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

Running title: Effects of concert on behavior of zoo animals

Jessica J. Harley[1,2*], Lewis J. Rowden[3], Lisa M. Clifforde[3], Aisling Power[4] and Christina R. Stanley[1]

[1] Animal Behavior & Welfare Research Group, Department of Biological Sciences, University of

Chester CH1 4BJ, UK[2] Knowsley Safari, Prescot, Merseyside, L344AN

[3] Zoological Society of London, Outer Circle, Regent's Park, London, NW1 4RY; UK

[4] Department of Conservation, Education & Research, Tayto Park Co. Meath, A84 EA02, Ireland

Correspondence: J.harley@knowsley.com

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Abstract: To increase visitor footfall and engagement, zoos may host public events which may extend outside of 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 = 64.5dB) when compared with both pre- (mdn = 60.7dB) and post-event Phases (mdn = 59.4dB), whilst dB(A) levels were only significantly higher during the event (51.7dB) when compared with the pre-event Phase (mdn = 49.8dB). 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 which 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

30   be encouraged to provide evidence-based assessment of how music events may affect animal welfare

31   and behavior and to test the efficacy of mitigation strategies that are implemented to safeguard

32   animal welfare.

33   Keywords: event; behavior; welfare; environmental disturbance

34   **1. Introduction**

35   Zoos must actively market to attract visitor footfall, which often includes undertaking new

36   development projects, adding novel attractions, or promoting special events such as music concerts.

37   However, increasing visitor numbers, noise and other novel stimuli may, in turn, affect the behavior

38   and physiology of animals (Sellinger & Ha, 2005; Powell, Carlstead, Taurou, Brown & Monfort 2006;

39   Morgan & Tromborg, 2007). Zoos may therefore face a dilemma in balancing the significant

40   monetary benefits of special events and increased visitor footfall with safeguarding the well-being of

41   the animals under their care (Davey, 2006; Fernandez, Tamborski, Pickens & Timberlake, 2009).

42   Music events hosted at zoos date back to the early 19th century, with zoological gardens in

43   Europe featuring concert halls and open-air theaters (Peel, 1903; Meade, Formella & Melfi, 2017).

44   Today, concert events occur in zoos across Australia, Europe, and the United States. Oregon Zoo in

45   Portland was the first American zoo to introduce a summer concert series in 1979. Taronga recently

46   celebrated their 25th Anniversary of Sydney's summer concert series 'Twilight at Taronga'. Despite

47   the history and frequency of music events at zoos, a literature review revealed few peer-reviewed

48   articles on the effects of music events on the behavior or physiology of animals. Meade et al. (2017)

49   found no effect on the behavior of the two domestic dogs (*Canis lupus familiaris*) exposed to summer

50   music concerts at Tarango zoo.   Shepardson et al., 2004 found honeycreepers (*Cyanerpes sp.*) at the

51   Honolulu Zoo showed increased secretion of glucocorticoid secretion (a hormonal response to stress)

52   the day after summer evening music concerts.   Finally, in a study investigating the impact of a music

53   festival on wild urban hedgehogs (*Erinaceus europaeus*) living in Treptower Park, Berlin, researchers

54   found that hedgehogs decreased their nightly activity range size during the concert days. However,

55   there was no pattern in how the hedgehogs reacted to the disturbance; individual hedgehogs employed

56   different behavioral strategies in the same environment (Rast, Barthel, Berger, 2019). These studies

57 elucidate the variation among species and individuals in their response to potentially aversive and

58 novel stimuli.

59   Despite a lack of literature on the effects on the behavioral effects of concert related disturbance,

60 there are numerous studies focused on the impact of visitors and ambient noise on zoo animals. These

61 two variables are often linked in studies; it is assumed that a rise in visitor numbers will correlate with

62 an increase in noise levels, without this relationship being specifically studied. In terms of responses

63 to visitor-related ambient noise, there are varying results, from mild behavioral changes in giant

64 pandas (*Ailuropoda melanoleuca*) (Owen, Swaisgood, Czekala, Steinman & Linburg, 2004) to no

65 effect on waterbuck (*Kobus ellipsiprymnus*), a male African elephant (*Loxodonta africana*) and two

66 female chimpanzees (*Pan troglodytes*) (Quadros, Goulart, Passos, Vecci, Young, 2014). In contrast,

67 felids may spend more time resting, off-show or withdrawing to remote parts of the exhibit when

68 subjected to construction noise (Sulser, Steck & Baur, 2008; Chosy, Wilson & Santymire, 2014).

69 Gorillas (*Gorilla gorilla gorilla*) exposed to a month-long after-hours 'Zoo lights' event at the

70 Smithsonian's National Zoo rested less during the event than during pre- or post-event Phases. The

71 gorillas also expressed more abnormal behavior in the daytime during the zoo lights event than pre-

72 or post-event (Bastian, Glendinning, Brown & Edwards, 2020). Queiroz & Young (2018) investigated

73 the factors affecting species' susceptibility to visitor disturbance and found that those from closed

74 habitats, herbivores, terrestrial species and species in the active phase of their activity cycle are more

75 frequently affected.

76   As part of the summer events season for 2019, Tayto Park, a zoo and theme park in Meath,

77 Ireland, hosted the FunFest weekend music concert. This event provided the opportunity to

78 investigate the effects of a music concert on animal behavior across a range of animals. In this study,

79 we focus on activity, resting, abnormal behaviors and whether the animals were out of sight to

80 ascertain if the music and novel stimuli associated with the concert affected behavior. It was

81 hypothesized that the music concert would result in higher visitor and sound levels during the event.

82 We predicted that some species would express reduced activity and others would use their off-show

83 enclosure more frequently during the concert event but that not all species would be affected by the

84 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 three 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 (SPL) dBA of approximately 17% (Harley, 2014). All other enclosures received no additional soundproofing. The World of Raptors bird of prey flying display (510m 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 one 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 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 500m 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. Whilst 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 (FOH) mixing desk (behind the audience) were designated not to

exceed LAeq, 5mins 92 dB(A) (the average A-weighted sound pressure level measured over five

minutes), a maximum level of 100dB(A) (LAmax, 100 dB(A)) and a maximum of 112 dB(C) (LCmax

112 dB(C)). The noise limit for the event was 75LAeq, 15mins 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 65LAeq, 15mins and C-

weighted maximum sound level was set at LCmax of 80 within 2 meters of each animal enclosure.

These limits were similar to the maximum noise levels during peak visitor times. If the noise

measurement came within 3dB(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.

Figure 1. Animal enclosures geographically closest to the concert event are labelled 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, labelled as C and D are also given here with their distances from the main stage in meters. Location of stage and arena are shown in the top right. Zoo perimeter is outlined in blue.

2.2. Data collection protocol

130   Observers collected data on animal behavior and environmental noise following a set,

131   unidirectional route around the park, with data being collected at each of the animal enclosures

132   highlighted in Table 1. In addition to the date and time of each observation, information on animal

133   behavior and noise levels were recorded. The park's admissions office provided daily visitor totals for

134   each Phase (pre-concert, during concert or post-concert) of the study, along with the number of

135   visitors entering the park each hour, which was used as a proxy for visitor presence in subsequent

136   analyses.

137   Before the study commenced, a point at each enclosure's visitor stand-off barrier was marked to

138   indicate where the observer would stand to view the animals and record sound pressure level (SPL).

139   Identification of these specific points ensured the consistency of all observations throughout the study.

140   Observers (n=5) participated in a group tutorial, followed by a group walk to locate all fixed

141   observation points. Individual training sessions were held for each observer with the lead investigator.

142   This session incorporated all species in the study and included recording behavior and SPLs. The

143   training was carried out until the observers' reached at least 90 percent agreement with the lead

144   investigator. All observers (JH, AP, 3 zookeepers) were experienced with the study subjects and

145   conducting behavioral observations as part of their daily work in addition to having contributed to

146   several behavioral studies in the park. Observation sessions were either afternoon (12:00 to 17:00) or

147   evening (17:01 to 23:00). Each observer participated in data collection across all three phases, and

148   afternoon/evening observation sessions were evenly distributed across observers. All observers wore

149   civilian clothing. Observations were not carried out during active periods of rain unless the rain was

150   intermittent and light or when a keeper was working with the animals (feeding/husbandry). As a

151   result, an average of three observations per species were missed in Phase 1 and 3. In Phase 2 no

152   observations were missed except for three for the puma. The total observations by species and Phase

153   are illustrated in Table 1.

154   2.3. Study Animals

155   The study was pre-approved by the Tayto Park Ethics Committee (13th March 2019). All typical

156   husbandry protocols were carried out, including feeding, cleaning and enrichment protocols. Study

157   subjects included 54 individual animals across 22 species housed at the zoo (Table 1). Enclosure

158   locations were representative of all animal sections and areas across the zoo, and all animals were

159   captive-bred. The observed animals were all adults except for one juvenile Japanese crane (*Grus*

160   *japonensis*, <1 month old) and resided at the park for multiple years, with the exception of the golden

161   jackals (*Canis aureus*, which were at the park for <12 months).

162   Table 1: Zoo species monitored during the FunFest concert event. The table includes information on
163   animal sex (male.females.unknown) and the number of observations by Phase (pre-, during and post-
164   event). Total observations for each species are presented in the final column.

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	*Pathera tigris altaica*	1.1.0	30	33	30	93
Puma	*Puma concolor*	1.0.0	30	30	30	90
Alpaca	*Vicungna pacos*	2.1.0	30	33	31	93
Eurasian eagle owl	*Bubo bubo*	0.1.0	30	33	30	93
Golden jackal	*Canis aureus*	0.5.0	30	33	29	92
Silvery marmoset	*Mico argentatus*	1.1.0	30	33	31	94
Japanese crane	*Grus japonensis*	1.1.1	30	33	30	93
Raccoon	*Procyon lotor*	0.3.0	30	33	31	94
Asian small-clawed otter	*Aonyx cinereus*	2.2.0	30	33	31	94
Binturong	*Arctictis binturong*	1.1.0	30	33	28	91
Eurasian lynx	*Lynx lynx*	1.4.0	30	33	30	93
Amur leopard	*Panthera pardus orientalis*	2.0.0	29	33	30	92
Tayra	*Eira barbara*	2.0.0	30	33	30	93
Ring-tailed coatimundi	*Nasua nasua*	1.2.0	30	33	29	92
Red-bellied tamarin	*Saguinus labiatus*	0.3.0	30	33	30	93
Cape porcupine	*Hystrix africaeustralis*	1.1.0	30	33	29	92
Ocelot	*Leopardus pardalis*	1.0.0	30	33	29	92
Vultures (Griffon & white-backed) (mixed-species exhibit)	*Gyps fulvus & G.africanus*	2.2.0	30	33	29	92
Squirrel monkey	*Saimiri sciureus*	3.0.0	30	33	29	92
Reindeer/Guanaco (mixed-species exhibit)	*Rangifer tarandus & Lama guanicoe*	0.1.0	30	33	30	93

165

166   2.4. Behavioral data collection

167   The first observation Phase (pre-event) was carried out two weeks before the event, between

168   June 14-16, 2019. The second Phase (during event) was carried out between June 28-30, 2019. The

169   third Phase occurred one week after the festival event (post-event) between July 5-7, 2019 (Table 1)

170   Behavioral observations were conducted using 60-min interval scan sampling. At each sampling

171   point, the presence (1) or absence (0) of at least one individual carrying out each behavior in the study

172   ethogram (Table 2) was recorded. Data were therefore collected at the group level (unless individuals

173   were individually housed) and treated as one sample point. Observations occurred every hour from

174   12:00 to 23:00, Friday to Sunday during each Phase of the study. Data points recorded at one hour

175   intervals were assumed to be independent as this length of time gave animals ample opportunity to

176   change their behavior. Abnormal behaviors described in the study ethogram were previously observed

177   in individual animals (Amur leopard, ocelot, puma (pacing), squirrel monkey (head twirl) and jackals

178   (excessive locomotion (restless/agitated)) prior to the concert event. Video footage of the jackals'

179   excessive locomotion behavior was shared with all observers prior to the study as they were recent

180   arrivals at the zoo, assuring the accurate identification of this behavior. If an animal performed an

181   abnormal behavior the observer recorded presence and describe behavior in detail in the notes section

182   of the datasheet. Any observed behaviors not listed in the ethogram were specified in the notes section

183   of the datasheet, and (due to their low occurrence) were not analyzed further. Hourly scan samples

184   enabled the observation of a wide range of taxa during the duration of the concert event by a limited

185   number of highly trained observers. When studying large numbers of animals, more traditional

186   sampling methods such as continuous focal sampling can be prohibitive due to the extensive labor

187   the method necessitates (Mitlöhner, Morrow-Tesch, Wilson, Dailey & McGlone 2001). Margulis and

188   Westhus (2008) state that when carrying out zoo research "even very limited amounts of data as little

189   as 5 to 10-point samples per day, over time can provide invaluable information for future research,

190   management and husbandry". Furthermore, hourly scans had been validated to reasonably

191   approximate continuous behavior sampling for state behaviors such as lying for dairy and feedlot

192   cattle (Gonyou & Stricklin, 1984; Mitlohner et al 2001; Overton, Sischo, Temple & Moore 2002),

193   and validated for active and inactive behaviors in nursery pigs (Bowden, Karriker, Stalder & Johnson

194   2008).

195   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 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.

196   2.5. Sound pressure level recording

197   Sound pressure levels (SPLs) and behavioral data were collected concurrently. The sound

198   pressure level at each enclosure was recorded with a Roline sound survey meter (Model 1350,

199   Rotronic logistics, Basserdorf, Switzerland). Field calibration occurred at the commencement of each

200   series of measurements using a sinewave signal of 1000hz generated by a built-in oscillator.   The

201   accuracy rating for the monitor is ± 2dB at 94dB, sound level with decay <1db/3 minutes. The

202   observer held the sound pressure meter with the point of the meter facing toward the animal enclosure

203   at the marked spot on the stand-off barrier 1.2 meters above the ground. The observer recorded

204   frequency A-weighting followed by frequency C-weighting. The time weighting dynamic response

205   setting was set at slow for average noise level with the SPL reported in decibel units (dB). A-

206   weighting covers the range from 20Hz to 20,000Hz, but the filter focuses more on the frequencies

207   that correlate with human sensitivity and are expressed as dB(A).   Humans have an audible range of

208   20Hz to 20,000Hz with the greatest sensitivity between 1,000 to 4,000Hz (Ganong, 1997). The C-

209   weighting is a wide-band frequency-weighting and is essentially linear over several octaves. The C-

210   weighting is used to measure peak, impact or explosive noises and is expressed as dB(C) (ISO, 2003).

211   Both dB(A) and dB(C) measures were used as it has been found that the assessment of sound with

212   strong low-frequencies (10 to 100) Hz, which we expected with bass instruments, should be

213   conducted using Z- (no weighting for human ear) or C-weighting rather than A-weighting (Ziaran,

214   2014). In addition to monitoring at animal enclosures, an independent noise monitoring firm

215   [iAcoustics, Dublin, Ireland] carried out noise monitoring on the 29th & 30th of June from 12:00 to

216   21:30 at two fixed sites (nearest residence and nearest animal enclosure to the event). SPLs were

217   recorded with an NTi XL2-TA (NTi Audio AG, Liechtenstein, Europe), logging sound level meter

218   and associated hardware, a condenser microphone (NTi XL2 M M2330, NTiAudio AG,

219   Liechtenstein, Europe) and outdoor microphone wind shield protection kit (Roycote Softie,

220   Gloucestershire, UK). A remote noise monitoring kit NTi Netbox (NTi Audio AG, Liechtenstein,

221   Europe), was used to capture a live feed that was made available via an e-mail link for management

222   and the sound mixing board (located behind audience). SPL measurements were made per guidelines

223   detailed in ISO 1996/1:2003 Acoustics: Description and measurement of Environmental Noise (Part

224   1). Sound pressure was recorded as LAeq.T, which is the A-weighted equivalent continuous SPL,

225   measured over a period of time. iAcoustic's role was to ensure that the event did not exceed the

226   prescribed noise limits for residential areas and animal enclosures during the event (Appendix Figure

227   A2).

228   2.6. Statistical Analysis

229   Sound pressure and behavioral data were analyzed and plotted using R version 4.0.0 (R Core

230   Team, 2020). As outcome data could not be transformed to approximate a normal distribution,

231   Kruskal Wallis tests were used to test for a difference in total visitor numbers and SPLs across Phases

232   with Mann-Whitney U test being used for post hoc comparisons.

233   We investigated the effects of various explanatory factors on behavior by fitting separate

234   Generalized Linear Models (GLMs) for each species and behavior using the "bayesglm" command in

235   the package arm (Gelman, Jakulin, Pittau & Su 2008) in the R environment. This method allows for

236   data showing complete separation (when a linear combination of explanatory variables perfectly

237   predicts the outcome variable, Albert & Anderson, 1984); this occurred in several of our models.

238   The binomial distribution was specified with the "logit" link function as behaviors were recorded

239   as either present (1) or absent (0). The outcome variable for each species-specific model was one of

240   the six binary behavioral measures (Table 2). The explanatory variables included in each model were

241   sound pressure levels (dB(A) and dB(C)), Phase, Date (as environmental factors such as the weather

242   could impact on behavior; these would be expected to vary on different days) and Time (as this

243 frequently predicts the likelihood of a behavior occurring, due to the species' circadian rhythm). The

244 best model was then selected by using the "stepAIC" command in the package MASS (Venables &

245 Ripley, 2002). The fit of the best model to the data was ascertained by examination of a plot of

246 expected versus observed residual values; binned residuals plots were used as these are deemed

247 appropriate for logistic regression models (Gelman & Hill, 2007). As dB(C) levels were not recorded

248 at four timepoints on the first day of data collection for all species and on three separate scans on 28th

249 June (one scan for Amur leopards and two for vultures), these data points were omitted from models

250 where dB(C) was an explanatory variable in the best model.

3. Results

252   Visitor numbers did not significantly differ between the pre-, during and post-event Phases

253 ($H(2)$=3.47, p=0.18). Although, there was an effect of time of day on visitor numbers, this pattern

254 was consistent across the three Phases (Appendix, Figure A1). However, SPLs did significantly differ

255 for both dB(A) ($H(2)$=61.11, p<0.001) and dB(C) ($H(2)$=63.01, p<0.001) levels (Figure 2). Post-hoc

256 tests showed that SPL levels during the event were significantly higher in terms of dB(C) (mdn =

257 64.5dB) when compared with both pre (mdn = 60.7dB; $U = 215807$, $p < 0.001$) and post event (mdn

258 = 59.4dB; $U = 185533$, $p < 0.001$) levels. SPL levels during the event were also significantly higher

259 in terms of dB(A) (mdn = 51.7dB) than in the post-event Phase (mdn = 49.8dB; $U = 301076$, $p <$

260 0.001); however, they did not significantly differ to those in the pre-event Phase (mdn = 51.3dB; $U =$
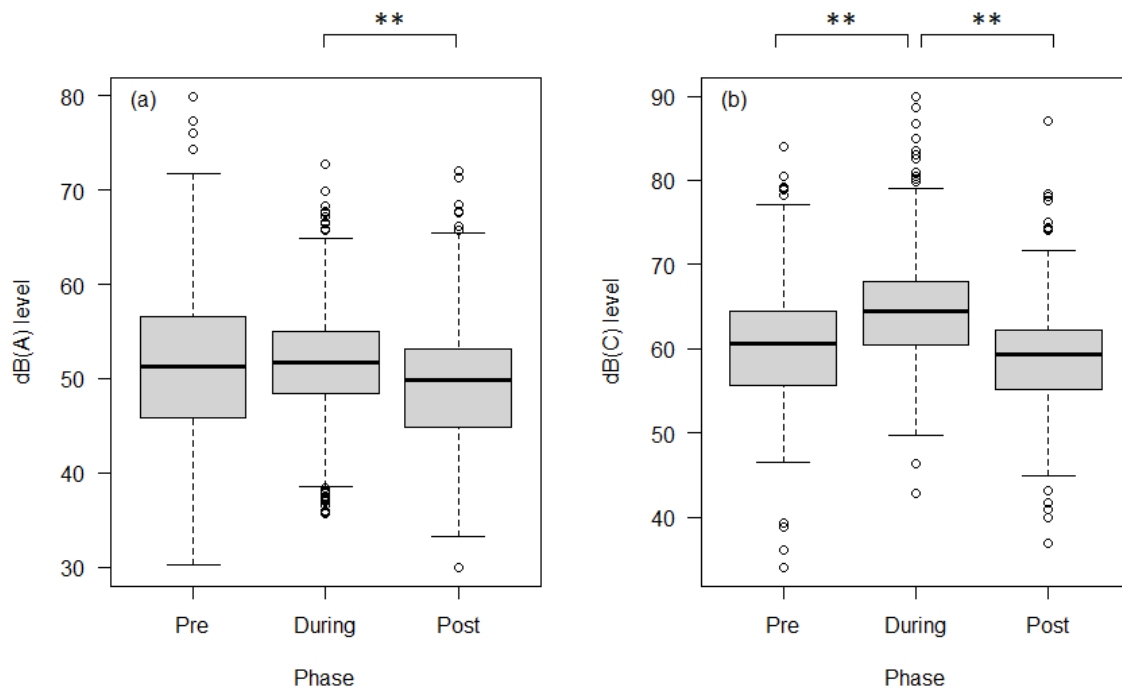
261 376268, $p = 0.34$).

262

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 < 0.001).

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 plus/minus 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 the Appendix, 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, $z = 2.00$, $p = 0.046$; Figure 3a). Tigers were significantly more active (estimate = 0.25±0.07, $z = 3.62$, $p < 0.001$; Figure 3b) and less likely to be resting (estimate = -0.07±0.03, $z = -2.11$, $p = 0.04$; Figure 3c) with higher dB(C) levels but were less active with higher dB(A) levels (estimate = -0.26±0.07, $z = -3.69$, $p < 0.001$; 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, $z = 2.09$, $p = 0.04$; Figure 4e).

280   Ocelot showed significantly more abnormal behavior at lower dB(A) levels (estimate = -0.24±0.11,

281   z = -2.27, p = 0.02; Figure 3f). The ocelot was significantly less likely to be resting in the post-event

282   period than during the event (estimate = -2.11±0.88, z = -2.39, p = 0.02; pre-event: 23% of

283   observations resting; during event: 30% of observations resting; post-event: 3% of observations

284   resting) and more likely to be showing abnormal behavior in the pre-event period than during the

285   event (estimate = 3.43±1.66, z = 2.06, p = 0.04; pre-event: 13% of observations showing abnormal

286   behavior; during event: no observations showing abnormal behavior; post-event: no observations
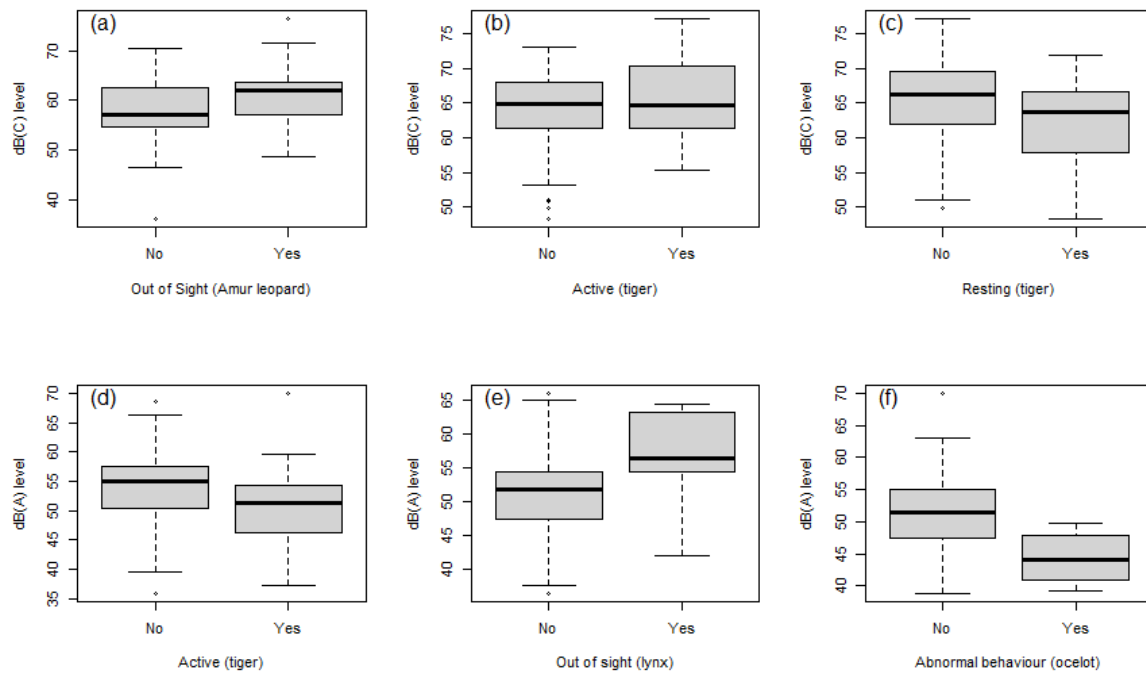
287   showing abnormal behavior).

289   Figure 3. Boxplots representing the effects of sound pressure levels in terms of dB(C) on the likelihood that **a.**
290   Amur leopards were out of sight of observers and tigers were **b.** active or **c.** resting, and in terms of dB(A) on
291   the likelihood that tigers were **d.** active, that **e.** lynx were out of sight and that **f.** ocelot showed abnormal
292   behavior. All differences are significant at the α = 0.05 level. The thick line in the middle of each box shows the
293   median sound pressure level at which the behavior was most commonly seen (yes) or not seen (no). The lower
294   and upper limits of the box are the first and third quartiles. The whiskers extend to 1.5 times the interquartile
295   range, with any outliers being represented by asterisks.

296   3.1.2. Canids

297   Jackals were significantly more active with higher dB(C) levels (estimate = 0.07±0.04, z = 2.00,

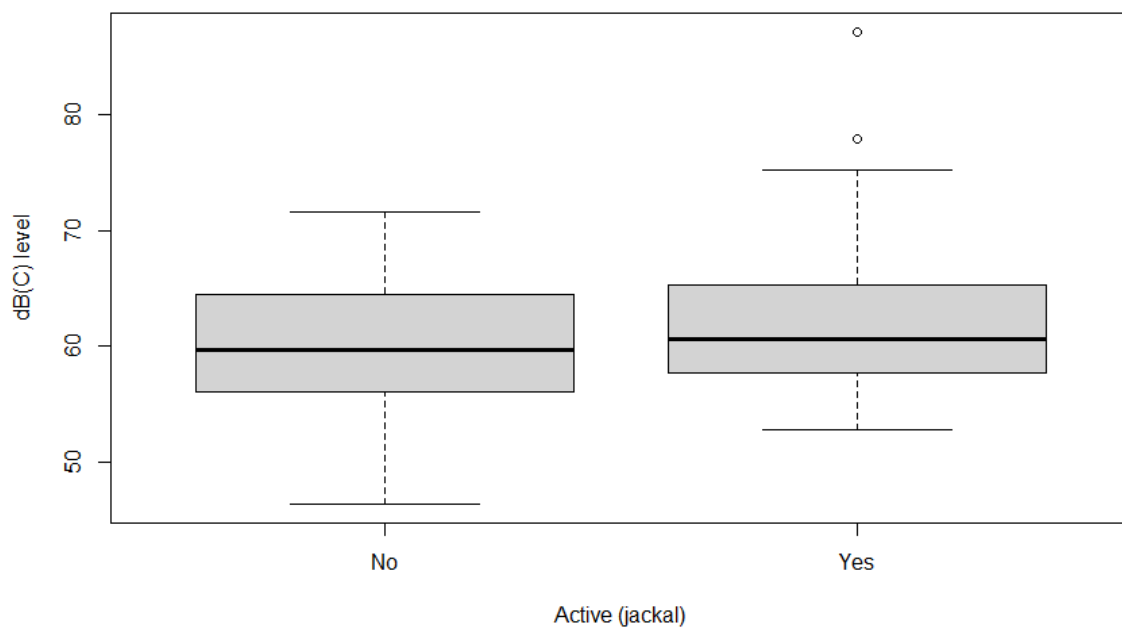298 p = 0.045; Figure 4).

300 Figure 4. Boxplot showing that at higher sound pressure levels in terms of dB(C), jackals were significantly
301 more likely to be active. Difference is significant at the α = 0.05 level. The thick line in the middle of each box
302 shows the median sound pressure level at which the behavior was most commonly seen (yes) or not seen (no).
303 The lower and upper limits of the box are the first and third quartiles. The whiskers extend to 1.5 times the
304 interquartile range, with any outliers being represented by asterisks.

305 ### 3.1.3 Ungulates

306 Alpaca were significantly more active (estimate = 0.08±0.03, z = 2.47, p = 0.01; Figure 5a) and

307 less likely to be resting (estimate = -0.11±0.04, z = -2.95, p = 0.003; Figure 5b) at higher dB(C) levels.

308 There was also a trend (estimate = -1.09±0.57, z = -1.923, p = 0.054, indicating that more resting

309 behavior occurred during the event than in the pre-event period (pre-event: 36% of observations

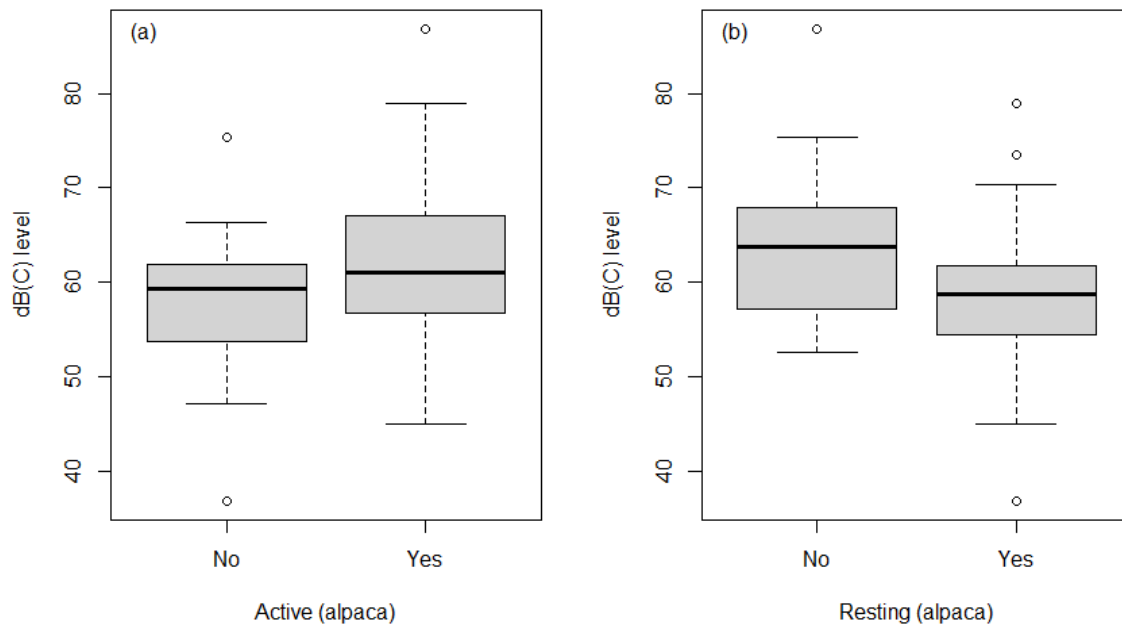310 resting; during event: 54% of observations resting; post-event: 70% of observations resting).

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 α = 0.05 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.

3.1.4. 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 = 0.02), with this increase persisting to the post-event period (estimate = 1.37±0.69, z = 2.00, p = 0.046; pre-event: 43% of observations active; during event: 67% of observations active; post-event: 69% of observations active).

3.1.5. Small mammals

Porcupines were significantly less active with higher dB(C) levels (estimate = -0.18±0.07, z = -2.66, p = 0.008; 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 = 0.007; 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 = 0.02; pre-event: 66% of observations out of site, during event 88% of observations out of site; post-event 79% of observations

329   out of site). Raccoons were significantly more active with higher dB(A) levels (estimate = 0.21±0.07,

330    $z = 3.21$, $p = 0.001$; Figure 6b). They were also significantly more likely to be resting during the event

331   than in the pre-event period (estimate = -1.82±0.70, z = -2.58, p = 0.01; pre-event: 20% of

332   observations active; during event: 42% of observations active; post-event: 26% of observations

333   active) and were less likely to be asleep at higher dB(A) levels (estimate = -0.16±0.06, z = -2.80, p =

334   0.005; Figure 6c). Binturong were more likely to be resting at higher dB(A) levels (estimate =

335   0.13±0.06, $z = 2.26$, $p = 0.02$; Figure 6d) and tayra were less likely to be asleep (estimate = -0.17±0.06,

336   z = -2.66, p = 0.008; Figure 6e) at higher dB(A) levels.
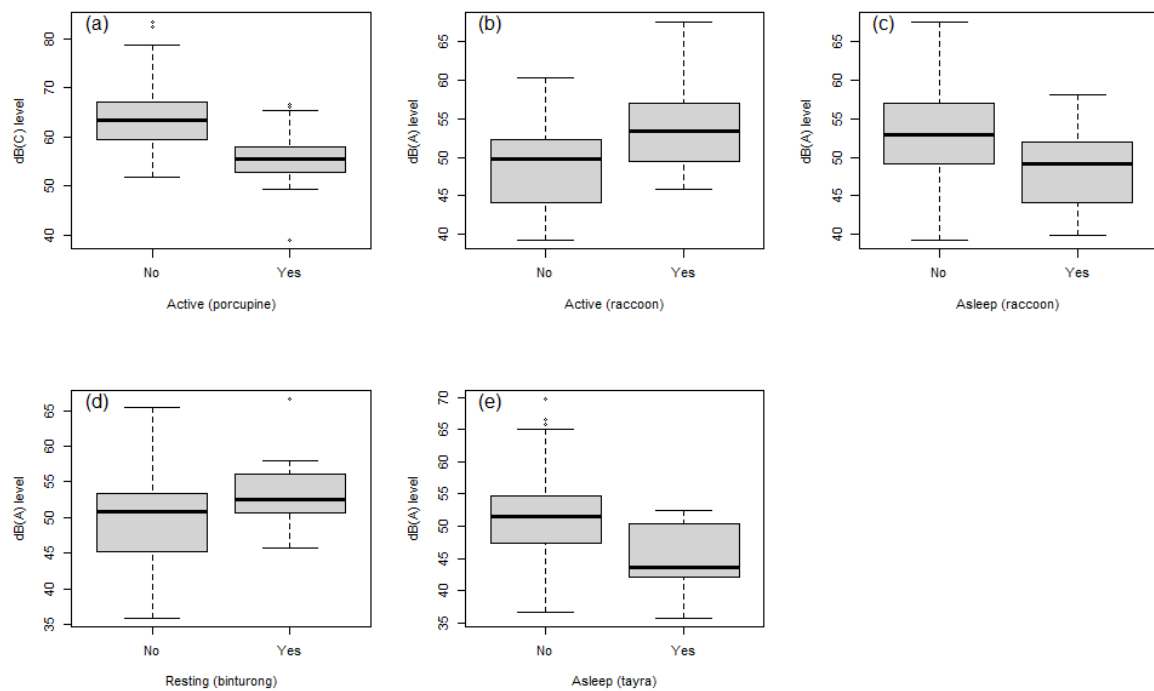
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340   Figure 6. Boxplots showing that at higher sound pressure levels in terms of dB(C), **a.** porcupines were less likely
341   to be active, whilst at higher dB(A) levels, **b.** raccoons were more likely to be active, **c.** less likely to be asleep
342   and **d.** binturong were more likely to be resting and **e.** tayra were less likely to be asleep. All differences are
343   significant at the $\alpha = 0.05$ level. The thick line in the middle of each box shows the median sound pressure level
344   at which the behavior was most seen (yes) or not seen (no). The lower and upper limits of the box are the first
345   and third quartiles. The whiskers extend to 1.5 times the interquartile range, with any outliers being represented
346   by asterisks.

347   3.1.6. Birds

348   Japanese cranes were less likely to be either resting (estimate = -0.10±0.05, z = -2.21, p = 0.03)

349   or asleep (estimate = -0.19±0.06, z = -3.056, p = 0.002) at higher dB(A) levels (Figure 7). Vultures

350   were significantly less likely to be asleep either during (estimate = -1.53±0.70, z = -2.18, p = 0.03) or

351   in the post-event period (estimate = -2.01±0.76, z = -2.64, p = 0.008) in comparison with the pre-

352   event period (pre-event: 47% of observations asleep; during event: 24% of observations asleep; post-

353   event: 17% of observations asleep). They were also significantly more likely to be resting in the post-

354   event period than during the event (estimate = 1.41±0.64, z = 2.19, p = 0.03; pre-event: 53% of

355   observations resting; during event: 64% of observations resting; post-event: 79% of observations
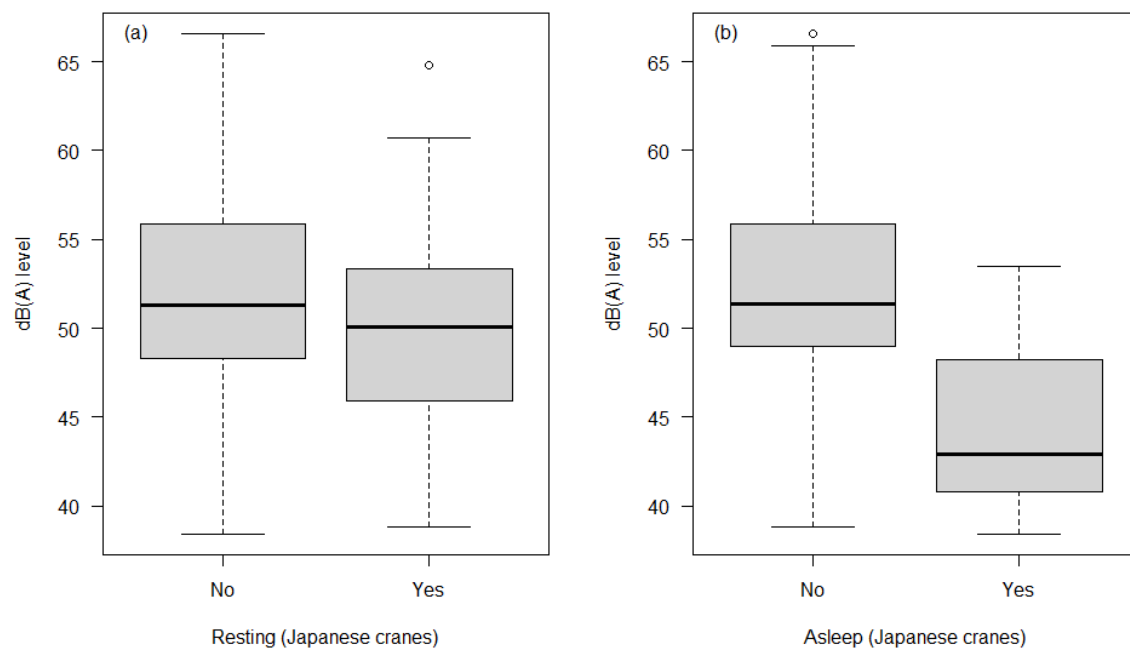
356   resting).

358   Figure 7. Boxplot showing that at higher sound pressure levels in terms of dB(A), Japanese cranes were
359   significantly less likely to be **a.** resting or **b.** asleep. All differences are significant at the α = 0.05 level. The
360   thick line in the middle of each box shows the median sound pressure level at which the behavior was most
361   commonly seen (yes) or not seen (no). The lower and upper limits of the box are the first and third quartiles.
362   The whiskers extend to 1.5 times the interquartile range, with any outliers being represented by asterisks.

363   **4. Discussion**

364   4.1. Visitor numbers and SPLs

365   Our expectation that visitor numbers would be higher during the event Phase was not found to

366   be true, and results indicate that the number of visitors does not necessarily correlate with ambient

367 noise levels. Indeed, other factors, such as atmospheric conditions that affect sound propagation

368 (Liptai, Badida & Lukáčová, 2015) as well as the behavior of the visitors themselves (passive or

369 active) may contribute to the overall visitor noise levels (Mitchell et al., 1992). In a theme park and

370 zoo, visitor impact is not restricted to the visitor's proximity to an animal enclosure; instead, it is the

371 visitor's contribution to the overall ambient sound. This includes how they engage with the

372 amusement attractions (e.g., if they are reserved or exuberant or if all visitors ride attractions).

373 Quadros et al. (2014) also demonstrated the complex relationship between visitor number, sound

374 levels and animal behavior, confirming no linear relationship between these variables. Evidence also

375 exists that the total visitor number to a zoo site does not necessarily best explain changes in

376 animal behavior (Lewis et al., 2020). Thus, the relationship between visitor number, noise and

377 behavioral changes is not straightforward.

378 The median dB(C) levels were significantly higher during the music event than during either the

379 pre- or post-event Phase, whilst dB(A) levels were only significantly higher during the event

380 compared with the pre-event Phase. Low-frequency sounds are commonly associated with bass

381 (percussive and string) instruments that form part musical compositions and are therefore increased

382 in magnitude where live instrumentation features in a concert performance. The difference in the A

383 and C weighted measures suggests the prevalence of low-frequency sound and is likely to account for

384 the higher dB(C) levels during the event Phase (Knauert et al., 206). Although the SPLs were higher

385 during the event Phase, the conditional C-weighted limit for animal enclosures of LCmax of 80 dB

386 was not exceeded at any time. The independent noise monitoring results concluded that the noise limit

387 of 65 LAeq, 15mins was not exceeded at the animal enclosure closest to the concert (Appendix, Figure

388 A2). These data indicate that the preventive measures taken relating to event distance, stage position

389 and orientation of speakers to reduce sound propagation were successful.

390 4.2. Animal behavior

391 In this study, we observed a wide range of zoo animals to determine whether a music concert

392 event and the accompanying noise and stimuli were associated with changes in behavior. We found

393 some species-specific behavioral changes that correlated with increased SPLs and/or event itself.

394 However, as predicted, numerous species did not respond with any change in behavior to the

395 increased SPLs or the event itself and the behavioral responses, where observed, varied between

396 species.

397 4.2.1 Out of sight & Abnormal behavior

398   An animal's ability to hide or conceal themselves from visitors, conspecifics or novel stimuli

399 may be an essential coping mechanism. Hiding or utilizing areas with cover has been documented in

400 various species, including gorillas (Blaney & Wells, 2004), pygmy goats (Anderson, Benne,

401 Boomsmith & Maple, 2002), domestic cats (*Felis catus*) (Rochlitz, 2000), and wild felid species

402 confronted with environmental stressors (Chosy et al., 2014; Harley, Chaisson & Handel, 2019).

403 During periods of higher SPLs, the Amur leopards and Eurasian lynx spent more time off-show. The

404 Amur leopards and Eurasian lynx viewing windows were fitted with wooden inserts to serve as a

405 visual and sound barrier, no other soundproofing was fitted. Sound pressure levels were not recorded

406 inside the houses; however, attenuation of sound due to the solid walls would be expected. Houses

407 were constructed with brick covered in wooden exterior. When sound waves meet the walls of the

408 house, a portion of the sound is reflected, and the remainder passes through the building.   Materials

409 with hard, dense structures such as concrete bricks have weaker sound absorption but stronger

410 reflecting properties (Li & Ren, 2011) and reduce sound. Provision of the additional retreats as well

411 as covering the viewing windows of houses provided animals with opportunities to withdraw to

412 remote areas of their exhibit. Evidence indicates that empowering captive animals with the freedom

413 to choose benefits their well-being (Owen et al. 2004; Kurtycz, Wagner & Ross, 2014). Ensuring the

414 provision of accessible retreat space is an essential consideration during event planning as a reduction

415 or lack of retreat opportunities can be a basis of distress for captive animals (Morgan & Tromborg,

416 2007).

417   Abnormal behavior occurred at low rates in most felids and the golden jackals during observation

418 Phases. The squirrel monkeys also had low rates of observed abnormal behavior; however, head-

419 twirling may be underrepresented due to the short duration of this behavior and the chosen

420 methodology which is not as sensitive to detection of behavioral events. Compared to other

421   observation days, the jackals expressed a higher frequency of abnormal behavior (excessive

422   locomotion) during the two days of the FunFest concert event. During the event, the main restaurant

423   was used as the headquarters for distributing food and drinks to the FunFest event. The main

424   distribution entry/exit was adjacent to the jackal enclosure. As a result, additional staff footfall and

425   noise from catering trollies occurred in proximity to the jackals. The distribution hub was an aspect

426   of event operations that was not identified in the risk assessment for the event, and as a result, no

427   mitigations were actioned. This elucidates that despite extensive cross-departmental planning,

428   potential stressors may be inadvertently overlooked.

429   The ocelot expressed more abnormal behavior in the pre-event Phase, which was also correlated

430   with lower SPLs. The ocelot did not express any abnormal behavior during or after the event. While

431   this result is difficult to explain conclusively, the observer's presence, which would not typically occur

432   at this time of day, may have triggered the ocelot's abnormal behavior during the pre-event Phase. It

433   is important to note that the observer may influence behavior and for some species/individual animals,

434   cameras may be necessary to avoid observer disturbance. There was no significant change in the

435   frequency of observations of abnormal behavior across the Phases for any other species.

436   4.2.2. Activity, Resting & Sleep

437   Many of the significant changes observed across the study species were associated with

438   variations in the occurrence of active and resting behaviors. However, there was no clear predictor

439   for changes in activity levels within or across taxa. Changes in activity patterns were associated with

440   the during and post-event Phases, as well as dB(A) and dB(C) SPLs.

441   Our Amur tigers were less active with higher dB(A) levels. Increased inactivity has been noted

442   in felids (Sulser et al., 2008; Chosy et al., 2014) exposed to noise from construction work. Conversely,

443   our tigers were also found to be more active and less likely to be resting during periods of higher

444   dB(C) levels. It is understood that tigers show greater sensitivity in the low-frequency portion of their

445   audible spectrum (Walsh et al., 2003). This could explain this response to dB(C) levels, although this

446   result should be treated with caution as it is based on a sample size of two individuals. Our Amur

447   leopards, lynx and ocelot expressed no changes in activity based on event Phase or SPLs.

448   Interpretations of the correlation between activity, the event, and SPLs and whether these

449   constitute a negative or positive change in the animal's welfare state are currently open to debate.

450   Certainly, activity takes on many forms; in the context of this study, active behaviors included

451   locomotor activity as well as grooming, preening, and feeding, but excluded excessive locomotion as

452   that was defined as abnormal behavior. Increased locomotor activity linked to the frustration of

453   motivations such as frustrated appetitive behavior, when animals attempt to look for food in a

454   restricted environment, is well understood (Clubb & Vickery, 2006; Mason, 2006). However, the

455   relationship between activity and welfare state is not always clear. The same holds for resting;

456   excessive inactivity is linked to a negative welfare state in captive animals (Mcphee & Carlstead,

457   2010). However, inactivity in animals can also be indicative of the animal's needs being satiated and

458   in relation to residing in a safe and familiar environment (Nowak, 2006; Cockram, 2014; Fureix &

459   Meagher, 2015). Further work is needed to clearly define and validate various form(s) of activity and

460   inactivity and their potential to indicate positive or negative welfare states in different species (Fureix

461   & Meagher, 2015).

462   As suggested by Queiroz & Young (2018), variation in species responses may be attributed to

463   the timing of the auditory stimulus to the normal activity period and their usual behavior at this time.

464   For example, diurnal species routinely experience auditory stressors during zoo operating hours when

465   they are naturally in the active Phase of their diurnal cycle. The inactive Phase (evening and night) is

466   typically quieter due to a reduction in human activity. Consequently, any increased anthropogenic

467   noise at these times may have a more significant impact on behavior for these species as they are less

468   habituated to this pattern of temporal disturbance. Nocturnal and crepuscular species experience the

469   opposite and have potentially already developed coping mechanisms that facilitate rest during periods

470   of auditory stimulus, e.g., moving to indoor areas that are quieter (Quadros et al., 2014). Therefore,

471   behavioral changes in response to an auditory stressor may vary between active and resting phases of

472   diurnal cycles and between diurnal and nocturnal species. We found that our nocturnal porcupines

473   decreased their activity during the event and were less active during periods of

474   higher dB(C) levels. Emergence from their dens was also affected; pre-event they were seen active

475   from 18:00. However, during the event, they spent more time out of sight and emergence from their

476   dens and expression of active behaviors occurred after 21:00 on Saturday (the first night of the

477   concert) and 22:00 on Sunday (the last night of the event), delaying the onset of their active period.

478   In the post-event Phase, they were seen to be active from 19:00. Although the park's raccoons have

479   adapted their activity cycle in line with the keepers' husbandry practices, they were observed sleeping

480   more during periods where the dB(A) levels were lower and observed resting more during the event

481   Phase compared with the pre-event Phase.

482   For diurnal species, habitual resting periods may have been altered due to extended hours of

483   operation. The vultures slept less during the event and after the event compared with the pre-event

484   Phase. In the pre-event Phase, the vultures were mostly recorded as asleep from 19:00; during the

485   event, this changed to 21:00, and post-event, it moved to just after 20:00. Although, the zoo was

486   closed to the public during the evening, the staff had access to a path adjacent to the vulture aviary to

487   access a temporary staff car park.

488   4.3 Limitations

489   Individuals within populations vary in behavioral expression (personality), and this difference

490   may affect survival or the way they respond to or cope with environmental challenges (Moiron,

491   Laskowski & Niemelä, 2020). We realize that investigating individual differences may have

492   highlighted specific individuals' unique responses, which in turn would enable management strategies

493   to be tailored for the individual. However, this was not within the context of this study, which aimed

494   to study a broad range of species to identify whether changes in behavior occurred as an effect of the

495   concert event, with the goal of informing future practice when organizing a music event at the zoo.

496   This project was not conducted to pinpoint causal factors for individual changes in behavior; instead,

497   it provided data that would enable us to identify at risk species for welfare planning and management

498   in future events/activities. Furthermore, there are limitations of the chosen sampling method. Due to

499   the limited nature of the concert event (a one-off festival), the emphasis was placed on collecting data

500   on as many species as possible. This method works well for behavioral states; however, behaviors

501   occurring as events are unlikely to be recorded. The authors recommend that in future studies (when

502   feasible) methodologies that support recording both event and state behaviors should be performed

503 as behavioral events are important for interpreting animal behavior. The authors also recommend that

504 in future studies the quality of the retreat space is investigated, which could be quantified by installing

505 sound data loggers in each retreat space. This would enable sound attenuation and characteristics of

506 the retreat space to be determined and in turn inform recommendations for best practice when

507 planning mitigations for proposed events. Finally, the authors appreciate that "resting" behavior could

508 have potentially been erroneously recorded as "sleeping", and vice versa; however, since observers

509 had significant experience of these species' behaviors and, in addition, had adequate time to observe

510 an animal until their behavior could be reliably identified, we can be confident that such errors were

511 infrequent.

512 **5. Conclusions**

513 Our study found changes in state behaviors across a wide range of taxa; however, there was

514 no clear predictor for changes in behavior within or across taxa. The study confirmed that

515 precautionary measures, i.e., event risk assessment, location, stage position, and initial mitigations,

516 effectively controlled noise in the zoo. As zoological collections continue to undertake new

517 development projects, add novel attractions, and promote special events such as music concerts, to

518 maximize footfall, it is essential to recognize that this may result in changes in animal behavior. The

519 authors encourage more research in this area for in-house event planning as well as to contribute to

520 multi-institutional studies to ascertain if there are consistent and predictable behavior changes in the

521 same species or taxonomic groups across different captive collections. Findings on this subject could

522 have a significant impact on the ability of captive facilities to mitigate against event effects in the

523 future.

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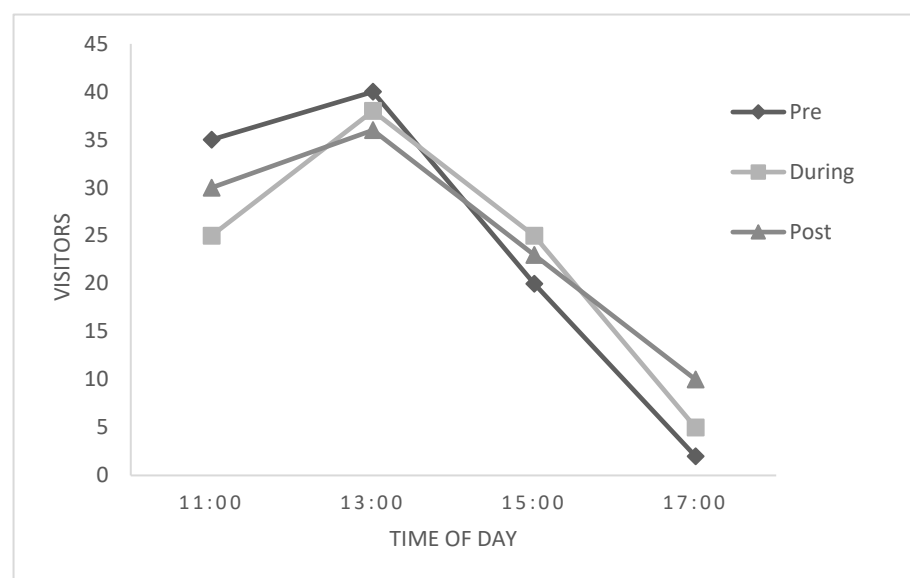721
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730 **Appendix**

731

Figure A1. Percentage of the overall daily visitors entering the park by 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.

732 Table A1. Results for all models fit to behavioral measures for all species. Generalized linear models
733 were fit, specifying the binomial distribution and logit link function. The full models include the
734 factors dB(A), dB(C), event Phase, date and time.   NS=not significant, - = behavior not observed, ↑ =
735 significant increase in behavior, ↓ = significant decrease in behavior. ↑dB(A/C) =increased decibel level
736 ↓dB(A/C) decreased decibel levels.

Species	Sex ratio	Active (ACT)	Resting (REST)	Asleep	Abnormal (ABN)	Out of sight (OOS)
Felids						
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
Canids						
Golden jackals	0.5.0	↑ACT↑dBC	NS	NS	NS	NS
Ungulates						
Alpaca	2.1.0	↑ACT↑dBC	↓REST↑dBC	NS	-	NS
Reindeer & Guanaco Mixed Exhibit	0.3.0	NS	NS	NS	-	NS
Primates						
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
Small mammals						
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
Birds						
Griffon & white-backed vulture	2.2.0	NS	↑ REST Post-event	↓Sleep Event & Post-event	-	NS
Japanese crane	1.1.1	NS	↑REST↓dBA	↓Sleep↑dBA	-	NS
Eurasian eagle owl	0.1.0	NS	NS	-	-	-

737 Table A2. Summary information for all models fit to behavioral measures for all species. Generalized
738 linear models were fit specifying the binomial distribution and logit link function. The full models
739 included the factors dB(A), dB(C), Event (with categories pre-event, during event or post-event), Date
740 and Time. The best model was then selected in terms of the lowest AIC value (see Methods for full
741 details). Only results from the best models are shown here; if the best model did not include any of
742 the factors of interest (dB(A), dB(C) and Event) it is listed as NA and no further information is given
743 for the sake of brevity. Factors found to significantly affect behavioral measures are highlighted by
744 bold text. The Estimate column gives the effect size for each factor.

Group	Species	Behavior	Factors	Estimate	St Error	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				
		Active	NA				
		Resting	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				

		Abnormal	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
		Active	NA				
	Puma	Active	NA				
		Resting	NA				
		Asleep	NA				
		OOS	NA				
		Abnormal	NA				
Canids	Jackal	Active	(Intercept)	-5.089	2.233	-2.279	0.023
			dB(C)	**0.073**	**0.036**	**2.003**	**0.045**
		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				
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	0.040
			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				
		OOS	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				
		OOS	NA				
	Porcupine	Active	(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
			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
		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**				

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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 meters from the event.