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Artículo

THE EFFECT OF VISITATION ON THE BEHAVIOR OF CAPTIVE INDIVIDUALS OF *Panthera onca* (LINNAEUS, 1758)

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ABSTRACT. The jaguar (*Panthera onca*) is the biggest living feline in the Americas and, like many large predators, is threatened by habitat loss and persecution. One response to these threats is *ex situ* conservation through zoos. However, captive environments do not have the same diversity as natural environments with potentially negative effects on the general health of individuals and their behavior. Here, we assess the behavior of four captive jaguars in Curitiba Zoo, Southern Brazil, on days with different visitation rates with the aim of testing if there is a relation between human visitation and stereotypic behaviors. All four jaguars predominantly engaged in resting behavior but showed an increase of stereotypy on days with more visitations. Moreover, it was also possible to show that each animal responds differently to negative stimuli from visitation and that its behavior presents marked differences because they are in captivity and on display.

RESUMO. O efeito da visitação no comportamento de indivíduos de *Panthera onca* (Linnaeus,1758) cativos. A onça-pintada (*Panthera onca*) é o maior felino vivente nas Américas e como outros grandes predadores, sofre com a perda de habitat e com a caça ilegal. Uma resposta a essas ameaças é a conservação *ex situ* por meio de zoológicos. Entretanto, os ambientes de cativeiro não possuem a mesma diversidade que o ambiente natural, podendo causar efeitos negativos na saúde geral dos indivíduos e em seu comportamento. Assim, este trabalho teve como intuito registrar o comportamento de quatro onças-pintadas cativas no Zoológico Municipal de Curitiba, no sul do Brasil, em dias com diferentes fluxos de visitação, para analisar se existe relação entre a visitação e a presença de estereotipias. Todos os indivíduos apresentaram a categoria de repouso como a mais significativa em todos os dias e aumento da estereotipia em dias com maior visitação. Foi possível evidenciar ainda que cada animal responde de uma forma diferente aos estímulos negativos provenientes da visitação e que seu comportamento apresenta diferenças marcantes por estarem em cativeiro e em exposição.

Key words: captivity, jaguar, stereotypy, visitors, zoos.

Palavras-chaves: cativeiro, estereotipia, onça-pintada, zoológicos

INTRODUCTION

The jaguar *Panthera onca* Linnaeus, 1758 is the biggest living feline in America (Leite 2000; Silva 2011; Vidal et al. 2016). Due to their dependence on larger prey, they are particularly sensitive to the extensive habitat loss and fragmentation that is associated with industrial, farming, and infrastructural activities (Silveira 2004). Like many other large predators, jaguars are also targets of persecution, mainly as a consequence of their perceived threat

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to livestock (Mantovani & Pereira 1998; Silveira 2004; Zeilhofer et al. 2014). This threat increases as natural resources dwindle and the jaguars replace their natural prey with domestic animals (Zeilhofer et al. 2014).

The most adequate way to conserve viable populations of the jaguar is through the preservation of its natural habitat. However, given the large area requirements and limited resources for new protected areas, this strategy is ineffective through much of the jaguar's range (Silveira 2004). A complementary strategy is ex situ conservation by means of sanctuaries or zoos (Sepúlveda 2008). In addition to education and entertainment, most zoos also promote the conservation of endangered species and are actively involved in scientific research and captive breeding programs (Garcia 2009; Pimentel et al. 2009). These programs pursue to increase the genetic variability of the species, dismissing individuals that result from a high level of inbreeding due to small population size, and genetic adaptations to captivity that can be dangerous to wild populations are not the subjects to these programs (Frankham 2008; Robert 2009). The ultimate aim of many captive breeding programs is maintaining populations that can eventually be reintroduced in the natural environment when conditions are favorable (Javorouski & Biscaia 2007; Garcia 2009) improving the genetic load of wild populations (Robert 2009).

Clearly, the captive environment is very different from the wild (Davey 2007; Vidal et al. 2016), especially in terms of lack of structural/ecological complexity, greater predictability, and ease in obtaining food with little energetic costs (Vasconcellos 2009; Silva 2011). Under such conditions, large predators may suffer from neurological and developmental problems. In extreme cases, captivity may result in anatomical and physiological alterations, associated with stress and abnormal behavior (Pereira et al. 2009; Gonçalves et al. 2010; Silva 2011). One of the most characteristic abnormal behaviors shown by captive animals is called stereotypy: repetitive behaviors that lack an obvious function or clear objective (Castro 2009). The most common stereotypy seen in captive felines is pacing, the behavioral act in which the animal repeatedly walks from one side of the enclosure to the other (Mason et al. 2007; Silva 2011; Vidal et al. 2016). Nevertheless, captivity is not necessarily synonymous with stress and a low welfare condition. The "use" of an animal for conservation and environmental education purposes should be tied to the obligation to maintain its quality of life, encapsulated by the five freedoms created by the Brambell committee (Brambell 1965; Fischer & Oliveira 2012; Ohl & . Van Der Staay 2012). These are defined as: being free from thirst, hunger and malnutrition; free from discomfort, possessing shelter and a comfortable resting area; free from pain, lesion or any type of illness; free to express its natural behavior and free from any type of fear or stress (Gonyou 1994; Hötzel & Machado Filho 2004; Fischer & Oliveira 2012).

One of the obvious challenges for zoo management is how to manage the influence of visitation on captive animals. Most wild animals have very little interaction with humans (Montanha et al. 2009) and simple, direct contact with visitors could have negative consequences (Wells 2005; Gonçalves et al. 2010; Silva 2011). Moreover, the constant noise associated with visitors (Carvalho 2008), could also cause multiple physical and psychological alterations (Almeida et al. 2008).

This study assessed the influence of different visitation rates on the frequency of stereotypic movements of captive jaguars in the Municipal Zoo of Curitiba, Southern Brazil. We propose measures to minimize stress and promote the welfare of captive jaguars.

MATERIALS AND METHODS

Study area

The Municipal Zoo of Curitiba is localized inside the Municipal Park of Iguaçu in the city of Curitiba in an area of 589 000 m^2. It is open to the public from Tuesday to Sunday, including holidays. The zoo was created in 1976 with the aim of preserving the rearmost valley of the Iguaçu River, sheltering large mammals that were confined to other zoos in the same city ("Passeio Público") and also with the intention of captive breeding native animals, and as a safe harbor for migrating birds (Sans 2008). The zoo currently hosts about 1 800 animals, including mammals, birds, and reptiles (Almeida et al. 2008).

Study animals

We analyzed four captive jaguars: two females (Angélica and Maya) and two males (Apollo and Ares). Angélica and Apollo came from Manaus (Amazonas State, Brazil) in 2006, without a previous record, but it is known that both are over 20 years old. Maya and Ares are cubs from the couple born in the zoo in 2007 and 2010 respectively. Each animal has its own enclosure with an area of about 86 m^2, containing trunks, earth, sand, and some grass. Each enclosure has a covered area in the back, occupying approximately a third of the enclosure, and an open area that has a net above it. **Fig**. 1 shows the distribution of the enclosures and their divisions.

Data Collection

Before data collection started, the jaguars went through a process of habituation to get used to the presence of

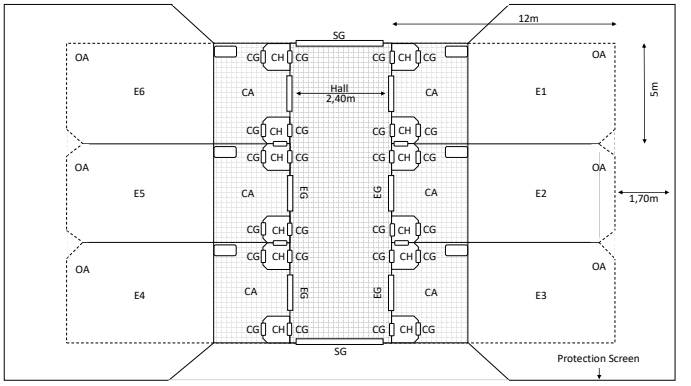

Fig. 1. Schematic representation of the enclosures and spatial distribution of the jaguars in the exhibition sector of the Municipal Zoo of Curitiba. Where: E1 =Enclosure 01, Maya (F1); E2 = Enclosure 02, Apollo (M1); E3 = Enclosure 03, Ares (F2) and E4 = Enclosure 04, Angélica (M2); E5 = *Puma concolor* (female); E6 = *Puma concolor* (male); and SG = sector access gate; CA = covered area; OA = open area; CH =covered house; EG = enclosure access gate; CP = covered house access gate.

the observer. During the habituation period, we adopted the ad libitum method (Altmann 1974), whereby observed behaviors were described and afterward organized into categories with the intent to compile a behavioral catalog. Some behaviors that were seen in the period of quantitative observations were added later to the catalog. To assist in this task, we used a repertoire previously elaborated by Silverio (2015) and Stanton et al. (2015)

The habituation period lasted for 32 days, with observations of the individuals during four different days of the week, taking place in the morning with sessions of one hour per animal, four hours per day, totaling 32 hours per animal (eight hours each on Mondays, Wednesdays, Saturdays, and Sundays). The focal animal sampling was used to quantify behaviors. It consists of the record of all behaviors and their duration for a determined period of time for each selected individual (Altmann 1974). Throughout the course of this phase, every animal was observed, alternately, for one hour per day, divided into 15-minute sessions, totaling 15 hours by sample group (fifteen hours each on Mondays, Wednesdays, Saturdays, and Sundays) and ending up with a total of 60 hours per animal.

To evaluate the effect of visitation rates on the behavior, sampling took place on Mondays, Wednesdays, Saturdays, and Sundays in the morning. While there is no visitation on Mondays, Wednesdays are characterized by a low frequency of visitors and Saturdays by high rates of visitation. On Sundays, the animals are not fed, because they tend to be less active after eating, and also because it is the day with the highest flux of visitors (Noga 2010). Additionally, depending on the items offered, a carnivorous diet can be disturbing for some visitors.

The order in which the animals were sampled was random. The frequency and duration of the behavioral categories were analyzed to verify if behavioral differences existed between days of the week and the number of visitors. We also recorded the noise level (dB) in front of each enclosure using a decibel meter (Akso – AK824). These data were registered every 15 minutes in each enclosure and compared through an ANOVA.

The animals were analyzed individually according to the duration of the behavioral categories between the days with different visitation fluxes. Data on the duration of behavioral acts were added to the respective behavioral category and transformed into relative frequency (duration of the category x 100/total duration of the step) (Silverio 2015). Behavioral category frequencies were analyzed by the chi-square test in the software Past 3.x., comparing the different categories to each sample grouping (Mondays, Wednesdays, Saturdays, and Sundays). Values of P lower than 0.05 were considered significant.

This work was approved by the Ethics Commission in Animal Use of PUCPR (01101/2016).

RESULTS

A behavioral repertoire of the individual jaguars was successfully collected during the habituation period (32 hours per animal), summing 37 behavioral acts in nine behavioral categories (**Table** 1).

Behavioral categories in each sample grouping

Resting was the most common behavior for all four individuals, independent of grouping (**Table** 2). In Angélica's case, locomotion was the next most frequent behavior, while Maya had high frequencies of both stereotypy and the locomotion . Ares also had a high frequency of stereotypic behavior and engaged in the highest amount of stereotyping each day. The other male, Apollo, had the second-highest level of stereotypy. It was observed that all four individuals had a strong tendency to engage in stereotypic behavior near the border of the enclosure closest to the visitors (**Fig**. 2).

Behavioral categories by days

Angélica showed a significantly higher frequency of territorial marking behavior on Mondays (χ_3^2=92,33; $p < 0.0001$) and less social interaction (χ_3^2=35.89; $p < 0.001$) (**Fig**. 2). On Wednesdays, she presented less maintenance behavior (χ_3^2=33.96; $p < 0.001$) and more stereotypy on Saturdays (χ_3^2=10.58; $p < 0.05$) (**Fig**. 2).

Maya showed more territorial marking behavior on Wednesdays (χ_3^2=65.60; $p < 0.001$) (**Fig**. 2)

Table 1

Behavioral repertoire of the jaguars at the Municipal Zoo of Curitiba (adapted from Silverio (2015) and Stanton et al. (2015).

Behavioral category	Behavioral act	Description
Maintenance	Stretching	Stretches the body or part of it, stretching the muscles
	Groom	Performing maintenance of the fur through the removal of dirt, water or body fluids, with the direct help of the tongue.
	Scratching	Scratches its body using the claws, teeth or structures within the enclosure.
	Insect control	Removal of insects through dorsal tremors and/or whipping movements with the tail towards the back and/or ear movement. In some cases, the animal tries to remove the insects by biting them.
	Vomiting	Ejects stomach contents - digested or not - out of its mouth.
Territorial/ Marking	Clawning	Scraping claws on the substrate.
	Defecate	Smelling the ambient in search of a specific local and expelling feces.
	Urinate	Smelling the ambient in search of a specific local and expelling urine.
	Face Rub	Rubbing the side of the face and/or chin on an object.
Exploratory	Play	Entertaining itself in activities that are usually related to the environmental enrichment material.
	Alert	Interrupting an activity and concentrating its attention on something in the environment. Directing the eyes and auricles towards a visual and/or sonorous stimulus.
	Sniff	Inhaling environmental odors. The animal can direct itself to the source of the odor or just sniff the air. Note, in some moments, the animal moves the nose and chest; in some cases, the animal can raise its chin and inspire the air vigorously.
	Flehmen	The animal stays with its mouth open, raising the upper lip and exposing the tip of its tongue while inspiring.
	Lick	Licking a substrate not related to feeding or cleaning.
	Foot on the grid	Supporting its body on its hind legs while its front legs are supported on the grid.
	Inside the house	When they go inside the covered house.
	Dig	Turning the dirt or digging a hole with its paws.
Social interaction	Social face rub	Rubbing the side of its face on another individual, even if separated by the grid.
	Charge	Charging against another.
	Social play	Developing activities with another individual, similar or not.
	Vocalize	Produce sounds or calls with the throat and mouth..
	Crouch	Maintaining the eyes fixed on something, body clouse to the ground and silent steps.
Stereotypes	Pacing	Walking from one side to the other repeatedly following a pattern.
Rest	Sleeping	Staying horizontally extended on the substrate, with the thoracic and pelvic members relaxed and/or flexed with the eyes closed.
	Lying	Staying horizontally extended on the substrate, with the thoracic and pelvic members relaxed and/or flexed, but, maintaining the eyes open without being vigilant.
	Sitting	The non-vigilant animal in an upright position, with the hind legs flexed and resting on the ground, while front legs are extended and straight.
	Accommodate	Changing the stance without any displacement.
Foraging	Drink	Ingesting water by lapping up with the tongue.
	Eat	Consuming organic substances.
Locomotion	Locked	Its food is placed inside the covered house and as soon as it is inside, they are locked.
	Walking	Moving around at a slow gait.
	Running	Moving around at a rapid gait.
	Jumping	Animal leaps from one point to another.
Reproduction	Masturbation	The female rides a log and starts a series of come and go movements with its hip; can end the behavior with vocalization and running.
	Roll	Turning from one side to the other, in dorsal decubitation, having as base the longitudinal axis of the body.
	Lordosis	The female directs her posterior part to the male with the tail up, showing the vulva.
	Roll + dig	Before completing the rolling behavior, still in dorsal decubitation, the jaguar moves its paws as if digging the air.

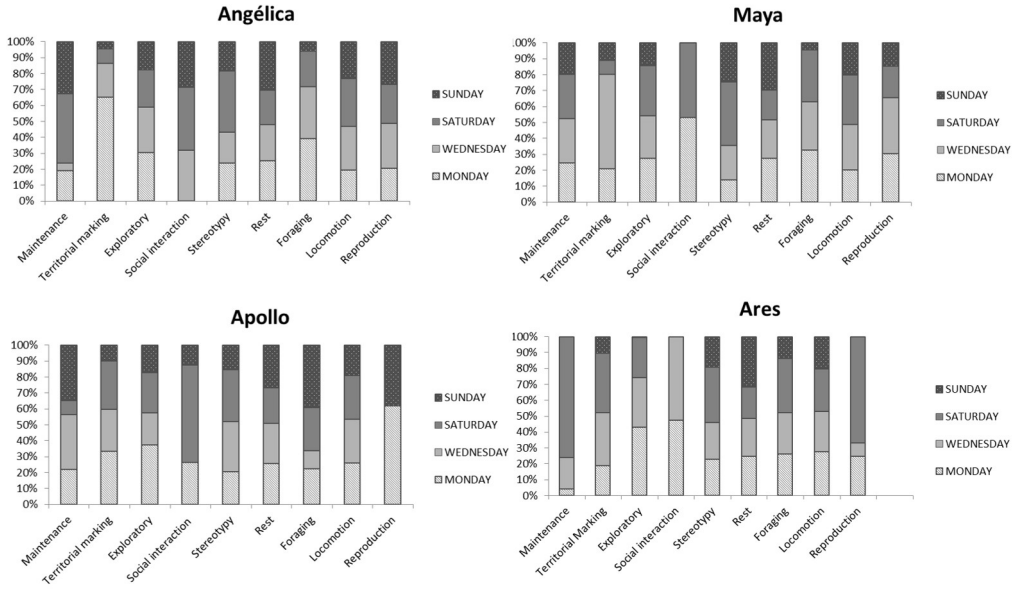

Fig. 2. Relative frequency of the different behavioral categories presented by jaguars between the different sample groupings.

and more stereotypic behavior on Saturdays. On Mondays, stereotypic behavior was significantly lower (χ_3^2=14.13; p < 0.01) (**Fig**. 2).

Ares had significantly higher levels of social interaction on Wednesdays (χ_3^2=14.13; p < 0.01) (**Fig**. 2) and higher maintenance behavior on Saturdays (χ_3^2=146.93; p < 0.001). Reproduction behavior was also higher on Saturdays (χ_3^2=105.55; p < 0.01); although it is worth mentioning that this behavioral category had a duration of only 16 seconds on Saturday (24 seconds in total over all the study days). Exploratory behavior was the highest on Sundays (χ_3^2=38.81; p < 0.001) and the territorial marking significantly lower on this same day (χ_3^2=19.30; p < 0.01) (**Fig**. 2).

Apollo engaged in more exploratory behavior on Mondays (χ_3^2=9.65; p < 0.05) and less maintenance behavior on Saturdays (χ_3^2=17,56; p < 0,01) (**Fig**. 2). Social interaction was significantly higher on Saturdays and lower on Wednesdays (χ_3^2=85.25; p < 0.001); he also engaged in less territorial marking behavior on Sundays (χ_3^2=13.04; p < 0.001). Reproduction behavior significantly differed in all the sample groupings (χ_3^2=111.37; p < 0.001). Finally, foraging behavior was higher on Sundays (χ_3^2=15.78; p < 0.05) (**Fig**. 2); although as commented previously, the animals did not receive food on this day, being the value significantly related to the behavioral act of "drinking water".

Visitation and noise

The number of visitors on the days with observation varied significantly between Wednesdays, Saturdays, and Sundays (**Table** 3), with the highest quantity on Sundays (F=27.54; p < 0.001). In terms of decibels, Angélica's enclosure had similar levels of noise on Wednesdays, Saturdays, and Sundays, with Mondays similar to Saturdays and quieter than the rest (F=6.46; p < 0.001). A similar pattern was observed at Maya's enclosure, although in this case, Sundays were clearly louder (F=7.98; p < 0.001). At Ares' enclosure, there was a similarity between Mondays and Saturdays (quieter), Wednesdays, and Sundays (louder) and a significant difference between these two groups (F=18.21; p < 0.001). At Apollo's enclosure, the sound on Mondays was significantly lower than the other groupings (F=8.47; p < 0.001).

It is also worth mentioning that on Wednesdays the visitors were usually related to school groups, and on weekends most visitors were families or informal groups. Many visitors on the weekends screamed, trying to wake up the animals. Others came with very loud music and even utilized the cellphone to emit gunshots sounds near the enclosures. Other visitors ate near the enclosures and on one Sunday, a visitor threw water on Apollo to see if it would wake up.

Table 2
Relative frequency of the behavioral categories presented by jaguars in the different observation days. The asterisk accompanies the significant value (P<0.05) between the categories in each day.

Behavioral categories	Mon	Wed	Sat	Sun
"Angelica"				
Maintenance	0.54	0.13	1.20	0.90
Territorial marking	0.65	0.21	0.09	0.04
Exploratory	8.69	8.04	6.64	4.94
Social interaction	0.00	0.10	0.12	0.09
Stereotypy	5.47	4.40	8.80	4.14
Rest	50.11*	45.36*	42.52*	60.35*
Foraging	11.15	9.21	6.41	1.62
Locomotion	20.23	28.21	30.48	23.84
Reproduction	3.16	4.34	3.74	4.08
"Maya"				
Maintenance	1.49	1.68	1.68	1.21
Territorial marking	0.10	0.29	0.04	0.05
Exploratory	5.79	5.60	6.60	3.04
Social interaction	0.04	0.00	0.04	0.00
Stereotypy	7.56	11.62	21.62	13.29
Rest	64.04*	55.87*	43.66*	69.98*
Foraging	9.27	8.63	9.29	1.30
Locomotion	10.39	14.78	16.20	10.50
Reproduction	1.32	1.53	0.86	0.63
"Ares"				
Maintenance	0.04	0.18	0.66	0.00
Territorial marking	0.21	0.40	0.42	0.11
Exploratory	9.41	7.06	5.47	5.65
Social interaction	0.02	0.02	0.00	0.00
Stereotypy	24.08	25.31	36.11	19.88
Rest	50.20*	51.18*	39.78*	63.97*
Foraging	5.90	6.19	7.67	3.09
Locomotion	10.13	9.66	9.86	7.29
Reproduction	0.01	0.00	0.03	0.00
"Apollo"				
Maintenance	0.31	0.49	0.13	0.50
Territorial marking	0.79	0.63	0.72	0.24
Exploratory	2.82	1.51	1.90	1.29
Social interaction	0.08	0.00	0.18	0.04
Stereotypy	13.02	19.92	20.67	9.72
Rest	63.81*	61.81*	55.09*	65.92*
Foraging	8.20	4.15	9.85	14.25
Locomotion	10.95	11.48	11.47	8.03
Reproduction	0.02	0.00	0.00	0.01

DISCUSSION

Our study demonstrated that visitation has an influence on the behavior of captive jaguars, altering the frequency of several behaviors and increasing the frequency of stereotypy. Furthermore, we demonstrated very high levels of individual variation between individuals in how they respond to stressful stimuli.

Jaguars do not have a single activity period. According to studies of Harmsen et al. (2011) and Monroy-Vilchis et al. (2009) this period is highly related to the period of its prey, in these studies it was shown that a jaguar can be both nocturnal, crepuscular or even diurnal. However, although the individuals studied for this research were observed in the morning – the same period that they are fed – rest behavior was always the most frequent behavioral category. High levels of inactivity may indicate a problem with the animal's well-being (Mitchell & Hosey 2005; McPhee & Carlstead 2010). A similar study with pumas at Curitiba zoo showed that the presence of visitors interfered with the behavior of the male of the species, with the animal resting for long periods (Costa et al. 2014).

It is important to note that data related to stress evaluation must be analyzed individually, because every animal will react differently, and this is related to its age, gender, personality or reproductive condition (McPhee & Carlstead 2010). For this reason, we analyzed the animals individually at every step, and will now discuss the differences found in detail.

Our analyses indicated that Ares had high levels of stereotypy in comparison to, for example, Angélica who engaged in the "normal" behavior of locomotion. The lack of stereotypic behavior does not, however, indicate a lack of stress as even normal locomotion behavior could be a sign of restlessness. This is corroborated by Guimarães's (2012) study of capuchin monkeys which showed that an excess of displacement can also be tied to stress.

Territorial marking and maintenance behavior appear to be lower on days of higher visitation, suggesting that more "natural" behaviors are depressed in response to the stress of visitation. Jaguars commonly use these marks - scratches, urine or feces - in their natural habitat to inform about their presence, identity, and health, for the species or others (Palomares et al. 2018). Moreover, inadequate level of territorial markings is an indicator of poor well-being in various species (Mitchell & Hosey 2005). The restricted space in captivity likely makes the jaguar spend less time patrolling and marking its territory, even though these behaviors are very common under natural conditions (Szokalski et al. 2012). Recent work on captive lions (*Panthera leo* (Linnaeus 1758)) also found that inactivity and pacing were the two main behavioral categories (Novo & Santos 2014). However, after the application of environmental enrichment techniques (EE), the behavioral repertoire increased to include natural behaviors such as territorial marking (Novo & Santos 2014). Silverio's (2015) study of the same jaguar individuals used in the present study also demonstrated that the introduction of EE promoted the expression of natural behaviors and significantly lowered stereotypic ones.

Table 3

Mean values and standard deviation of the number of visitors at the Municipal Zoo of Curitiba and of sound intensity (dB) in each one of the four enclosures during the moments of observation of the different sample groupings. The letters represent the similar and different values between the groupings at each enclosure.

Sample grouping	Visitors	Angélica	Maya	Ares	Apollo
Mondays	No visitation	56.88 ± 2.07a	56.94 ± 1.87a	57.0 ± 2.17a	56.73 ± 2.17a
Wednesdays	230 ± 188a	58.85 ± 4.63b	58.79 ± 2.70b	59.37 ± 3.43b	59.53 ± 4.66b
Saturdays	871 ± 544b	58.48 ± 3.9ab	58.04 ± 3.87ab	55.86 ± 3.49a	58.99 ± 3.63b
Sundays	1815 ± 807c	59.89 ± 4.51b	59.64 ± 4.17c	60.04 ± 4.20b	59.92 ± 4.26b

Noise levels varied between days and enclosures. In general, these levels were higher on Sundays (peak visitation) and similar on Saturdays and Wednesdays. If compare these measurements with the background-noise level in natural environments such as forests, the later can be predominantly lower (Ellinger & Hödl 2003). In a neotropical rainforest, the sound varies from 20 to 30 dB for most of the day, picking in short periods in the sunrise and sunset (50-60 dB) due to dawn chorus of birds and dusk chorus of insects, respectively (Ellinger & Hödl 2003). So, the sound intensity measured for prolonged periods in this study is thought to be associated with stress in captive mammals (Morgan & Tromborg 2007). Indeed, a study on pumas demonstrated that visitor noise significantly influenced individual behavior, with inactivity being positively associated with higher noise levels (Maia 2009).

We observed that both females, Angélica and Maya, presented significantly higher stereotypic behavior on Saturdays, though showed very little of this behavior on Sundays (even though this is the peak day for visitation). Likewise, Apollo engaged in less stereotypic behavior on Sundays. These findings are probably related to the lack of food on this day (the jaguars are not fed on Sundays), with individuals responding by saving energy and engaging in more resting behavior. Maya also engaged in less stereotypic behavior on Mondays when the zoo is closed to visitors, once again suggesting a causal link with visitation levels. These findings support the recent work of Vidal et al. (2016) on jaguars, which showed an increase in stereotypic behaviors was related to visitors near the enclosure. Nevertheless, all the animals still engaged in low levels of stereotypy on Mondays, possibly related to the longer-term effects of Sunday visitation or in response to other aspects of the captive environment (Mitchell & Hosey 2005). Moreover, almost all the stereotypic behaviors took place near the viewing area of the enclosure (near the visitors), supporting the results of a study of leopards (*Panthera pardus*) in an Indian zoo (Mallapur et al. 2005).

High numbers of visitors have been shown to increase cortisol levels in jaguars, indicating that visitation is stressfull for the animals (Montanha et al. 2009; Silva 2011). Similar results have been seen for other physiological indicators of stress, such as fecal metabolites of glucocorticoids (Silverio 2015). Glucocorticoids (cortisol, cortisone and corticosterone), also known as the stress hormones (Moyes & Schulte 2010), are generated through a cascade of biochemical events related to emotional responses to negative environmental stimuli (Montanha et al. 2009).

As previously mentioned, many zoos seek to fulfil the dual function of education/environmental recreation aimed at visitors along with conservation and scientific research (Garcia 2009; Pimentel et al. 2009). The environmental education conducted at zoos is highly connected to the behavior of the captive animals, because the visitors tend to have a higher interest in conservation when they are exposed to healthy, active animals (McPhee & Carlstead 2010). Increasing the well-being of animals is therefore priority of zoo management. Possible strategies to this end include: i) the construction of appropriate sized enclosures with structures consistent to a species' ecology (Clarke et al. 1982); ii) the implementation of glass windows that can muffle ambient noise and reduce the ability of the exhibits to see their human visitors, if they do not increase the temperature in the enclosures; iii) having places within the enclosure where the animal can hide itself from public view when it wishes to, and; iv) applying EE techniques that promote natural behaviors and reduce inappropriate behaviors.

Finally, we recommend that the Curitiba zoo adopts measures to control (or reduce) the number of visitors per day to the jaguar exhibits. Moreover, visitors should be better educated concerning the factors that influence the well-being of captive animal,

and to be shown how they can reduce the impact of their visit on the exhibited animals. For example, in a small zoo such as Curitiba, visitors could be divided into smaller groups on the weekends and accompanied by employees of the environmental education area during their visit - similar to what already occurs for schools and scheduled groups.

CONCLUSIONS

Our study confirms the results of previous research that visitation harms the behavior of captive jaguars, causing an increase in stereotypic behavior and an excess of inactivity. Possible solution to this problem includes restrictions on visitation and the improvement of the enclosure environment to promote natural behavior. Such improvements could include the insertion of new stimuli specific to each animal, being aware of their differences, as well as modifications to enclosures, regulation of visitor numbers and environmental education to change visitor behavior in front of the exhibits.

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