

Preliminary investigation of the effects of a concert on the behavior of zoo animals

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Abstract

To increase visitor footfall and engagement, zoos may host public events that may extend outside typical opening hours. With plans to hold a 2-day concert at Tayto Park, Ireland, this study aimed to identify the behavioral response to the music event of a selected group of species in the zoo. Twenty-two species were observed across three phases of the event (pre-, during, and post event). Specific behaviors of interest were categorized as active, resting, asleep, abnormal, and out of sight, with repeated observations being made at each enclosure during each phase. Alongside these behavioral data, sound pressure levels (SPLs) were concurrently recorded at the observation locations in terms of both dB(A) and dB(C). The median dB(C) levels during the event were found to be significantly higher (mdn = 64.5 dB) when compared with both pre-event (mdn = 60.7 dB) and postevent phases (mdn = 59.4 dB), while dB(A) levels were only significantly higher during the event (51.7 dB) when compared with the pre-event phase (mdn = 49.8 dB). We found some species-specific behavioral changes (mainly associated with active and resting behaviors) correlated with increased SPLs and/or event itself. However, the behavioral responses varied between species and there were numerous species that did not respond with any change in behavior to the increased SPLs or the event itself. This variation in response across species reinforces the need for monitoring of behavioral changes as well as consideration of their natural behavioral ecology when implementing appropriate mitigation strategies. Further research should be encouraged to provide an evidence-based assessment of how music events may affect animal welfare and behavior and to test the efficacy of mitigation strategies that are implemented to safeguard animal welfare.

KEYWORDS

behavior, environmental disturbance, event, welfare

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1 | INTRODUCTION

Zoos must actively market to attract visitor footfall, which often includes undertaking new development projects, adding novel attractions, or promoting special events such as music concerts. However, increasing visitor numbers, noise, and other novel stimuli may, in turn, affect the behavior and physiology of animals (Morgan & Tromborg, 2007; Powell et al., 2006; Sellinger & Ha, 2005). Zoos may therefore face a dilemma in balancing the significant monetary benefits of special events and increased visitor footfall with safeguarding the well-being of the animals under their care (Davey, 2006; Fernandez et al., 2009).

Music events hosted at zoos date back to the early 19th century, with zoological gardens in Europe featuring concert halls and open-air theaters (Meade et al., 2017; Peel, 1903). Today, concert events occur in zoos across Australia, Europe, and the United States. Oregon Zoo in Portland was the first American zoo to introduce a summer concert series in 1979. Taronga recently celebrated their 25th Anniversary of Sydney's summer concert series "Twilight at Taronga." Despite the history and frequency of music events at zoos, a literature review revealed few peer-reviewed articles on the effects of music events on the behavior or physiology of animals. Meade et al. (2017) found no effect on the behavior of the two domestic dogs (*Canis lupus familiaris*) exposed to summer music concerts at Tarango zoo. Shepherdson et al. (2004) found honeycreepers (*Cyanerpes* sp.) at the Honolulu Zoo showed increased secretion of glucocorticoid secretion (a hormonal response to stress) the day after summer evening music concerts. Finally, in a study investigating the impact of a music festival on wild urban hedgehogs (*Erinaceus europaeus*) living in Treptower Park, Berlin, researchers found that hedgehogs decreased their nightly activity range size during the concert days. However, there was no pattern in how the hedgehogs reacted to the disturbance; individual hedgehogs employed different behavioral strategies in the same environment (Rast et al., 2019). These studies elucidate the variation among species and individuals in their response to potentially aversive and novel stimuli.

Despite a lack of literature on the effects on the behavioral effects of concert-related disturbance, there are numerous studies focused on the impact of visitors and ambient noise on zoo animals. These two variables are often linked in studies; it is assumed that a rise in visitor numbers will correlate with an increase in noise levels, without this relationship being specifically studied. In terms of responses to visitor-related ambient noise, there are varying results, from mild behavioral changes in giant pandas (*Ailuropoda melanoleuca*) (Owen et al., 2004) to no effect on waterbuck (*Kobus ellipsiprymnus*), a male African elephant (*Loxodonta africana*) and two female chimpanzees (*Pan troglodytes*) (Quadros et al., 2014). In contrast, felids may spend more time resting, off-show, or withdrawing to remote parts of the exhibit when subjected to construction noise (Chosy et al., 2014; Sulser et al., 2008). Gorillas (*Gorilla gorilla gorilla*) exposed to a month-long after-hours "Zoo lights" event at the Smithsonian's National Zoo rested less during the event than during

pre- or postevent phases. The gorillas also expressed more abnormal behavior in the daytime during the zoo lights event than pre- or post event (Bastian et al., 2020). Queiroz and Young (2018) investigated the factors affecting species' susceptibility to visitor disturbance and found that those from closed habitats, herbivores, terrestrial species, and species in the active phase of their activity cycle are more frequently affected.

As part of the summer events season for 2019, Tayto Park, a zoo and theme park in Meath, Ireland, hosted the FunFest weekend music concert. This event provided the opportunity to investigate the effects of a music concert on animal behavior across a range of animals. In this study, we focus on activity, resting, abnormal behaviors, and whether the animals were out of sight to ascertain if the music and novel stimuli associated with the concert affected behavior. It was hypothesized that the music concert would result in higher visitor and sound levels during the event. We predicted that some species would express reduced activity and others would use their off-show enclosure more frequently during the concert event, but that not all species would be affected by the event in the same way.

2 | MATERIALS AND METHODS

2.1 | FunFest concert

A welfare management action plan, including a risk assessment for the event, was undertaken 3 months before the FunFest concert. The welfare plan was reviewed by the park's Ethics Committee and the Zoo Working Group; mitigations were discussed, agreed, and actioned as part of the park's in-house event planning process. Animal enclosures closest to the stage (Figure 1) were fitted with polycarbonate sheets to provide a reduction in sound pressure levels (SPLs) dBA of approximately 17% (Harley & Power, 2014). All other enclosures received no additional soundproofing. The World of Raptors bird of prey flying display (510 m from the main stage) was suspended during the FunFest event. The lemur walkthrough and the petting farm operated from 12:00 to 16:00. In addition, the zoo was closed to visitors from 18:30 on both evenings of the FunFest event, which was in line with the park's typical summer operating hours of 9:30 to 19:00 daily. Modification plans for all animal enclosures included the installation of additional retreat areas for all exterior enclosures. Retreats were constructed and placed in enclosures approximately 1 month before the commencement of the study to allow time for habituation. Viewing windows into an animal's interior enclosure (house) were fitted with inserts to provide either complete or partial privacy from visitors during the FunFest event. Management policy is such that all animals always have full access to the interior and exterior aspects of their enclosures (except during cleaning/feeding), and this remained in place during the concert.

The FunFest event was a 2-day music concert, the park opened at 9:30, and live music commenced at 12:30 and concluded



FIGURE 1 Animal enclosures geographically closest to the concert event are labeled as A and B, with their distances from the main stage being given in meters within the legend. Animal enclosures furthest from the concert event, labeled as C and D, are also given here with their distances from the main stage in meters. The location of the stage and arena are shown in the top right. Zoo perimeter is outlined in blue

at 21:30. Artists included rock and pop acts with live instrumentation or performances to a backing track. The stages (main and secondary) and ancillary food and drink vendors were confined to an adjacent field behind the amusement park approximately 500 m from the nearest animal enclosure in the zoo (Figure 1). The ticket for the FunFest event also included access to the zoo and amusement park. While the event was primarily self-contained in the adjacent field, there were promotional signs, decorations, and associated activities (e.g., costumed characters) in the amusement park and to a lesser extent in the zoo during the event days. Operational noise levels at the front of house mixing desk (behind the audience) were designated not to exceed equivalent continuous sound level (LAeq), 5 min 92 dB(A) (the average A-weighted SPL measured over 5 min), a maximum level of 100 dB(A) (LAm_{ax}, 100 dB(A)) and a maximum of 112 dB(C) (LC_{max} 112 dB(C)). The noise limit for the event was 75 LAeq, 15 min at the nearest human residence under the licensing conditions and the Code of Practice on Environmental Noise Control at Concerts (Noise Council, 1995). As there are no prescribed limits for wildlife or zoo animals in relation to noise control at outdoor concerts, we used previous data collected for sound levels during our closed and peak periods and set the limit for the closest animal enclosure (Amur tigers) at 65 LAeq, 15 min and C-weighted maximum sound level was set at LC_{max} of 80 within 2 m of each animal enclosure. These limits were similar to the maximum noise levels during peak visitor times. If the noise measurement came within 3 dB(A) of the noise limits, the event stage manager was notified and was instructed to implement adequate strategies to reduce any further increase in noise.

2.2 | Data collection protocol

Observers collected data on animal behavior and environmental noise following a set, unidirectional route around the park, with data being collected at each of the animal enclosures highlighted in Table 1. In addition to the date and time of each observation, information on animal behavior and noise levels were recorded. The park's admissions office provided daily visitor totals for each phase (preconcert, during concert, or post concert) of the study, along with the number of visitors entering the park each hour, which was used as a proxy for visitor presence in subsequent analyses.

Before the study commenced, a point at each enclosure's visitor stand-off barrier was marked to indicate where the observer would stand to view the animals and record SPL. Identification of these specific points ensured the consistency of all observations throughout the study. Observers ($n = 5$) participated in a group tutorial, followed by a group walk to locate all fixed observation points. Individual training sessions were held for each observer with the lead investigator. This session incorporated all species in the study and included recording behavior and SPLs. The training was carried out until the observers' reached at least 90% agreement with the lead investigator. All observers (J. J. H., A. P., and three zookeepers) were experienced with the study subjects and conducting behavioral observations as part of their daily work in addition to having contributed to several behavioral studies in the park. Observation sessions were either afternoon (12:00–17:00) or evening (17:01–23:00). Each observer participated in data collection across all three phases, and afternoon/evening observation sessions were evenly distributed across observers. All observers wore civilian clothing. Observations

TABLE 1 Zoo species were monitored during the FunFest concert event

Species common name	Scientific name	Sex ratio	# Observations by phase			Total
			Pre (June 14–16)	During (June 28–30)	Post (July 5–7)	
Amur tiger	<i>Panthera tigris altaica</i>	1.1.0	30	33	30	93
Puma	<i>Puma concolor</i>	1.0.0	30	30	30	90
Alpaca	<i>Vicungna pacos</i>	2.1.0	30	33	31	93
Eurasian eagle owl	<i>Bubo bubo</i>	0.1.0	30	33	30	93
Golden jackal	<i>Canis aureus</i>	0.5.0	30	33	29	92
Silvery marmoset	<i>Mico argentatus</i>	1.1.0	30	33	31	94
Japanese crane	<i>Grus japonensis</i>	1.1.1	30	33	30	93
Raccoon	<i>Procyon lotor</i>	0.3.0	30	33	31	94
Asian small-clawed otter	<i>Aonyx cinereus</i>	2.2.0	30	33	31	94
Binturong	<i>Arctictis binturong</i>	1.1.0	30	33	28	91
Eurasian lynx	<i>Lynx lynx</i>	1.4.0	30	33	30	93
Amur leopard	<i>Panthera pardus orientalis</i>	2.0.0	29	33	30	92
Tayra	<i>Eira barbara</i>	2.0.0	30	33	30	93
Ring-tailed coatimundi	<i>Nasua nasua</i>	1.2.0	30	33	29	92
Red-bellied tamarin	<i>Saguinus labiatus</i>	0.3.0	30	33	30	93
Cape porcupine	<i>Hystrix africaeustralis</i>	1.1.0	30	33	29	92
Ocelot	<i>Leopardus pardalis</i>	1.0.0	30	33	29	92
Vultures (Griffon and white-backed) (mixed-species exhibit)	<i>Gyps fulvus</i> and <i>G. africanus</i>	2.2.0	30	33	29	92
Squirrel monkey	<i>Saimiri sciureus</i>	3.0.0	30	33	29	92
Reindeer/Guanaco (mixed-species exhibit)	<i>Rangifer tarandus</i> and <i>Lama guanicoe</i>	0.1.0	30	33	30	93

Note: The table includes information on animal sex (male, females, and unknown) and the number of observations by phase (pre-event, during, and post event). Total observations for each species are presented in the final column.

were not carried out during active periods of rain unless the rain was intermittent and light or when a keeper was working with the animals (feeding/husbandry). As a result, an average of three observations per species were missed in Phases 1 and 3. In Phase 2 no observations were missed, except for three for the puma. The total observations by species and phase are illustrated in Table 1.

2.3 | Study animals

The study was preapproved by the Tayto Park Ethics Committee (March 13, 2019). All typical husbandry protocols were carried out, including feeding, cleaning, and enrichment protocols. Study subjects included 54 individual animals across 22 species housed at

the zoo (Table 1). Enclosure locations were representative of all animal sections and areas across the zoo, and all animals were captive-bred. The observed animals were all adults, except for one juvenile Japanese crane (*Grus japonensis*, <1 month old), and resided at the park for multiple years, with the exception of the golden jackals (*Canis aureus*, which were at the park for <12 months).

2.4 | Behavioral data collection

The first observation phase (pre-event) was carried out 2 weeks before the event, between June 14 and 16, 2019. The second phase (during event) was carried out between June 28 and 30, 2019. The

third phase occurred 1 week after the festival event (post event) between July 5 and 7, 2019 (Table 1)

Behavioral observations were conducted using 60-min interval scan sampling. At each sampling point, the presence (1) or absence (0) of at least one individual carrying out each behavior in the study ethogram (Table 2) was recorded. Data were therefore collected at the group level (unless individuals were individually housed) and treated as one sample point. Observations occurred every hour from 12:00 to 23:00, Friday to Sunday during each phase of the study. Data points recorded at 1-h intervals were assumed to be independent as this length of time gave animals ample opportunity to change their behavior. Abnormal behaviors described in the study ethogram were previously observed in individual animals (Amur leopard, ocelot, puma (pacing), squirrel monkey (head twirl), and jackals (excessive locomotion) before the concert event. Video footage of the jackals' excessive locomotion behavior was shared with all observers before the study as they were recent arrivals at the zoo, assuring the accurate identification of this behavior. If an animal performed an abnormal behavior, the observer recorded the presence and described the behavior in detail in the notes section of the datasheet. Any observed behaviors not listed in the ethogram were specified in the notes section of the datasheet, and (due to their low occurrence) were not analyzed further. Hourly scan samples enabled the observation of a wide range of taxa during the duration of the concert event by a limited number of highly trained observers. When studying large numbers of animals, more traditional sampling methods such as continuous focal sampling can be prohibitive due to the extensive labor the method necessitates (Mitlöchner et al., 2001). Margulis and Westhus (2008) state that when carrying out zoo research "even very limited amounts of data as little as 5- to 10-point samples per day, over time can provide invaluable information for future research, management and husbandry." Furthermore, hourly scans had been validated to reasonably approximate continuous behavior sampling for state behaviors such as lying for dairy and feedlot cattle (Gonyou & Stricklin, 1984; Mitlohner et al., 2001; Overton et al., 2002), and validated for active and inactive behaviors in nursery pigs (Bowden et al., 2008).

2.5 | SPL recording

SPLs and behavioral data were collected concurrently. The SPL at each enclosure was recorded with a Roline sound survey meter

(Model 1350; Rotronic Logistics). Field calibration occurred at the commencement of each series of measurements using a sine wave signal of 1000 Hz generated by a built-in oscillator. The accuracy rating for the monitor is ± 2 dB at 94 dB, sound level with decay < 1 dB/3 min. The observer held the sound pressure meter with the point of the meter facing toward the animal enclosure at the marked spot on the stand-off barrier 1.2 m above the ground. The observer recorded frequency A-weighting followed by frequency C-weighting. The time weighting dynamic response setting was set at slow for average noise level, with the SPL reported in decibel units (dB). A-weighting covers the range from 20 to 20,000 Hz, but the filter focuses more on the frequencies that correlate with human sensitivity and are expressed as dB(A). Humans have an audible range of 20–20,000 Hz, with the greatest sensitivity between 1000 and 4000 Hz (Ganong, 1997). The C-weighting is a wide-band frequency weighting and is essentially linear over several octaves. The C-weighting is used to measure peak, impact, or explosive noises and is expressed as dB(C) (ISO, 2003). Both dB(A) and dB(C) measures were used as it has been found that the assessment of sound with strong low frequencies (10–100 Hz), which we expected with bass instruments, should be conducted using Z-weighting (no weighting for human ear) or C-weighting, rather than A-weighting (Ziaraan, 2014). In addition to monitoring at animal enclosures, an independent noise monitoring firm (iAcoustics) carried out noise monitoring on June 29th and 30th from 12:00 to 21:30 at two fixed sites (nearest residence and nearest animal enclosure to the event). SPLs were recorded with an NTi XL2-TA (NTi Audio AG), a logging sound level meter and associated hardware, a condenser microphone (NTi XL2 M M2330; NTiAudio AG), and an outdoor microphone windshield protection kit (Roycote Softie). A remote noise monitoring kit NTi Netbox (NTi Audio AG) was used to capture a live feed that was made available via an e-mail link for management and the sound mixing board (located behind the audience). SPL measurements were made per guidelines detailed in ISO 1996/1:2003 Acoustics: Description and measurement of Environmental Noise (Part 1). Sound pressure was recorded as LAeq,T, which is the A-weighted equivalent continuous SPL, measured over a period of time. iAcoustic's role was to ensure that the event did not exceed the prescribed noise limits for residential areas and animal enclosures during the event (Figure A2).

TABLE 2 Ethogram of behaviors recorded during the FunFest concert study

Behavior	Definition
Active	Directional movement, allogrooming/self-grooming, birds preening, feeding/drinking and social interaction
Resting	Stationary, eyes open—laying down, sitting, standing, perching, the animal may be looking around
Asleep	Stationary, eyes closed—lying still, not engaged with surroundings (birds may have tucked head)
Abnormal	Head twirling, pacing (repetitive, fixed pattern) or excessive locomotion (restlessness/agitated trotting or running, repeatedly around the area of the enclosure)
Out of sight	Not visible to the observer, the animal may be in an off-show house or off-show retreat spaces within the exterior enclosure

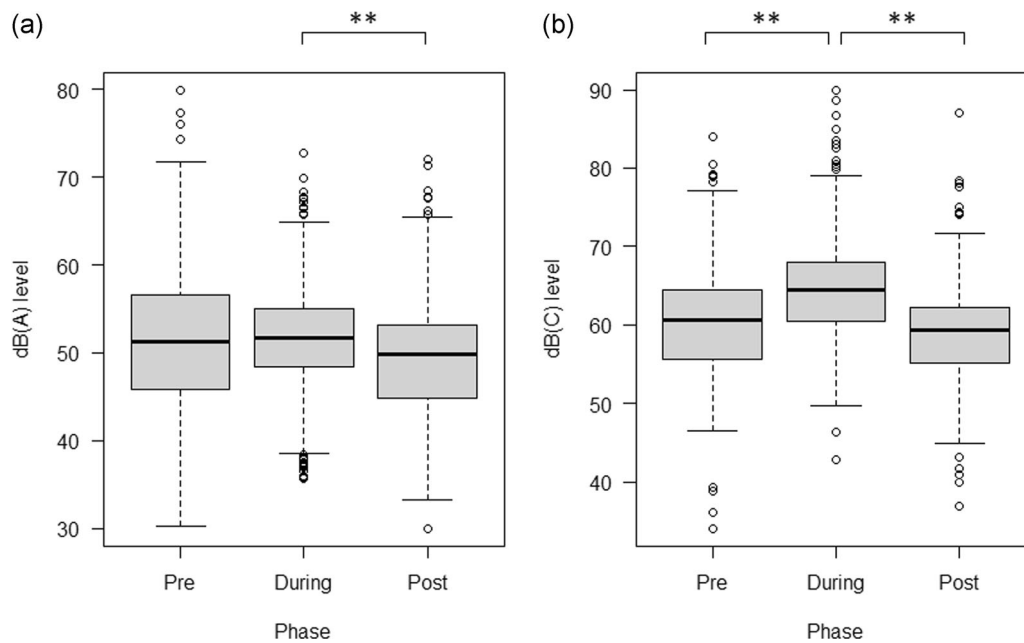


FIGURE 2 Boxplots representing sound pressure levels in terms of (a) dB(A) and (b) dB(C) in decibels according to phase (pre, during or post the FunFest event held at Tayto Park in 2019). Significant pairwise differences identified by post hoc test results are indicated (** $p < .001$)

2.6 | Statistical analysis

Sound pressure and behavioral data were analyzed and plotted using R version 4.0.0 (R Core Team, 2020). As outcome data could not be transformed to approximate a normal distribution, Kruskal–Wallis tests were used to test for a difference in total visitor numbers and SPLs across phases, with Mann–Whitney U test being used for post hoc comparisons.

We investigated the effects of various explanatory factors on behavior by fitting separate generalized linear models for each species and behavior using the "bayesglm" command in the package arm (Gelman et al., 2008) in the R environment. This method allows for data showing complete separation (when a linear combination of explanatory variables perfectly predicts the outcome variable; Albert & Anderson, 1984); this occurred in several of our models.

The binomial distribution was specified with the "logit" link function as behaviors were recorded as either present (1) or absent (0). The outcome variable for each species-specific model was one of the six binary behavioral measures (Table 2). The explanatory variables included in each model were SPLs (dB(A) and dB(C)), phase, date (as environmental factors such as the weather could impact on behavior; these would be expected to vary on different days), and time (as this frequently predicts the likelihood of a behavior occurring, due to the species' circadian rhythm). The best model was then selected by using the "stepAIC" command in the package MASS (Venables & Ripley, 2002). The fit of the best model to the data was ascertained by examination of a plot of expected versus observed residual values; binned residual plots were used as these are deemed appropriate for logistic regression models (Gelman & Hill, 2007). As dB(C) levels were not recorded at four timepoints on the first day of

data collection for all species and on three separate scans on June 28th (one scan for Amur leopards and two for vultures), these data points were omitted from models where dB(C) was an explanatory variable in the best model.

3 | RESULTS

Visitor numbers did not significantly differ between the pre-, during, and post event phases ($H(2) = 3.47$, $p = .18$). Although there was an effect of time of day on visitor numbers, this pattern was consistent across the three phases (Figure A1). However, SPLs did significantly differ for both dB(A) ($H(2) = 61.11$, $p < .001$) and dB(C) ($H(2) = 63.01$, $p < .001$) levels (Figure 2). Post hoc tests showed that SPL levels during the event were significantly higher in terms of dB(C) (mdn = 64.5 dB) when compared with both pre-event (mdn = 60.7 dB; $U = 215,807$, $p < .001$) and post-event (mdn = 59.4 dB; $U = 185,533$, $p < .001$) levels. SPL levels during the event were also significantly higher in terms of dB(A) (mdn = 51.7 dB) than in the postevent phase (mdn = 49.8 dB; $U = 301,076$, $p < .001$); however, they did not significantly differ to those in the pre-event phase (mdn = 51.3 dB; $U = 376,268$, $p = .34$).

3.1 | Behavioral changes across species

We found various species-specific behavioral changes attributed to either SPLs or the event itself. Significant results are discussed here on a taxon by taxon basis (with model effect sizes \pm standard error, z values, and p values being reported), with a summary of all results from the best models that included SPL or event phase as a factor is given in Table A1.

3.1.1 | Felids

Amur leopards were significantly more likely to be out of sight with higher dB(C) levels (estimate = 0.07 ± 0.04 , $z = 2.00$, $p = .046$; Figure 3a). Tigers were significantly more active (estimate = 0.25 ± 0.07 , $z = 3.62$, $p < .001$; Figure 3b) and less likely to be resting (estimate = -0.07 ± 0.03 , $z = -2.11$, $p = .04$; Figure 3c) with higher dB(C) levels, but were less active with higher dB(A) levels (estimate = -0.26 ± 0.07 , $z = -3.69$, $p < .001$; Figure 3d). The best model for tigers for out of sight included dB(A) level as a factor, but its effect was not significant. Lynx were significantly more likely to be out of sight with higher dB(A) levels (estimate = 0.19 ± 0.09 , $z = 2.09$, $p = .04$; Figure 3e). Ocelot showed significantly more abnormal behavior at lower dB(A) levels (estimate = -0.24 ± 0.11 , $z = -2.27$, $p = .02$; Figure 3f). The ocelot was significantly less likely to be resting in the postevent period than during the event (estimate = -2.11 ± 0.88 , $z = -2.39$, $p = .02$; pre-event: 23% of observations resting; during event: 30% of observations resting; post event: 3% of observations resting) and more likely to be showing abnormal behavior in the pre-event period than during the event (estimate = 3.43 ± 1.66 , $z = 2.06$, $p = .04$; pre-event: 13% of observations showing abnormal behavior; during event: no observations showing abnormal behavior; post event: no observations showing abnormal behavior).

3.1.2 | Canids

Jackals were significantly more active with higher dB(C) levels (estimate = 0.07 ± 0.04 , $z = 2.00$, $p = .045$; Figure 4).

3.1.3 | Ungulates

Alpaca were significantly more active (estimate = 0.08 ± 0.03 , $z = 2.47$, $p = .01$; Figure 5a) and less likely to be resting (estimate = -0.11 ± 0.04 , $z = -2.95$, $p = .003$; Figure 5b) at higher dB(C) levels. There was also a trend (estimate = -1.09 ± 0.57 , $z = -1.923$, $p = .054$), indicating that more resting behavior occurred during the event than in the pre-event period (pre-event: 36% of observations resting; during event: 54% of observations resting; post event: 70% of observations resting).

3.1.4 | Primates

Squirrel monkeys were significantly more active during the event than in the pre-event period (estimate = -1.54 ± 0.69 , $z = -2.25$, $p = .02$), with this increase persisting to the postevent period (estimate = 1.37 ± 0.69 , $z = 2.00$, $p = .046$; pre-event: 43% of observations active; during event: 67% of observations active; post event: 69% of observations active).

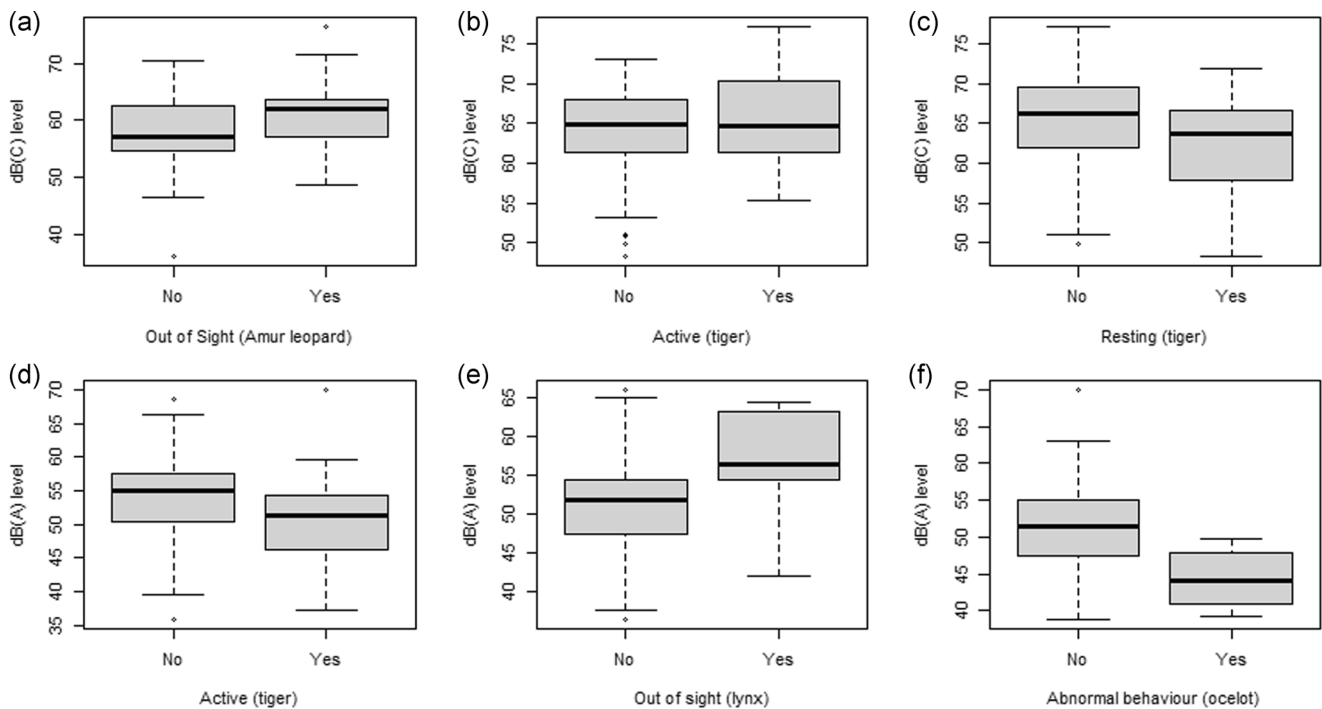


FIGURE 3 Boxplots representing the effects of sound pressure levels in terms of dB(C) on the likelihood that (a) Amur leopards were out of sight of observers and tigers were (b) active or (c) resting, and in terms of dB(A) on the likelihood that tigers were (d) active, that (e) lynx were out of sight and that (f) ocelot showed abnormal behavior. All differences are significant at the $\alpha = .05$ level. The thick line in the middle of each box shows the median sound pressure level at which the behavior was most commonly seen (yes) or not seen (no). The lower and upper limits of the box are the first and third quartiles. The whiskers extend to 1.5 times the interquartile range, with any outliers being represented by asterisks

FIGURE 4 Boxplot showing that at higher sound pressure levels in terms of dB(C), jackals were significantly more likely to be active. The difference is significant at the $\alpha = .05$ level. The thick line in the middle of each box shows the median sound pressure level at which the behavior was most commonly seen (yes) or not seen (no). The lower and upper limits of the box are the first and third quartiles. The whiskers extend to 1.5 times the interquartile range, with any outliers being represented by asterisks

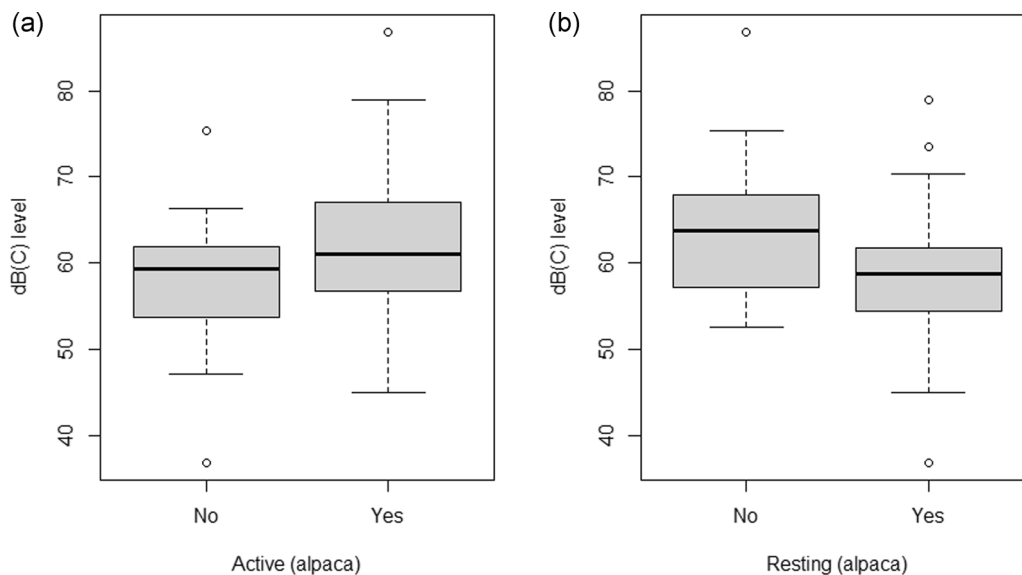
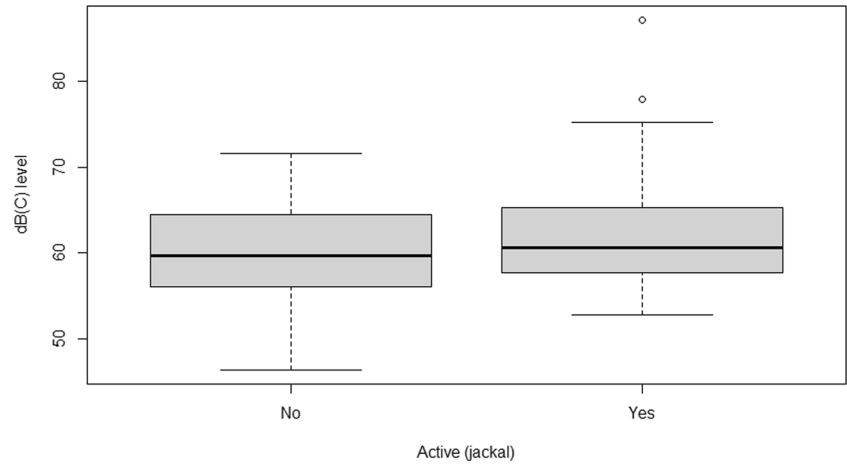


FIGURE 5 Boxplots showing that at higher sound pressure levels in terms of dB(C), alpaca were significantly (a) more likely to be active and (b) less likely to be resting. All differences are significant at the $\alpha = .05$ level. The thick line in the middle of each box shows the median sound pressure level at which the behavior was most commonly seen (yes) or not seen (no). The lower and upper limits of the box are the first and third quartiles. The whiskers extend to 1.5 times the interquartile range, with any outliers being represented by asterisks

3.1.5 | Small mammals

Porcupines were significantly less active with higher dB(C) levels (estimate = -0.18 ± 0.07 , $z = -2.66$, $p = .008$; Figure 6a) and were also significantly less active during the event than in the pre-event period (estimate = 2.32 ± 0.87 , $z = 2.68$, $p = .007$; pre-event: 33% of observations active; during event: 6% of observations active; post event: 17% of observations active). During the event, the porcupine were significantly more out of sight (estimate = -1.74 ± 0.75 , $z = 2.32$, $p = .02$; pre-event: 66% of observations out of site, during event 88% of observations out of site; post event 79% of observations out of site). Raccoons were significantly more active with higher dB(A) levels (estimate = 0.21 ± 0.07 , $z = 3.21$, $p = .001$; Figure 6b). They were also significantly more likely to be resting during the event than in the pre-event period (estimate = -1.82 ± 0.70 , $z = -2.58$, $p = .01$;

pre-event: 20% of observations active; during event: 42% of observations active; post event: 26% of observations active) and were less likely to be asleep at higher dB(A) levels (estimate = -0.16 ± 0.06 , $z = -2.80$, $p = .005$; Figure 6c). Binturong were more likely to be resting at higher dB(A) levels (estimate = 0.13 ± 0.06 , $z = 2.26$, $p = .02$; Figure 6d) and tayra were less likely to be asleep (estimate = -0.17 ± 0.06 , $z = -2.66$, $p = .008$; Figure 6e) at higher dB(A) levels.

3.1.6 | Birds

Japanese cranes were less likely to be either resting (estimate = -0.10 ± 0.05 , $z = -2.21$, $p = .03$) or asleep (estimate = -0.19 ± 0.06 , $z = -3.056$, $p = .002$) at higher dB(A) levels (Figure 7). Vultures were significantly less likely to be asleep either during (estimate = $-1.53 \pm$

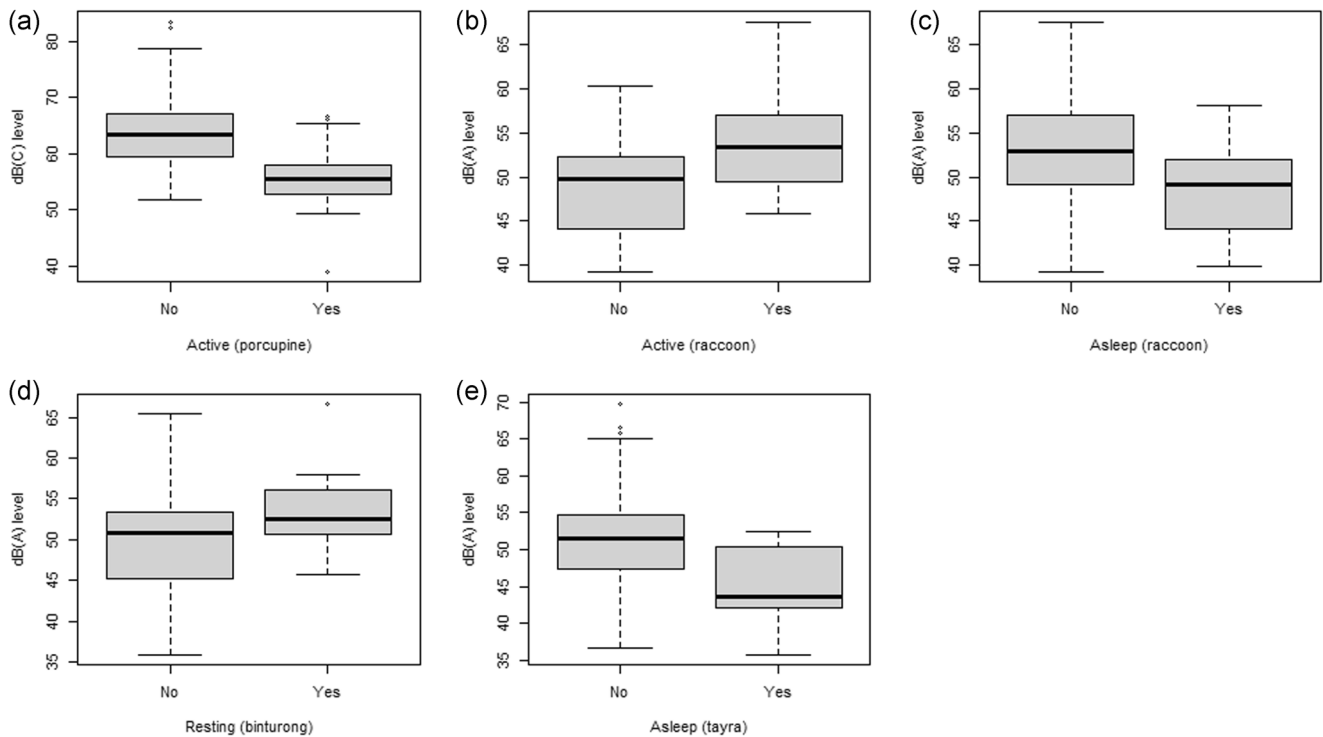


FIGURE 6 Boxplots showing that at higher sound pressure levels in terms of dB(C), (a) porcupines were less likely to be active, while at higher dB(A) levels, (b) raccoons were more likely to be active, (c) less likely to be asleep and (d) binturong were more likely to be resting and (e) tayra were less likely to be asleep. All differences are significant at the $\alpha = .05$ level. The thick line in the middle of each box shows the median sound pressure level at which the behavior was most seen (yes) or not seen (no). The lower and upper limits of the box are the first and third quartiles. The whiskers extend to 1.5 times the interquartile range, with any outliers being represented by asterisks

0.70, $z = -2.18$, $p = .03$) or in the postevent period (estimate = -2.01 ± 0.76 , $z = -2.64$, $p = .008$) in comparison with the pre-event period (pre-event: 47% of observations asleep; during event: 24% of observations asleep; post event: 17% of observations asleep). They were also significantly more likely to be resting in the postevent period than during the event (estimate = 1.41 ± 0.64 , $z = 2.19$, $p = .03$; pre-event: 53% of observations resting; during event: 64% of observations resting; post event: 79% of observations resting).

4 | DISCUSSION

4.1 | Visitor numbers and SPLs

Our expectation that visitor numbers would be higher during the event phase was not found to be true, and results indicate that the number of visitors does not necessarily correlate with ambient noise levels. Indeed, other factors, such as atmospheric conditions that affect sound propagation (Liptai et al., 2015) as well as the behavior of the visitors themselves (passive or active), may contribute to the overall visitor noise levels (Mitchell et al., 1992). In a theme park and zoo, visitor impact is not restricted to the visitor's proximity to an animal enclosure; instead, it is the visitor's contribution to the overall ambient sound. This includes how they engage with the amusement attractions (e.g., if they are reserved or exuberant or if all visitors ride

attractions). Quadros et al. (2014) also demonstrated the complex relationship between visitor number, sound levels, and animal behavior, confirming no linear relationship between these variables. Evidence also exists that the total visitor number to a zoo site does not necessarily best explain changes in animal behavior (Lewis et al., 2020). Thus, the relationship between visitor number, noise, and behavioral changes is not straightforward.

The median dB(C) levels were significantly higher during the music event than during either the pre- or postevent phase, while dB (A) levels were only significantly higher during the event compared with the pre-event phase. Low-frequency sounds are commonly associated with bass (percussive and string) instruments that form part musical compositions and are therefore increased in magnitude where live instrumentation features in a concert performance. The difference in the A- and C-weighted measures suggests the prevalence of low-frequency sound and is likely to account for the higher dB(C) levels during the event phase (Knauer et al., 2016). Although the SPLs were higher during the event phase, the conditional C-weighted limit for animal enclosures of LCmax of 80 dB was not exceeded at any time. The independent noise monitoring results concluded that the noise limit of 65 LAeq, 15 min was not exceeded at the animal enclosure closest to the concert (Figure A2). These data indicate that the preventive measures taken relating to event distance, stage position, and orientation of speakers to reduce sound propagation were successful.

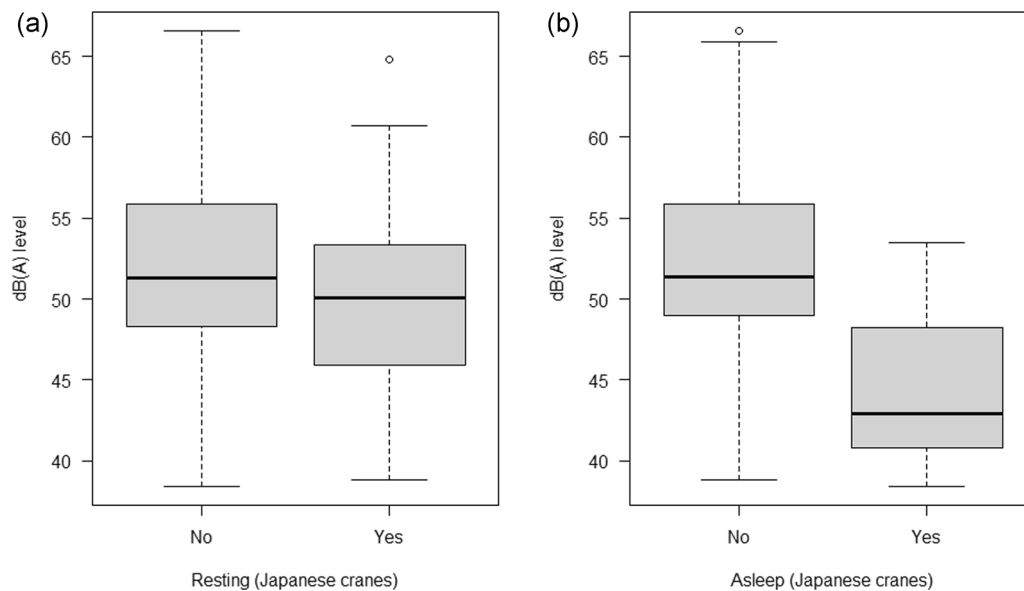


FIGURE 7 Boxplot showing that at higher sound pressure levels in terms of dB(A), Japanese cranes were significantly less likely to be (a) resting or (b) asleep. All differences are significant at the $\alpha = .05$ level. The thick line in the middle of each box shows the median sound pressure level at which the behavior was most commonly seen (yes) or not seen (no). The lower and upper limits of the box are the first and third quartiles. The whiskers extend to 1.5 times the interquartile range, with any outliers being represented by asterisks

4.2 | Animal behavior

In this study, we observed a wide range of zoo animals to determine whether a music concert event and the accompanying noise and stimuli were associated with changes in behavior. We found some species-specific behavioral changes that correlated with increased SPLs and/or event itself. However, as predicted, numerous species did not respond with any change in behavior to the increased SPLs or the event itself and the behavioral responses, where observed, varied between species.

4.2.1 | Out of sight and abnormal behavior

An animal's ability to hide or conceal itself from visitors, conspecifics, or novel stimuli may be an essential coping mechanism. Hiding or utilizing areas with cover has been documented in various species, including gorillas (Blaney & Walls, 2004), pygmy goats (Anderson et al., 2002), domestic cats (*Felis catus*) (Rochlitz, 2000), and wild felid species confronted with environmental stressors (Chosy et al., 2014; Harley et al., 2019). During periods of higher SPLs, the Amur leopards and Eurasian lynx spent more time off-show. The Amur leopards and Eurasian lynx viewing windows were fitted with wooden inserts to serve as a visual and sound barrier, no other soundproofing was fitted. SPLs were not recorded inside the houses; however, attenuation of sound due to the solid walls would be expected. Houses were constructed with brick covered in a wooden exterior. When sound waves meet the walls of the house, a portion of the sound is reflected, and the remainder passes through the building. Materials with hard, dense structures such as concrete bricks have weaker

sound absorption, but stronger reflecting properties (Li, 2011) and reduce sound. Provision of the additional retreats as well as covering the viewing windows of houses provided animals with opportunities to withdraw to remote areas of their exhibit. Evidence indicates that empowering captive animals with the freedom to choose benefits their well-being (Kurtz et al., 2014; Owen et al., 2004). Ensuring the provision of accessible retreat space is an essential consideration during event planning as a reduction or lack of retreat opportunities can be a basis of distress for captive animals (Morgan & Tromborg, 2007).

Abnormal behavior occurred at low rates in most felids and the golden jackals during observation phases. The squirrel monkeys also had low rates of observed abnormal behavior; however, head-twirling may be underrepresented due to the short duration of this behavior and the chosen methodology, which is not as sensitive to the detection of behavioral events. Compared to other observation days, the jackals expressed a higher frequency of abnormal behavior (excessive locomotion) during the 2 days of the FunFest concert event. During the event, the main restaurant was used as the headquarters for distributing food and drinks to the FunFest event. The main distribution entry/exit was adjacent to the jackal enclosure. As a result, additional staff footfall and noise from catering trollies occurred in proximity to the jackals. The distribution hub was an aspect of event operations that were not identified in the risk assessment for the event, and as a result, no mitigations were actioned. This elucidates that despite extensive cross-departmental planning, potential stressors may be inadvertently overlooked.

The ocelot expressed more abnormal behavior in the pre-event phase, which was also correlated with lower SPLs. The ocelot did not express any abnormal behavior during or after the event. While this

result is difficult to explain conclusively, the observer's presence, which would not typically occur at this time of day, may have triggered the ocelot's abnormal behavior during the pre-event phase. It is important to note that the observer may influence behavior, and for some species/individual animals, cameras may be necessary to avoid observer disturbance. There was no significant change in the frequency of observations of abnormal behavior across the phases for any other species.

4.2.2 | Activity, resting, and sleep

Many of the significant changes observed across the study species were associated with variations in the occurrence of active and resting behaviors. However, there was no clear predictor for changes in activity levels within or across taxa. Changes in activity patterns were associated with the during and postevent phases, as well as dB(A) and dB(C) SPLs.

Our Amur tigers were less active with higher dB(A) levels. Increased inactivity has been noted in felids (Chosy et al., 2014; Sulser et al., 2008) exposed to noise from construction work. Conversely, our tigers were also found to be more active and less likely to be resting during periods of higher dB(C) levels. It is understood that tigers show greater sensitivity in the low-frequency portion of their audible spectrum (Walsh et al., 2003). This could explain this response to dB(C) levels, although this result should be treated with caution as it is based on a sample size of two individuals. Our Amur leopards, lynx, and ocelot expressed no changes in activity based on the event phase or SPLs.

Interpretations of the correlation between activity, the event, and SPLs and whether these constitute a negative or positive change in the animal's welfare state are currently open to debate. Certainly, activity takes on many forms; in the context of this study, active behaviors included locomotor activity as well as grooming, preening, and feeding, but excluded excessive locomotion as that was defined as abnormal behavior. Increased locomotor activity linked to the frustration of motivations such as frustrated appetitive behavior, when animals attempt to look for food in a restricted environment, is well understood (Clubb & Vickery, 2006; Mason, 2006). However, the relationship between activity and the welfare state is not always clear. The same holds for resting; excessive inactivity is linked to a negative welfare state in captive animals (McPhee & Carlstead, 2010). However, inactivity in animals can also be indicative of the animal's needs being satiated and in relation to residing in a safe and familiar environment (Cockram, 2014; Fureix & Meagher, 2015; Nowak, 2006). Further work is needed to clearly define and validate various form(s) of activity and inactivity and their potential to indicate positive or negative welfare states in different species (Fureix & Meagher, 2015).

As suggested by Queiroz and Young (2018), variation in species responses may be attributed to the timing of the auditory stimulus to the normal activity period and their usual behavior at this time. For example, diurnal species routinely experience auditory stressors

during zoo operating hours when they are naturally in the active phase of their diurnal cycle. The inactive phase (evening and night) is typically quieter due to a reduction in human activity. Consequently, any increased anthropogenic noise at these times may have a more significant impact on behavior for these species as they are less habituated to this pattern of temporal disturbance. Nocturnal and crepuscular species experience the opposite and have potentially already developed coping mechanisms that facilitate rest during periods of the auditory stimulus, for example, moving to indoor areas that are quieter (Quadros et al., 2014). Therefore, behavioral changes in response to an auditory stressor may vary between active and resting phases of diurnal cycles and between diurnal and nocturnal species. We found that our nocturnal porcupines decreased their activity during the event and were less active during periods of higher dB(C) levels. Emergence from their dens was also affected; pre-event they were seen active from 18:00. However, during the event, they spent more time out of sight and emergence from their dens and expression of active behaviors occurred after 21:00 on Saturday (the first night of the concert) and 22:00 on Sunday (the last night of the event), delaying the onset of their active period. In the postevent phase, they were seen to be active from 19:00. Although the park's raccoons have adapted their activity cycle in line with the keepers' husbandry practices, they were observed sleeping more during periods where the dB(A) levels were lower and observed resting more during the event phase compared with the pre-event phase.

For diurnal species, habitual resting periods may have been altered due to extended hours of operation. The vultures slept less during the event and after the event compared with the pre-event phase. In the pre-event phase, the vultures were mostly recorded as asleep from 19:00; during the event, this changed to 21:00, and post event, it moved to just after 20:00. Although the zoo was closed to the public during the evening, the staff had access to a path adjacent to the vulture aviary to access a temporary staff car park.

4.3 | Limitations

Individuals within populations vary in behavioral expression (personality), and this difference may affect survival or the way they respond to or cope with environmental challenges (Moiron et al., 2020). We realize that investigating individual differences may have highlighted specific individuals' unique responses, which in turn would enable management strategies to be tailored for the individual. However, this project was not conducted to pinpoint causal factors for individual changes in behavior; instead, it provided data that would enable us to identify at-risk species for welfare planning and management in future events/activities. Furthermore, there are limitations to the chosen sampling method. Due to the limited nature of the concert event (a one-off festival), the emphasis was placed on collecting data on as many species as possible. This method works well for behavioral states; however, behaviors occurring as events are unlikely to be recorded. The authors recommend that in future studies (when feasible) methodologies that support recording both event

and state behaviors should be performed as behavioral events are important for interpreting animal behavior. The authors also recommend that in future studies the quality of the retreat space is investigated, which could be quantified by installing sound data loggers in each retreat space. This would enable sound attenuation and characteristics of the retreat space to be determined and in turn inform recommendations for best practice when planning mitigations for proposed events. Finally, the authors appreciate that “resting” behavior could have potentially been erroneously recorded as “sleeping,” and vice versa; however, since observers had significant experience of these species' behaviors and, in addition, had adequate time to observe an animal until their behavior could be reliably identified, we can be confident that such errors were infrequent.

5 | CONCLUSIONS

Our study found changes in state behaviors across a wide range of taxa; however, there was no clear predictor for changes in behavior within or across taxa. The study confirmed that precautionary measures, that is, event risk assessment, location, stage position, and initial mitigations, effectively controlled noise in the zoo. As zoological collections continue to undertake new development projects, add novel attractions, and promote special events such as music concerts, to maximize footfall, it is essential to recognize that this may result in changes in animal behavior. The authors encourage more research in this area for in-house event planning as well as to contribute to multi-institutional studies to ascertain if there are consistent and predictable behavior changes in the same species or taxonomic groups across different captive collections. Findings on this subject could have a significant impact on the ability of captive facilities to mitigate against event effects in the future.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

- Albert, A., & Anderson, J. A. (1984). On the existence of maximum likelihood estimates in logistic regression models. *Biometrika*, 71(1), 1–10.
- Anderson, U. S., Benne, M., Boomsmith, M. A., & Maple, T. L. (2002). Retreat space and human visitor density moderate undesirable behavior in petting zoo animals. *Journal of Applied Animal Welfare Science*, 5, 125–137.
- Bastian, M. L., Glendinning, D. R., Brown, J. L., & Edwards, K. L. (2020). Effects of a recurring late-night event on the behavior and welfare of a population of zoo-housed gorillas. *Zoo Biology*, 39, 217–229.
- Blaney, E. C., & Walls, D. L. (2004). The influence of camouflage net barrier on the behavior, welfare and public perception of zoo-housed gorillas. *Animal Welfare*, 13, 111–118.
- Bowden, J. M., Karriker, L. A., Stalder, K. J., & Johnson, A. K. (2008). Scan sampling techniques for behavioral validation in nursery pigs. *Animal Industry Report*, 654(1), ASL R2342.
- Chosy, J., Wilson, M., & Santymire, R. (2014). Behavioral and physiological responses in felids to exhibit construction. *Zoo Biology*, 33, 267–274.
- Clubb, R., & Vickery, S. (2006). Locomotory stereotypies in carnivores: Does pacing stem from hunting, ranging, or frustrated escape. In G. Mason, & J. Rushen (Eds.), *Stereotypic animal behavior: Fundamentals and applications to welfare* (2nd ed., pp. 58–79). Cabi. <https://doi.org/10.1079/9780851990040.0058>
- Cockram, M. S. (2014). A review of behavioral and physiological responses of sheep to stressors to identify potential behavioral signs of distress. *Animal Welfare*, 13, 283–291.
- Davey, G. (2006). Visitor behavior in zoos: A review. *Anthrozoos: A Multidisciplinary Journal of the Interactions of People & Animals*, 19, 143–157.
- Fernandez, E. J., Tamborski, M. A., Pickens, S. R., & Timberlake, W. (2009). Animal–visitor interactions in the modern zoo: Conflicts and interventions. *Applied Animal Behaviour Science*, 120, 1–8.
- Fureix, C., & Meagher, R. K. (2015). What can inactivity (in its various forms) reveal about affective states in nonhuman animals? A review. *Applied Animal Behaviour Science*, 171, 8–24. <https://doi.org/10.1016/j.applanim.2015.08.036>
- Ganong, W. F. (1997). *Review of medical physiology* (18th ed.). Appleton and Lange.
- Gelman, A., & Hill, J. (2007). *Data analysis using regression and multilevel/hierarchical models*. Cambridge University Press.
- Gelman, A., Jakulin, A., Pittau, M. G., & Su, Y. S. (2008). A weakly informative default prior distribution for logistic and other regression models. *The Annals of Applied Statistics*, 2, 1360–1383.
- Gonyou, H. W., & Stricklin, W. R. (1984). Diurnal behavior patterns of feedlot bulls during winter and spring in northern latitudes. *Journal of Animal Science*, 58(5), 1075–1083.
- Harley, J. J., Chaisson, J., & Handel, I. (2019). Effects of assembly and operation of an amusement ride on the behavior of a pair of captive Amur tigers (*Panthera tigris altaica*). *Journal of Zoo and Aquarium Research* 7, 218–222.
- Harley, J. J., & Power, A. (2014) *Effects of amusement ride on the behaviour of felids* (unpublished; internal document, Tayto Park, Ireland).
- ISO 1996-1. (2003). *Acoustics-Description, measurement and assessment of environmental noise Part1: Basic quantities and assessment procedures*. International Organization for Standardization.
- Knauer, M., Jeon, S., Murphy, T. E., Yaggi, H. K., Pisani, M. A., & Redeker, N. S. (2016). Comparing average levels and peak occurrence of overnight sound in the medical intensive care unit on A-weighted and C-weighted decibel scales. *Journal of Critical Care*, 36, 1–7.
- Kurtycz, L. M., Wagner, K. E., & Ross, S. R. (2014). The choice to access outdoor areas affects the behavior of great apes. *Journal of Applied Animal Welfare Science*, 17, 185–197.
- Lewis, R. N., Chang, Y. M., Ferguson, A., Lee, T., Clifforde, L., & Abeyesinghe, S. M. (2020). The effect of visitors on the behavior of zoo-housed Western Lowland Gorillas (*Gorilla gorilla gorilla*). *Zoo Biology*, 39, 283–296.
- Li, S. R. (2011). Acoustic and thermal insulating material. In Y. Li, & S. Ren (Eds.), *Woodhead publishing series in civil and structural engineering, building decorative materials* (pp. 359–374). Woodhead Publishing. <https://doi.org/10.1533/9780857092588.359>
- Liptai, P., Badida, M., & Lukáčová, K. (2015). Influence of atmospheric conditions on sound propagation—mathematical modeling. *Óbuda University e-Bulletin*, 5, 127.

- Margulis, S. W., & Westhus, E. J. (2008). Evaluation of different observational sampling regimes for use in zoological parks. *Applied Animal Behavior Science*, 110(3-4), 363–376.
- Mason, G. (2006). Stereotypic animal behavior: Fundamentals and applications to welfare and beyond. In G. Mason, & J. Rushen (Eds.), *Stereotypic animals behaviour: Fundamentals and applications to welfare* (2nd ed., p. 325). Cabi.
- McPhee, M. E., & Carlstead, K. (2010). The importance of maintaining natural behaviors in captive mammals. In D. G. Kleiman, K. V. Thompson, & C. K. Baer (Eds.), *Wild mammals in captivity, principles, and techniques for zoo management* (2nd ed., pp. 303–313). University of Chicago Press.
- Meade, J., Formella, I., & Melfi, V. (2017). A note on the effect of concerts on the behavior of domestic dogs *Canis lupus familiaris* at Taronga Zoo, Sydney. *International Zoo Yearbook*, 51, 225–231.
- Mitchell, G., Tromborg, C. T., Kaufman, J., Bargabus, S., Simoni, R., & Geissler, V. (1992). More on the 'influence' of zoo visitors on the behavior of captive primates. *Applied Animal Behaviour Science*, 35, 189–198.
- Mitlöchner, F. M., Morrow-Tesch, J. L., Wilson, S. C., Dailey, J. W., & McGlone, J. J. (2001). Behavioral sampling techniques for feedlot cattle. *Journal of Animal Science*, 79(5), 1189–1193.
- Moiron, M., Laskowski, K. L., & Niemelä, P. T. (2020). Individual differences in behavior explain variation in survival: A meta-analysis. *Ecology Letters*, 23, 399–408.
- Morgan, K. N., & Tromborg, C. T. (2007). Sources of stress in captivity. *Applied Animal Behaviour Science*, 102, 262–302.
- Noise Council. (1995). *Code of practice on environmental noise at concerts*. Chartered Institute of Environmental Health. <https://www.cieh.org/policy/>
- Nowak, R. (2006). Suckling, milk, and the development of preferences toward maternal cues by neonates: From early learning to filial attachment? *Advances in the Study of Behavior*, 36, 1–58.
- Overton, M. W., Sischo, W. M., Temple, G. D., & Moore, D. A. (2002). Using time-lapse video photography to assess dairy cattle lying behavior in a free-stall barn. *Journal of Dairy Science*, 85(9), 2407–2413.
- Owen, M. A., Swaisgood, R. R., Czekala, N. M., Steinman, K., & Lindburg, D. G. (2004). Monitoring stress in captive giant pandas (*Ailuropoda melanoleuca*): Behavioral and hormonal responses to ambient noise'. *Zoo Biology*, 23, 147–164.
- Peel, C. V. A. (1903). *The zoological gardens of Europe: Their history and chief features*. FE Robinson & Company.
- Powell, D. M., Carlstead, K., Tarou, L. R., Brown, J. L., & Monfort, S. L. (2006). Effects of construction noise on behavior and cortisol levels in a pair of captive giant pandas (*Ailuropoda melanoleuca*). *Zoo Biology*, 25, 391–408.
- Quadros, S., Goulart, V. D., Passos, L., Vecci, M. A., & Young, R. J. (2014). Zoo visitor effect on mammal behavior: Does noise matter? *Applied Animal Behaviour Science*, 156, 78–84.
- Queiroz, M. B., & Young, R. J. (2018). The different physical and behavioral characteristics of zoo mammals that influence their response to visitors. *Animals: An Open Access Journal from MDPI*, 8, 78–84. <https://doi.org/10.3390/ani8080139>
- R Core Team. (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. <https://www.R-project.org/>
- Rast, W., Barthel, L. M., & Berger, A. (2019). Music festival makes hedgehogs move: How individuals cope behaviorally in response to human-induced stressors. *Animals: An Open Access Journal from MDPI*, 9, 455.
- Rochlitz, I. (2000). Recommendations for the housing and care of domestic cats in laboratories'. *Laboratory Animals*, 34, 1–9.
- Sellinger, R. L., & Ha, J. C. (2005). The effects of visitor density and intensity on the behavior of two captive jaguars (*Panthera onca*). *Journal of Applied Animal Welfare Science*, 8, 233–244.
- Shepherdson, D., Carlstead, K., & Wielebnowski, N. (2004). Cross-institutional assessment of stress responses in zoo animals using longitudinal monitoring of faecal corticoids and behavior. *Animal Welfare*, 13, S105–S114.
- Sulser, C., Steck, B., & Baur, B. (2008). Effects of construction noise on behavior of and exhibit use by Snow leopards *Uncia uncia* at Basel Zoo. *International Zoo Yearbook*, 42, 199–205.
- Venables, W. N., & Ripley, B. D. (2002). *Modern applied statistics with S* (4th ed.). Springer.
- Walsh, E. J., Wang, L. M., Armstrong, D. L., Curro, T., Simmons, L. G., & McGee, J. A. (2003). Acoustic communication in *Panthera tigris*: A study of tiger vocalization and auditory receptivity. *Journal of Architectural Engineering*, 38, 2275.
- Ziara, S. (2014). The assessment and evaluation of low-frequency noise near the region of infrasound. *Noise & Health*, 16(68), 10–17.

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APPENDIX

Figures A1 and A2 and Tables A1 and A2

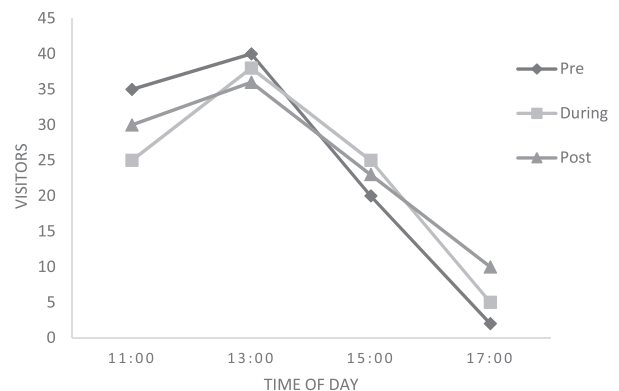


FIGURE A1 Percentage of the overall daily visitors entering the park by the time of day (11:00, 13:00, 15:00, and 17:00) for each phase (pre, during, or post) of the FunFest event held at Tayto Park in 2019. Although there was an effect of time of day on visitor numbers, the pattern of entry was consistent across the phases



Date [YYYY-MM-DD]	Start Time [hh:mm:ss]	Stop Time [hh:mm:ss]	LAeq [dB]	Date [YYYY-MM-DD]	Start Time [hh:mm:ss]	Stop Time [hh:mm:ss]	LAeq [dB]
29/06/2019	11:47:56	12:02:56	58.2	30/06/2019	12:14:38	12:29:38	59.6
29/06/2019	12:02:56	12:17:56	58.4	30/06/2019	12:29:38	12:44:38	60.2
29/06/2019	12:17:56	12:32:56	59.2	30/06/2019	12:44:38	12:59:38	61.3
29/06/2019	12:32:56	12:47:56	59.2	30/06/2019	12:59:38	13:14:38	59.9
29/06/2019	12:47:56	13:02:56	59.5	30/06/2019	13:14:38	13:29:38	59.8
29/06/2019	13:17:44	13:32:44	60.8	30/06/2019	13:29:38	13:44:38	59.6
29/06/2019	13:32:44	13:47:44	60.6	30/06/2019	13:44:38	13:59:38	58.4
29/06/2019	13:47:44	14:02:44	59.5	30/06/2019	13:59:38	14:14:38	58.7
29/06/2019	14:02:44	14:17:44	59.5	30/06/2019	14:14:38	14:29:38	69.5
29/06/2019	14:17:44	14:32:44	59.3	30/06/2019	14:29:38	14:44:38	61
29/06/2019	14:32:44	14:47:44	59.6	30/06/2019	14:44:38	14:59:38	62.9
29/06/2019	14:47:44	15:02:44	59.4	30/06/2019	14:59:38	15:14:38	60.1
29/06/2019	15:02:44	15:17:44	59.6	30/06/2019	15:14:38	15:29:38	60.5
29/06/2019	15:17:44	15:32:44	59.8	30/06/2019	15:29:38	15:44:38	61.1
29/06/2019	15:32:44	15:47:44	59.8	30/06/2019	15:44:38	15:59:38	58.7
29/06/2019	15:47:44	16:02:44	59.4	30/06/2019	15:59:38	16:14:38	59.8
29/06/2019	16:02:44	16:17:44	59.9	30/06/2019	16:14:38	16:29:38	57.8
29/06/2019	16:17:44	16:32:44	58.7	30/06/2019	16:29:38	16:44:38	59.6
29/06/2019	16:32:44	16:47:44	58.8	30/06/2019	16:44:38	16:59:38	60
29/06/2019	16:47:44	17:02:44	58.1	30/06/2019	16:59:38	17:14:38	61.5
29/06/2019	17:02:44	17:17:44	57.9	30/06/2019	17:14:38	17:29:38	61.8
29/06/2019	17:17:44	17:32:44	58.3	30/06/2019	17:29:38	17:44:38	60.4
29/06/2019	17:32:44	17:47:44	58	30/06/2019	17:44:38	17:59:38	62
29/06/2019	17:47:44	18:02:44	59.8	30/06/2019	17:59:38	18:14:38	61.4
29/06/2019	18:02:44	18:17:44	59.5	30/06/2019	18:14:38	18:29:38	60.2
29/06/2019	18:17:44	18:32:44	60.3	30/06/2019	18:29:38	18:44:38	60.2
29/06/2019	18:32:44	18:47:44	58.6	30/06/2019	18:44:38	18:59:38	58
29/06/2019	18:47:44	19:02:44	59.1	30/06/2019	18:59:38	19:14:38	59.1
29/06/2019	19:02:44	19:17:44	59.7	30/06/2019	19:14:38	19:29:38	59.6
29/06/2019	19:17:44	19:32:44	60.3	30/06/2019	19:29:38	19:44:38	58.7
29/06/2019	19:32:44	19:47:44	60.3	30/06/2019	19:44:38	19:59:38	57.4
29/06/2019	19:47:44	20:02:44	59.6	30/06/2019	19:59:38	20:14:38	52.6
29/06/2019	20:02:44	20:17:44	59.7	30/06/2019	20:14:38	20:29:38	58.8
29/06/2019	20:17:44	20:32:44	58.3	30/06/2019	20:29:38	20:44:38	60.1
29/06/2019	20:32:44	20:47:44	58.1	30/06/2019	20:44:38	20:59:38	58.7
29/06/2019	20:47:44	21:02:44	51.8	30/06/2019	20:59:38	21:14:38	55.8
29/06/2019	21:02:44	21:17:44	51.2	30/06/2019	21:14:38	21:29:38	52
29/06/2019	21:17:44	21:29:44	52	30/06/2019	21:29:38	21:32:12	51.2

FIGURE A2 iAcoustics noise monitoring raw data recorded on Saturday 29th and Sunday 30th of June 2019. SPLs were recorded in dB(A) at the nearest animal enclosure (Amur tigers) 487 m from the event

TABLE A1 Results for all models fit to behavioral measures for all species

Species	Sex ratio	Active (ACT)	Resting (REST)	Asleep	Abnormal (ABN)	Out of sight (OOS)
<i>Felids</i>						
Amur tiger	1.1.0	↑ACT↑dBC ↓ACT↑dBA	↓REST↑dBC	NS	-	NS
Amur leopard	2.0.0	NS	NS	NS	NS	↑OOS↑dBC
Ocelot	1.0.0	NS	↓REST post event	NS	↑ABN pre-event ↑ABN↓dBA	NS
Eurasian lynx	1.4.0	NS	NS	NS	NS	↑OOS↑dBA
Puma	1.0.0	NS	NS	NS	NS	NS
<i>Canids</i>						
Golden jackals	0.5.0	↑ACT↑dBC	NS	NS	NS	NS
<i>Ungulates</i>						
Alpaca	2.1.0	↑ACT↑dBC	↓REST↑dBC	NS	-	NS
Reindeer and Guanaco mixed exhibit	0.3.0	NS	NS	NS	-	NS
<i>Primates</i>						
Squirrel monkey	3.0.0	↑ACT event	NS	NS	NS	NS
Silvery marmoset	1.1.0	NS	NS	-	-	NS
Red-bellied tamarin	0.3.0	NS	NS	-	-	NS
<i>Small mammals</i>						
Raccoon	0.3.0	↑ACT↑dBA	↑REST event	↓Sleep↑dBA	-	NS
Binturong	1.1.0	NS	↑REST↑dBA	NS	-	NS
Cape porcupine	1.1.0	↓ACT event ↓ACT↑dBC	NS	-	-	↑OOS event
Short-clawed otter	2.2.0	NS	NS	-	-	NS
Coatimundi	1.2.0	NS	NS	NS	-	NS
Tayra	2.0.0	NS	NS	↓Sleep↑dBA	-	NS
<i>Birds</i>						
Griffon and white-backed vulture	2.2.0	NS	↑REST post event	↓Sleep event and post event	-	NS
Japanese crane	1.1.1	NS	↑REST↓dBA	↓Sleep↑dBA	-	NS
Eurasian eagle owl	0.1.0	NS	NS	-	-	-

Note: Generalized linear models were fit, specifying the binomial distribution and logit link function. The full models include the factors dB(A), dB(C), event phase, date, and time. NS = not significant; - = behavior not observed; ↑ = significant increase in behavior; ↓ = significant decrease in behavior; ↑dB(A/C) = increased decibel level; ↓dB(A/C) = decreased decibel levels.

TABLE A2 Summary information for all models fit to behavioral measures for all species

Group	Species	Behavior	Factors	Estimate	SE	z value	p value		
Felids	Amur leopard	Out of sight	(Intercept)	-3.669	2.132	-1.721	0.085		
			dB(C)	0.072	0.036	2.000	0.046		
		Active	NA						
		Asleep	NA						
		Abnormal	NA						
	Amur tiger	Active	(Intercept)		-3.482	2.572	-1.354	0.176	
				dB(A)	-0.258	0.070	-3.686	<0.001	
			dB(C)	0.247	0.068	3.620	<0.001		
			Resting	(Intercept)	4.490	2.212	2.030	0.042	
				dB(C)	-0.073	0.034	-2.110	0.035	
		Out of sight	(Intercept)		-2.945	1.613	-1.826	0.068	
				dB(A)	0.053	0.030	1.752	0.080	
			Asleep	NA					
			Lynx	OOS	(Intercept)	-12.933	5.036	-2.568	0.010
					dB(A)	0.192	0.091	2.094	0.036
Active	NA								
Resting	NA								
Asleep	NA								
Ocelot	OOS	(Intercept)		3.480	2.838	1.226	0.220		
			dB(A)	-0.096	0.057	-1.69	0.090		
		Resting	(Intercept)	-0.889	0.371	-2.39	0.017		
			Post event	-2.109	0.883	-2.39	0.017		
		Pre-event	-0.101	0.554	-0.184	0.854			
		Abnormal	(Intercept)		6.591	5.083	1.297	0.194	
	dB(A)			-0.242	0.1.68	-2.267	0.023		
	Post event		-0.665	1.827	-0.364	0.716			
	Pre-event		3.427	1.664	2.060	0.039			
	Asleep		(Intercept)	-4.428	2.539	-1.744	0.081		
			dB(C)	0.056	0.040	1.394	0.163		
	Puma	Active	NA						
NA									
Resting		NA							
Asleep		NA							
OOS		NA							
Abnormal	NA								
	NA								
Canids	Jackal	Active	(Intercept)	-5.089	2.233	-2.279	0.023		
			dB(C)	0.073	0.036	2.003	0.045		

(Continues)

TABLE A2 (Continued)

Group	Species	Behavior	Factors	Estimate	SE	z value	p value
		Abnormal	(Intercept)	-5.291	4.992	-1.060	0.289
			dB(C)	0.031	0.078	0.396	0.692
			Date 06/07/2019	-0.582	1.804	-0.323	0.746
			Date 07/07/2019	0.695	1.239	0.561	0.574
			Date 14/06/2019	3.402	1.637	2.078	0.037
			Date 15/06/2019	-1.014	1.661	-0.610	0.541
			Date 16/06/2019	-0.959	1.665	-0.576	0.564
			Date 28/06/2019	-1.003	1.655	-0.606	0.544
			Date 29/06/2019	3.378	1.157	2.919	0.003
			Date 29/06/2019	3.414	1.157	2.950	0.003
			Time 13:00	0.862	1.173	0.735	0.462
			Time 14:00	2.122	1.218	1.742	0.081
			Time 15:00	-0.260	1.177	-0.222	0.824
			Time 16:00	0.900	1.166	0.772	0.439
			Time 17:00	-0.245	1.185	-0.207	0.835
			Time 18:00	-0.601	1.139	-0.528	0.597
			Time 19:00	-2.241	1.597	-1.403	0.160
			Time 20:00	-2.030	1.613	-1.258	0.208
			Time 21:00	-2.003	1.622	-1.235	0.216
			Time 22:00	-2.040	1.609	-1.268	0.204
		Resting	NA				
		Asleep	NA				
		OOS	NA				
Ungulates	Alpaca	Active	(Intercept)	-4.211	1.919	-2.195	0.028
			dB(C)	0.079	0.032	2.467	0.014
		Resting	(Intercept)	7.431	2.477	2.999	0.003
			dB(C)	-0.112	0.038	-2.951	0.003
			Post event	-0.209	0.587	-0.356	0.722
			Pre-event	-1.086	0.564	-1.926	0.054
		Asleep	(Intercept)	-14.602	6.175	-2.365	0.018
			dB(C)	0.142	0.083	1.704	0.088
			Post event	-0.189	2.104	-0.090	0.928
			Pre-event	2.840	1.653	1.717	0.085
		OOS	NA				
	Reindeer/ Guanaco	Active	NA				
		Resting	NA				
		Asleep	NA				
		OOS	NA				

TABLE A2 (Continued)

Group	Species	Behavior	Factors	Estimate	SE	z value	p value	
Primates	Silvery marmoset	Active	NA					
		Resting	NA					
		OOS	NA					
	Tamarin	Active	NA					
		Resting	NA					
		OOS	NA					
	Squirrel monkey	Active	(Intercept)		1.766	0.709	2.490	0.013
			Post event		1.368	0.685	1.997	0.046
			Pre-event		-1.543	0.685	-2.252	0.024
		Resting	NA					
		Asleep	NA					
		OOS	NA					
		Abnormal	NA					
		Small mammals	Otter	Active	(Intercept)	-4.620	2.251	-2.052
dB(A)	0.070				0.043	1.642	0.101	
Post event	0.423				0.540	0.782	0.434	
Pre-event	-0.862				0.670	-1.287	0.198	
Resting	NA							
Coatimundi	Asleep		(Intercept)	0.803	2.835	0.283	0.777	
			dB(C)	-0.044	0.046	-0.964	0.335	
	Active		NA					
	Resting		NA					
	OOS		NA					
Binturong	Resting		(Intercept)	-8.491	3.041	-2.792	0.005	
			dB(A)	0.129	0.057	2.257	0.024	
	Asleep		(Intercept)	-2.716	1.891	-1.436	0.151	
			dB(A)	0.065	0.038	1.725	0.084	
	Active		NA					
Porcupine	Active		OOS	NA				
			(Intercept)	12.463	3.816	3.266	0.001	
			dB(A)	-0.088	0.058	-1.511	0.131	
		dB(C)	-0.175	0.066	-2.658	0.008		
		Post event	0.274	0.807	0.340	0.734		
	Pre-event	2.323	0.868	2.677	0.007			
	OOS	(Intercept)	3.041	0.844	3.602	0.000		
Post event	-0.639	0.759	-0.842	0.399				

(Continues)

TABLE A2 (Continued)

Group	Species	Behavior	Factors	Estimate	SE	z value	p value
			Pre-event	-1.742	0.752	-2.315	0.020
			Time 13:00	1.289	1.565	0.824	0.410
			Time 14:00	-0.285	1.110	-0.257	0.796
			Time 15:00	1.289	1.565	0.824	0.410
			Time 16:00	1.289	1.565	0.824	0.410
			Time 17:00	-0.2858	1.110	-0.257	0.796
			Time 18:00	0.7205	0.973	-0.740	0.459
			Time 19:00	-1.6130	0.958	-1.682	0.092
			Time 20:00	-0.7205	0.973	-0.740	0.459
			Time 21:00	-3.220	1.021	-3.153	0.001
			Time 22:00	-4.020	1.150	-3.493	0.000
		Resting	NA				
	Tayra	Asleep	(Intercept)	6.360	3.011	2.112	0.347
			dB(A)	-0.167	0.062	-2.658	0.007
			Post event	0.040	0.691	0.058	0.953
			Pre-event	-2.911	1.539	-1.891	0.058
		Active	NA				
		OOS	NA				
		Resting	NA				
	Raccoon	Active	(Intercept)	-10.332	3.468	-2.979	0.003
			dB(A)	0.213	0.066	3.211	0.001
			Time 13:00	-0.749	0.866	-0.865	0.387
			Time 14:00	-2.313	1.049	-2.205	0.027
			Time 15:00	-0.368	0.880	-0.418	0.676
			Time 16:00	2.766	1.567	1.765	0.078
			Time 17:00	-0.648	0.887	-0.730	0.465
			Time 18:00	-2.499	1.027	-2.433	0.015
			Time 19:00	-1.981	1.057	-1.874	0.061
			Time 20:00	-1.344	0.923	-1.456	0.145
			Time 21:00	-0.448	0.959	-0.467	0.640
			Time 22:00	-1.565	1.121	-1.397	0.163
		Resting	(Intercept)	-0.425	0.605	-0.702	0.482
			Post event	-0.810	0.569	-1.422	0.154
			Pre-event	-1.816	0.703	-2.581	0.009
		Asleep	(Intercept)	8.319	3.041	2.735	0.006
			dB(A)	0.161	0.057	-2.801	0.005
		OOS	NA				
Birds	Eagle owl	Active	(Intercept)	7.718	3.426	2.252	0.024
			dB(A)	-0.092	0.054	-1.707	0.088
			dB(C)	-0.072	0.052	-1.397	0.162

TABLE A2 (Continued)

Group	Species	Behavior	Factors	Estimate	SE	z value	p value
		Inactive	NA				
	Cranes	Resting	(Intercept)	0.550	2.532	0.217	0.828
			dB(A)	-0.103	0.047	-2.205	0.028
			dB(C)	0.064	0.051	1.259	0.208
		Active	(Intercept)	-1.847	2.092	-0.883	0.377
			dB(A)	0.066	0.042	1.560	0.119
		Asleep	(Intercept)	7.050	2.842	2.481	0.013
			dB(A)	-0.186	0.061	-3.055	0.002
		OOS	NA				
	Vultures	Asleep	(Intercept)	-0.891	0.743	-1.199	0.231
			During event	-1.533	0.702	-2.183	0.029
			Post event	-2.012	0.763	-2.637	0.008
			Time 13:00	0.102	1.107	0.092	0.927
			Time 14:00	-1.426	1.562	-0.913	0.361
			Time 15:00	-1.405	1.565	-0.898	0.369
			Time 16:00	-1.459	1.556	-0.938	0.348
			Time 17:00	1.595	0.983	1.622	0.105
			Time 18:00	0.517	0.974	0.531	0.595
			Time 19:00	0.817	0.994	0.822	0.411
			Time 20:00	3.284	1.011	3.247	0.001
			Time 21:00	2.364	0.966	2.446	0.014
			Time 22:00	3.796	1.138	3.335	0.001
		Inactive	(Intercept)	-9.882	3.397	-2.908	0.003
			dB(A)	0.104	0.064	1.615	0.106
			dB(C)	0.072	0.050	1.436	0.150
			During event	0.052	0.555	0.094	0.925
			Post event	1.509	0.630	2.394	0.016
		Active	NA				
		OOS	NA				

Note: Generalized linear models were fit specifying the binomial distribution and logit link function. The full models included the factors dB(A), dB(C), event (with categories pre-event, during the event, or post event), date, and time. The best model was then selected in terms of the lowest AIC value (see "Methods" for full details). Only results from the best models are shown here; if the best model did not include any of the factors of interest (dB(A), dB(C), and event), it is listed as NA and no further information is given for the sake of brevity. Factors found to significantly affect behavioral measures are highlighted by bold text. The Estimate column gives the effect size for each factor.