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Daily tayra (*Eira barbara*, Linnaeus 1758) activity patterns and habitat use in high montane tropical forests

Karen Cristina Braga Lima [a], Marcelo Passamani [a], Clarissa Rosa [a,b,*]

[a] *Laboratório de Ecologia e Conservação de Mamíferos, Setor de Ecologia, Departamento de Biologia, Universidade Federal de Lavras, Campus Universitário, 37200-000, Lavras, Minas Gerais, Brazil*
[b] *Instituto Nacional de Pesquisas da Amazônia, Coordenação de Biodiversidade, 69067375, Manaus, AM, Brazil*

ABSTRACT

Activity patterns and habitat use are important for understanding the natural history of a species and its ecology. Some species of carnivore are abundant, but little studied, such as the tayra (*Eira barbara*). In this context, the activity patterns and environmental factors that influence tayra frequency of occurrence in high montane tropical rainforests in the Atlantic Rainforest biome were evaluated. A total of 32 points distributed in the Itatiaia National Park and the Alto Montana Natural Heritage Reserve were investigated for three years, in a gradient ranging from 800 to 2200 m elevation. Tayra frequency of occurrence was evaluated using camera traps and environmental variables were obtained. Photo time data indicate that tayra are predominantly diurnal and their frequency of occurrence is higher at lower elevations and in areas more distant from human habitation. Although this species occurs at all elevation, the tayra may prefer lower elevation habitats, due to the higher productivity of these areas compared to higher elevational environments. The results reported herein contribute to a better knowledge of the species and may aid in planning models and conservation actions for ecological function and tropical biodiversity maintenance.

1. Introduction

Studies on the activity patterns (temporal distribution of activities during a 24-h cycle) and habitat use (frequency of activity in each habitat) of a species allow for the assessment of temporal and spatial ecological niche dimensions (Farris et al., 2015) that determine species coexistence (Schoener, 1974) and prey-predator relationships (Kronfeld-Schor and Dayan, 2003). Ecological niches are affected by both intrinsic (e.g. hormonal, physiological, etc.) and extrinsic (e.g. habitat, elevation, anthropization) factors (Farris et al., 2015). The habitat represents a physical place where species may inhabit (Kearney, 2006; Schoener, 1974) and that can be used disproportionately to its availability (Beyer et al., 2010). Habitat selection depends on the spatial heterogeneity of resource availability (Valenzuela and Ceballos, 2000), the reduction of predation risks and both inter- and intraspecific competition (Falkenberg and Clarke, 1998).

Many studies assessing spatial and temporal niches are focused on lowland habitats and endangered species (e.g. Kasper et al., 2015; Massara et al., 2015; Vynne et al., 2014) to the detriment of well-distributed species and even those common in many environments.

This is noted for the tayra (*Eira barbara*), one of the most common Atlantic Rainforest mesocarnivores (Lima et al., 2017), displaying important ecological functions such as pest control and seed dispersal (Bonaccorso et al., 1980; Camargo-Sanabria and Mendoza, 2016). The tayra has a home range estimated at 500 ha (Michalski et al., 2006), is scansorial (Cassano et al., 2014) and diurnal or crepuscular (Huck et al., 2017; Kavanau, 1971), and able to use anthropogenic habitats, but presenting a preference for well-conserved forest areas with low human occupation (Bogoni et al., 2016; Cassano et al., 2014; Michalski et al., 2006). Although those information on its autoecology is available, few studies are based on systematic records obtained in a long-term survey. In addition, there is a gap of studies in tropical montane forest.

Elevation affects both environmental (e.g. climate and vegetation) and physical variables (e.g. radiation, reduction of land area and temperature) and both are reflected in faunal and floral composition (Lieberman et al., 1996), vegetation phytophysiognomy (Oliveira-Filho and Fontes, 2000; Sanchez et al., 2013) and, consequently, biodiversity patterns (Körner, 2007). Especially with regard to mammals, both richness and species abundance patterns are complex along altitudinal gradients (Bogoni et al., 2016; Di Bitetti et al., 2013; Martins et al., 2015;
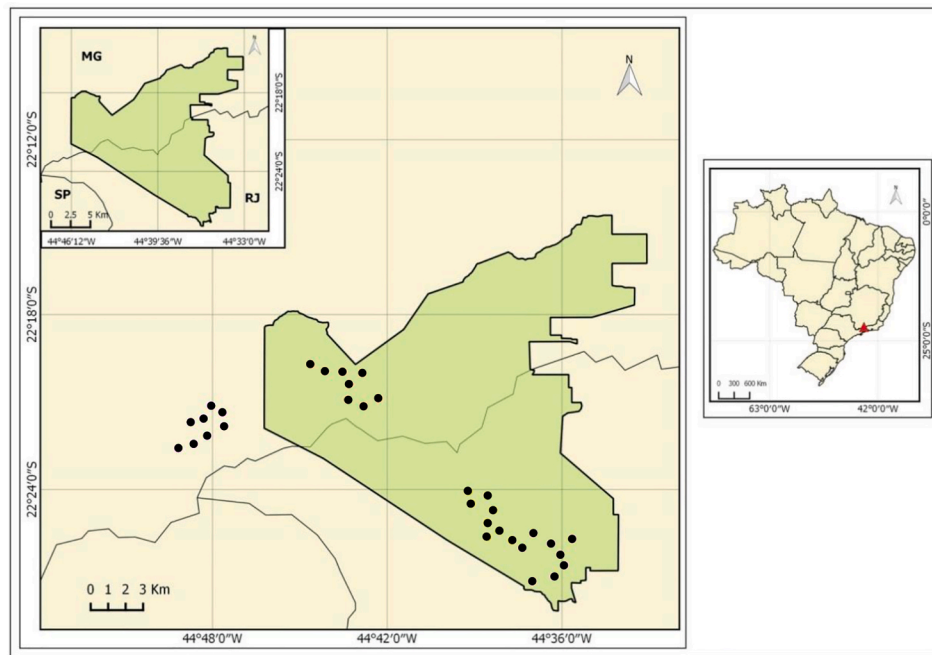
Fig. 1. Map of the study area, indicating the Itatiaia National Park perimeter (green), sampled points (black dots) and Brazilian state borders (MG-Minas Gerais; SP-São Paulo; RJ-Rio de Janeiro). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Pinho et al., 2017), and depend on the proportion of the forest cover (Sunarto et al., 2012), vegetation patterns and area productivity (Sunarto et al., 2012; Velez-Liendo et al., 2013).

In this context, the aims of this study were to evaluate tayra activity patterns and the environmental factors that influence its frequency of occurrence at Serra da Mantiqueira, a well conserved Atlantic Rainforest region presenting a wide altitudinal range. The following questions were addressed herein: Do environmental variables (elevation, forest cover and distance from human habitation and highways) determine tayra occurrence frequencies in conserved areas? Do tayra activity patterns differ between different habitats (dense ombrophylous forest and semideciduous montane forest)? The evaluated hypotheses are as follows: (1) tayra will display a predominantly diurnal activity pattern in conserved tropical forests, as observed for disturbed and human-modified habitats; (2) high montane forests areas and a low proportion of vegetation will negatively influence the presence of tayra specimens; (3) tayra will avoid human habitation and highways areas.

2. Material and methods

2.1. Study area

Samplings was conducted at Serra da Mantiqueira, a mountain range that occurs along the states of São Paulo (SP), Minas Gerais (MG) and Rio de Janeiro (RJ), Brazil. Serra da Mantiqueira comprises f 8206 km², 14.1% of which is made up of forest environments (Ribeiro et al., 2011). The region represents one of the great Atlantic Rainforest remnants in southeastern Brazil (Ribeiro et al., 2009) and one of the world's most irreplaceable ecosystems for vertebrate conservation (Le-Saout et al., 2013). Two protected areas, the Itatiaia National Park (INP) and the Alto Montana Private Reserve of Natural Heritage (AMPR), were assessed herein (Fig. 1). The INP is located in the municipalities of Itamonte (MG), Resende and Itatiaia (RJ), while the AMPR is located in the municipality of Itamonte (MG), and together represent 28,756 ha of preserved Atlantic Rainforest.

The INP extends from 600 to 2791 m of elevation and the AMPR, between 1500 and 2500 m of elevation. A humid subtropical climate predominates at lower INP elevation (600–1500 m), with a rainy season

in the summer (Köppen, 1936). Vegetation is categorized as a dense ombrophilous forest (Veloso et al., 1991), characterized by species such as *Euterpe edulis*. On the other hand, a subtropical montane climate predominates at the highest INP elevations and at the AMPR (from 1500 to 1999 m), with rainfall distributed throughout the year (Köppen, 1936). Vegetation at both locations is characterized by a semideciduous montane forest, with the presence of *Araucaria angustifolia*, while high elevation grasslands are predominant above 2000 m elevation, (Safford, 1999).

2.2. Data collection and analysis

The study was carried out between October 2013 and October 2016 along 32 sampling points distributed at the INP and AMPR, with a minimum distance of 1 km between any pair of sampling points (Fig. 1). A total of 13 sampling points were located in dense ombrophylous forest (DOF) and 19 in semideciduous montane forest (SMF). A motion-activated camera trap (Bushnell HD, © Bushnell Outdoor Products, California, USA) was installed at each sampling point, with a total sample effort of 35,040 trap/night. The camera traps were installed in places commonly used by mammals, recognized through animals signs and trails (Srbek-Araujo and Chiarello, 2013). No bait was used, in order to avoid artificial animal attraction and maintain the premise of equal catchability (Karanth and Nichols, 2002). The camera traps were programmed to take three photos in 30 s intervals when triggered by an animal. Camera trap maintenance was performed every two months for battery replacement and data collection. Tayra were identified through photographic records and at least 1 h apart were considered to be independent observations (Srbek-Araujo and Chiarello, 2013).

Four environmental variables were measured for every camera trap station, namely forest cover, elevation, distance from highways and from human habitation. A handheld GPS (Garmin GPSmap 62s) with a barometric altimeter and maximum error of 5 m was used to measure the elevation of each sampling point. To measure forest cover, 500-m radar buffers were established, with the camera trap as the center, and the percentage of forest cover was measured using a mosaic of geo-referenced images (UTM 23S, WGS 84) from the RapidEye satellite, with a spatial resolution of 5 m, using ARCGis 9.3. Forest types were
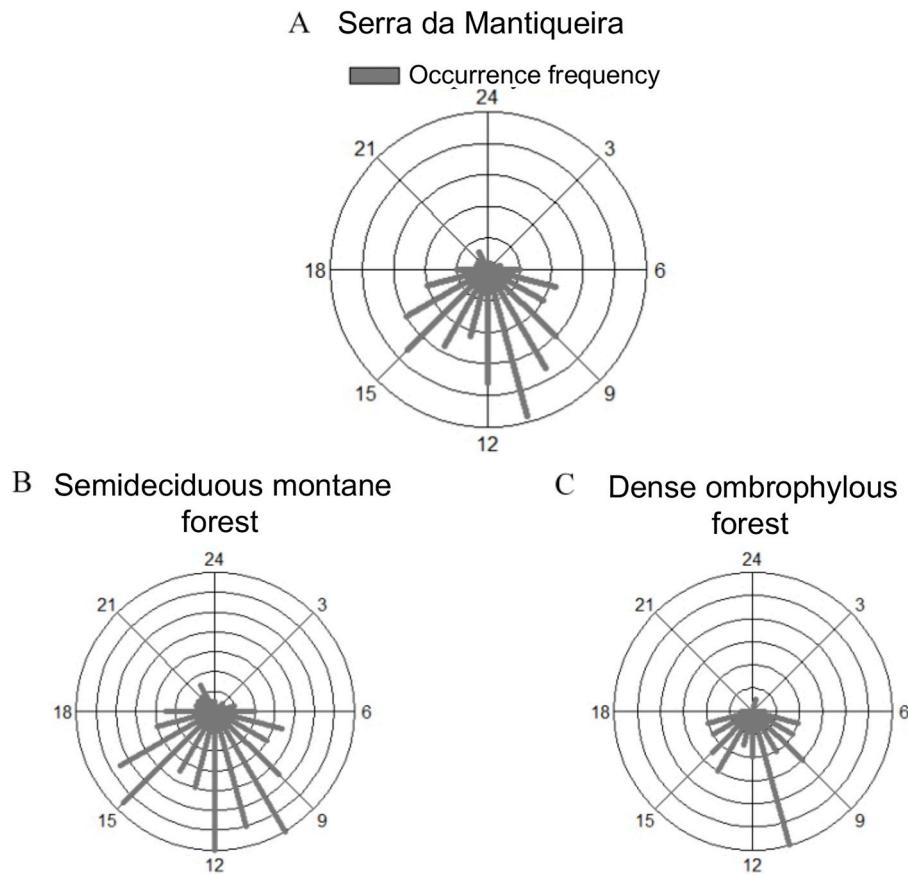
A   Serra da Mantiqueira

B   Semideciduous montane forest

C   Dense ombrophylous forest

Fig. 2. Tayra activity patterns across the study area (A-Serra da Mantiqueira) and in different forest types (B-Semideciduous montane forest and C-Dense ombrophylous forest) during the course of the 24-h day.

classified as DOF or SMF from the location of each sampling point. Finally, distances from the sampling point to the nearest highway and human habitation were determined by applying a straight line using the "Google Earth Pro" software.

Table 1
Ranking of the best generalized linear mixed-effects models with negative binomial distribution to predict the effects of the explanatory variables on tayra habitat use in the Atlantic Rainforest, Southeastern Brazil. Variation in AICc (ΔAICc) and Akaike weight (ωi).

Models	AICc	ΔAICc	ωi
Elevation (−)	783.35	0.00	0.21
Elevation (−) + Distance from human habitation (−)	785.34	1.99	0.08
Elevation (−) + Distance from highways (−)	785.36	2.00	0.08
Elevation (−) + Forest type (DOF) (+)	785.38	2.03	0.08
Forest type (DOF) (+)	785.49	2.14	0.07
Distance from highways (−) + Forest type (DOF) (+)	785.7	2.41	0.06
Distance from human habitation (−)	785.89	2.54	0.06
Null model	785.95	2.60	0.06
Distance from human habitation (−) + Forest type (DOF) (+)	786.28	2.93	0.05
Distance from highways (−)	786.42	3.07	0.05
Distance from highways (−)+ Forest type (DOF) (+) + Forest cover (−)	786.93	3.58	0.04
Distance from human habitation (−) + Forest cover (−) + Forest type (DOF) (+)	787.13	3.78	0.03
Elevation (−) + Distance from highways (−) +Forest type (DOF) (+)	787.34	3.99	0.03
Elevation (−) +Distance from human habitation (−) + Forest type (DOF) (+)	787.36	4.01	0.03
Forest cover (−)	787.46	4.11	0.03
Forest cover (+)	787.47	4.12	0.03
Distance from human habitation (−) + Forest cover (−)	787.89	4.50	0.02
Distance from highways (−) + Forest cover (+)	788.35	5.00	0.02

In order to evaluate tayra activity patterns, data obtained at the 32 sampled points and evaluated separately at DOF and SMF were used. The time records of the photographs obtained, considering ach independent observation, at the traps of each sampling point were used for this end. Rao's spacing (U) test was applied to determine if tayra activity was uniform during the course of the 24-h day, using the "circular" package (Agostinelli and Lund, 2013) available in the R Studio version 3.3.2 software package (R Development Core Team, 2016).

Generalized linear mixed-effects models (GLMM) were used to assess the environmental factors that influence tayra frequency of occurrence (i.e. frequency of photographic records at each sampling point). Before starting the analysis, we standardized all variables using the "decostand" function in the "vegan" R software package, version 3.3.2 (R Development Core Team, 2016). We used the "standardize" method, which is a z-transformation that have a mean value of 0 and a variance of 1, by transforming variables relative to other variables on the same scale of magnitude (Oksanen et al., 2008). The response variable was the number of independent photographic records, and fixed effects included forest cover, elevation, forest type (DOF or SMF), distance from human habitation and distance from highways. Sampling points were included as a random factor to account for unmeasured environmental variation associated with the investigated sampling locations. Continuous explanatory variables were previously tested for multicollinearity using Spearman's correlation. No variables with correlation coefficients >0.6 were used in the same model. Models were constructed using a negative binomial distribution (Zuur et al., 2009) and the "glmer" function available in the "lme4" R software package, version 3.3.2 (R Development Core Team, 2016). The Akaike Information Criterion corrected for small samples (AICc) was used for model selection, to identify the variables that best explain tayra frequency of occurrence in the assessed habitats. The best models were considered as those with ΔAICc lower
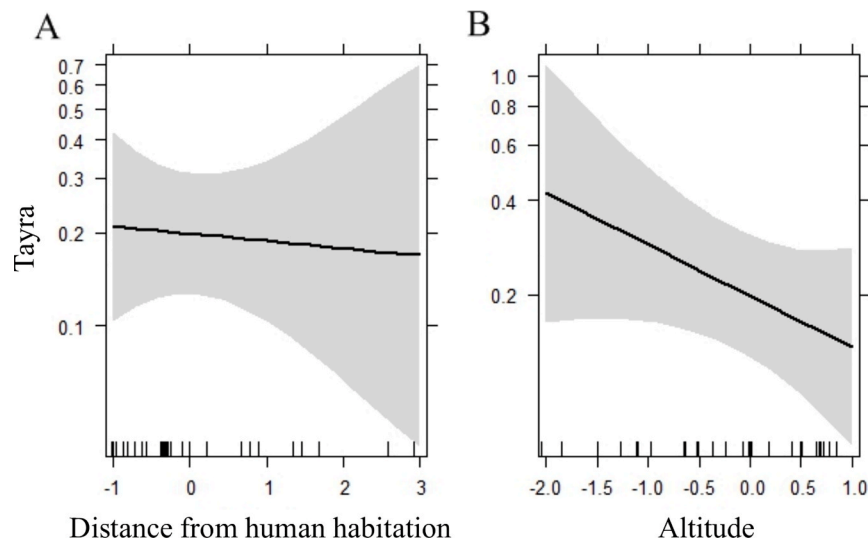
Fig. 3. Standardized data showing the effect of distance from human habitation (A) and elevation (B) on tayra frequency of occurrence at the Serra da Mantiqueira, Southeast Brazil.

Table 2
Weighted parameters of the variables by model averaging of the best models that explain tayra habitat use in the Atlantic Rainforest, Serra da Mantiqueira, Southeastern Brazil. (ΔAICc $\leq$ 2). β = estimated coefficient; SE = standard error, Z-value = Z test, P-value = significance in Z test.

Variables	β	SE	Z-value	P-value
Elevation	−0.4000	0.2119	1.883	0.0597
Distance of human habitation	−0.0544	0.2423	0.224	0.8227
Variables	**Relative importance**			
Elevation	1.00			
Distance from human habitation	0.27			

than 2 (Burnham and Anderson, 2002; Burnham et al., 2011). For models with Δ AIC ≤2, "model averaging" was applied to calculate the parameter estimates and standard errors of the best models.

3. Results

A total of 189 independent tayra records were obtained, 59 at the DOF and 139 at the SMF. Tayra activity patterns were not uniformly distributed over the 24-h period (Rao's test (U) = 223.2381, P < 0.001), and were mostly concentrated during the day (N = 163, 102 and 61 records obtained during the afternoon and during the morning, respectively) (Fig. 2). Tayra peak activity level occurred, in general, at 11 a.m., while at 6 p.m. activity levels decreased drastically, remaining low up to 6 a.m. (Fig. 2) and returning from 6 a.m. onwards. Likewise, tayra activity patterns were also concentrated in the diurnal period at the DOF (Rao's test (U) = 221.9263, P < 0.001) and the SMF (Rao's test (U) = 206.1923, P < 0.001) (Fig. 2). At the DOF, peak activity was concentrated at 11 a.m., sparser at the SMF, occurring between 10 a.m. and 12 a.m., and at 3 p.m. (Fig. 2).

Elevation appears as the only variable in the best model influencing tayra occurrence frequency in the habitat. In the second-best model, distance from human habitation and elevation were also important variables concerning tayra habitat use (Table 1). Therefore tayra frequency of occurrence is best explained by these two variables, in which this species is more frequently at lower elevations and far from human habitation (Fig. 3). Elevation was the only variable significantly and negatively related to the number of tayra records (Table 2).

4. Discussion

With predominantly diurnal habits, tayra prefer lower elevational areas in montane tropical forests, and more distant from human habitations. This species seems to adopt a daytime behavior in both conserved (the present study) and anthropized areas (e.g. Blake et al., 2015; González-Maya et al., 2009, 2015; Huck et al., 2017).

Carnivorous mammals display both diurnal and nocturnal habits, depending on the species and adopted foraging strategies (e.g. Bianchi et al., 2016; Blake et al., 2015; Di Bitetti et al., 2010; Gómez et al., 2005). Nocturnal habits can be associated with avoidance of human activities, which are usually concentrated during the day (Belotti et al., 2012; Díaz-ruiz et al., 2015; Farris et al., 2015; Ordiz et al., 2012). However, the results reported herein demonstrate that, in conserved areas, even diurnal mammals can avoid human presence. In addition, certain carnivorous species, such as *Nasua* sp. and larger mustelids, tend to be active during at least part of the day (e.g. Crego et al., 2018; Solina et al., 2018; Mena and Yagui, 2019), which can be a reaction to competition with native and exotic species (Crego et al., 2018; Farris et al., 2015), or simply based on their foraging strategies and visual acuity (e.g. colored fruits and seeds) (Chausseil, 1992). Displaying no significant conflicts with humans, with the exception of attacking bee hives in search of honey (Presley, 2000), diurnal tayra activity patterns may be a strategy to avoid competition with other carnivores and obtain better resource foraging time (González-maya et al., 2015; Kronfeld-Schor and Dayan, 2003).

Tayra habitat use and distribution is affected by seasonality and resource availability. Temperature decrease and precipitation variation trends are noted in higher elevational areas, influencing area productivity (Dulamsuren et al., 2014; Körner, 2007; Williams and Middleton, 2008). Climatic variations and soil conditions along the elevational gradient result in changes in the floristic, physiological and physiognomic vegetation composition (Gerold, 2008; Heaney, 2001; Mokarram and Sathyamoorthy, 2015; Richter, 2008), thus modifying resource availability and mammal abundance and activity patterns (Mccain, 2004, 2005; Moreira et al., 2009; Sánchez-Cordero, 2001; Sunarto et al., 2012; Velez-Liendo et al., 2013; Williams et al., 2002). Changes in vegetation are observed in the study region evaluated in this study, from denser forests in lower areas (dense ombrophylous forest), to transitional forests with lower canopy height, such as semideciduous montane forest, followed by open environments (high elevation grasslands) (Safford, 1999, 2007; Veloso et al., 1991). Although the best models determined herein do not demonstrate that tayra are directly affected by

vegetation cover, it may prefer lower areas in high elevational tropical forests (Bogoni et al., 2016) due to higher productivity (Richter, 2008; Sánchez-Cordero, 2001; Williams et al., 2002) and greater connectivity among treetops (Cassano et al., 2014), which may favor scansorial species such as tayra (Cassano et al., 2014; Fabre et al., 2015; Falconi et al., 2015). In addition, tayra is a dietary (Bisbal, 1986; Konecny, 1989; Presley, 2000) and habitat generalist (Devictor et al., 2008), allowing this species to use natural habitats in conserved regions (our study; Bogoni et al., 2016; Cassano et al., 2014), as well as modified habitats in areas with human presence (Lyra-Jorge et al., 2008; Michalski et al., 2006).

Decreasing available habitats and changes in biodiversity distribution patterns are some of the consequences of climate change (Bellard et al., 2012; Johnston et al., 2012; Svenning et al., 2009). Endangered species, such as the maned wolf (*Chrysocyon brachyurus*), for example, will experience an estimated 33% habitat reduction during the next 40 years, due to climate change (Torres et al., 2012). Therefore, although studies on endemic and endangered species are paramount, knowledge of ecological aspects that aid in modeling future scenarios for common species such as the tayra is similarly vital for sustainability efforts aiming at biodiversity conservation and maintenance of ecological function provided by species of carnivorous. In a climate change scenario, generalist species such as the tayra present the greatest chances of survival in sufficient abundances to maintain their ecological function in tropical ecosystems.

Author contribution

KCBL analyzed the data and wrote the manuscript; MP concivied the sampling design and wrote the manuscript; CAR concivied the sampling design, collected data and wrote the manuscript.

Funding

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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