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We, the disturbing animal: effects of anthropogenic noise in a Brazilian zoo

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ABSTRACT+

Loud noise impacts human and non-human animals' health and welfare after some hours of exposure. Worried about animals' life quality, a Civil Inquiry was informed against using a protected area (the Morro do São Bento municipal park) at Ribeirão Preto, SP, Brazil, for public festivities, where there was a zoo. Attending the Public Prosecutor's request concerning potentially harmful effects on captive and free-living animals in the zoo, thetechnical study reported here was carried out. Two moments were compared –a weekend during an Italian Festival (event, EV) and a weekend with no event (NE)– concerning the sound pressure level in predefined locations within the zoo and behavior in video recordings taken from a sample of captive animals (two ocelots, two curassows, a European deer and a maned wolf). The soundscape in the zoo was monitored with an automatic recorder (Wildlife Acoustics' Song meter 3). It was found that the peak SPL measure was higher in almost all zoo locations in EV than in NE; the animals changed their activity (spent more time moving throughout the day in EV) and resting patterns (briefer in EV), and the EV soundscape was more diverse across species (intense vocal activity) than in NE, but dominated by alarm calls. The conclusion was that the animals underwent changes in their circadian behavioral patterns related to food intake and resting. Resting and foraging times were directed at self-defense behaviors. The attention of potential stakeholders to animal welfare is urgent since there is no legal regulation protecting non-human ears from damage and life quality, and the animals in the zoo have no chance to avoid noise since they are caged.

Keywords: acoustic communication, alarm call, Cracidae, mammals, noise pollution, soundscape.

RESUMO

O ruído alto afeta a saúde e o bem-estar de animais humanos e não humanos após algumas horas de exposição. A preocupação com a qualidade de vida de animais de um zoológico instalado em uma área de proteção ambiental (o Parque Municipal Morro do São Bento, em Ribeirão Preto, SP, Brasil), levou um grupo de pessoas e entidades a instaurar um Inquérito Civil contra o uso da área para a realização de eventos culturais. Atendendo a solicitação do Ministério Público, conduzimos um estudo dos efeitos do barulho gerado pelo evento em animais cativos e de vida livre do zoológico, e o relatamos aqui. Comparamos dois momentos, o fim de semana tradicional do Festival Italiano (evento, EV) e um fim de semana sem evento (NE), em relação ao nível de pressão sonora em locais pré-definidos dentro do zoológico e padrões de comportamento avaliados em gravações de vídeo tiradas de uma amostra de animais cativos (duas jaguatiricas, dois mutuns, um cervo europeu e um lobo-guará). Também monitoramos a paisagem sonora do zoológico com um gravador automático (Song meter 3 da Wildlife Acoustics). Nossos resultados fornecem pistas de como as festividades podem afetar os animais de vida livre e de cativeiro: a medida do pico de SPL foi maior em quase todas as localidades do zoológico em EV do que em NE; os animais mudaram sua atividade (locomoveram-se por mais tempo ao longo do dia em EV) e padrões de repouso (encurtados em EV), e a paisagem sonora de EV foi mais diversificada em espécies (atividade vocal intensa) do que em NE, mas predominada por chamados de alarme. Concluímos que os animais sofreram alterações em seus círculos comportamentais circadianos relacionados à ingestão alimentar ou ruminação e repouso. Ainda, os tempos de descanso e de forrageamento foram dirigidos a comportamentos de autodefesa. Apesar disso, os protocolos de segurança contra os efeitos da exposição prolongada à poluição sonora e os instrumentos jurídicos brasileiros ainda ignoram a saúde e o conforto do animal não humano. Essa é outra questão que decorre do especismo e que precisa ser contestada.

Palavras-chave: Comunicação acústica, Cracidae Chamado-de-alarme, Mamíferos, Poluição sonora, Paisagem sonora.

Introduction

The human being is a disturbing species. Many of our activities produce loud sounds (Chepesiuk, 2005) that are not even part of our communicative system (e.g., derived from traffic and industrial activities). They constitute pollutants that threaten our health and concern the World Health Organization (Berglund *et al.*, 1999). Human noise does not disturb only our life; there is an increasing number of researchers in behavioral sciences and conservation pointing at the harmful effects of loud and annoying sounds on free-living animals and biodiversity aspects (Slabbekoorn & Ripmeester, 2008; Barber, *et al.*, 2010; Blickley & Patricelli, 2010; Barber *et al.*, 2011; Francis & Barber, 2013).

The acoustic communication is one of the behaviors that may be affected by noise. Communication signals were selected throughout the evolutionary history of species due to their consequences on the emitter's fitness (Lorenz, 1958; Bradbury & Vehrencamp, 2000) and, in some cases, also on receivers' and eavesdroppers' ones (Guilford & Dawkins, 1991; Grinnell & McComb, 2001; Monticelli, 2021). Human noise is more recent and a new issue for many species communicating through sound, for instance, in terms of transmission effectiveness (Wiley & Richards, 1978). In acoustic species, sounds that mask communication signals or reduce the distance over which acoustic signals can be perceived interfere with individual decisions and social coordination of activities involved in foraging, mate selection, territory defense, and anti-predation strategies (in avian: Slabbekoorn & Ripmeester, 2008; and mammals: Chan & Blumstein, 2011; Duarte, Vecci, Hirsch & Young, 2011). Among anurans, birds, aerial, terrestrial, and aquatic mammals are species able to alter the spectral and temporal characteristics or the loudness of their acoustic signals to avoid or reduce the masking effects of noise (Brumm & Slannekoon, 2005; Patricelli & Blickley, 2006; Warren *et al.*, 2006; Ey & Fischer, 2009; Parks et al., 2012). Unfortunately, this cognitive plasticity is not an ability of most species, and the ones that cannot adapt their signals or move away (Stankowich, 2008; Fidino *et al.*, 2020) will eventually become locally extinct (Barber et al., 2010).

Besides acoustic communication, noise negatively affects hearing, damaging auditory sensory cells and primary auditory inter-synapses nerve fibers (Sliwinska-Kowalska & Davis, 2012; Slabbekoorn *et al.*, 2018). For instance, hearing loss impacts cognition and language acquisition, sometimes with negative consequences in adulthood (WHO, 2017; Graydon *et al.*, 2019). Thus, non-human animals suffering from hearing loss are more susceptible to death (Stankowich, 2008; Barber *et al.*, 2010); that would be the case for species using auditory cues in hunting, like alligators, lizards, robins, birds of prey, and bats (Payne, 1971; Rice, 1982; Neuweiler, 1989; Montgomerie & Weatherhead, 1997; Carr & Christensen-Dalsgaard, 2015). Even non-heard sounds , like the infrasound (1-20Hz) for our hearing system, may cause hearing damage (ISO-7196, 1995).

The ontogenetic development, mood, behavior and other non-auditory physiological mechanisms are also affected by chronic noise exposition (WHO, 2017; Slabbekoorn et al., 2018). In laboratory animals, all eighth rats daily subjected to a brief 15-min exposure to white noise (90 dB) suffered disruption of the intestinal mucosa in only three weeks (Baldwin et al., 2006). The immune functions of male rats were also affected over time by low-intensity chronic intermittent and unpredictable noise (10h/day, 15min/h over three weeks, Van Raaij et al., 1996). For instance, serum IgM levels were increased, and peripheral phagocytic activity was decreased after only 24h of exposition to the protocol routine.

In zoos, it is already stated that the public presence per se acts as a noise pollutant and increases its effects as increases the audience (Quadros *et al.*, 2014). The most visited species suffered from the human noise, and half of the observed individuals in that Belo Horizonte zoo (state of Minas Gerais, Brazil) showed increased vigilance and locomotion behaviors with increasing sound levels.

Despite the evidence from literature about the harmful effects of human noise on other animals, the Brazilian National Program for the Education and Control of Sound Pollution of the Brazilian National Environment Council (CONAMA) shows no concern about non-human animals' welfare and health. The Brazilian Association of technical regulations (ABNT), responsible for determining the official noise evaluation protocols, establishes the use of a A-weighting curve (dBA) (NBR 10.151 and NBR 10.152) that does not evaluate low frequencies and peak sounds. The dBA is the best approximation to the human ear's logarithmic perception of sound (Burg *et al.,* 2017), but out of the range of other species' hearing perception and accuracy (Morgan & Tromborg, 2007). Moreover, dBA is limited to 55dB (Roberts & Neitzel, 2019).

NBR 10.151 states that the loudspeakers used in musical concerts produce sound at unhealthy levels for *humans* with only 15 minutes of exposure (ABNT Acústica 2000). The logical conclusion is that animals with equivalent hearing abilities would suffer the same harmful consequences. With that in mind, Brazilian civilians at Ribeirão Preto (SP) informed a Civil Inquiry against adverse impact of human concentration and loud noise on the welfare of captive and free-living animals in the municipal zoo and its surroundings. The zoo is part of a natural protected area that paradoxically was used by the municipal administration as a venue for public festivities. Attending the Public Prosecutor's request for a technical evaluation to answer the Civil Inquiry, we conducted this study on one weekend in 2016, during an Italian Festival in the zoo surroundings, comparing them with a control situation (a later weekend with no event taking place in the area).

Method

Study area

Zoológico Fábio Barreto (ZFB) is located in Ribeirão Preto (21º10'42"S; 47º48'24"W; Figure 1), one of the largest cities of São Paulo, Brazil (+600,000 inhabitants) and among the most deforested ones (green area reduced to less than 4% of the original coverage; Kotchetkoff-Henriques *et al.,* 2005). The ZFB is part of a legally established Environmental Preservation Area (APA, Portuguese), named Parque Municipal Morro do São Bento (PMMSB), created in 1988 and consisting of the zoo, two theater buildings, and an open square (250.880 m^2; Kotchetkoff Henrique *et al.*, 2018). The PMMSB should be conserving the APA biological integrity in its ecological aspects and promoting environmental education; conversely, it has been used as an open public place for cultural festivals for a long time.

According to the institution, there were more than 500 animals and 120 enclosures in the zoo when we started the study, including a quarantine sector, a veterinarian hospital, and a biology sector that received and cared for the rescued animals that used to come from the macroregion of Ribeirão Preto. At that time, in the quarantine sector there were several avian species, including hawks, owls, conures, macaws, a *Lycalopex vetulus fox*, two male maned wolves, a male baboon, and a small group of collared peccaries. In addition, free-living howler monkeys (*Alouatta caraya*), marmosets (*Callithrix sp*), and peacocks (*Pavo cristatus*) frequently visited all the zoo areas.

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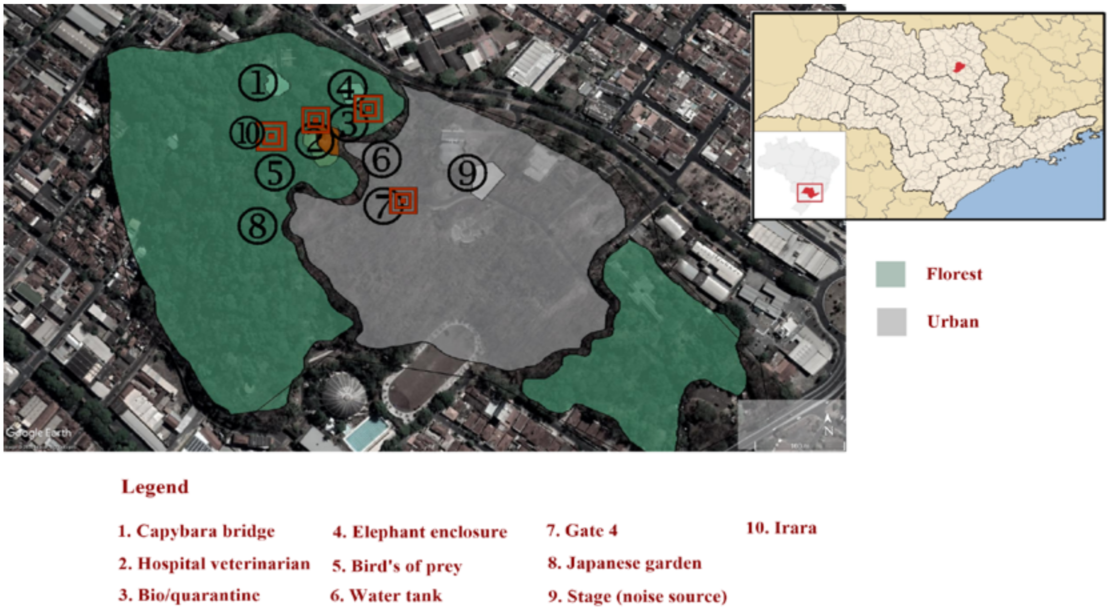
Figure 1. Aerial image of Morro do São Bento APA (in green and gray),



The Fábio Barreto Zoo (the green on the left), and the theaters and the open square area occupied by the band and the visitors of the Italian Festival (gray). The numbers indicate the georeferenced points where we measured the SPL. The recorder was installed in the quarantine sector (close to #3), and the four enclosures monitored by the video cameras are shown in red. There were two ocelots, an European deer, two curassows, and a maned wolf. The smaller map shows the location of Ribeirão Preto in the State of São Paulo, Brazil. Image obtained through Google Earth in September/2016. A photograph of the public at Festitalia in 2016 is available at http://festitaliaribeiraopreto.blogspot.com/2016/.

Animals

The cameras were installed in four enclosures; some of these places with more than one species (Figures 1 and 2). We recorded the behavior of two ocelots males living together, a male European deer, two curassows males separated by a fence (but observed together), and a maned wolf; they were in good health, except for the deer that was recovering from a wound at the base of the horn. The deer was housed in an enclosure between the ocelots and the Biology building (Figure 1), which had an open and a closed area (a resting room covered with hay; see Figure 2). The maned wolf was a young adult kept in a $50m^2$ place in the quarantine area divided into two similar sections in space and configuration, except that the food was offered on the left side and the resting place was on the right side. Finally, the two ocelots had the same size, and one of them exhibited stereotyped walking; the ocelots and the curassows were in the visitation area.

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Figure 2. Photographs taken from video files registered by Bushnell camera traps

There are three out of the four monitored enclosures and their residents. There are two images from the male Dama dama enclosure above; one at daylight (on the right, the animal is lying on the floor), and one at night (a rat shining eyes is over the door on the top left image). Below, the male maned wolf in his green enclosure and the two male ocelots in daylight.

Procedure

The next scheduled event in PMMSB when we started the study was the "Festitália," an Italian cultural commemoration. We obtained authorization and security support from the zoo's director to conduct recordings and noise level measurements on that occasion (a weekend starting on August 5th, 2016; see Festitalia schedule in Table 1) and a subsequent weekend (the control situation for comparison, starting one month later, on September 2nd).

We employed three procedures:

1. Sound pressure level (SPL) assessment of the speech and music produced during the festival (and the absence of that, in NE condition), at different points of the ZFB distributed *ad libitum.*
2. Comparative behavior analysis at the event (EV) and non-event (NE) conditions for a sample of species pointed by the zoo staff for their stronger reaction to the noise of festivals.
3. EV and NE soundscapes comparison about the number of species and the temporal distribution of vocal behavior (e.g., alarm, distress, contact calls and others).

August 5th - Friday
7:00 pm Opening of the Italian Immigrant Memorial Exhibition.
7:30 pm Official opening ceremony with Choir presentation.
8:30 pm Typical Dance Presentation.
9:20 pm Musical Show.
August 6th - Saturday
Noon Tenor musical lunch and Painting on open-air
1:00 pm Culinary workshop

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3:00 pm Venetian masks workshop and Musical Entertainment
4:30 pm Culinary Contest
5:00 pm Lecture
5:30 pm Typical Dance Choreography (with tarantellas)
6:00 pm Musical
7:15 pm Folk Group presentation with choreography
8:00 pm Musical Show
9:00 pm Musical Show
September 8th - Sunday
11:30 am Holy Mass in Italian
Noon Musical Lunch and Painting on open-air
3:00 pm Musical Entertainment
3:00 pm Lecture
4:30 pm Dancing with tarantellas
4:30 pm Culinary Contest
5:00 pm Musical show
6:00 pm Musical theater
7:15 pm Folk Group presentation with choreography
8:00 pm Culinary contest award
8:15 pm Musical show
8:45 pm Musical Show (tenor)

Table 1. Festitalia 2016 Schedule of cultural activities obtained in 2016 at http://festitaliaribeiraopreto.blogspot.com/2016/

Source: Authors

1. Sound pressure measurement

We adopted the C-weighting curve (dBC) to measure SPL peak noise of impulsive noise since the sounds of festivities vary in time and include impulsive noise (peak noise). There were human voices, traffic, band playing, people speaking on a microphone, and low-frequency components that were not addressed with dBA (Ordoñez et al., 2010; Dwisetyo et al., 2021). Low-frequency components are part of the broad frequency spectrum of non-human animals' hearing (for instance, Budgerigars' auditory frequency perception ranges from 125-8000Hz; cats, from 55-79000Hz; Fay 1988 and Fay & Popper 1994) that were included in our group of study (animals in that zoo and surroundings).

We considered that:

1. the energy of peak (impulsive) noise threatens humans to hearing damage in a single exposure exceeding 130-140 dBC (OSHA, 2013; Roberts & Neitzel, 2019);
2. the Festitalia event lasted from 4 (on Friday) to 8 hours, for three days of exposition, but concentrated SPL increase in the evening (Table 1);
3. the European noise regulation establishes a safe limit that should not exceed 85dBA for daily exposition (for an 8-hour period a day) or 135-137 dBC for peak noise for working places (Wong, 2011; Roberts & Neitzel, 2019); nevertheless, there are differences among federal regulations (Table 2).

Based on this information, we assumed the 85 dBC SPL (adopted by five out of eight regulations, Table 2) as the potential safety limit for daily exposition and took the peak noise of > 110 dBC (our instrument limit range) as potentially harmful even in one exposure. We had to adopt human hearing safety regulations due to the absence of any for other animals' hearing systems.

The SPL was measured at 10 sample points (see distribution map in Figure 1) on Saturdays (August 6th and September 3rd) between 7 and 9 pm; that was when the musical performance started. Each location was visited twice in EV: on a first tour from point 1 to 10, we took ten independent measurements of SPL and returned to the first point one hour later, repeating the ten SPL measurements. In NE, we took 20 measurements at each point in only one tour since there was no significant distinction to be made in the environmental soundscape.

dB SPL	EU	AU/NZ	OSHA	NIOSH/ ANSI/ACGIH	EPA
Peak noise	135-140 dB	140 dBC	140 dB	140 dB/dBC	
100 dB SPL			2 h	15'	NONE
96-97 dB SPL	1 h		3 h	30'	3'

dB SPL	EU	AU/NZ	OSHA	NIOSH/ ANSI/ACGIH	EPA
93-94 dB SPL	2 h	1 h	4 h	1 h	6’
90-91 dB SPL	4 h	2 h	7 h	2 h	11’
87-88 dB SPL	8 h	4 h	10 h	4 h	22’
85 dB SPL		8 h	16 h	8 h	45’
79 dB SPL			24 h	24 h	3 h
75-76 dB SPL			24 h	24 h	6-8 h

Table 2. Comparison between standards of different scientific or governmental agencies* for exposure limit to noise according to exposure time (sound pressure level, SPL) and peak noise (first line). Adapted from Roberts & Neitzel, 2019.

*EU: European Union Directive 2003, exposure limit; AU/NZ: Australian and New Zealand regulations for permitted exposure limit; ACGIH: scientist from Cincinnati, OH, US, threshold Limit Value; OSHA: Occupational Safety and Health Administration, EUA; NIOSH: National Institute for Occupational Safety and Health; ANSI: American National Standards Institute; EPA: Environmental Protection Agency, US.

Source: Authors

2. Behavior assessment

We used six Bushnell® camera traps (“cam traps”) to capture behavior in the enclosures in EV and NE conditions. This equipment has a motion sensor that, once triggered, records on video according to its settings. Infrared illumination allows for a good image even in low light. We set the cam traps to record for 20 seconds when triggered by the animals’ movement and to keep a 5-min interval between successive shots; that is, once triggered and after the 20 secs of recording, even if the animal is still moving, the cam trap would not register anything before a 5 minutes break. From installation until removal, the cams recorded continuously from Friday afternoon to Monday morning.

Behavior was obtained through video recording and analyzed under the ethological approach. We used a continuous registration of a focal animal (or the group, when more than one animal) sampling behavior for each file obtained from the camera trap. Behavior (including the vocal) was measured in frequency and duration of general categories related to activity level, stereotypes, self or social directed, and exploration.

3. Soundscape analysis

We also installed a passive acoustic monitoring unit (PAM) in a central area inside the zoo, expecting to register captive and free-living species vocalizations. Animals use different sounds according to their mood and other proximal causes and according to the environmental stimulus; alarm and distress calls have a typical structure that can be identified and compared between EV and NE conditions. The automatic recorder (SM3+) was installed in the quarantine sector (Figure 1). There were several avian species, including hawks and owls, Jandaya parakeet (*Aratinga jandaya*), Macaws (*Ara* species), Potoos (*Nyctibius sp*), and the mammals *Lycalopex vetulus* fox, two maned wolves (*Chrysocyon brachyurus*), a baboon *Papio sp* (removed from visitation for its sensitivity to contact with the public), and young peccaries. The SM3+ was fixed on a tree 1.5 meters from the ground, set to record continuously from 5 pm to 7 am, starting on EV and NE Fridays until the recorder removal the following Mondays.

Equipment

The decibel meter was the INSTRUTEMP ITDEC-4080 (INSTRUTEMP®), calibrated immediately before taking measurements with its specific device. Our decibel meter complied with the International Electrotechnical Commission standard (IEC 61672-1:2003, according to the INSTRUTEMP Manual). We set the decibel meter to a fast response circuit (FAST) and Leq (equivalent to a continuous sound level; Rossing 2007) in the range of 50-110 dBc. The sample points for SPL evaluation were georeferenced with a Garmin eTrex 30 GPS (+10 meters accuracy).

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The cam traps were the model 8MP Trophy Bushnell® that saved the records on one SD card in *.avi* files. The passive sound recorder was a Wildlife Acoustics® Automatic Recorder Model Songmeter 3 (SM3+, Wildlife Acoustics, Inc., Concord, Massachusetts) installed in the quarantine sector area, in front of the Biology building, to the right of the Veterinary Hospital (Figure 1). The digital recordings were obtained in two channels, in a sample rate of 44.1 kHz (i.e., capturing sounds until 22kHz), 36 dB gain, and in 16-bit files saved on secure digital (SD) cards (1 to 4 spots). The audio recording used the waveform audio format (*.wav*) fragmented into 30-min segments to make the spectrogram analysis faster. Sound analysis was performed on Raven Pro 1.6 (Cornell Lab of Ornithology).

Results

1. Sound pressure measurement

We obtained 20 SPL values on Saturdays, 6th August (EV) and 3rd September (NE), for each sample point (Table 3). Considering the 85 dBC limit for daily exposure and >110 dBC for peak noise, the only points where SPL values would risk physical damage on human hearing, and presumably on non-human animals with similar hearing systems, were the three outside the ZFB (the first three on the table, at the zoo gate to the theaters square, and both points about 3 meters away from the stage, in front and behind it), and in the water tank, between the quarantine room and the vet hospital (see Table 1 to locate the points). In the water tank, these higher values were registered in the second moment, during the band playing, when one out of the 10 SPL values of the vet hospital was also higher than 85dB.

The Environmental Protection Agency (EPA) of the US, which has a broader notion about harmful effects that go beyond hearing damage, inputs a limit for 6-8h of exposure between 75-76dB (Table 2). In this case, the big cats and elephants would be under noise effect even in the absence of events, and all the animals living close to all the sample points, except the capybaras' point, would be subject to harmful effects in EV, but not in NE condition.

		1	2	3	4	5	6	7	8	9	10	min	max
In front of the stage	EV	98.6	108.5	95.5	109.6	102.9	79.9	100.2	80.7	110	110	79.90	110.0
		110	102.5	110	110	100.9	109.2	106.5	107	101	103.1	100.90	110.0
		66.2	64.1	64.7	62.3	65.8	64.1	63.0	64.0	70.5	64.6	62.3	70.5
		68.2	69.2	68.7	65.4	65.4	68.1	-	-	-	-	65.4	69.2
Behind the stage	EV	93	87	88.3	86.9	90	69.7	95.8	110	110	91	69.70	110.0
		100.6	104.4	99.8	99.6	104.1	101.3	92.7	100.8	99.9	100.4	92.70	104.4
		64.9	65.3	68.6	70.0	72.1	65.9	68.1	63.3	62.9	65.1	62.9	72.1
		65.7	68.9	67.3	68.1	66.1	65.2	70.4	70.3	64.2	63.8	63.8	70.4
Gate	EV	71.6	71.3	80.4	83.8	75.7	91.1	93.5	93.5	77.2	94.5	71.30	94.5
		79.3	74.2	93.4	95	87.4	66	83.5	87	86.4	92.5	66.00	95.0
		61.8	64.4	62.3	61.8	61.5	60.9	62.5	62.7	65	63.6	60.9	65.0
		62.5	62.5	60.6	63.3	65.1	63.2	61.8	61.4	61.7	61.8	60.6	65.1
Elephants	EV	77	78.3	74.7	77.2	73.5	80.1	76.5	77.5	73.8	64	64.00	80.1
		79.7	82.3	78.5	82.3	74.2	78.7	79.6	80.8	81.5	77.6	74.20	82.3
		69.1	67.8	65.8	74.7	65.6	62.1	65.6	76	73.4	68.5	62.1	76.0

		1	2	3	4	5	6	7	8	9	10	min	max
		67.5	67.5	69.5	76.7	77.6	68.7	66.2	64	71.2	84.3	64.0	84.3
Big Cats	EV	65	77.7	72.3	66	68	72	73.6	62	70.1	67.8	62.00	77.7
		76.8	71.1	73.4	69.7	72.4	80.1	67.7	68	67.4	71.2	67.40	80.1
		71.4	62.6	60.7	65.8	67.6	78.0	63.1	74.5	71.5	71.1	60.7	78.0
		63.4	64.8	73.2	64.8	62.5	66.7	73.8	77.7	65	68.9	62.5	77.7
Water tank	EV	64.6	74.3	78.9	68.3	76.7	77.7	67.9	66.2	78.8	66	64.60	78.9
		88.6	90	92.3	79.2	84.8	91.4	88	83.8	90.1	92	79.20	92.3
		64.9	63.8	61.8	63.6	61.9	63.7	72	64.6	64.1	70.9	61.8	72.0
		64.1	65.7	64.3	63.6	63.0	67.0	70.2	60.9	61.5	67.4	60.9	70.2
Vet Hospital	EV	62	66.5	70.3	59.8	66.3	70	68.5	64.4	67.7	65.1	59.80	70.3
		82.1	76.9	78.1	87.7	79	83.6	84	80.8	79.9	83.1	76.90	87.7
		60.0	59.3	58.5	62.1	56.8	55.9	57.3	60.1	60.6	58.5	55.9	62.1
		57.6	61.4	59	57.1	58	56.9	57.9	58	59.1	58.3	56.9	61.4
Japanese garden	EV	65.1	63.5	61.9	73.5	61.3	66.1	67.5	66.8	64.6	64.8	61.30	73.5
		75.2	64.8	64.2	66.6	67.8	73	75.3	77.9	73.7	75.7	64.20	77.9
		61.3	62	61.9	62.5	63.5	66.4	65.9	63.4	63.2	63	61.3	66.4
		64.8	62.5	64.7	62.2	65.6	62.1	62.4	59.5	60.9	62.2	59.5	65.6
Birds of prey	EV	60.9	67.3	63.2	67.9	59.4	62.5	64.1	67.5	66.3	64.4	59.40	67.9
		70.7	74.3	75.7	74.8	76.1	77.9	72.7	78.1	72.6	71.9	70.70	78.1
		60.2	60	59.3	60.1	62.8	59	60	60.3	59.5	60.4	59	62.8
		59.1	58.5	61.5	64.9	58.7	59.8	58.7	57.7	59	58.7	57.7	64.9
Biology sector	EV	73.2	77.2	78.6	80.5	79.9	76.3	77.1	76.2	78.7	74.2	73.20	80.5
		-	-	-	-	-	-	-	-	-	-	-	-
		59.1	59	58.7	59.6	61.6	60.9	59.9	58.6	60.1	58.1	58.1	61.6
		58.5	61.6	60.6	61.3	59	57.5	57.3	59.3	57.5	61.4	57.3	61.6
Ocelots	EV	64.1	61.8	61.4	61.1	67.2	63.7	59.4	66.3	63.7	62.6	59.40	67.2
		75.4	67.2	74.4	76.1	64.1	68.6	74.8	74.8	69.8	74	64.10	76.1
		58.7	59.4	60.2	58.3	60.3	57.3	59.7	59	56.9	57.3	56.9	60.3
		60.6	58.6	57.8	59.7	60.4	58.7	58.4	57.5	59.3	58.2	57.5	60.6
Capybaras	EV	62.3	64.8	61.8	66.4	63	59.9	63.6	65	64.9	61.7	59.90	66.4
		70.8	71.1	61.9	63.2	61.8	60.7	63.8	68.5	69.9	72	60.70	72.0
		63	72.2	73.9	64.5	60	61.1	62.4	62.3	58.6	59.7	58.6	73.9
		57.5	60.1	60.9	57.9	60	61	59.9	60.9	58.4	61.5	57.5	61.5

Table 3. The dBC values of SPL were registered four times in each of the 10 sample points, two in EV (blue cells) and two in NE (August 6th and September 3rd, respectively) at night (7 to 9 pm). In EV, the measures were divided into two moments, first during a person speaking on the microphone (first blue line) and one hour later (second blue line), when the band started playing. Empty cells are due to data absence. Bold numbers show SPL values >85dBc, the limit for daily exposition (see methods).

Source: Authors

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2. Behavior assessment

As the video registry occurred when the animal's movement activated the cam trap sensor, what we call here a shot, we used the number of shots as a comparable index of the activity of the focal individuals in EV and NE (Table 4). The shooting rate corresponds to the number of videos per recording period, which ranged from 7 to 24h. The number of videos produced per day varied according to the time we took to complete the installation (and removal, at the end) among the enclosures (Table 4). There were recording errors in some SD cards and, consequently, the loss of data in some periods for some species. Thus, we noted later that the focal individuals could not have triggered some shots, which instead were provoked by humans or other animals passing by (see the rat in Figure 2), so we decided to exclude them from the analysis.

We adopted a common ethogram based on Sick (1970), Rodden (2007), and Srbek-Araujo et al. (2012) for all four species. It was a general classification of behaviors in Activity (foraging, attention, locomotion, moving without displacement, hiding, self-oriented behaviors), Stereotypic behaviors, Playing, and Resting (sleeping, lying down, relaxed seated, or standing). The results are presented by species to consider their particularities. Our aim was the comparison of EV and NE and not species against each other.

		Festitalia (EV)		A weekend (NE)	
Popular name (number of individuals)		video/day	shots rate	video/day	shots rate
Fallow deer (1)	Friday	--	--	6	0.9
Dama dama	Saturday	28	2.5	32	1.3
Artiodactyla: Cervidae	Sunday	57	2.4	76	3.2
	Monday	31	2.1	26	1.9
	Total	n=116 (~50h)		n=140 (~79 h)	
Curassows (2)	Friday	4	0.4	0	0.0
Crax fasciolata	Saturday	66	2.8	19	1.1
Galliformes: Cracidae	Sunday	53	2.2	19	0.8
	Monday	4	0.3	10	0.7
	Total	n=133 (~72h)		n=48 (~62 h)	
Maned-wolf (1)	Friday	--	--	30	4.3
Chrysocyon brachyurus	Saturday	55	5.5	63	9.0
Carnivora: Canidae	Sunday	119	5.0	7	3.5
	Monday	141	9.4	--	--
	Total		n=315 (~h)		n=100 (~h)
Ocelot (3)	Friday	--	--	2	--
Leopardus pardalis	Saturday	42	3.8	45	2.6
Carnivora: Felidae	Sunday	54	3.2	--	--
	Monday	22	3.1	--	--
	Total	n=118 (~35h)		n=47 (~18 h)	

Table 4. Number of video recordings (n) per day generated by animal movement in front of the cam trap sensor (shots) in EV (August 5 to 8) and NE (September 2 to 4). The shot rate represents the number of videos per recording period (varying from 7 to 24h). Species' popular and scientific names (according to ZFB) are present in the first column with the number of focal individuals and their taxonomic position (Order: Family). All individuals were adult males.

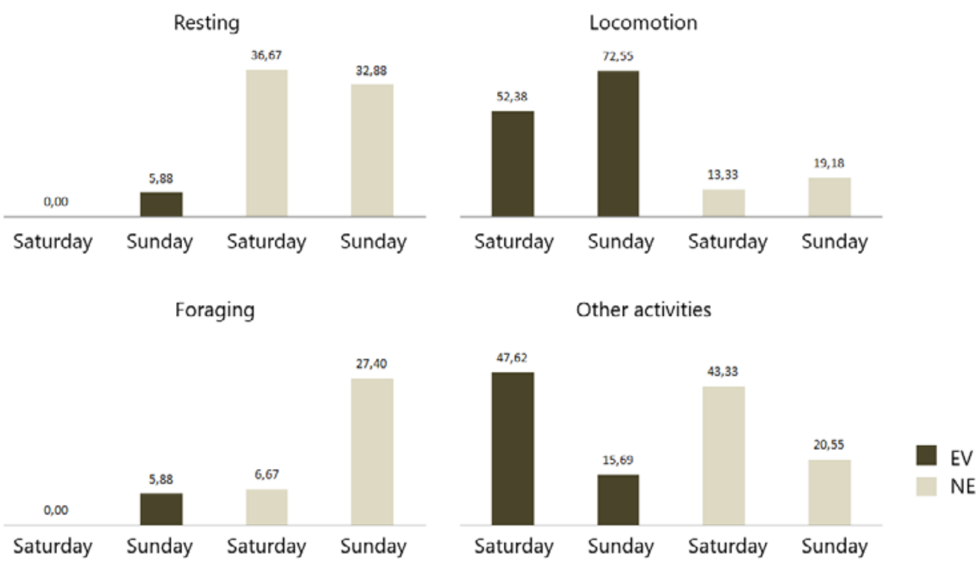
Source: Authors

A. European deer Dama Dama

We recorded 116 videos in EV from Saturday to Monday (there was no record on Friday) and 140 in NE (from Friday to Monday). The camera trap was attached to the window and filmed almost the entire closed area, but it did not film the outside area. Nevertheless, whenever the animal came in, the camera shot and served as an index of the movement intensity of the animal. On Saturday, the number of shots per hour in EV was twice the one for NE; on Sunday, the opposite was observed: there were 1.3 times as many shots/h in NE.

In Figure 3, we present an analysis of the animal's behavior associated with rest and foraging (obtaining nutrients by searching, chewing and, in this case, species, rumination). The behaviors are presented in percentages. The deer hardly rested, nor did he feed in EV, and spent a long time moving around. We noticed five events of vocal behavior; one on NE while lying vigilant and the others in EV during locomotion, grooming and stretches. In three out of four occurrences (in EV), the band was playing when the animal vocalized.

Figure 3. Percentage of time the European deer spent in the different activities on Saturday and Sunday at EV (Festitalia) and NE (control) conditions. Ruminating is included in resting when performed and laid down. Other activities include head movements, moving around, self-cleaning, standing upright, rubbing the head against the substrate, knocking on the floor, and shaking the head.



Source: Authors

B. Curassow Crax fasciolata

One of the two males had been better focused by the camcorder (the *Crax fasciolata*) and used for behavior quantification. The observed behaviors were climbing the perch or lying down on the ground (resting); scratching the ground, foraging, vigilance (stopping and standing still), alarm calling, social behaviors (other calls, interaction through the grid), locomotion (slow locomotion, locomotion from one side to another) and other activities (moving without displacement, self-cleaning). Figure 4 presents the relative frequencies of behaviors. EV and NE Fridays are not presented due to their small sample of data (the cam trap was installed at 5:30 pm, and the animals went soon to perch).

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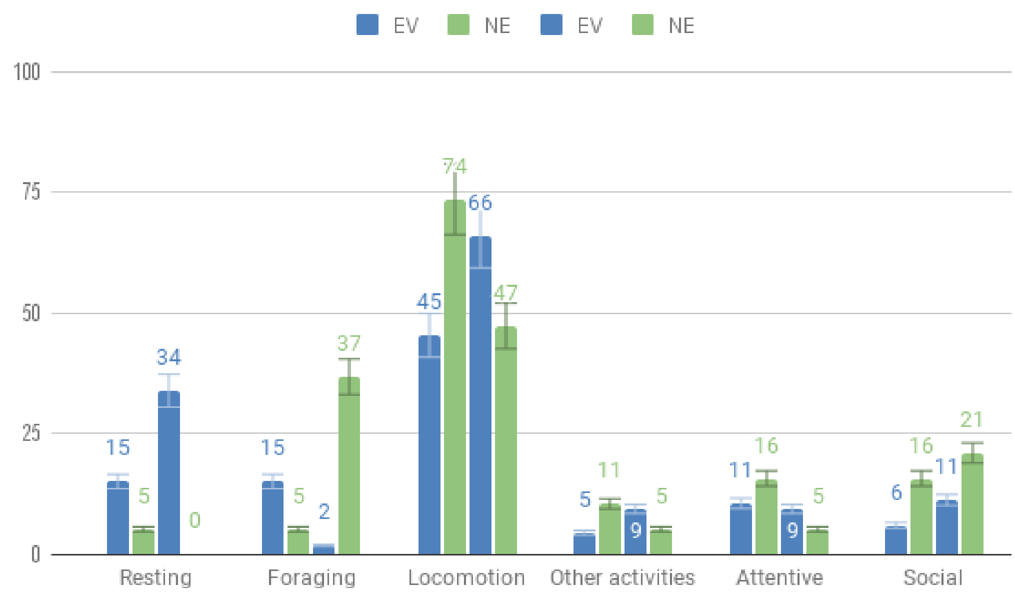
The animal was more attentive on EV than NE, standing up with head movements, alarm calls, and walking on the floor more frequently (Figure 4). We identified curassows' vocalizations in 12 videos on EV, and half of them were alarm calls (three Friday nights during band playing, between 10:55 and 11:03 pm). On NE, there were alarm calls in three out of eight videos; the others were contact calls, and one was an aggressive display among the two individuals through the fence. Resting values were more frequent on EV; nevertheless, they were short: the resting had been interrupted, and the animal left the perch and went back again after some time, increasing the frequency of resting. In NE, once the animal went to the perch at the end of the day, he went down again only once.

Figure 4. Percentage of time the Curassow spent with different activities on Saturday and Sunday at EV (Festitalia) and NE (control) conditions.



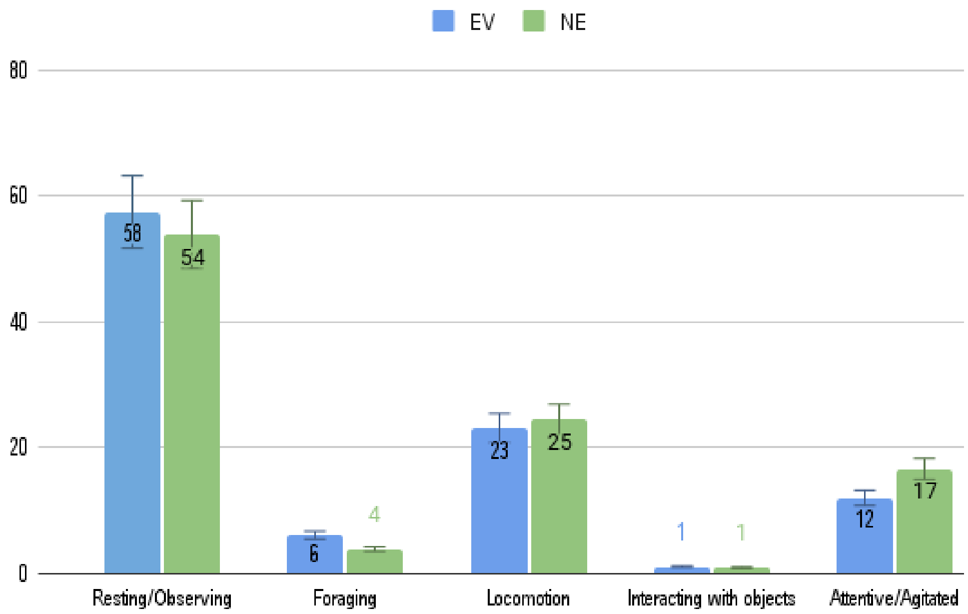
Source: Authors

C. Maned wolf Chrysocyon brachyurus

Either the cam trap or the SD card we used there did not work well. On EV, nothing was recorded on the first day (August 5), and on NE, there were reduced recording intervals (8h on Friday and eighth on Saturday) (Table 5). Consequently, we had a small window for comparison: EV Sunday and NE Saturday between 7:00 am to 1:00 pm and EV and NE working days (Monday and Friday, respectively) between 11:50 am and 5:30 pm. There were 18 shots (movement sensor activation for recording) on EV, and in 6 of them, the maned-wolf was resting (sleeping or standing still). In that same interval and period of the day (hot in the city), there were 30 shots in NE condition, but in 23 of them the animal was resting. Thus, there were 55 shots on EV, and in 30 of them, the maned wolf was resting. On NE, there were 60 shots, and in 33 of them, the animal was resting. We noticed what seemed to be a stereotype only in NE (10 of the 27 events of his activities were locomotion through all the enclosures in a repeated circuit).

The behaviors performed in the activity time were foraging (scratching the ground, eating, drinking, walking with head down, walking with food in the mouth), attentive (stop and stand still, lateral movements of the head, ears up and moving), agitated (walking frantically from one side to another or walking sideways), resting plus observing (standing, following humans' movements, sniffing the wall or floor while lying down and upright sniffing around, and grooming), moving (locomotion, moving slowly with lowered head, moving without displacement, circling before lying down and scratching the ground, head-shaking, yawning and stretching), and interacting with objects (he used a piece of wood, the food tray, hop and knocked the ground and playing-hunt over the wooden section he used to rest). (Figure 5). The wolf vocalized two times, one on each condition, and it growled bristling when a man approached.

Figure 5. Percentage of the number of shots the maned wolf spent with different activities on EV (Festitalia) and NE (control) conditions.



Source: Authors

D. Ocelots *Leopardus pardalis*

Again, we grouped all the EV moments (Saturday to Monday) and all the NE (Friday and Saturday) and presented their relative frequency in Figure 6. Of the 39 EV resting records, only four had both ocelots resting. In the other 35, the most agitated animal was walking.

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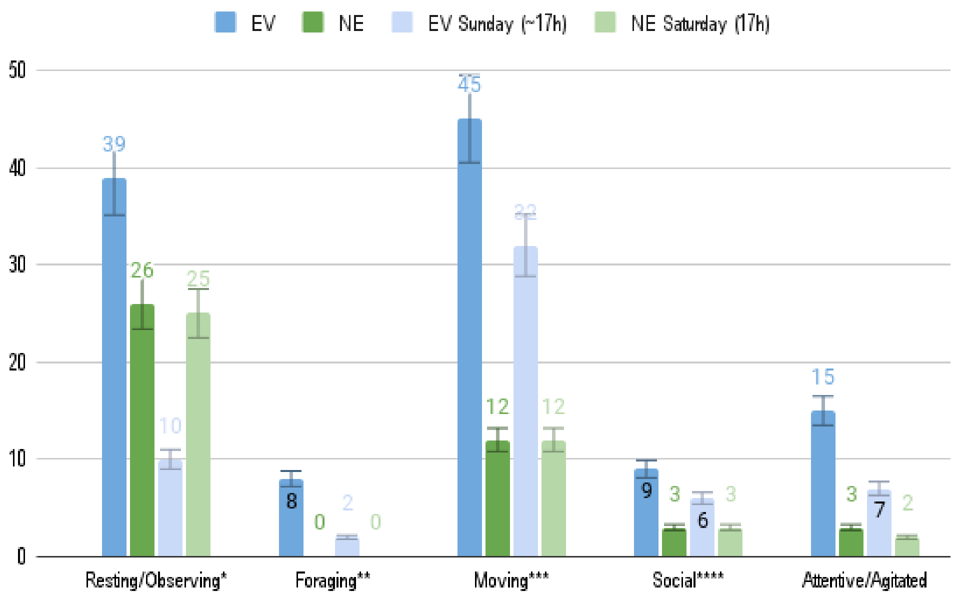
Figure 6. The absolute number of shots (occurrences) the ocelots spent with different activities on EV (Festitalia) and NE (control) conditions (darker colors of blue and green, respectively) and in a comparable size sample window of analysis, in lighter shades of blue (EV Sunday) and green (Saturday NE).



Source: Authors

3. Soundscape

We counted the occurrences (number of vocal episodes per type of sound and species) of vertebrates in the recordings in one-hour time intervals. Table 5 lists the sounds we identified in the audio recordings. Ana Carla Aquino is an adept ornithologist, and Patrícia Monticelli leads a bioacoustics lab and is responsible for a sound library specialized in Neotropical mammal vocalizations and behavior (FOCA).

There were more species calling in NE than in EV, except in the later interval (from 11:50 pm - 00:50 am), when it was almost the same. Note that diurnal species also vocalized late on Friday in EV (9:50 pm-00:50a); they were parrots, macaws, and the gray-cowled wood rail. The carnivore mammals we had identified by sound, the lion, the maned wolf, and the rail called only in EV conditions. The potoo called seven times its species-specific song, all in NE. There was also a higher occurrence of peacock vocalizations in NE than in EV; most of them were of two kinds: a loud meow that the male emits as a long-distance call to signal his territory and draw the females closer to him (mostly during the light), and the species alarm call (much more frequent in EV condition, at night).

Table 5. Natural sounds of birds and mammals captured and identified by us from recordings obtained on Fridays in EV and NE. When it was possible to identify, we gave the number of the species; otherwise, we adopted the popular name and taxon. Numbers in parentheses represent the occurrences of each type. NI indicates unidentified vocalizations. When there was rain, it was indicated. Speech into the microphone was recorded from 18:25 until changed by the band that stopped playing at 10:30 pm (in red).

		EV	NE
5:50 - 6:50 pm	Picazuro Pigeon (pomba-asa-branca), Patagioenas picazuro	7	2
Mic, music	Blue-and-yellow Macaw (arara-azul), Ara ararauna	15	5
	Great Kiskadee (Bem-te-vi), Pitangus sulphuratus	1	2

		EV	NE	
	Peafowl (pavão), Pavo, sp.	87	110	
	Orange-winged Parrot (papagaio-curica), Amazona amazonica	2	---	
	Psittacidae, NI	----	11	
	Potoo (urutau), NI	----	4	
	Owl (coruja), NI	1	----	
	Tropical Screech-Owl (corujinha-do-mato), Megascops choliba	1	----	
	Gray-cowled wood rail (saracura), Aramides cajaneus	1	----	
	Lion (leão), Panthera leo	1	----	
	NI	2	19	
Total		118	153	
6:50- 7:50 pm	Peafowl (pavão), Pavo, sp.	8	57	
Mic, music	Psittacidae, NI	2	----	
	Lion (leão), Panthera leo	1	----	
	NI	20	38	
Total		31	95	
7:50 - 8:50 pm	Peafowl (pavão), Pavo, sp.	2	39	
Mic, music	Tropical Screech-Owl (corujinha-do-mato), Megascops choliba	1	---	
	Burrowing Owl (coruja-buraqueira), Athene cunicularia	---	4	
	Blue-and-yellow Macaw (arara-azul), Ara ararauna (15)	1	----	
	Lion (leão), Panthera leo	1	----	
	NI	4	35	
Total		9	78	
8:50 - 9:50 pm	Peafowl (pavão), Pavo, sp.	9	50	(RAIN)
Mic, music	Burrowing Owl (coruja-buraqueira), Athene cunicularia	---	2	
	NI	3	14	
Total		13	66	
9:50 - 10:50	Peafowl (pavão), Pavo, sp.	---	7	(RAIN)
	Psittacidae, NI	1	---	
	Maned-wolf (lobo-guará), Chrysocyon brachyurus	1	----	
	Lion (leão), Panthera leo	1	----	
	NI	1	31	
Total		4	38	
10:50 - 11:50	Peafowl (pavão), Pavo, sp.	---	18	
	Psittacidae, NI	3	---	
	Potoo (urutau), NI	---	3	
	Maned-wolf (lobo-guará), Chrysocyon brachyurus	1	----	
	NI	3	28	
Total		7	49	
11:50 pm - 00:50 am	Peafowl (pavão), Pavo, sp.	1	6	
	Gray-cowled wood rail (saracura), Aramides cajaneus	1	----	
	Owl (coruja), NI	1	----	
	Psittacidae, NI	2	---	
	Maned-wolf (lobo-guará), Chrysocyon brachyurus	1	----	

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	EV	NE
Lion (leão), Panthera leo	1	----
NI	3	6
Total	10	12

Find vocalization samples of the Brazilian avian species at https://www.wikiaves.com.br/midias.php?t=s&s=10395

Source: Authors

Discussion

The data we present here comes from a technical study conducted to evaluate the effects of loud human activities on animals in a zoo during public festivities. We compared two moments, EV and NE, and noticed the animals underwent changes in their circadian behavioral circles related to food intake and resting, and they spent less time in these activities, relocating them to self-defense behaviors. These results are concerning since there is no legal regulation protecting non-human animals from damage and a bad welfare condition when subjected to impulsive or daily exposure to noise, even when the literature is full of examples about the harmful effects of loud and annoying sounds on free-living animals and biodiversity (Slabbekoorn & Ripmeester, 2008; Barber, et al., 2010; Blickley & Patricelli, 2010; Barber et al., 2011; Francis & Barber, 2013).

The simple speech into the microphone with no music playing came to produce worrying values in areas where animals were in recovery; the water tank, for instance, is between the quarantine sector and the vet hospital. There was a female marsh deer in isolation with her calf and a capybara recovering from a non-diagnosed illness. Long-time exposure to noise is known to cause intense irritation and risk to health in humans (Wong, 2011), so it is plausible to suppose it would have a similar effect on other mammals.

The European deer was the one that concerned us the most. The music was loud enough for us to identify the lyrics on the cam trap when we were watching videos. He almost did not stop walking on EV days; for instance, from Saturday at 9 pm to Sunday at 3:30 am, thus dragging his activity clock. According to what we watched in the videos, he sat ruminating only on Monday. The curassow also had the nocturnal resting interrupted during the music playing. It could have been caused by the music or the alarm calls of other avian species. Only during the NE did we see social displays and species-specific calls that may positively affect captive animals (Broom, 2011).

In most cases, the shooting rate was higher in the EV situation than in NE, and this higher shooting rate agrees with the activity versus resting patterns identified using the ethogram. One of the ocelots and a tayra (*Eira barbara*) in the neighbor enclosure that appeared in our videos when moving displayed stereotyped behaviors (walking for a long time and always in the same circuit) that were enhanced in EV condition (see “moving” in Figure 6).

The soundscape was richer in the number of species calling in EV, but it should be evaluated cautiously, distinguishing alarm calls and positive social interactions (courtship and contact or affiliative calls; Bradbury & Vehrencamp, 2000; Chan & Blumstein, 2011). Diurnal species were vocalizing during the dark in EV and in a long-time window (9:50 pm-00:50a), and some called only in EV condition. That change in patterns should be longer monitored; we recorded almost four days (Friday to Monday in

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each condition), but we could not analyze all of them. Nevertheless, our recordings are stored in our Fonoteca Cesar Ades (FOCA), and we would be happy to share them for future investigations. Environmental sound recordings and studies constitute a non-invasive and cost-effective study method in Ecology and Conservation, acoustic ecology, and soundscape analysis (Pijanowski et al., 2011).

Despite our data not being as robust as we planned, due to technical and temporal issues, they may contribute to promoting an ethical reflection about the responsibility of our species for this fast-changing world. The zoos in Brazil are often managed by public services, which is important to give access to any civilian having or not the possibility to pay for the visitation, but which depends on a public investment that barely comes. Much of what is done for animal welfare is volunteer work of biology or veterinarian students that stay for a short time. For political reasons, the mayor attends to a cultural agenda that has a disconnected view of "culture." Can we separate human traditions from nature when we are a cultural, biological species? Just in the western and capitalist way of living, in which animals disturb human life, and forests must open space for buildings.

We conducted this study by attending a Brazilian Civil Inquiry. We submitted this data to the public prosecutor, who received back a contestation from CETESB, the Environmental Company of the State of São Paulo, arguing that the Brazilian Norm for the evaluation of hearing damages due to noise (ABNT 2000, NBR 10.151 and NBR 10.152) should adopt the A-weighting curve. The dBA is the best approximation *to the human ear's logarithmic perception* of sound (Burg et al., 2017), but perception of the sound ability of non-human animals is not established. Moreover, the ABNT (2000) refers only to constant noise evaluation in terms of daily exposure and admits it has no use for impulsive noise. We argued back and insisted that our study focused on non-human animals, and the C-weighting correction factor follows international norms. Moreover, dBA reading can be influenced by octave band combinations (for instance, the 1 kHz octave band that extends from 707 Hz to 1.414 kHz would produce the same dBA reading; Wolf, 2010) and is limited to sound and noise below 55 dB SPL, so it should not be used to evaluate whether a hazard to hearing exists.

We are a noisy species and the one that has dominated others in a variety of ways. The effects of loud sounds on wild and captive animals were not even noticed (or assumed) by zoo veterinarians, who stated in the criminal inquiry that "No animal died during the festivities in PMMSB." Being alive is not being out of suffering in behavioral sciences. Vets would need specific analysis for evaluating endocrine parameters (they take time and are costly) or knowing about the behavioral biology of the species. In Brazil, veterinarians rarely receive training in behavioral observation and analysis; in many undergraduate courses, Ethology is not even on a curricular basis. Captive animals do not need to forage for food nor have the chance to attract a sexual partner. Nevertheless, being deprived of performing species-typical behavior diminishes the animal welfare state (Broom, 2011), causing stress, a physiological condition of loss of homeostasis associated with deviations in endocrine parameters (Möstl & Palme, 2002). When these deviations become chronic, they alter immune responses (Van Raaij et al., 1996; WHO, 2017), which may be a risk condition for animals recovering from surgery or undergoing medical treatment (Broom, 2011). The Forest and Municipal Zoo Fábio Barreto configures a zone sensitive to noise; it contains species that might get harmed by acute or chronic exposure to noise. Besides the loud music and thousands of people talking, there is an increase

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in vehicle traffic in the APA, which generates air and noise pollution and increases the chance of running over free-living animals. Even now that the festivities have been legally canceled, the PMMSB urges measures to mitigate the impact caused by traffic on Avenida Capitão Salomão (close to the elephant and big cats). It is possible to implement measures to alleviate noise, such as producing sound barriers (Slabbekoorn & Ripmeester 2008) or closing the roads during the night period (Groot Bruinderink et al., 2002; Makarewicz & Kokowski 2007); it just needs human initiative.

Conclusions

We compared two moments, EV and NE, and noticed the animals underwent changes in their circadian behavioral circles related to food intake and resting, and they spent less time in these activities, relocating them to self-defense behaviors. Thus, high SPL values close to unhealthy animals could have affected their recovery and frightened the cervids especially. Brazilian norms are not adequate for noise hazard evaluation since they adopt the dBA ponderation curve; the world needs to discuss the impact of noise pollution in zoos, rural areas, and natural habitats having non-human animals, also getting free from speciesism; human cultural traditions include our well-being which depends on nature quality.

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