, at the same time, hold greatest raptor diversity. Some species were restricted to the veredas, what makes the habitat even more important for these species and, consequently, to local ecological community. The fact that it is only protected by one margin is a worrying issue and it is suggested that the reserve boundaries augment towards this area, once important water supply also comes from there.

Considering the costs and benefits of the method selected, a considerable proportion of the local assemblage seemed to be detected, as well as independent variables' influences on species richness and abundance. The method and the design presented reliable results and minimum adjustments were suggested to improve future efforts with similar goals and conducted in similar habitats.

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