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Adaptation of British Standards to Identify Construction Site Activity Noise Sources with the Potential to Cause Stress to Giant Pandas

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ABSTRACT

Giant pandas have a broader hearing range than humans and have higher sensitivity in different frequency bands. Giant pandas are known to become stressed when subjected to undesirable noise, therefore noise which humans may deem unobtrusive has the potential to cause stress in giant pandas. As giant panda breeding programmes are taking place in zoos throughout the world it is important to understand the impact that anthropogenic noise has on these mammals and how it affects their wellbeing. This paper discusses the adaptation from international standards on noise to appropriately address the impact from construction site noise on giant pandas.

1. INTRODUCTION

As part of an animal welfare and conservation breeding programme by The Royal Zoological Society Scotland (RZSS) at Edinburgh Zoo, a series of acoustic assessments have taken place to determine the impact that a neighbouring construction site may have on the giant pandas (Ailuropoda melanoleuca). The results from the analysis will be used to determine the impact on several noise sensitive animals; however, this document only considers the impact on the giant panda species. The results of this assessment will also be used to inform design considerations for future enclosure design for noise sensitive animals.

2. PREVIOUS ASSESSMENTS OF NOISE IMPACT ON HUMAN AND ANIMAL WELLBEING

The scope and magnitude of anthropogenic noise pollution are often much greater than those of natural noise and are predicted to have an array of deleterious effects on wildlife [Kight and Swaddle, 2011]. It has been shown that noise can lead to DNA damage, alterations in gene expression and changes to a myriad of cellular processes related to appropriate neural, developmental, immunological and physiological functioning [Kight and Swaddle, 2011]. In addition, previous authors have discussed ways in which noise can impact animal behaviour and community ecology [Francis et al. 2009; Barber et al. 2010].

However, studies on the effects of noise on the wellbeing of animals have had variable results [Powell et al., 2006]. Studies of captive and free living non-human mammals have uncovered only mild or temporary effects [Krausman et al., 1998; Owen et al, 2004]. Studies have also shown that when interpreting results from aircraft noise on wildlife, difficulties can arise because of species-specific sensitivity to noise and challenges in separating the effects of acoustic and visual stimuli, along with difficulties in interpreting species specific behaviour responses [Kempf and Hueppop, 1996]. Studies have also concluded that animals can apparently adapt to high noise exposure and that noise is a less important disturbance than visual stimuli [Reijnen et al., 1995]. Noise is associated with changes in song characteristics [Ill'chev et al., 1995], decreases in reproduction and density [Reijnen et al., 1995, 1996, 1997; Forman and Deblinger, 2000], and reduced feeding and weight gain [Esmail, 1997] in some bird species whereas other bird species seem to be unaffected or only temporarily disturbed by ambient noise [Delaney et al., 1999]. Whether or not environmental noise has a negative impact on welfare probably depends on a variety of factors including individual

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and species differences.

Human children exposed to chronic, loud (> 60 dB) noise show a lack in motivation when exposed to problem solving puzzles, higher systolic blood pressure, greater heart rate reactivity to acute stressors, higher overnight cortisol levels, report more stress symptoms, and show significant decreases in quality of life [Evans et al., 2001].

In giant panda species, ambient noise has been shown to have long-lasting effects on stress indices; where days characterised by louder levels of noise were associated with increased locomotion, restless manipulation of the exit door of the enclosure, increased scratching and vocalizations indicative of agitation, and/or increased glucocorticoids excreted in urine [Owen et al, 2004]. For the giant panda, vocalizations are typically emitted in proximity to conspecifics and studies suggest that information is likely encoded in a number of different frequency ranges of the panda hearing curve [Owen et al, 2016] and therefore the broadband spectrum of Panda hearing (0.1 kHz to 70 kHz) is important for reproduction of the species [Kleiman and Peters, 1990]. The ability to discriminate between fine-scale differences in vocalizations is important for successful reproduction (Charlton et al., 2011, 2010a, 2009b) as there is a unique vocalization which pandas use to validate intromission [Keating, 2011] and therefore noise should be carefully managed during reproductive periods [Owen et al, 2004]. A comparative graph of Panda hearing vs. Human hearing can be found in Figure 1 [Owen et al., 2016].

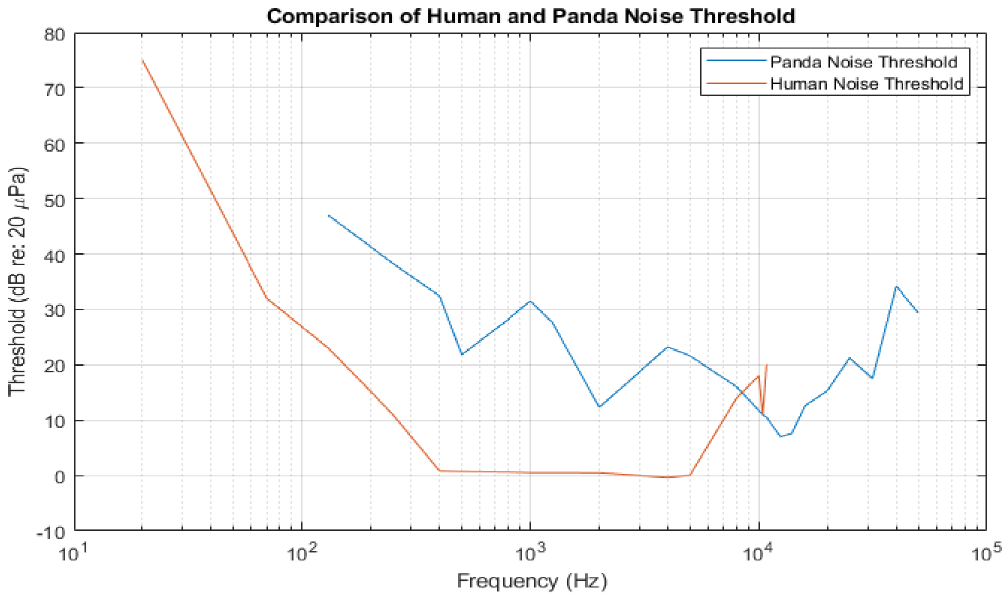

Figure 1 – Panda hearing curve [Owen et al., 2016] compared against the human hearing curve. Note. Logarithmic frequency axis.

3. BRITISH ACOUSTIC STANDARDS

There are several International and British Standards (BS) currently used for rating sound pressure level (SPL) and noise characteristics; such as tonal noise, intermittent noise, continuous noise etc, for a range of different industries and applications. For example, BS 5228:2009 is used for rating noise and vibration from construction and open sites. Each standard has their own methodology of rating noise impact and assigning noise penalties to the SPL reading for noise characteristics which can be perceived as irritating, such as tonality and intermittency.

Almost all acoustic standards, however, apply an "A-weighting" [BS EN 61672-1:2013] to the frequency spectra of the noise readings so that each frequency band is weighted to compensate for sensitivities in the human hearing range. This has many benefits when determining the acoustic impact that machinery and construction site activities will have on the human population. However, when calculating the impact on other animals that have a different hearing curve to humans this A-weighting is unlikely to give a representative level of noise impact.

In order to provide a representative noise impact assessment for the pandas and other non-human animals at Edinburgh Zoo a series of measurement and modelling techniques were adapted from British Standards for application into the ultrasonic spectrum.

4. METHODOLOGY

In order to determine the impact that construction site noise would have on the giant pandas, a baseline assessment was completed at locations throughout the zoo and at a construction site. Acoustic modelling was then used to predict noise ingress and impact from the proposed construction site onto the non-human noise sensitive receptors located within Edinburgh Zoo.

As giant pandas have hearing capability at frequencies higher than of the human ear, acoustic measurement equipment used for human hearing is not capable of detecting the higher frequency range of a panda. It is important that measurement equipment is capable of measuring the full hearing range of the species which will be exposed to the noise. In line with WWF best practice for acoustic monitoring [Ella Browning, 2017] two sets of equipment have been used to capture the full hearing range of the giant panda [Table 1]. Acoustic measurements for human hearing have been carried out using BS 5228-1:2009. The ultrasonic hearing range acoustic measurements have followed the same methodology as BS 5228-1:2009, however all data has been recorded as a Z-weighting (i.e. unadjusted raw data) between 8 kHz and 100 kHz.

Due to the large frequency range of the ultrasonic song meter the frequency response of the microphone's low frequency range is very nonlinear. In order to compensate for this, the lower end of the results (8 kHz to 20 kHz) were calibrated to that of the Class 1 Sound Level Analyser and then the ultrasonic acoustic data was weighted against the frequency response curve for microphone provided by the equipment supplier.

Two types of predictive modelling were deployed; NoiseMap SiteNoise software used to predict construction site noise levels within the human hearing range; and ultrasonic predicative modelling completed using acoustic hemispherical propagation calculations. Both modelling techniques also considered mitigation barriers between the construction site and panda enclosure.

Table 1- Acoustic Equipment used to capture baseline acoustic data for construction site noise and background noise levels in Edinburgh Zoo

Acoustic Measurement Equipment	
Human Hearing Range:	Class 1 Noise level meter NTi Audio XL2 Sound Level Analyser Cirus Research CR515 Class 1 single level acoustic calibrator
Ultrasonic Hearing Range:	Song meter SM4BAT FS Bioacoustics Recorder Song meter SM4BAT FS Bioacoustics Recorder calibrator

5. MEASUREMENT RESULTS

The baseline acoustic assessment showed A-weighted equivalent continuous sound level (LAeq) background noise levels between 45 dB(A) and 55 dB(A) for locations throughout the zoo premises [Figure 2] which are normal background levels for a public space during daylight hours. For the ultrasound measurements at Edinburgh Zoo, a logarithmic average was used to generate the graphs in Figure 3 which shows the SPL at different 1/3 octave frequency bands at locations throughout the zoo. The average background noise level for ultrasonic noise throughout the zoo was around 58.7 dB(Z). However, during the measurement at the Location 4 power tools were being used in the distance which is attributed to the high energy above 25 kHz.

- Position 1: On the pathway outside of the male panda enclosure
- Position 2: Inside the female panda's outdoor enclosure
- Position 3: South of the hilltop viewpoint at the edge of the grass verge
- Position 4: On the grass verge to the west of the Camel House

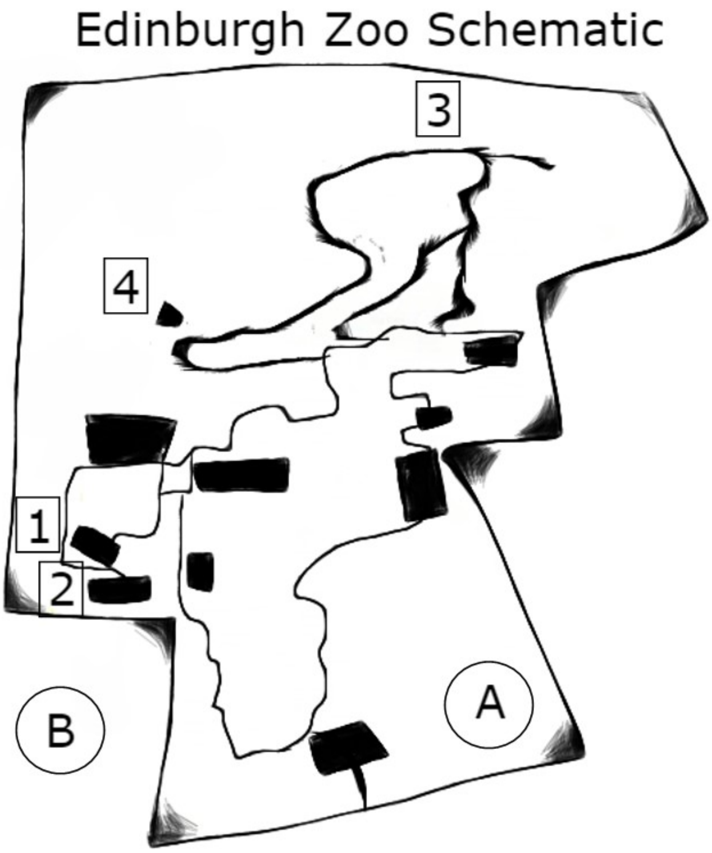

Figure 2 – Acoustic measurement locations throughout Edinburgh Zoo.
location A = Edinburgh Zoo premises, location B = proposed construction site location,

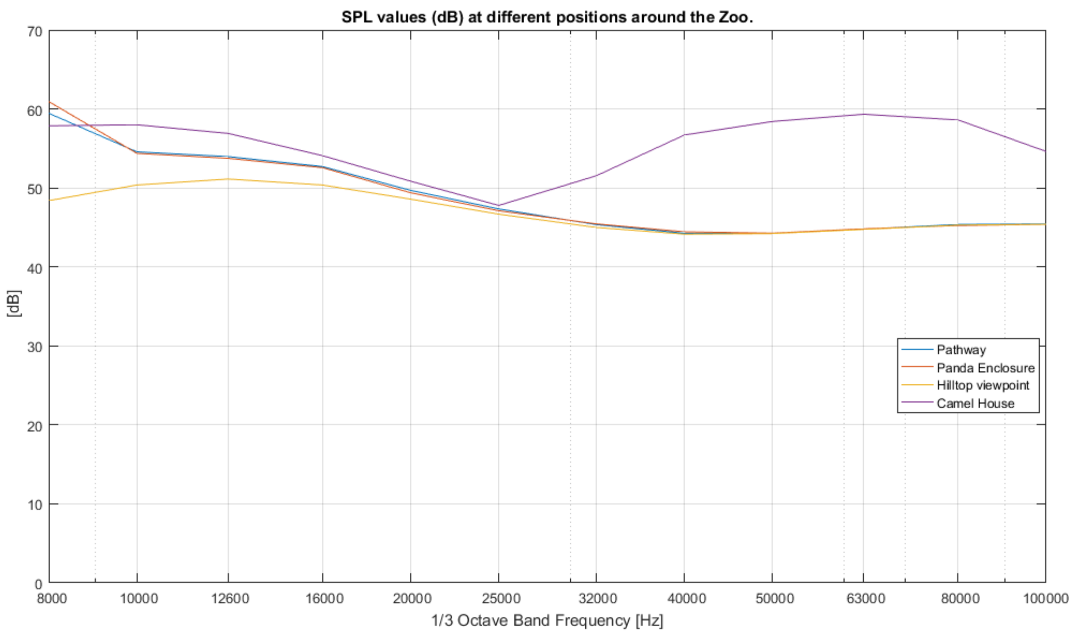

Figure 3 – Z-weighted 1/3 octave band frequency data for 4 separate locations throughout Edinburgh Zoo premises between 8 kHz and 100 kHz. High energy above 25 kHz at Location 4 can be attributed to use of power tools at a nearby location.

The acoustic measurements at the construction site were taken during operation of a rotary piling machine and Stihl saw. The graph shows very high energy levels within the human hearing spectrum. However, it is evident from the graph that there are high energy levels right up to 50 kHz and harmonic tones from the operation of the rotating equipment can be seem in the ultrasonic noise spectrum [Figure 4]. To determine the source Sound Power Level (Lw) of the two machines, standard acoustic hemispherical spreading was used form the recorded data.

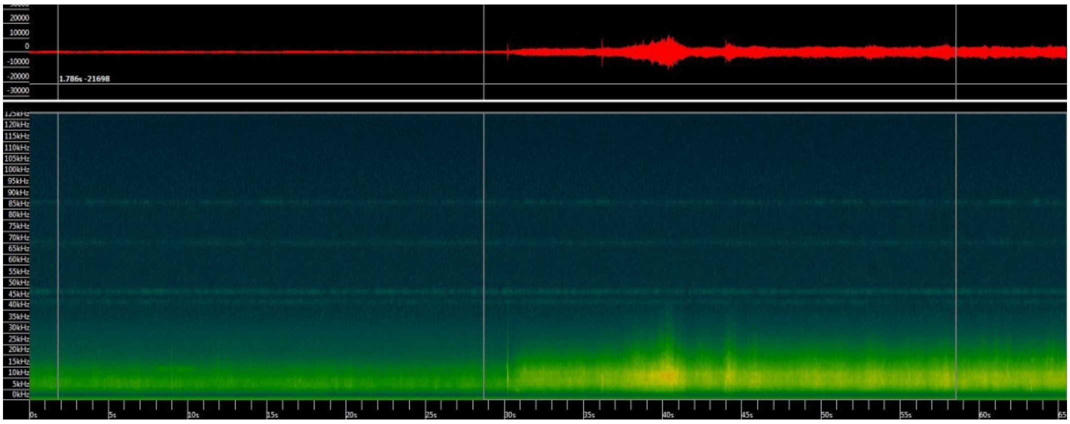

Figure 4 –Ultrasonic song meter results prepared in Kaleidoscope Pro Analysis Software showing frequency (y-axis) and time (x-axis)

6. MODELLING RESULTS

The results from the modelling assessment for the A-weighted acoustic modelling using NoiseMap software show that expected noise levels in the panda enclosure could be in region of 60 dB(A) to 70 dB(A) during standard demolition and construction site activities; with rock removal by blasting reaching up to 85 dB(A). The Lw of each machine was taken from BS 5228-1:2009 as well as provided by suppliers for specific activities (i.e. rock blasting).

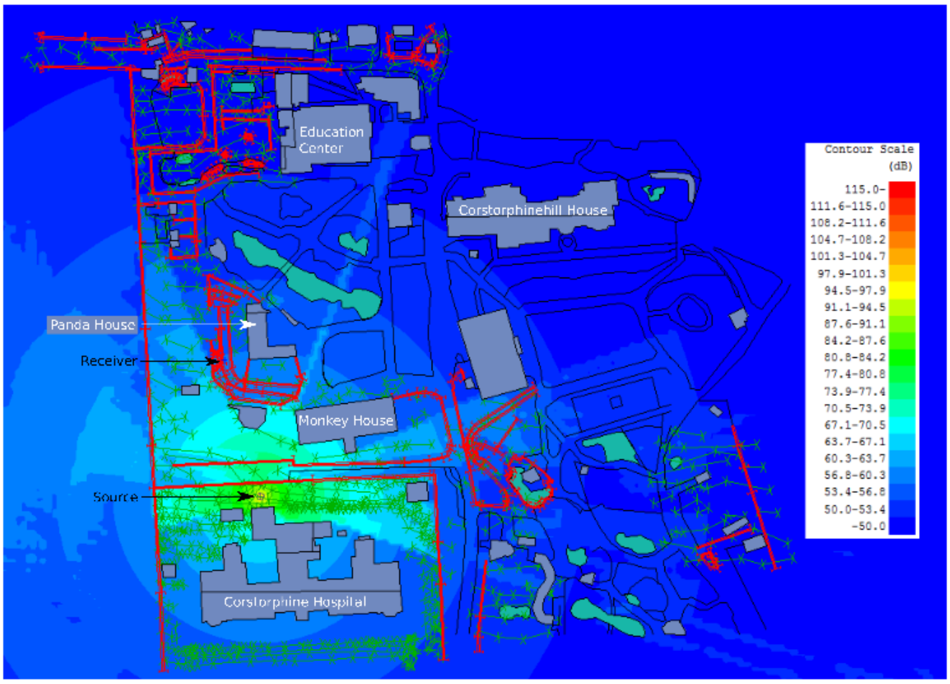

Figure 5 – Results from NoiseMap SiteNoise software for modelling roof works on top of the proposed development and expected impact at locations throughout Edinburgh Zoo.

The results from the ultrasonic noise modelling considered the broadband noise from 8 kHz to 100 kHz [Table 2]. The sound power level for each machine was calculated and then standard acoustic hemispherical spreading calculations were used for rating the noise impact. The results show that the broadband levels from the rotary piling activities are unlikely to breach the broadband background noise levels at the panda enclosure, whereas the Stihl saw is likely to breach the background noise levels and cause disturbance to the animals.

It should be noted that this modelling technique does not consider the tonal noise emissions captured in acoustic assessment, nor the additional irritation and impact that this would have on the animals.

Table 2 - Results from Ultrasonic noise modelling

Tools	8 kHz to 100 kHz Z-weighted noise level at source dB(Z)	8 kHz to 100 kHz Z-weighted Background at panda receiver dB(Z)	8 kHz to 100 kHz Z-weighted noise level at panda receiver dB(Z)
Rotary Piling	105.9	58.7	52.4
STIHL Saw	115.0	58.7	61.5

7. DISCUSSION

The results from the measurement, modelling and analysis discussed in this document show that the British Standards for rating noise from construction sites do not give a representative assessment of the impact that these activities will have on non-human animals. The A-weighting curve used for rating noise impact from anthropogenic noise is restrictive with regards to impact on non-human animals. Using this system for implementing noise restrictions on construction sites adjacent to noise sensitive species like the giant panda is likely to give a misleading result on the actual noise impact on this species as a result of the anthropogenic noise.

The results show that construction site activities have high energy above the human hearing range of 20 kHz as well as prominent harmonic tones from rotating machinery. Standards on acoustic noise impact assessments regularly apply noise penalties for tonal characteristics due to their additional impact on top of the broadband noise from machinery and site activities [BS 4142, IEC 61400-11]. By limiting our acoustic measurements to the A-weighting we remove all the ultrasonic tones from our measurement range, which would likely have tonal noise penalties attributed to them if they were within the human hearing range. Previous studies referenced at the start of this paper have shown stress related health impacts on the giant panda species as a result of invasive acoustics from anthropogenic noise; the additional irritation of tonal noise from construction site activities is therefore expected to cause significant impact on animal wellbeing.

8. CONCLUSIONS

BS 5228-1:2009 discusses acceptable A-weighted noise restrictions on construction site activities; however, this does not consider the potential impact these activities would have on endangered and noise sensitive species that have a wider range of hearing than humans. Certain non-human animals such as pandas rely heavily on vocalisations for successful breeding and therefore, special care must be taken when rating anthropogenic noise within the vicinity of these delicate mammals. Although the current British and International acoustic standards are widely accepted throughout the world; it is the conclusion of this assessment that, in their current state, the standards are not suitable for rating noise impact on non-human species. Therefore, when completing a noise impact assessment near noise sensitive non-human animals; real care must be taken to ensure that the wellbeing of the animals is not negatively impacted as a result of incorrectly rating the noise impact on that species against the expected nose impact on humans.

9. FURTHER WORK

As a result of this work, acoustic considerations have been taken forward to inform the design of a new panda enclosure at Edinburgh Zoo. With regards to accurately rating the noise impact on this delicate species, additional studies are required to accurately determine the impact that ultrasonic noise levels will have with regards to panda welfare. One potential route would be to generate a species-specific acoustic weighting which can be applied to broadband acoustic data for different non-human animals to allow for accurate acoustic impact assessments to be made for individual species such as the M-weighting which is used for rating noise impact on marine mammals [Southall et al., 2007].

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