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# Assessing Giraffe Welfare During Seasonal Habitat Changes in Northern US Zoos

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## Abstract

Although there has been an increase in research studying the impact of housing on zoo animal welfare, there is still a lack of literature regarding the impact of seasonal housing differences on animal welfare. In northern American zoos, animals native to warmer climates inhabit an outdoor habitat during the summer and an indoor habitat during the winter. These habitats usually vary in size, in the amount of naturalistic habitat features and in the provision of diet. This study utilised a multi-faceted approach of behavioural observations, hormone monitoring and recumbency rates to assess giraffe welfare comparing outdoor, summer habitats and indoor, winter habitats at multiple institutions. A total of 13 giraffe were examined at four zoological institutions. Active non-forage behaviour was significantly higher in the outdoor habitat versus the indoor habitat ($Z=-2.34$, $P=0.02$), and active forage behaviour was significantly higher in the indoor habitat versus the outdoor habitat ($Z=-2.27$, $P=0.02$). In addition, higher levels of recumbency were exhibited in the indoor habitat than in the outdoor habitat. No significant differences were found for the other behavioural categories (inactive, abnormal) or for faecal glucocorticoid metabolite concentrations between the two seasons. With positive welfare implications displayed in both indoor and outdoor habitats, these results suggest that housing giraffe indoors likely does not compromise their welfare. Future research should continue utilising multi-faceted approaches across multiple institutions that will help in the management of species that could be impacted by differing seasonal habitats.

## Introduction

In recent years, research has emerged on how housing and management in zoos affects the welfare of animals (Carlstead et al. 2013). These efforts are critical as many zoo animals inhabit multiple habitats that differ in size or complexity. Measuring how animals utilise different spaces can lead to better understanding of an animal's needs and preferences which can optimise their overall welfare (Ross et al. 2009). In northern American zoos, animals originating from warmer climates tend to have an outdoor habitat during the summer months and an indoor habitat during the winter months. These two types of habitats are typically vastly different: the outdoor habitat is larger with natural substrate and more natural environmental stimuli, while the indoor habitat is smaller with little to no natural substrate and lower levels of environmental stimuli (Razal et al. 2017; Ross and Shender 2016). Previous research has shown that there are significant differences in activity and behaviour when animals are housed in differing indoor and outdoor habitats. More active behaviours were seen in outdoor habitats versus indoor habitats in both sifakas *Propithecus verreauxi* (Macedonia 1987) and African elephants *Loxodonta africana* (Posta et al. 2013). In addition, stereotypic behaviour was more prevalent in indoor habitats versus outdoor habitats. African lions *Panthera leo* (Bashaw et al. 2007) and Indian leopards *Panthera pardus* (Mallapur et al. 2002) engaged in more pacing behaviour, and okapis *Okapia johnstoni* and giraffe *Giraffa camelopardalis* engaged in more pacing and repetitive licking of non-food objects (Bashaw et al. 2001).

Previous research regarding this topic has typically only taken place at single institutions. This can limit the potential of identifying behavioural trends across multiple institutions that may advance best practices of animal care (Swaisgood and Shepherdson 2005). Recently, a study involving elephants focusing on housing management and its impact on animal welfare and health comprised of collecting data in 68 North American zoos (Meehan et al. 2016). In this study, the authors found low levels of habitat complexity may have significant impacts on overall activity levels. Although this is a positive direction towards studying this topic at a multi-institutional level, there is still a lack of research investigating the seasonal differences of these habitats at a multi-institutional level. A study examining the impact of giraffe welfare in an outdoor, summer habitat compared to an indoor, winter habitat found individual variation within the four subjects, which led the authors to suggest furthering this research with a larger sample size to investigate the impact of these significant differences (Razal et al. 2017).

Giraffe are one of the most common large vertebrate species in zoo collections that typically spend time in different seasonal habitats, which makes them an ideal species to utilise for a multi-institutional study (Razal et al. 2017; Veasey et al. 1996). In addition, previous research with giraffe suggests this species displays differences in behaviour when exposed to different environmental variables (Bashaw et al. 2001), which highlights the importance of examining whether seasonal housing impacts overall giraffe welfare. One of these environmental variables is the difference in the provision of diet in the summer and winter months. Many zoos provide browse in combination with lucerne hay and concentrated feeds to approximate the nutritional value of acacia leaves (Duggan et al. 2016; Myers 2004). This is because wild populations of giraffe reportedly spend about 60% of their day foraging their natural diet of acacia leaves (Bashaw et al. 2001; Pellew 1984). However, provision of browse becomes challenging in the winter months because many northern American zoos have limited forage available and give largely hay and pellets during this time (Myers 2004). These seasonal differences in diet add to other common factors of an indoor, winterised habitat as compared to a larger, outdoor, more natural habitat (i.e., reduced size, semi-natural or manufactured elements). Exploring all these environmental variables across institutions can help better understand best practices toward managing giraffe in seasonal habitats.

In addition to the importance of gathering data at multiple institutions, previous research has shown that measuring multiple indicators of welfare can help better understand how animals adapt to different environments (Walker et al. 2014; Whitham and Wielebnowski 2013). Many animal welfare studies combine hormone and behavioural monitoring to provide a better overall understanding of an animal's welfare state (Shepherdson et al. 2004, 2013; Wielebnowski and Brown 2003). Measuring faecal glucocorticoid metabolites (FGM) provides a measure of adrenal activity which can be related to stress response (Sapolsky 1992). In addition, recumbency (i.e., resting time while laying down) has been extensively studied in cattle welfare and has been used as an indicator of animal welfare for elephants (Holdgate et al. 2016) and more recently in the focal species, giraffe (Razal et al. 2017). The purpose of the current study was to apply a multi-faceted approach utilising behavioural observations, recumbency tracking and hormone monitoring to assess giraffe welfare in outdoor summer habitats compared to indoor winter habitats at multiple institutions. It is hoped that with the continuation of this research more information can be gained that will aid in the management of species that could be impacted by differing seasonal habitats.

## Materials and methods

### *Study subjects*

Data were collected from 13 subjects at four facilities: two female giraffe from Blank Park Zoo (BPZ) (Des Moines, Iowa), one male and three female giraffe from Chicago Zoological Society-Brookfield Zoo (CZS) (Brookfield, Illinois), five male giraffe from Columbus Zoo and Aquarium (CZA) (Powell, Ohio) and one female and one male giraffe from Milwaukee County Zoo (MCZ) (Milwaukee, Wisconsin). Subjects ranged from 1 year to 25 years old (mean=8.4 years) (Table 1).

### *Housing and management*

All institutions had giraffe herds that had similar housing and management environments and therefore were chosen to participate in this study. All institutions had giraffe herds that had access to their outdoor habitat 24 hours a day in the summer, and only had access to the indoor habitat in the winter. All outdoor habitats had natural substrates of dirt and grass with the majority of the diet being several varieties of leafy browse that were placed in foraging enrichment devices around the habitat. All indoor habitats had concrete flooring typically covered by rubber mats and wood chips and giraffe were fed a diet that primarily consisted of alfalfa hay and occasionally non-leafy browse (due to the constraints of maintaining leafy browse all year-long).

At BPZ, the outdoor habitat measured 4047 $m^2$ and the indoor habitat measured 288 $m^2$. At CZS, the outdoor habitat measured 4130 $m^2$ and the indoor habitat measured 153 $m^2$. At CZA, there were two summer outdoor habitats between which the giraffe rotated depending on the day. One outdoor habitat measured 32375 $m^2$ and the second outdoor habitat was 3035 $m^2$; the indoor habitat at CZA measured 557 $m^2$. At MCZ, the outdoor habitat measured 1535 $m^2$ and the indoor habitat measured 152 $m^2$.

**Table 1.** Demographics of all 13 study subjects with information of study institution, sex, and age (in years) at the start of the study.

| Giraffe | Institution | Sex | Age (years) |
|---|---|---|---|
| G1 | CZS | Female | 8 |
| G2 | CZS | Female | 10 |
| G3 | CZS | Female | 25 |
| G4 | CZS | Male | 2 |
| G5 | MCZ | Male | 12 |
| G6 | MCZ | Female | 25 |
| G7 | BPZ | Female | 3 |
| G8 | BPZ | Female | 1 |
| G9 | CZA | Male | 7 |
| G10 | CZA | Male | 4 |
| G11 | CZA | Male | 4 |
| G12 | CZA | Male | 2 |
| G13 | CZA | Male | 6 |

***Behavioural data collection***

Behavioural data from each institution were collected for one summer month and one month in the subsequent winter. For each study month, 15-minute observations were conducted on each subject twice per day for five days a week. CZS behavioural data collection occurred in August 2015 (representing summer) and February 2016 (representing winter) (Razal et al. 2017). At the other three institutions, each subject was recorded using video cameras in August 2017 (representing summer) and February 2018 (representing winter). The video cameras were placed on a tripod in a public viewing area, supervised by a volunteer from each institution with directions to only move the camera view and placement if the focal subject moved. The time each subject was observed at each institution was randomised, once between 1000 and 1300 and once between 1300 and 1600. Behavioural data were coded from the videos using the same ethogram from the CZS behavioural data collection, mimicking the method of instantaneous sampling of behavioural states at one-minute intervals (Altmann 1974). The same observer used in Razal et al. (2017) randomly selected a video sample from each institution and coded each sample to ensure inter-observer reliability. Once reliable (>85%), this observer coded all the videos using BORIS (Behavioural Observation Research Interactive Software) (Friard and Gamba 2016). All behaviours were mutually exclusive and for situations with multiple occurring behaviours, the observer scored based on a previously determined behavioural hierarchy: 1) abnormal, 2) active forage, 3) active non-forage and 4) inactive. This hierarchy was established to be consistent with the data collected by Razal et al. (2017), as well as to prioritise behaviours that are rarer to this species' natural history which are then followed by the most prominent natural behaviours (Bashaw et al. 2001). For all institutions, the data resulted in 40 15-minute observations per subject per season and a total of 20 hours of data per subject throughout the study.

Behavioural states were corrected for proportion of time visible and combined into four categories for analysis and control of Type 1 error. The four behavioural categories were active forage (feed, ruminate), active non-forage (locomote, bend, stand alert, stand non-alert, play, social positive, explore/interact enrichment, explore/interact environment, self-maintenance, keeper interaction, visitor interaction), inactive (rest/sleep) and abnormal (abnormal) (Razal et al. 2017) (Table 2). Social negative behaviour

**Table 2.** Ethogram of 18 behavioural states used in the study and their descriptions and behavioural category

| Behavior Category | Behavioral State | Definition |
|---|---|---|
| Active Forage | Feed | Animal is actively consuming food, in the form of chewing or drinking water |
| | Ruminate | Animal is chewing and swallowing a bolus of already ingested food. Happens after regurgitation, and can occur while standing, lying down, or locomoting |
| Active Non-Forage | Locomote | Movement from one location to another and excludes locomotor play |
| | Bend | Animal lowers head to the ground for investigating items on the ground |
| | Stand Alert | Animal is standing in one position, head is up, and attentive to surroundings |
| | Stand Non-Alert | Animal is standing in one position, head is up or down, but eyes are closed, and animal is not paying attention to surroundings |
| | Play | Animal is engaging in social (e.g., chasing), solitary (e.g., jumping/bucking) or object play (e.g., playing w/ object) |
| | Social Positive | Animal is engaging in grooming or affiliative contact with another individual |
| | Social Negative | Animal is engaging in head butt, head slap, kick or stomp behavior including chasing if preceded or followed by another aggressive behavior |
| | Explore/Interact Enrichment | Licking (for less than 5 seconds), sniffing, manipulating enrichment object (non-permanent, non-food) within the habitat |
| | Explore/Interact Environment | Licking (for less than 5 seconds), sniffing, manipulating environment including urine/feces but not including enrichment (non-permanent, non-food) |
| | Self-Maintenance | Animal is engaging in grooming self, urinating, or defecating; includes rubbing against habitat features |
| | Keeper Interaction | Includes any behavioral response in reaction to animal care presence. May include observing or directing attention towards keepers/trainers, such as begging for food or following keepers (with eyes or body) as they walk past the habitat. Also includes trainer/keeper training sessions where human is directly feeding the animal (i.e., food toss) |
| | Visitor Interaction | Includes any behavioral response to non-animal care presence (e.g., visitors, volunteers, researchers, etc.). Positive response may include observing people or following people with eyes or body as they walk past the habitat, as well as sessions/tours where human is directly feeding animal; negative response may include fleeing away from presence or any physically aggressive display towards the human |
| Inactive | Rest/Sleep | Animal is on the ground, sitting or lying down, with head up or down |
| Abnormal | Pace | Animal is engaging in a repetitive ambulatory movement after traversing the same pathway at least twice |
| | Abnormal | Animal is engaging in repetitive tongue activity, repetitive licking, and/or repetitive ruminating |
| Not Visible | Not Visible | Animal is completely not visible. |

was not observed during this study and therefore was removed from further analysis.

In addition, behavioural diversity was calculated using the behavioural categories with the Shannon-Wiener diversity index (Shannon and Weaver 1949), supporting previous research efforts suggesting that behavioural diversity can be used as a positive indicator of welfare (Miller et al. 2020).

### *Recumbency monitoring*

Hobo Pendant G data loggers (Onset Computer Corporation, Pocasset, Massachusetts) were used to record the percentage of time each focal animal spent recumbent. Hobo Pendant G data loggers are accelerometers that record on three axes (x, y, z). Each data logger weighed 18 g and had the dimensions of 60 mm in length, 33 mm in width and 23 mm depth. Each institution was given an elastic band per subject, which had a pouch that held the data logger. For institutions BPZ, CZA and MCZ, the data loggers and elastic bands were shipped three months prior to data collection to allow tactile training to occur to desensitise each focal subject to wearing the bands. During the study, an animal care staff member placed the bands on each subject's front right leg above the fetlock joint during a training session. This occurred once a week for a 24-hour period per season and the data loggers were programmed to record every minute. This resulted in a total of eight 24-hour periods (192 hours) per individual throughout the study. At the end of the data collection period, all data were sent to CZS for analysis.

All recumbency data were analysed using HOBOware© and a macro-enabled Excel document utilised for analysing recumbency in cattle (Gibbons et al. 2012; Medrano-Galarza et al. 2012) and elephants (Holdgate et al. 2016). Percentage of lying bouts (i.e., recumbency) was calculated during determined day and night times. Day hours were established in the data as 0600 to 1800 while night hours were established as 1800 to 0600, to account for average sunrise and sunset in the northern region of the US. In addition, to reveal any relationships of time spent recumbent per hour in each season, a Wilcoxon signed rank test was used to examine any differences (Siegel and Castellan 1988).

### *Faecal hormone collection and analysis*

Faecal samples were collected by staff at each institution three times a week during each season. During the day hours, defecation was observed by animal care staff and volunteers that were trained to identify its subjects. All faecal samples were collected within an hour of defecation and stored at −20 °C until shipped with dry ice to CZS for analysis.

To extract FGM from each faecal sample, 0.5 g of each sample was placed into polypropylene tubes and then 5 mL of 80% ethanol solution was added to each tube. Each tube was vortexed and placed on a rotator overnight (14–18 hours). Each tube was then centrifuged, and 1 mL of supernatant was pipetted into another tube containing 1 mL of assay buffer to produce an extract with 1:10 dilution. All extracts were stored at −20 °C until enzyme immunoassay (EIA) analysis.

EIAs (supplied from Enzo Life Sciences) were conducted using techniques based on previously validated assays (Bashaw et al. 2016; Chinnadurai et al. 2009; Morrow et al. 2002; Yadav et al. 2013). Although obtaining a biological validation for this study was not possible, assays were validated biochemically for this species (Razal et al. 2017). FGM concentrations were analysed using instructions and components supplied in each corticosterone commercial EIA kit. A photospectrometer plate reader was used to read plates. Average recovery of exogenous corticosterone was 140.37% (SD=75.56%). All FGM data were reported in ng/g wet faeces and calculated as means for each individual and as a group for each season.

### *Statistical analysis*

Since behavioural, recumbency and FGM data were not normally distributed, nonparametric tests were used for all data and analysed through SPSS (Version 22) with alpha levels considered significant at P<0.05. A Wilcoxon signed rank test was used to evaluate differences across all measures for all giraffe (n=13) comparing summer to winter (Siegel and Castellan 1988).

## Results

### *Behavioural data*

Giraffe engaged in significantly more active non-forage behaviour in the summer compared to winter (Z=−2.34, P=0.02). Average percentage of time spent in active non-forage behaviour for the group was 58.95% (SD=13.41%) in the summer and 45.52% (SD=19.11%) in the winter (Figure 1).

In addition, giraffe engaged in significantly more active forage behaviour in the winter compared to summer (Z=−2.27, P=0.02). Average percentage of time spent in active forage behaviour for the group was 45.52% (SD=17.98%) in the winter and 34.54% (SD=14.35%) in the summer (Figure 1). There were no significant differences in inactive behaviour (Z=−1.26, P=0.21), abnormal behaviour (Z=−0.38, P=0.70) or behavioural diversity (Z=−1.92, P=0.06) when comparing summer to winter (Figure 1).

### *Recumbency data*

Giraffe spent more time recumbent in the winter compared to summer (Z=−2.132, P=0.03). Average percentage of time spent recumbent for the group was 28.74% (SD=8.13%) in the winter and 24.92% (SD=6.18%) in the summer. However, time spent recumbent per hour in each season was found to be not significant (Z=−1.11, P=0.27) (Figure 2).

### *FGM results and analysis*

FGM concentrations were not significantly different when comparing summer to winter (Z=−0.66; P=0.51). Average FGM

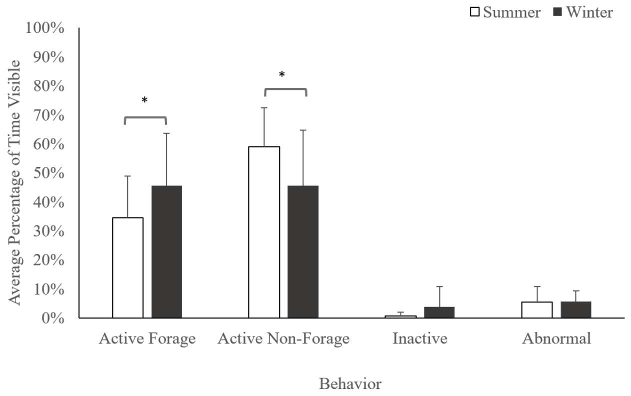

**Figure 1.** Average percentage of time spent engaging in each behavioural category comparing summer to winter for all individuals (n=13)

concentrations for all subjects were 7034.31 ng/g (SD=9147.52) in the summer and 2596.73 ng/g (SD=2157.07) in the winter (Table 3).

## Discussion

Understanding how an animal's welfare is impacted by different habitats can help better understand a species' needs and also aid in future habitat design and management of other species in similar conditions (Rose et al. 2018; Ross et al. 2009). With a larger sample size, general trends were expected to be identified across institutions that could be applied to advance animal welfare more broadly. The results of this study stress the importance of multi-institutional studies and how utilising this method can enhance understanding of seasonal habitat impacts on animal welfare.

Distinguishing animals that are thriving should be best practice in approaching optimal animal welfare as these animals provide examples of living conditions for other institutions to replicate (Melfi 2009). Thriving animals express positive indicators of welfare, such as engaging in species-specific behaviours (Melfi 2009; Miller et al. 2020). Giraffe being more active in the summer habitat than in the winter habitat in this study, possibly due to walking between environmental features, complements wild giraffe behaviour of moving from one food source to another (Bashaw et al. 2001; Posta et al. 2013). This result is similar to Razal et al. (2017) in which two giraffe displayed more active (non-forage) behaviours in the outdoor habitat versus the indoor habitat. Razal et al. (2017) suggested that the outdoor habitat possibly provided more environmental stimuli and because it was a larger habitat, it may have encouraged the giraffe to locomote to various areas as these habitat features are more spread out versus a smaller space (Bashaw et al. 2001; Posta et al. 2013; Scott and LaDue 2019). Authors of a recent study with elephants found the same result, but emphasise the importance of distinguishing between structured locomotion (locomotion due to walking between planted enrichment devices) and unstructured locomotion (locomotion that is not due to planted enrichment devices) to better understand why locomotion was more prevalent in the outdoor habitat (Scott and LaDue 2019). This difference was not accounted for in the current study, but future research should examine the impact of behavioural opportunities on overall activity levels regardless of the size of the habitat.

In addition to active behaviour, foraging behaviours were exhibited in higher levels in the group of study subjects during the winter compared to summer. Although the winter, indoor habitats in this study are smaller in size and had less natural environmental stimuli than the outdoor habitats, this increase in foraging behaviours could be due to the differences in diet between the two seasons. Razal et al. (2017) found that when subjects were provided a winter diet of more hay and non-leafy browse, all the subjects spent more time manipulating food. It has been suggested that more time spent manipulating food could explain the increase in foraging behaviour and decrease in locomotive behaviour in the indoor habitat versus the outdoor one, as was seen in a study with elephants (Posta et al. 2013). However, wild giraffe are known to not have extensive locomotive patterns and spend most of their time foraging, which is why most zoos promote this behaviour by providing specific diets for this species (Bashaw et al. 2001; Pellew 1984).

There were also significant differences in recumbency: higher levels of recumbency were exhibited in the group in the indoor habitat than in the outdoor habitat. Since recumbency was measured separately of the behavioural data, it is not clear which exact behaviours were displayed while giraffe were recumbent. In a study with cattle, higher rumination levels occurred while individuals were recumbent (Hassall et al. 1993). In the current study, giraffe were frequently observed ruminating while recumbent during behavioural coding (and according to the behavioural hierarchy, this was coded as ruminating behaviour) which may explain the simultaneous increase in overall foraging behaviours in the winter (i.e., the active forage category combines both feeding and ruminating behaviours). However, further examination into which behaviours correlate with recumbency should be a focus of future research. Recumbency levels have

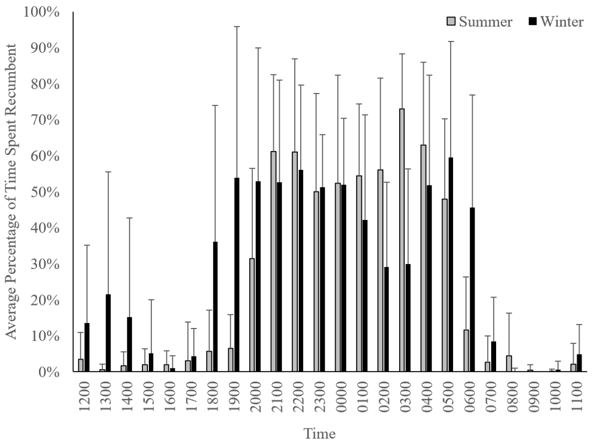

**Figure 2.** Average percentage of time spent recumbent per hour comparing summer to winter for all subjects (N=13).

**Table 3.** Average FGM concentrations (ng/g) for all 13 study subjects comparing summer and winter seasons

| Giraffe | Summer | Winter |
|---|---|---|
| G1 | 3504.68 | 5835.00 |
| G2 | 1782.23 | 4307.58 |
| G3 | 887.42 | 2576.11 |
| G4 | 3052.36 | 4327.88 |
| G5 | 39727.27 | 1933.17 |
| G6 | 12922.30 | 4764.77 |
| G7 | 18368.94 | 5769.84 |
| G8 | 8878.64 | 2160.66 |
| G9 | 883.38 | 626.07 |
| G10 | 317.36 | 331.32 |
| G11 | 333.00 | 366.50 |
| G12 | 420.75 | 304.02 |
| G13 | 367.65 | 454.58 |
| G13 | 367.65 | 454.58 |

been suggested to have positive welfare implications in dairy cattle (Ladewig and Smidt 1989) and elephants (Holdgate et al. 2016), in which individuals with higher recumbency levels were more comfortable in their environment (Vasseur 2017; Vasseur et al. 2012). Future research measuring recumbency in conjunction with behavioural monitoring could provide more information on recumbency being a welfare indicator for giraffe.

## Conclusion

Overall, the giraffe in this study demonstrated potential positive indicators of welfare such as higher levels of species-specific behaviour (i.e., active non-forage behaviour) in the outdoor habitats and higher levels of recumbency in the indoor habitat. With positive welfare implications displayed in both indoor and outdoor habitats, these results suggest that giraffe welfare appears to not be compromised in the smaller indoor habitat at BPZ, CZA, CZS and MCZ. However, there are many disparities between indoor and outdoor habitats, therefore it is important to further explore how each of these differences impact animal welfare. Studies involving elephants have further investigated these factors by not only looking at the impact of size differences, but also the complexity of each habitat and the number of behavioural opportunities (Glaeser et al. 2021; Meehan et al. 2016; Scott and LaDue 2019). In the current study, behavioural opportunities were provided in both indoor and outdoor habitats at all institutions, however the amount and complexity of the habitats were not studied and should be prioritised in future studies (Scott and LaDue 2019). In addition, future research should continue using multi-faceted approaches as well as across multiple institutions to have a more comprehensive look at patterns of best practices of animal welfare that could be applied on a larger scale. The results of this study can hopefully help supplement research into how different seasonal habitats can impact giraffe welfare and aid in the future of housing and management of species in similar situations.

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## References

Altmann J. (1974) Observational study of behavior: Sampling methods. *Behaviour* 49: 227–266. doi:10.1163/156853974X00534

Bashaw M.J., Tarou L.R., Maki T.S., Maple T.L. (2001) A survey assessment of variables related to stereotypy in captive giraffe and okapi. *Applied Animal Behaviour Science* 73(3): 235–247.

Bashaw M.J., Kelling A.S., Bloomsmith M.A., Maple T.L. (2007) Environmental effects on the behavior of zoo-housed lions and tigers, with a case study of the effects of a visual barrier on pacing. *Journal of Applied Animal Welfare Science* 10(2): 95–109.

Bashaw M.J., Sicks F., Palme R., Schwarzenberger F., Tordiffe A.S.W., Ganswindt A. (2016) Non-invasive assessment of adrenocortical activity as a measure of stress in giraffe (*Giraffa camelopardalis*). *BMC Veterinary Research* 12: 235. doi:10.1186/s12917-016-0864-8

Carlstead K., Mench J.A., Meehan C., Brown J.L. (2013) An epidemiological approach to welfare research in zoos: The Elephant Welfare Project. *Journal of Applied Animal Welfare Science* 16(4): 319–337. doi:10.1080/10888705.2013.827915

Chinnadurai S.K., Millspaugh J.J., Matthews W.S., Canter K., Slotow R., Washburn B.E., Woods R.J. (2009) Validation of fecal glucocorticoid metabolite assays for South African herbivores. *The Journal of Wildlife Management* 73(6): 1014–1020. doi:10.2193/2008-430

Duggan G., Burn C.C., Clauss M. (2016) Nocturnal behavior in captive giraffe (*Giraffa camelopardalis*)—A pilot study. *Zoo Biology* 35(1): 14–18. doi:10.1002/zoo.21248

Friard O., Gamba M. (2016) BORIS: A free, versatile open-source event-logging softwarefor video/audio coding and live observations. *Methods in Ecology and Evolution* 7(11): 1325–1330. doi:10.1111/2041-210X.12584

Gibbons J., Medrano-Galarza C., de Passillé A.M., Rushen J. (2012) Lying laterality and the effect of IceTag data loggers on lying behaviour of dairy cows. *Applied Animal Behaviour Science* 136(2–4): 104–107. doi:10.1016/j.applanim.2011.12.005

Glaeser S.S., Shepherdson D., Lewis K., Prado N., Brown J.L., Lee B., Wielebnowski N. (2021) Supporting zoo Asian elephant (*Elephas maximus*) welfare and herd dynamics with a more complex and expanded habitat. *Animals* 11(9): 2566. doi:10.3390/ani11092566

Hassall S.A., Ward W.R., Murray R.D. (1993) Effects of lameness on the behaviour of cows during the summer. *The Veterinary Record* 132(23): 578–580. doi:10.1136/vr.132.23.578

Holdgate M.R., Meehan C.L., Hogan J.N., Miller L.J., Rushen J., de Passillé A.M., Soltis J., Andrews J., Shepherdson D.J. (2016) Recumbence behavior in zoo elephants: Determination of patterns and frequency of recumbent rest and associated environmental and social factors. *PloS ONE* 11(7): e0153301. doi:10.1371/journal.pone.0153301

Ladewig J., Smidt D. (1989) Behavior, episodic secretion of cortisol, and adrenocortical reactivity in bulls subjected to tethering. *Hormones and Behavior* 23(3) 344–360. doi:10.1016/0018-506X(89)90048-2

Macedonia J.M. (1987) Effects of housing differences upon activity budgets in captive sifakas (*Propithecus verreauxi*). *Zoo Biology* 6(1): 55–67. doi:10.1002/zoo.1430060107

Mallapur A., Qureshi Q., Chellam R. (2002) Enclosure design and space utilization by Indian leopards (*Panthera pardus*) in four zoos in southern India. *Journal of Applied Animal Welfare Science* 5(2): 111–124. doi:10.1207/S15327604JAWS0502_02

Medrano-Galarza C., Gibbons J., Wagner S., de Passillé A.M., Rushen J. (2012) Behavioral changes in dairy cows with mastitis. *Journal of Dairy Science* 95(12): 6994–7002. doi:10.3168/jds.2011-5247

Meehan C.L., Mench J.A., Carlstead K., Hogan J.N. (2016) Determining connections between the daily lives of zoo elephants and their welfare: An epidemiological approach. *PLoS ONE* 11(7): e0158124. doi:10.1371/journal.pone.0158124

Melfi V.A. (2009) There are big gaps in our knowledge, and thus approach, to zoo animal welfare: A case for evidence-based zoo animal management. *Zoo Biology* 28(6): 574–588. doi:10.1002/zoo.20288

Miller L.J., Vicino G.A., Sheftel J., Lauderdale L.K. (2020) Behavioral diversity as a potential indicator of positive animal welfare. *Animals* 10(7): 1211. doi:10.3390/ani10071211

Morrow C.J., Kolver E.S., Verkerk G.A., Matthews L.R. (2002) Fecal glucocorticoid metabolite as a measure of adrenal activity in dairy cattle. *General and Comparative Endocrinology* 126(2): 229–241. doi:10.1006/gcen.2002.7797

Myers G. (2004) The giraffe in captivity: Diet and nutrition. In: Burgess A. (ed.). *The Giraffe Husbandry Resource Manual.* Silver Springs, Maryland: Association of Zoos and Aquariums Antelope/Giraffe Taxon Advisory Group, 116–126.

Pellew R.A. (1984) The feeding ecology of a selective browser, the giraffe (*Giraffa camelopardalis tippelskirchi*). *Journal of Zoology* 202(1): 57–81. doi:10.1111/j.1469-7998.1984.tb04288.x

Posta B., Huber R., Moore III D.E. (2013) The effects of housing on zoo elephant behavior: A quantitative case study of diurnal and seasonal variation. *International Journal of Comparative Psychology* 26(1): 37–52. doi:10.46867/ijcp.2013.26.01.05

Razal C.B., Bryant J., Miller L.J. (2017) Monitoring the behavioral and adrenal activity of giraffe (*Giraffa camelopardalis*) to assess welfare during seasonal housing changes. *Animal Behavior and Cognition* 4(2): 154–168. doi:10.12966/abc.03.05.2017

Rose P.E., Brereton J.E., Croft D.P. (2018) Measuring welfare in captive flamingos: Activity patterns and exhibit usage in zoo-housed birds. *Applied Animal Behaviour Science* 205: 115–125. doi:10.1016/j.applanim.2018.05.015

Ross S.R., Schapiro S.J., Hau J., Lukas K.E. (2009) Space use as an indicator of enclosure appropriateness: A novel measure of captive animal welfare. *Applied Animal Behaviour Science* 121(1): 42–50. doi:10.1016/j.applanim.2009.08.007

Ross S.R., Shender M.A. (2016) Daily travel distances of zoo-housed chimpanzees and gorillas: Implications for welfare assessments and space requirements. *Primates* 57: 395–401. doi:10.1007/s10329-016-0530-6

Sapolsky R.M. (1992) Neuroendocrinology of the stress response. *Behavioral Endocrinology* 1: 287–324.

Scott N.L., LaDue C.A. (2019) The behavioral effects of exhibit size versus complexity in African elephants: A potential solution for smaller spaces. *Zoo Biology* 38(5): 448–457. doi:10.1002/zoo.21506

Shannon C.E., Weaver W. (1949) The Mathematical Theory of Communication. Champaign,Illinois: University of Illinois Press.

Shepherdson D.J., Carlstead K.C., Wielebnowski N. (2004) Cross-institutional assessment of stress responses in zoo animals using longitudinal monitoring of faecal corticoids and behaviour. *Animal Welfare* 13(1): S105–S113. doi:10.1017/S0962728600014445

Shepherdson D., Lewis K.D., Carlstead K., Bauman J., Perrin N. (2013) Individual and environmental factors associated with stereotypic behavior and fecal glucocorticoid metabolite levels in zoo housed polar bears. *Applied Animal Behaviour Science* 147(3–4): 268–277. doi:10.1016/j.applanim.2013.01.001

Siegel S., Castellan N. (1988) *Nonparametric Statistics for the Behavioral Sciences, 2nd edition.* New York, New York: McGraw-Hill.

Swaisgood R.R., Shepherdson D.J. (2005) Scientific approaches to enrichment and stereotypies in zoo animals: What’s been done and where should we go next?. *Zoo Biology* 24(6): 499–518. doi:10.1002/zoo.20066

Vasseur E., Rushen J., Haley D.B., De Passillé A.M. (2012) Sampling cows to assess lying time for on-farm animal welfare assessment. *Journal of Dairy Science* 95(9): 4968–4977. doi:10.3168/jds.2011-5176

Vasseur E. (2017) Animal behavior and well-being symposium: Optimizing outcome measures of welfare in dairy cattle assessment. *Journal of Animal Science* 95(3): 1365–1371. doi:10.2527/jas.2016.0880

Veasey J.S., Waran N.K., Young R.J. (1996) On comparing the behaviour of zoo housed animals with wild conspecifics as a welfare indicator, using the giraffe (*Giraffa camelopardalis*) as a model. *Animal Welfare* 5(2): 139–153. doi:10.1017/S0962728600018571

Walker M., Diez-Leon M., Mason G. (2014) Animal welfare science: Recent publication trends and future research priorities. *International Journal of Comparative Psychology* 27(1): 80–100. doi:10.46867/ijcp.2014.27.01.03

Whitham J.C., Wielebnowski N. (2013) New directions for zoo animal welfare science*. Applied Animal Behaviour Science* 147(3–4): 247–260. doi:10.1016/j.applanim.2013.02.004

Wielebnowski N., Brown J.L. (2003) Applying noninvasive hormone monitoring and behavioral studies to address management issues in threatened and endangered felids. *Proceedings from the Society for Behavioral Neuroendocrinology 2003*. Cincinnati, Ohio: University of Cincinnati.

Yadav R., Mohan K., Kumar V., Sarkar M., Nitu K., Meyer H.H.D., Prakash B.S. (2013) Development and validation of a sensitive enzyme immunoassay (EIA) for blood plasma cortisol in female cattle, buffaloes, and goats. *Domestic Animal Endocrinology* 45(2): 72–78. doi:10.1016/j.domaniend.2013.05.003