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# Do Visitors Affect Zebra Behavior in Zoos?

Christine Conte
christineconte23@gmail.com

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**Christine Conte**

**University of Connecticut**

**Department of Biology**

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**Abstract**

I investigated the effects of visitors on the behavior of two zebra species (*Equus grevyi* and *Equus burchelli*) at eight zoos on the East Coast of the United States. I used instantaneous time sampling to record zebra behavior and visitor data. I used these data to run Bayesian hierarchical models and determined that visitors do not negatively affect zebra behavior. This is a positive finding for zoos, since it means that zebras, a highly skittish prey animal, are not disturbed in their exhibits. My data suggest there are behavioral differences between the zebra herds at different zoos, which may be caused by different exhibit designs, as well as different husbandry techniques.

## Introduction

As the human population increases, competition for resources increases between humans and the animal populations in the world. Humans have established zoos as places for studying and conserving animals, and as a temporary solution to the greater problem of rapidly disappearing species. Zoos provide many benefits to their visitors as well, primarily as entertainment, but also as a place of education where visitors can see animals close-up. In the meantime, zoos should ensure the highest quality of life for the animals, which involves study of their natural behaviors and habitats, as well as study of any possible detriments to their well-being caused by the zoo. Not only should zoos ensure this quality of life, if they wish to be accredited through an organization such as the Association of Zoos & Aquariums, they must meet the organization's standards of quality (Association of Zoos & Aquariums 2014). Since zoos depend on the business of visitors who naturally want to see the exotic animals housed there, it is necessary to understand how visitors affect the animals. Providing people with the experience of animals housed in a natural setting, exhibiting natural behaviors, benefits the animals and helps the educational purposes of the zoos.

Fàbregas *et al.* (2012) showed that the way the zoo enclosure reflects the natural environment affects animal behavior. Through a comprehensive study across a wide range of both zoos and species, the researchers concluded that naturalistic enclosures benefit animals, and also gain a positive response from visitors. From this study, I hypothesized that, since visitors are part of the zoo environment, they likely affect animals. Since humans are not a natural part of many animals' habitats, I thought their presence would lead to negative effects.

Studies investigating visitor effects include one on orangutans (*Pongo pygmaeus*) at the Singapore Zoo, which showed that people affected the animals' behaviors differently depending on the peoples' activity (Choo *et al.* 2011). The orangutans responded differently depending on whether the visitors had food, were looking at the animals, or were taking pictures. These effects, however, were minimal, perhaps due to the process of habituation, whereby animals become used to conditions over time. Enclosure design may have contributed to the minimal effects because the orangutans had a free-ranging exhibit, where they have platforms in the trees and are allowed to range between trees above the visitors' heads. This is a more natural orangutan habitat and allows them to move away from disturbances (Choo *et al.* 2011). Hosey and Druck (1987) studied many different primate species and showed that the animals' behaviors differed depending on the size of visitor groups and the activity levels of the groups. Choo *et al.* (2011) furthered this study by including noise disturbance, visitor activity, and distance from the animals in their study. In their introduction, Hosey and Druck (1987) referred to other studies that found increased aggression, increased abnormal behaviors such as pacing, and increased stress due to visitors. The main conclusion the researchers made was that, in general, zoo primates do not habituate to or ignore visitors. Most of the behaviors the researchers looked for, including aggressive and non-aggressive behaviors, did not change at all with different visitor numbers. Generally, the primates exhibited increased activity with active crowds, and tended to direct their activity towards active crowds. Factors such as personality traits or rearing methods may mean that individual groups of Western lowland gorillas (*Gorilla gorilla gorilla*) are affected differently (Stoinski 2012). Therefore, the variations between individual animals might be essential to the studies of animal behavior.

Fernandez *et al.* (2009) provide a comprehensive overview of studies of the interactions of humans and captive animals. Many primates in captive conditions, ranging from zoos to laboratories, are more aggressive towards other primates when in captivity and when in contact with humans (Fernandez *et al.* 2009). All primate studies discussed in Fernandez *et al.* (2009) suggested visitors negatively affected primates because social and reproductive behaviors decreased (e.g. lion-tailed macaques *Macaca silenus*; Mallapur *et al.* 2005), and aggression increased (e.g. golden-bellied mangabeys *Cercocebus galeritus chrysogaster*; Mitchell *et al.* 1991) when there were more visitors at the exhibits. One study in particular showed that when visitors were standing, the primates engaged in less natural behavior and more aggressive behavior than when visitors crouched so that only their heads were visible (Chamove et al. 1988).

Though most research has been done on primates, some has been on non-primates including a long-billed corella (*Cacatua tenuirostris*), Indian leopards (*Panthera pardus*), African pygmy goats (*Capra hircus*), and black rhinos (*Diceros bicornis*). In most of these studies, visitor interactions negatively affected the animals, causing stress, pacing, and aggression. The long-billed corella was the only species that seemed to try to attract visitors, which may indicate visitors can provide additional enrichment for some animals (Fernandez *et al.* 2009). Until natural habitats can be restored enough to return animals to the wild, zoos must find a balance between entertaining visitors and keeping animals in suitable environments. Behavioral factors are essential to this because animals cannot thrive in stressful habitats.

Because most prior studies focused on primates, I focused on zebras to further the research on visitor effects on zoo animals. I also focused on zebras because visitor effects on ungulates have not been widely studied, but ungulates are more common at zoos than top predators. Zebras are a skittish prey species and it is important to study a variety of animals to understand the range of effects visitors have on zoo animals. Studying prey animals may provide a basis for studying visitor effects because they may need to be more wary than predatory animals. For example, zebras may require larger habitats with trees or bushes to give them cover from visitors. Using this information, zoos may be able to adjust enclosures in ways that benefit both the animals and the visitors.

I studied two of the world's three zebra species: Grevy's zebra (*Equus grevyi*) and Grant's zebra (*Equus burchelli*). These species behave similarly in their feeding patterns, eating dry grass, and their general ecology, but differ primarily in their social structure (Simpson *et al.* 2012). The main behavioral difference between the two species is in their social interactions: Grevy's zebras are the only zebra species to exhibit resource-defense mating systems, where a stallion guards an area with a water hole so he can mate with the females that drink there. Grant's zebras are more similar to other zebras in that they live in harems consisting of one stallion and up to six females. The stallion may be replaced, but the mares live in stable herds with a dominance hierarchy that is primarily age-based (Pluha'c˘ek *et al.* 2005).

Both species are hindgut fermenters that receive nutrients from coarse grasses, so they must spend a large amount of time feeding. Lactating females need even more time to feed, so, in order to allow themselves uninterrupted feeding time, females associate with males for protection from bachelor males that harass the females for mating opportunities. In Grant's zebras, stallions band their harems together into herds to protect their females from bachelor herds that harass females and try to sneak copulations (Groves 1974). Even in Grevy's zebras, with their resource-defense mating system, lactating females will stay within a male's territory because he defends essential water sources. The females also need his protection so they may spend more time feeding and less time avoiding harassment from many males (Sundaresan *et al.* 2007). Therefore, when considering the effects of visitors on the behavior of animals, disturbance from visitors that detracts from feeding time may negatively affect zebra welfare.

By studying zebra populations at eight different zoos, I examined the effects of visitors on zebra behavior. Such effects may indicate stress due to high visitor numbers or noise levels. As visitor numbers increase and noise levels increase, I hypothesize zebras will be stressed. Consequently, I predict that zebras will spend less time feeding as visitor numbers increase and noise levels increase, and will therefore have poorer welfare. If the visitors disturb zebras in their feeding, then the zebras will likely spend more time in vigilant or standing behaviors than feeding. One keeper at the Maryland Zoo reported that zebras were one of the most suspicious and alert species to handle and reacted strongly to new stimuli in the environment (personal communication). Therefore, I hypothesized that the alert behavior would be one of the most indicative behaviors of stress because zebras are highly skittish prey animals. Studies in the wild show the species differ in their mating systems, but not in other aspects of their general biology, so I predicted that the two species would not differ in their behaviors. Finally, I hypothesized that taller visitors would cause more stress than shorter visitors because larger visitors would be more threatening.

In this study, I investigated how visitors affect zebra behaviors. I test whether visitors affect the animals' time feeding because this may indicate increased stress as well as affecting other aspects of the animals' lives such as reproduction. I also test whether the animals are more alert due to visitors, spent less time lying down, because these behaviors are likely to indicate stress.

## Methods

Data collection: I observed the behaviors of Grevy's zebras and Grant's zebras at eight different zoos in the northeastern United States. I observed Grevy's zebras at four zoos (Bronx Zoo, New York; Franklin Park Zoo and Southwicks Zoo, Massachusetts; National Zoo, Washington, D.C.) and Grant's zebras at four zoos (Maryland Zoo; Buffalo Zoo, New York; Roger Williams Park Zoo, Rhode Island; Cape May County Zoo, New Jersey). I collected all data between June and August, 2013.

Zebras are easily identifiable from their individual stripe patterns, so pictures and written descriptions allowed me to identify the animals consistently. I recorded behaviors for individual zebras because the effects of visitors may differ for each animal. I collected all of the data myself, allowing consistency in both identification and behavior records.

Before beginning observations, I observed the zebras at the Roger Williams Park Zoo for three days to compile an ethogram of common behaviors, and to identify those that might be affected by visitor behavior. To collect the zebra behavior and the human data, I used instantaneous time sampling. I completed seven observation periods at each zoo. Each observation period lasted approximately two hours and, during each period, I recorded individual zebra's behavior instantaneously every two minutes. In conjunction with each observation, I counted the number of visitors approximately taller than 1.5 m and the number of visitors shorter than 1.5 m. I only recorded the people who stopped to view the animals, not those who walked past. I recorded the visitor disturbance in the following categories: shouting, loud noise, quiet talking, and no sound.

Every two minutes, I recorded which activity each zebra was doing. I created mutually exclusive behavioral categories: lying, rolling, walking, running, grooming, feeding, vocalizing, standing, alert, and miscellaneous. Lying was when the zebra had folded all four legs so the animal's body was on the ground. Rolling was a separate action in which the animal laid down then turned to its back with its hooves off the ground. Walking was ambulating when one leg was moving at a time, while running was ambulating at any pace faster than a walk; all four legs had to step for a behavior to count as walking or running. Grooming was when the animal used its mouth or hoof to scratch or otherwise move fur or skin on itself or another zebra. Feeding was when the zebra was at a food source biting and chewing, or grazing on grass. Vocalizing was any noise from the zebra's mouth. Standing was the animal motionless with four legs on the ground. Alert was distinct from standing as the animal's head above its shoulder with its ears forward (after Neuhaus and Ruckstuhl 2002). I also recorded when the animal was drinking, though this did not happen often.

Miscellaneous behaviors included cases when an animal shook its head, or was not in view. I also noted rare behaviors outside the instantaneous sampling, such as something startling the animals, though this was not used in the analyses.

Data Analysis:

I conducted all the statistical analyses in RStudio 0.97.551. I ran correlation tests using the Stats, HMisc, and Rcmdr packages. For the scatter plots, I used the lattice package. To determine the species and visitor effects, I used R2WinBUGS 2.1-19 to run a Bayesian linear hierarchical model. I included the zoos and the individuals as random effect variables while I used total people and species as the test variables. I ran four models, one each for Feed, Lay, Walk, and Alert.

## Results

I completed seven observation periods, approximately two hours long, at each of the eight zoos. I varied the time of day for the observation periods, obtaining data in the morning and the afternoon. Between all eight zoos, I observed 24 zebras. Both species of zebras spent approximately half their time feeding, with the bulk of their remaining time spent being alert, lying, or walking (Fig. 1). There also appear to be behavioral differences between the zoos.

To see if the disturbance variables could be condensed, I tested whether human disturbance measures were closely correlated with each other. I found that all measures were highly correlated with each other; e.g., the total number of people is highly correlated with the number of people over 1.5 m tall ($r = 0.991$, $p < 0.001$), the number less than 1 m tall ($r = 0.9559$, $p < 0.001$), and the amount of noise ($r = 0.7144$, $p < 0.001$). Because these variables are too closely related to separate the effects, I ran the tests of visitors with behavior using only the total number of people.

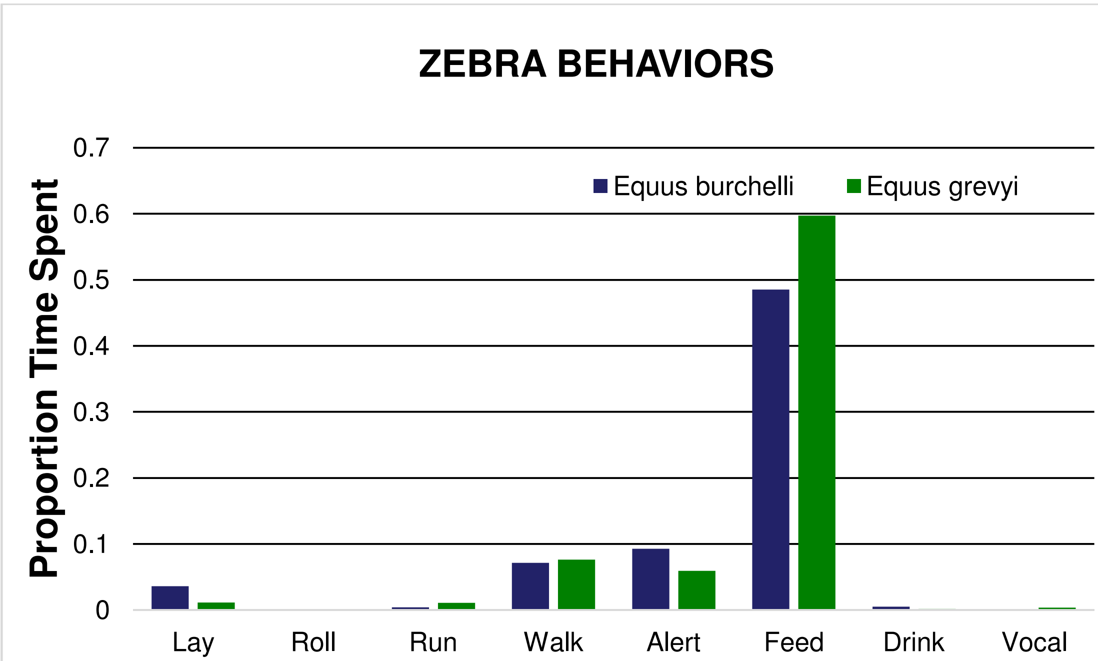



**Figure 1**: Behaviors of two zebra species studied at eight zoos in the eastern United States.

There do not appear to be extreme behavioral differences between the two zebra species (Fig. 1), but there may be differences between the zoos (Fig. 2). Walk, feed, alert, and lay are the most common behaviors among both species, which is similar to the behavioral characteristics presented in much of the literature (Grzmicek's 2003).

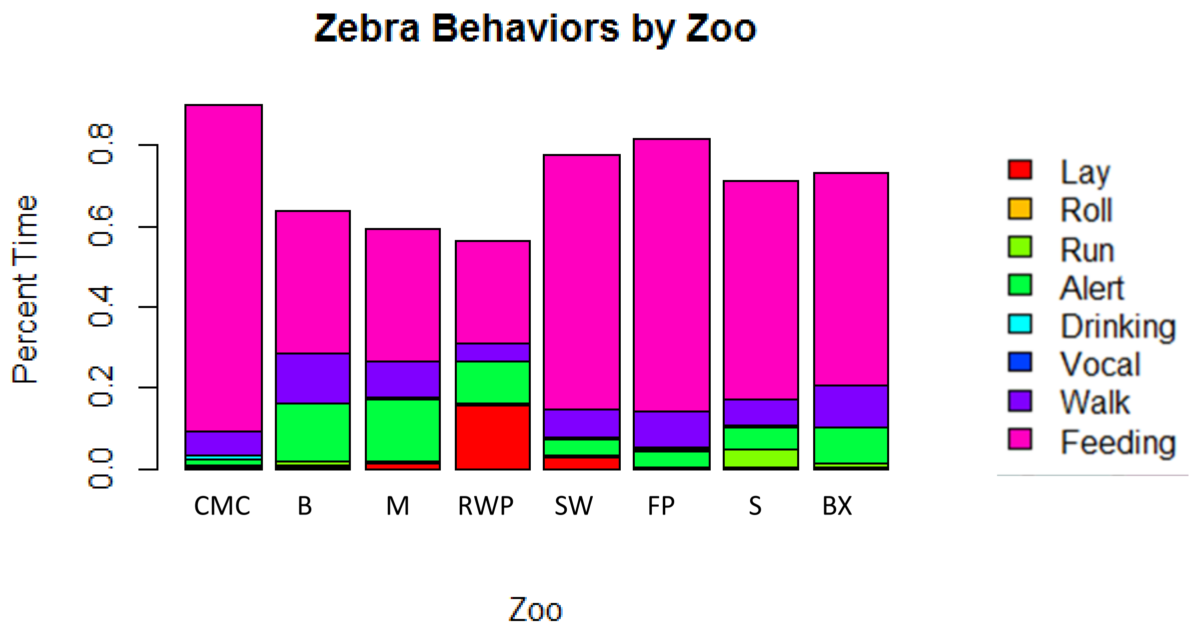



**Figure 2**: The differences between the percent time zebras at each zoo spent in every behavior. Behaviors not included are standing, grooming, and those placed in the miscellaneous category. (CMC = Cape May County, B = Buffalo, M = Maryland, RWP = Roger Williams Park, SW = Southwicks, FP = Franklin Park, S = Smithsonian, BX = Bronx)

Zebras at Cape May County Zoo spent more time feeding than any other group of zebras, while zebras at the Buffalo, Maryland, and Roger Willimas zoo spent more time alert than any others.

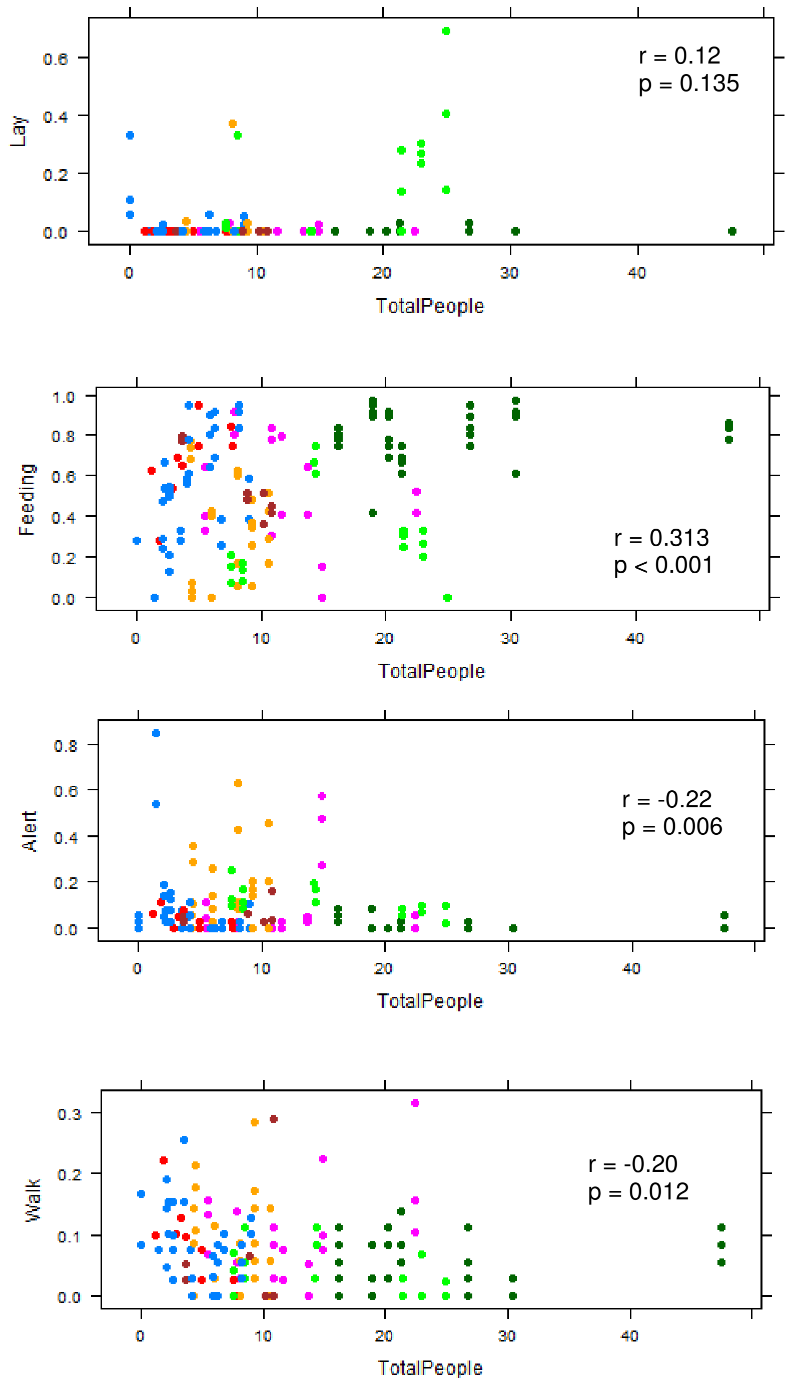
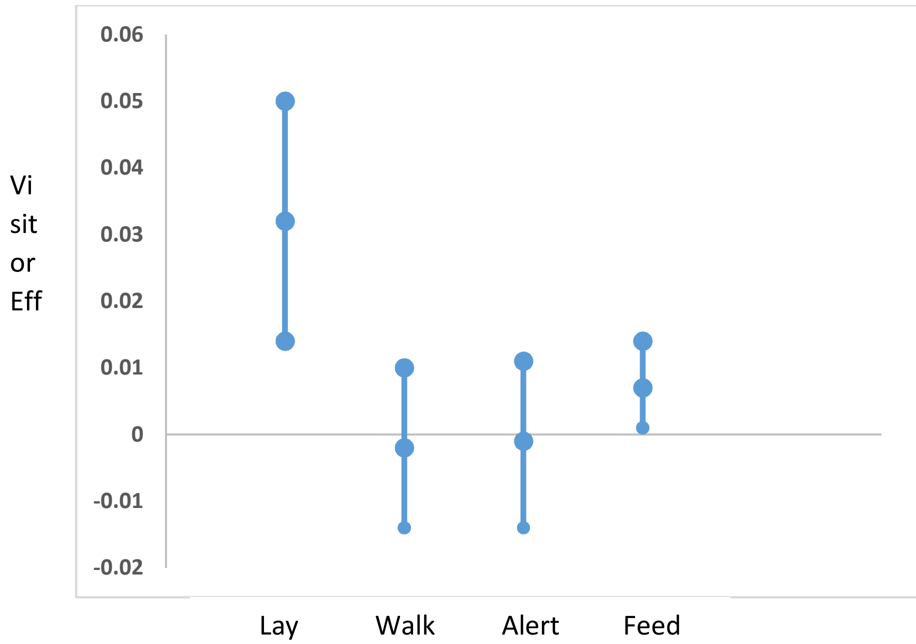



**Figure 3:** Graphs showing the correlations between the total number of people and the percent time spent in each behavior. Colors correspond to zoos: light blue = Buffalo; pink = Bronx; dark green = Cape May County; red = Franklin Park; yellow = Maryland; light green = Roger Williams Park; brown = Smithsonian; dark blue = Southwicks

I found that when there were more people at an exhibit, the amount of time zebras spent feeding increased, and the amount of time spent walking or being alert decreased (Fig. 3). The number of people did not significantly affect the amount of time zebras spent lying down. Figure 2 shows the number of people are significantly correlated with three of the behaviors (walk, alert, feed), but much of the variation in behaviors is not explained by the number of people. It appears that the Buffalo Zoo had the fewest people visiting the zebra exhibit, while the Cape May County Zoo had the highest numbers.

To determine whether the total number of people or the species affect zebras' behavior, I used a Bayesian hierarchical model to determine the general effects. I then graphed the 95% credible intervals to show the estimated effect size for each behavior. The analysis suggests the number of people present at an exhibit may affect the amount of time zebras spend lying down and feeding. In both cases, however, the effect was positive, with more time spent on these behaviors when there were more people around. The analysis also suggests the number of people at an exhibit do not affect the amount of time zebras spend walking for being alert. The analysis of species effects suggests the species of zebra does not affect the amount of time zebras spend walking, lying, feeding, or alert.

a.

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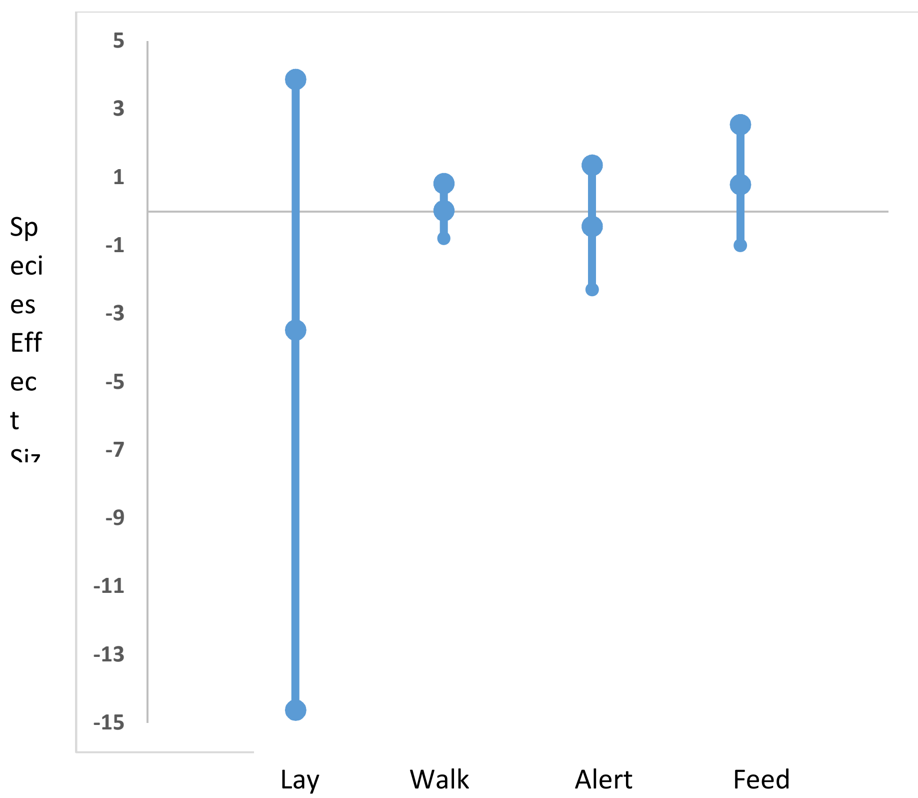


**Figure 4:** Bayesian hierarchical linear models showing the effects of total people (a) and species (b) on zebra behavior

## Discussion

From these eight zoos, I could not find support for my hypotheses. The number of taller people are too highly correlated with the total number of visitors to test the hypothesis of taller people causing more stress, and noise was too highly correlated to the number of people to distinguish the effects of the two variables. Because of these correlations, I used the total number of visitors to test the effects of visitors on zebra behavior.

I found zebras increased feeding and decreased alert and walking behaviors when there were more people. I used the Bayesian hierarchical models to determine there were no species effects. I found people do not affect alert or walking behaviors, and may have a positive effect on lying and feeding. If people have a negative effect on zebras, I would expect to see decreased feeding and lying as numbers of people increase, and to see increased walking and alert behaviors, but this was not the case. These zebras may be habituated to visitors, like the orangutans in Choo *et al.*'s study (2011), but I have no data about how long the zebras have been at each zoo. If habituation has occurred, it means zebras eventually become accustomed to humans around them, especially when those humans do not cause harm.

This research on zebras may give insight into other equine or ungulate species in zoos. Studies that add to the range of knowledge about visitor effects will allow zoos to provide for the animals, which should be an attractive aspect for visitors. Visitors to zoos appreciate when the animals appear to be active, engaged, and housed in a naturalistic environment, so it is to the zoo's benefit to provide stimuli and habitats which resemble the animals' natural habitats both to educate the public and to engage them (Fernandez *et al.* 2009). For zebras, this may involve providing natural grass in their habitats for the animals to graze. An experiment to determine if there were differences due to exhibit design would need to examine the area of the exhibit, the substrate provided (I noticed sand, gravel, and grass for the zebras), and the natural cover (such as trees and bushes). The results from a study on exhibit design could provide examples of preferred living conditions which other zoos could use as examples. Studying one prey species may give insight into how other prey species may react as opposed to predatory or omnivorous species such as primates.

This research not only shows the visitor effects on zebra behavior, but the behaviors common in captive zebras. Zebras in zoos spend most of their time feeding, and the majority of the rest of the time they spend lying, walking, and alert. As hind-gut fermenting grazing animals, zebras are expected to spend up to sixteen hours feeding throughout the day (Hack & Rubenstein 1998).

Most of the zebras in each zoo showed the same behavioral patterns, but there appear to be differences between the zoos. Investigating the effects of food types or substrate would be a beneficial study. An investigation into the differences of hay, natural grass, or a mix of grass and hay would benefit the animals' health. An investigation into substrate preference would show whether zebras fare better in a gravel exhibit or a grassy exhibit.

Different times of feeding, keepers, feeding methods, forms of enrichment, enclosure size, where the animals originated, and more can all affect animal health and welfare (Clubb & Mason 2007; Kawata 2008). I did not have the chance to determine whether the zebras in this study were hand-raised or not, but that can also affect behavior and how animals react to visitors (Meder 2004).

Further study may measure stress-induced hormones. Franceschini *et al.* (2008) analyzed glucocorticoid metabolites in Grevy's zebra feces as a non-invasive measurement of stress. That study focused on stress in zebras taken from a national park in Kenya, held in captivity for three to six weeks, and then returned to the park. The researchers found elevated glucocorticoid levels in the zebras during captivity, which decreased when returned to the park (Franceschini *et al.* 2008). Using stress hormone analyses would provide a more precise indicator of stress than behavioral observations.

A stronger test for visitor effects, in which the disturbance variables were controlled and not correlated, would allow for better assessment of visitor effects. An experiment of this sort could control for the number of visitors, the time of day the study was conducted, and the amount of noise the zebras experienced. If observations were possible with no visitors, that would provide a control to compare the visitor effects.

These findings presented in this study are positive for zoos housing zebras because visitors want to know the animals are cared for properly and are not disturbed by their presence. The discovery that visitors do not appear to have an adverse effect on these behaviors may be an attraction for visitors who worry about their impact on the animals.

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# Chapter 2: Behavior of Mexican wolves after relocation to the Beardsley Zoo


## Abstract

In this study, I investigated the effects of visitors on a pack of Mexican wolves (*Canis lupus baileyi*) newly arrived to the Beardsley Zoo from the California Wolf Center. Since the California Wolf Center has more space and fewer visitors than the zoo, I hypothesized the wolves would be more stressed at the beginning of the summer, but would gradually habituate to the new environment. I used instantaneous time sampling to record wolf behavior and visitor data every two minutes over two hour intervals, repeated five times between July 17 and August 19, 2013, to describe how the wolves' behavior changed over time.


## Introduction

The Mexican wolf (*Canis lupus baileyi*) population has been federally endangered under the U.S. Endangered Species Act since 1976 due to overhunting and habitat loss (American Society of Mammologists 2007). Since Mexican wolves were nearly extinct in the wild, few studies have been completed on wild wolves. Not much is known about their behavior, territoriality, or diets in the wild (Reed *et al.* 2006). Inferences from the other subspecies of gray wolf (*Canis lupus*) and red wolf (*Canis rufus*) can help, but until more is known about their wild behavior, scientists will have to rely on captive observations.

By capturing the five last wild Mexican wolves to create a breeding population, the numbers of individuals increased enough to reintroduce some wolves to the wild in 1997 (American Society of Mammologists 2007). These wolves have all originated from three captive wolf populations, and have been successful in maintaining genetic diversity (Hedrick & Frederickson 2008). Despite these efforts, the Mexican wolf is still listed as endangered and is one of the most endangered mammals on the continent (U.S. Fish & Wildlife Services 2013).

In order for the population to increase, federal action will be necessary, but for now, zoos are necessary to maintain the genetic population to a level necessary for the Species Survival Plan to be successful (Association of Zoos and Aquariums). Stress can negatively affect reproduction, as Dobson and Smith (2000) found in their study on reproduction in dairy cows (*Bos taurus*), and therefore it is important for the survival of the species to have calm captive animals. This is especially important for endangered animals like the Mexican wolf.

In this study, I investigated stress in a pack of three Mexican wolves at the Beardsley zoo. The three sisters came from the California Wolf Center, which has more space and fewer visitors, so the staff at the Beardsley Zoo wanted to see if the wolves habituated to their new surroundings. Besides the specifics of this case, it will be important in the study of visitor effects to understand the relationship between visitors and animals with a number of different species.

Wolves are social animals that live in packs of family members. The breeding pair of the pack are traditionally called the "alphas," meaning for this species the other wolves act submissively to these wolves. The second in the hierarchy was traditionally labelled the "beta" and the lowest the "omega." Scientists originally believed wolves had a rigid social hierarchy, defined and stable, but studies have shown wolves have a more fluid hierarchy (Mech 1999). Studies in the wild have not shown much aggression involved with maintaining pack hierarchy: it seems to be inherent that the breeding pair is dominant (Mech 1999). In captive animals, especially non-breeding packs, there can be more definite hierarchies because, without a breeding pair or familial bonds, the determination of hierarchy is less natural (Peterson *et al.* 2002).

Through this study, I expected to find that increased numbers of visitors as well as increased noise would affect the animals' behaviors. Though Mexican wolves were extirpated before many studies could be completed on them in the wild, it can be reasoned from the behavior of other wolf populations that Mexican wolves need large territories (Reed *et al.* 2006). I expected that the transition from the larger space of the California Wolf Center to the smaller enclosure at the Beardsley Zoo would mean the visitors have more negative effects on the wolves. Consequently, I predicted that increased numbers of visitors and increased noise would cause the wolves to spend less time lying and more time alert, walking, and trotting. I also predicted that, over time, the animals would habituate and spend less time in alert and active behaviors.

## Methods

When I began observations at Beardsley, I identified the individual wolves by the zookeepers' descriptions of the alpha, beta, and omega, along with provided photos. These names were the keepers' terms, and I did not use any methods to confirm the dominance relationships. I did observe the omega bringing food to the alpha, and I observed what Mech (1999) called "licking up" submissive behavior where the omega crouched under the alpha and touched her tongue to the alpha's mouth.

I studied the wolves from inside the wolf cabin of the zoo, where visitors can view both the Mexican and red wolves in their adjacent enclosures from behind glass walls. The wolves were housed in a fenced enclosure with access to a back holding and to a den under the building. Halfway through my observations the zoo installed cameras in that den; until that point I could not determine behaviors when the animals were in the den.

<u>Experimental Design:</u>

Before beginning observations, I spent two days compiling an ethogram of common behaviors, and to identify those that might be affected by visitor behavior. I completed five days of observations from July 17 to August 19, 2013. I observed for two observation periods of two hours per day. One observation period took place in the morning and the other in the afternoon while the zoo was open.

I used instantaneous time sampling every two minutes to record which activity each wolf was doing. I created mutually exclusive behavioral categories: lying, sitting, walking, trotting, running, grooming, feeding, vocalizing, standing, alert, and miscellaneous. Lying was the wolf's body being on the ground with all four legs folded. Sitting was the animal's back legs folded with its front legs holding up its torso. Walking was ambulating when one leg was moving at a time; trot was ambulating with longer, bounding strides; run was the fastest pace when all paws leave the ground. Grooming was when the animal used its paw to scratch itself. Feeding was when the wolf was at a food source biting and chewing. Vocalizing was any noise from the wolf's mouth. Standing was the animal motionless with four legs on the ground. Alert was distinct from standing as a posture with the head up and ears pricked forward. I also recorded when the animal was drinking, though this did not happen often.

Miscellaneous behaviors included cases when an animal shook its head, or was not in view. I also noted rare behaviors outside the instantaneous sampling, such as something startling the animals, though this was not used in the analyses.

<u>Data Analysis:</u>

I conducted all the statistical analyses in RStudio 0.97.551. I ran correlation tests using the Stats, HMisc, and Rcmdr packages. For the scatter plots, I used the lattice package to show the differences in behaviors over time.

**Results**

I used the proportion of time for the behaviors across all the observation periods to show the typical behaviors of these wolves, as well as the differences between them.

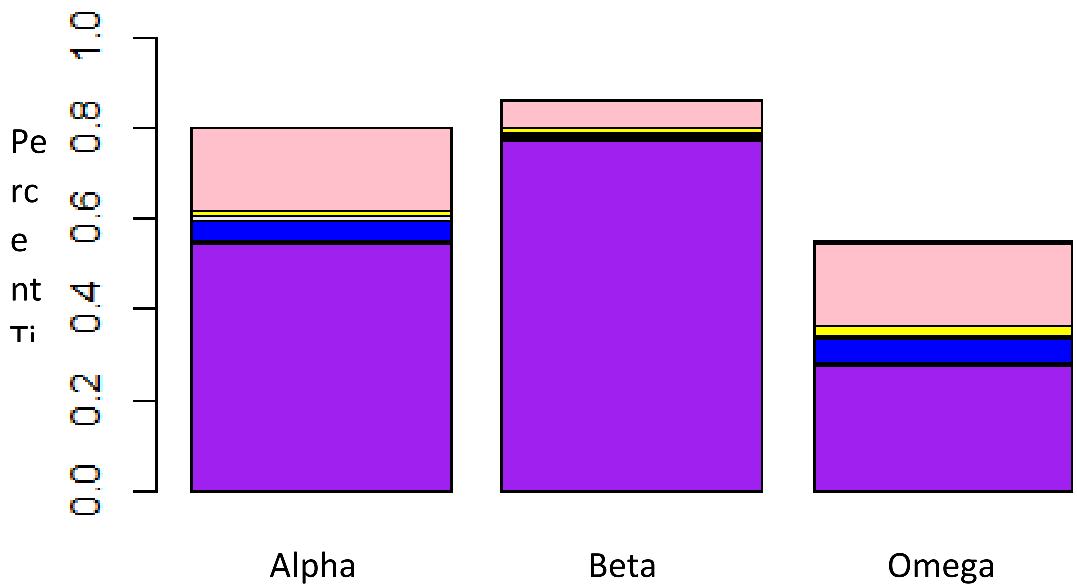
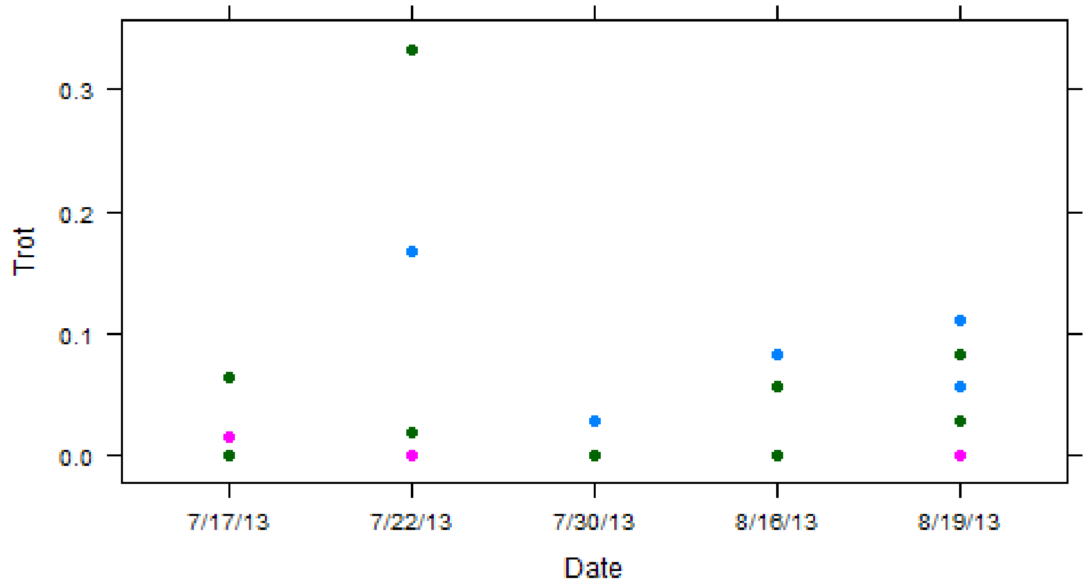
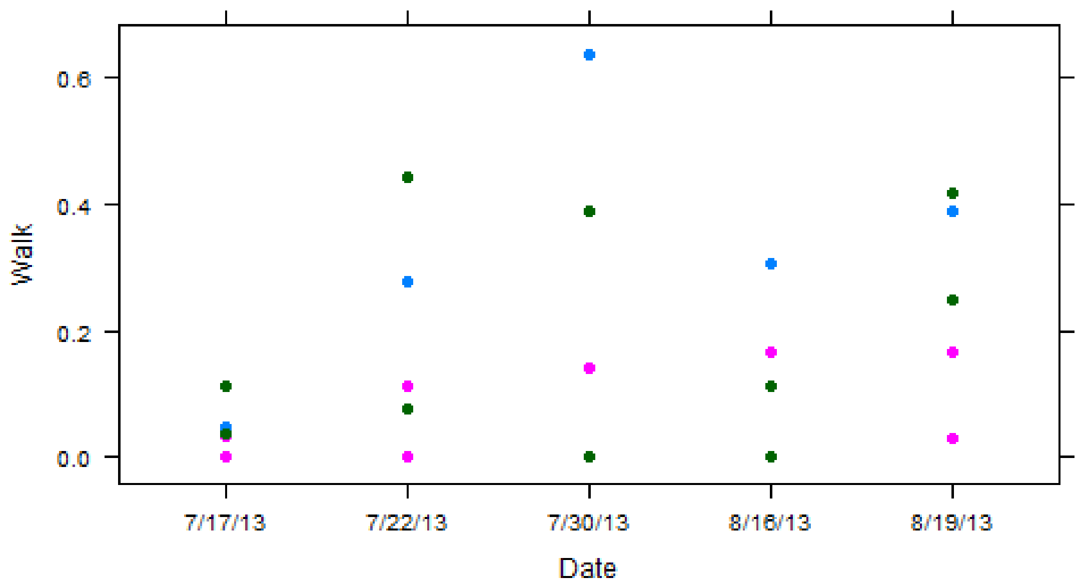



**Figure 1:** An overview of the percent time the wolves spent in the four key behaviors (trot = blue; walk = pink; lay = purple, alert = yellow).

The Beardsley Zoo wolves spent most of their time lying down and walking, and much less time in other behaviors. There appear to be behavioral differences between the three wolves.


Trot
0.3
0.2
0.1
0.0
7/17/13
7/22/13
7/30/13
8/16/13
8/19/13
Date


Walk
0.6
0.4
0.2
0.0
7/17/13
7/22/13
7/30/13
8/16/13
8/19/13
Date

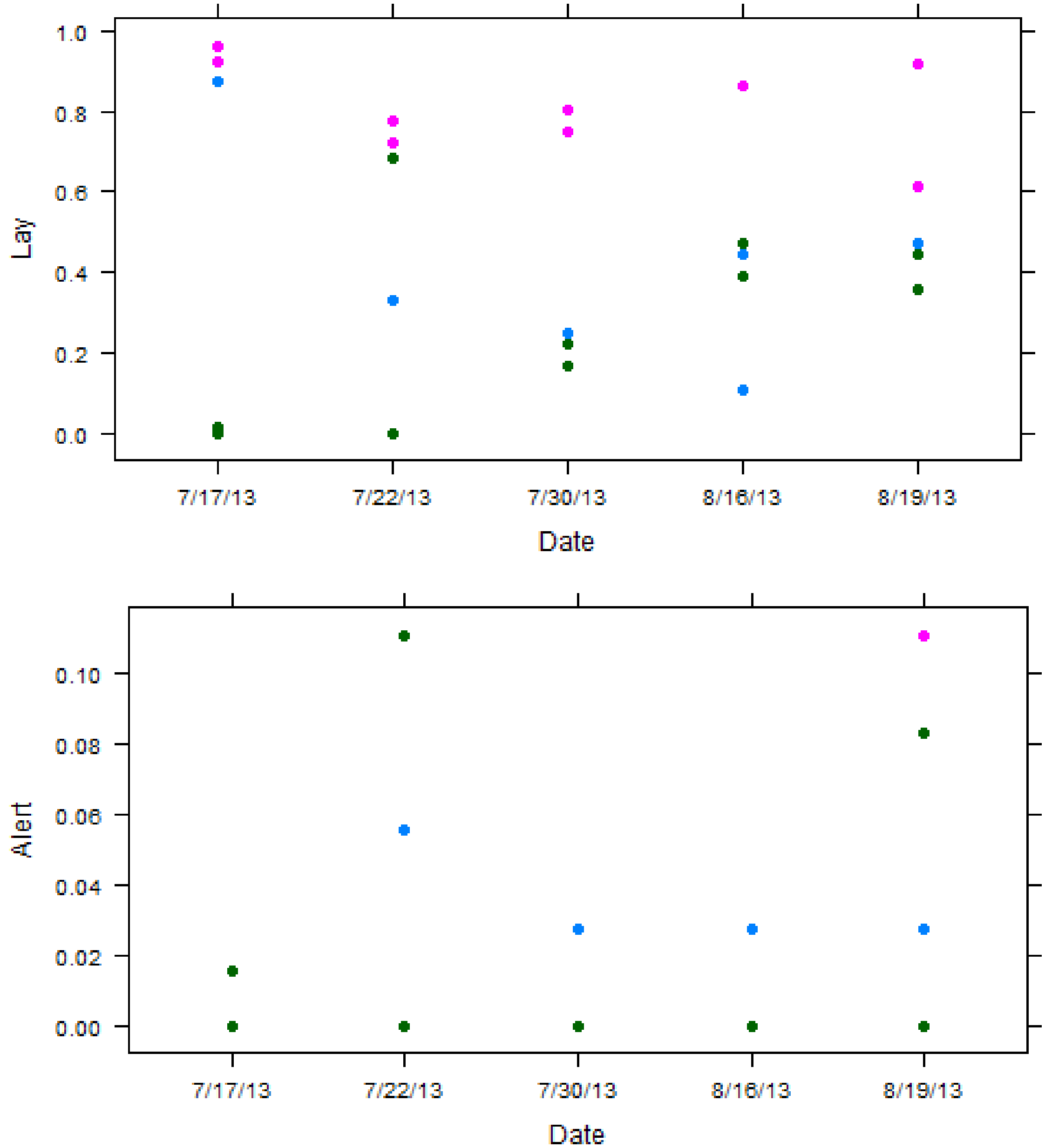



**Figure 2:** Analyses of the proportions of time each wolf spent in each behavior on each day of observations. The colors correspond to the wolf rankings (blue=alpha, pink=beta, green=omega).

The amount of time spent walking seems to have increased over the course of the summer in the beta and decreased in the omega. Similarly, the amount of time spent lying down seems to have increased in the omega. There was no sign of any change in the amount of time spent trotting or being alert, although the latter behavior was infrequent.

## Discussion

Studies on stress in these animals will allow for better breeding conditions to increase captive populations. However, captive populations are not sufficient. Wolves are apex predators that roam large territories to hunt prey, so if we are to recover their populations, humans must focus on the restoration of wolves to their natural habitats. This means, while endangered animals are housed in zoos, there needs to be a conscious effort by policy makers and scientists to reintroduce the Mexican wolf to its natural habitat.

The amount of data I collected from the Beardsley Zoo wolves is insufficient to extrapolate to other wolves. To answer the specific question of whether these wolves, coming from a larger, more open enclosure to a small exhibit with more people, the data suggest these wolves slightly habituated to their environment. The increased time the omega spent lying down shows a change in behavior from the beginning of the summer when she walked more. Unfortunately, I do not have data on their behaviors while at the California Wolf Center, so I cannot compare the behaviors I saw to their original behaviors. The collection of data at the original enclosure would give observers a comparison for analyses in future relocation studies.

Given the limitations of this data set, it is useful to consider how best one could determine if wolves are stressed by moves between zoos. Predators that usually have large territories are of concern to many zoo visitors, and it would be interesting to see if they are stressed in these conditions. Clubb and Mason (2007) found that animals with large home ranges have greater difficulty breeding successfully in zoos, and that these species tend to have high infant mortality rates in captivity.

Rather than simply looking at behavioral cues, studies could be done to focus on the hormonal indicators of stress, such as the study of Mexican wolves by Pifarré *et al.* (2012), which showed that higher numbers of visitors correspond with higher levels of fecal cortisol, as well as behavioral changes. A study of this sort could use behavioral observations and link those observations to the presence of cortisol in feces. This is a non-invasive measure of animal stress that shows the links between stress and behavior.

As the wolves in this study became more accustomed to their surroundings, Heilhecken *et al.* found wild wolves seem to become more habituated to people as they return to their original habitats. This not only indicates wolves' increasing tolerance of humans, but humans' increasing tolerance of wolves (Heilhecken *et al.* 2007). In zoos and the wild, wolves become used to humans' presence, especially when these humans pose no threat.

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