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Seasonal and Diurnal Variations in African Elephant (*Loxodonta africana*) and Black Rhinoceros (*Diceros bicornis*) Behavior in a Northern Climate Zoo

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African elephants (*Loxodonta africana*) and black rhinoceroses (*Diceros bicornis*) are charismatic mammals that help draw visitors into zoological institutions. Because they evolved in the same habitat utilizing similar food resources, the two species have many physiological similarities yet behaviorally remain very different. Limitations of the zoo environment, such as constraints on exhibit size, social complexity, and behavior, may be associated with health and behavioral problems seen in both species and thought to be exacerbated in northern, temperate climates. The purpose of this study was to determine how the behavioral patterns of two large-bodied African ungulate species were affected by seasonal changes in a northern climate zoo. The behavior of three African elephants and three black rhinoceroses was observed for one year at Cleveland Metroparks Zoo. We found average resting levels of African elephants and black rhinos were similar to expected values based on data from wild and captive studies. Both species adapted their behavior to cope with high temperatures and increased sun exposure. Increased time spent inside during winter months was associated with decreased investigatory behaviors in elephants and decreased locomotion in rhinos. To increase species-typical behaviors, exhibits should include substrates for dusting, mud wallows, shade structures, and resting sites for all individuals. Time spent feeding may be increased through natural food items such as browse. Indoor exhibits should include environmental variation, enrichment, and adequate space so as to encourage these behaviors. Physiological and health measurements might be measured to determine sufficient levels of exercise for zoo-housed elephants and rhinos.

African elephants (*Loxodonta africana*) and black rhinoceroses (*Diceros bicornis*) are key species in American zoos: both are recognizable mammals that help draw visitors into

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zoological institutions. Because they evolved in the same habitat using the same food resources, the two species have many physiological similarities including large bodies, a prehensile appendage for browsing, and armaments possessed by both males and females (Archie, Morrison, Foley, Moss, & Alberts, 2006; Estes, 1991). Despite this, African elephants and black rhinos are behaviorally very different. Elephants are active, moving and foraging for up to 20 hours per day; they are highly social and live in matriarchal groups consisting of related females and offspring (Estes, 1991; Kioko, Zink, Sawdy, & Kiffner, 2013; Shannon, Page, Mackey, Duffy, & Slotow, 2008; Sukumar, 2003; Vidya & Sukumar, 2005). Rhinos can spend up to half the day sleeping and wallowing, and as adults are solitary (Hutchins & Kreger, 2006; Tatman, Stevens-Wood, & Smith, 2000).

These similarities and differences are fundamental variables in determining how best to manage each of these species in captivity, where both elephants and rhinos are faced with similar challenges. Captive enclosures cannot replicate the size and environmental diversity of the African savannah (Mench & Kreger, 1996; Veasey, 2006), resulting in decreased space and sensory stimulation. Natural diets of browse are replaced for the most part with hay and concentrated pellets, reducing the need and ability to forage (Hutchins & Kreger, 2006; Stoinski, Daniel, & Maple, 2000; Wiedenmayer, 1998). Animals are often housed in unnatural social groupings: elephants are generally kept in small unrelated groups that may never interact with calves, males, or other groups of females (Dow, Holaskova, & Brown, 2011; Hutchins, 2006; Schulte, 2000) and rhinos may be housed with other adult rhinos, both male and female (Hutchins & Kreger, 2006). Unnatural physical and social environments may be associated with the health and behavioral problems seen in both species, such as obesity, low reproduction rates, calf mortality, stress, and stereotypy (Carlstead, Fraser, Bennett, & Kleiman, 1999; Hutchins, 2006; Price & Stoinski, 2007; Veasey, 2006).

An additional management parameter that has sparked debate within the zoo community is climate, specifically whether northern U.S. zoos can successfully maintain these African species. The colder winter and unpredictable autumn and spring seasons in the northern U.S. often result in housing elephants and rhinos indoors for longer periods of time. Indoor enclosures are often smaller and less environmentally diverse than outdoor enclosures, leading to speculation that increased indoor housing results in boredom, lethargy, or abnormal behaviors (Hutchins, 2006; Veasey, 2006). Although some research has investigated influences on elephant activity levels in southern U.S. zoos (Leighty, Soltis, Wesolek, Savage, Mellen, & Lehnhardt, 2009; Miller, Andrews, & Anderson, 2012), little or no research is available documenting seasonal behavioral patterns in elephants and rhinos housed in northern zoos.

All species have the ability to adapt their behavior to changes in environmental or social surroundings, and the degree to which an animal adapts to the conditions of captivity depends upon its species natural behavior and its individual history and experiences (Carlstead et al., 1999; Freeman, Schulte, & Brown, 2010a, 2010b; Mason & Mendl, 1993; Mason & Veasy, 2010). Successfully housing an animal in captivity is reliant upon an understanding of both its natural behavior and the degree to which that behavior can be altered without affecting psychological or physical health (Veasey, 2006). The purpose of this study was to characterize the behavior of two large-bodied African ungulate species in a northern zoo setting and examine seasonal and diurnal variations in solitary and social behavioral patterns for each species.

Method

Subjects

Subjects included three unrelated female African savannah elephants (*Loxodonta africana*), and one male and two female eastern black rhinoceroses (*D.b. michaeli*) housed at Cleveland Metroparks Zoo (see Table 1). All subjects could be easily visually identified. Both species were handled under a protected contact system which included daily training sessions and daily or semi-daily presentation of enrichment (logs, branches, scrub brush, ball, browse, etc.). Hay and fresh water were available to the animals throughout the day.

Table 1
African Elephants and Black Rhinoceroses at Cleveland Metroparks Zoo

	Name	Sex	Weight (kg)*	Year Born	Birth	Captivity	To CMZ
Elephants:	Jo	F	3996	1967	Wild	1969	1997
	Moshi	F	3864	1976	Wild	1978	1997
	Tika	F	3752	1985	Wild	1983	1997
Rhinos:	Jimma	M	1313	1990	Captivity	n/a	2005
	Inge	F	1236	1993	Wild	1997	1997
	Kibibbi	F	1080	2003	Captivity	n/a	2003

*Elephant weights as of 28 Oct 2007; rhino weights as of 6 Nov 2007

Housing

Both species were housed in exhibits consisting of indoor and outdoor enclosures. Subjects were observed in the indoor enclosures only during inclement weather and/or when kept inside due to low temperatures. When the animals were housed inside and ambient temperatures allowed, the doors of the enclosures remained open to allow for air circulation. When outdoors, animals were occasionally provided access to indoor areas depending on the temperature, weather, and time of day. Decisions to provide access or not were made by animal management staff on a daily basis. When temperatures dropped below approximately 10°C the enclosure doors were closed and the buildings were maintained at 18-21°C.

Elephants. The elephants were housed in the CMZ Pachyderm Building and adjacent outdoor enclosure (see Appendix A). The indoor enclosure consisted of two stalls (each 78 m^2) and a bathing/holding area (19 m^2) with concrete substrates. When housed inside, two elephants (Martika and Jo) were held in one stall and one elephant (Moshi) in the remaining stall; the shift door between the two stalls was kept slightly ajar to permit tactile interaction between all individuals. This arrangement was made to minimize the potential for social conflict between two elephants (Jo and Moshi) who were largely incompatible indoors. The ceiling contained multiple skylights and artificial lighting was only used when needed by the keepers. Zoo visitors could enter the Pachyderm Building to view the elephants but remained at a minimum distance of approximately 2 m. The outdoor enclosure was approximately 1416 m^2 with level ground composed of various substrates, and included a pool, mud wallow, rock for scratching, and multiple trees protected with fencing. The enclosure perimeter not adjacent to the Pachyderm Building (70% of the total perimeter) was surrounded by a moat, followed by a landscaped grass area and fence. The public had access to the entire fence line, at a distance of approximately 3 m from the elephants.

Rhinos. The rhinos were housed in an indoor barn with two adjacent outdoor yards (see Appendix B). The indoor enclosure contained five adjacent stalls (each 30 m^2) with concrete substrates. When housed inside the rhinos were given access to more than one stall and the male was separated from the females to minimize the potential for social conflict. The stall walls consisted of four horizontal metal bars that allowed for visual, olfactory, auditory, and some tactile contact between separated individuals. The ceiling contained multiple skylights and artificial lighting was only used when needed by the keepers. Zoo visitors could not enter the rhino barn but instead utilized a large viewing window at the front of the barn above the animals' level. The front outdoor enclosure was approximately 2160 m^2 and consisted of both level and sloped areas composed of various substrates, and included a pool, mud wallow, and multiple logs and wooden scratching posts. Two viewing platforms were available for zoo visitors, both directly above the animals' level; these platforms accounted for approximately 17% of the exhibit perimeter. The remaining perimeter consisted of either tall vertical wooden plank fencing, rock walls, or short post fencing with a top rail and bottom wire backed by thick shrubs. The back outdoor enclosure was approximately 500 m^2 and was separated from the front enclosure with a vertical plank fence that provided auditory and olfactory contact between enclosures but not visual or tactile contact. The rear wall was composed of vertical plank fencing and was directly adjacent to a service road used by zoo employees, visitors, and maintenance vehicles. When outdoors, the female rhinos were only housed and thus observed in the front yard; the male rhino was housed and thus observed in both the front and back yards.

Data Collection and Analysis

Animals were observed from the public viewing areas of their exhibits. Data on behavior and social proximity were collected using 20-minute continuous focal animal observations, allowing for frequency, rate, and bout lengths to be accurately calculated (Crockett, 1996; Lehner, 1996). Ethograms were exhaustive and mutually exclusive (see Appendices). Data were recorded on the HP® iPAQ pocket PC h2215 using Pocket Observer® 2.0 software (Noldus Information Technology, Inc, Wageningen, The Netherlands). Each subject was observed once per day, three days per week between 0900 and 1700 hours. Observations were balanced between AM (900-1259) and PM (1300-1700) hours. The order in which individuals were observed was randomized to eliminate observer bias (Altmann, 1974). Independent variables noted before each observation included enrichment presence [yes, no], ambient temperature [degrees C], and weather conditions [sun, clouds, overcast, rain, snow]. Data were collected on the elephants from September 2005 through January 2007 for a total of 201 hrs; data were collected on the rhinos from June 2006 through July 2007 for a total of 156 hrs.

Data were summarized using Noldus Observer® 5.0 (Noldus Information Technology, Inc, Wageningen, The Netherlands) and Microsoft® Excel XP software (Microsoft Corporation, Redmond, WA). Due to the very small sample sizes, results are presented using descriptive statistics with significance determined based on overlap of respective standard errors of the mean (Crockett, 1996; Kuhar, 2006). Activity budgets were calculated by averaging the monthly rate (min/hr) individuals spent exhibiting each behavior and averaging those values for within each species. Rhino data were also summarized to compare adults vs. juvenile and male vs. females. Only observations in which subjects were housed socially were included in analysis of social behavior. Seasonal changes were calculated by averaging species values for months within each season: Spring (March, April, May), Summer (June, July, August), Fall (September, October, November), and Winter (December, January, February); all other results include data from all months. Results are presented as average time displaying behavior (min/hr); bout lengths (time of one behavioral stint) are presented as average time (s). All results are mean±SEM unless otherwise noted. The following variables were compared between species: enclosure (inside vs. outside); time of day; ambient temperature; weather; season.

Results

To compare overall activity, behaviors were characterized as eitherinactive (Rest) or active (all other visible behaviors). The elephants were more active than the rhinos, averaging 52.92±1.01 minutes of activity per hour (Figure 1). The rhinos had similar values for average time spent active (29.01±5.14 min/hr) and inactive (29.59±4.89 min/hr). Time spent not visible averaged 0.19±0.22 min/hr with no species difference.

Species did differ in performance of specific active behaviors (Figure 2). Rhinos spent less time eating and more time locomoting, and also had longer bouts of locomotion than elephants (bout lengths averaged 24.08±4.96 s for rhinos vs. 11.84±0.82 s for elephants). Elephants spent a larger amount of time displaying environment-oriented behaviors (including Object Rub, Bathe/Wallow, Dust, Dig, and Investigation [object and enrichment]).

Diurnal Variation in Behavior

Few behaviors varied throughout the day. In both species, time spent eating rose slightly at 1000 and 1300 hrs, which corresponded to approximate feeding times. Rhinos had a peak in resting at 1300 hrs, with near-mirrored values both before and after that time (Figure 3). Elephants showed virtually no change in their resting behavior until late afternoon, and the following rise was comparatively small. Rhinos also showed hourly trends in locomotion and object rub that ran opposite to their resting pattern (with the lowest values at 1300 hrs), but the changes were smaller and not likely meaningful.

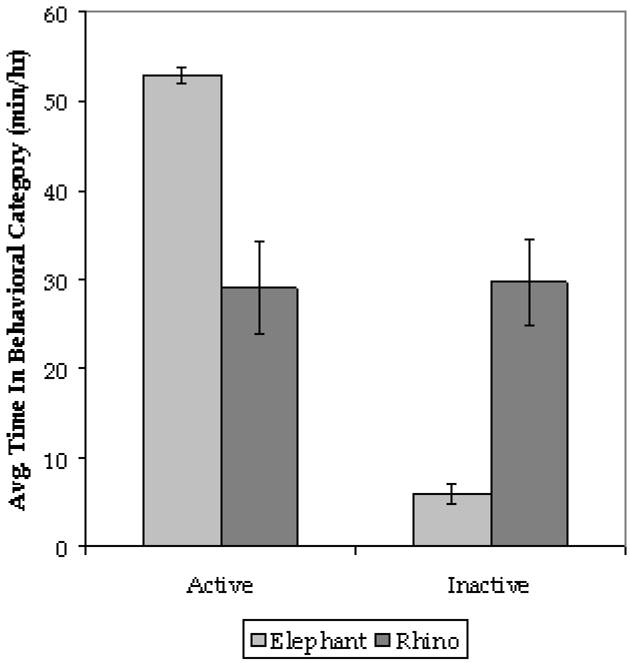

Figure 1. Mean time (min/hr) elephants (*N* = 3 elephants, 201 hrs observation) and rhinos (*n* = 3 rhinos, 156 hrs observation) engaged in active vs. inactive behaviors.

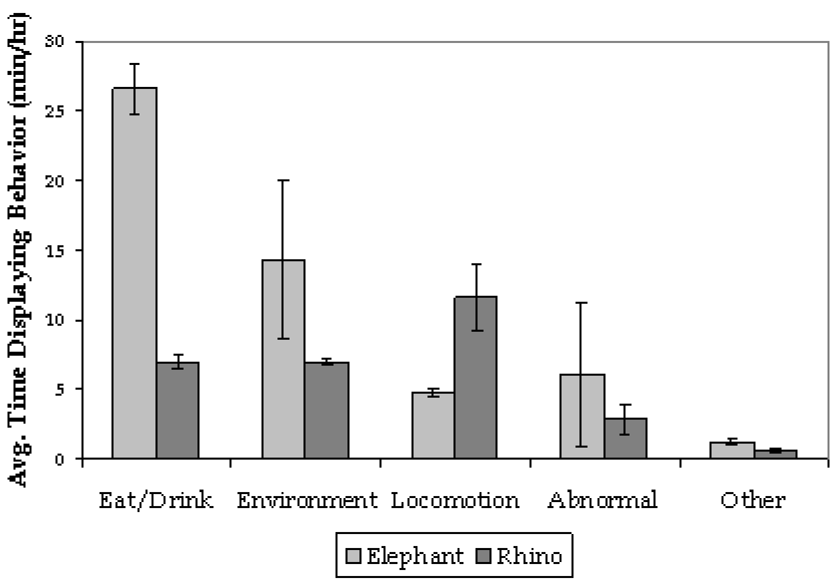

Figure 2. Mean time (min/hr) elephants and rhinos spent engaging in various active behaviors.

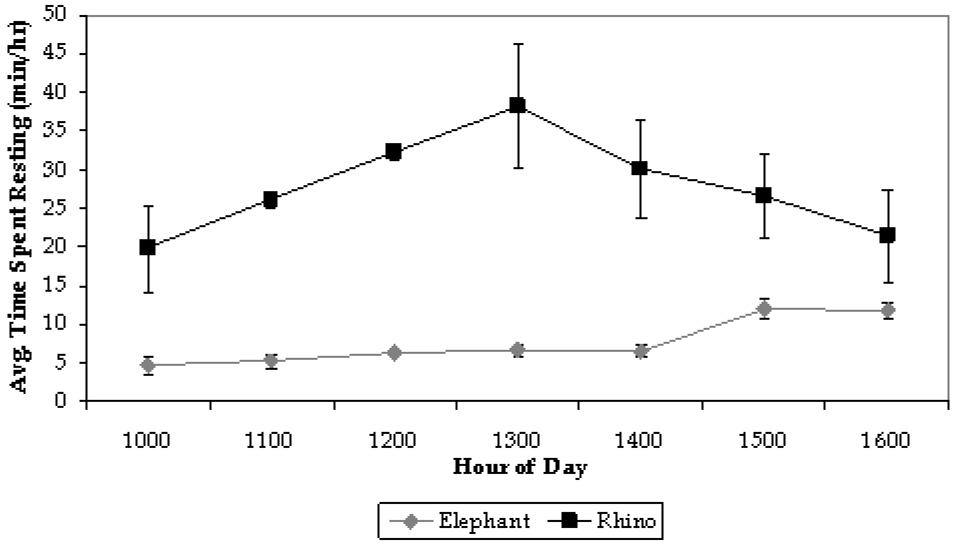

Figure 3. Diurnal fluctuations in mean time (min/hr) elephants and rhinos spent resting.

Seasonal Variation in Behavior

Seasonal changes in behavior also differed between species. In elephants, average time spent locomoting fluctuated less than four minutes per hour throughout the six seasons they were observed. In rhinos, this behavior was much more variable, with higher levels in the fall and lower levels in the winter and spring (Figure 4). Rhinos showed no other seasonal differences in behavior. In the elephants, investigation (object and enrichment) was lowest during the winter and most variable during winter and spring. Environment-oriented behaviors (rub, dig, dust, wallow) were highest in the spring and summer and lower in fall and winter (Figure 5).

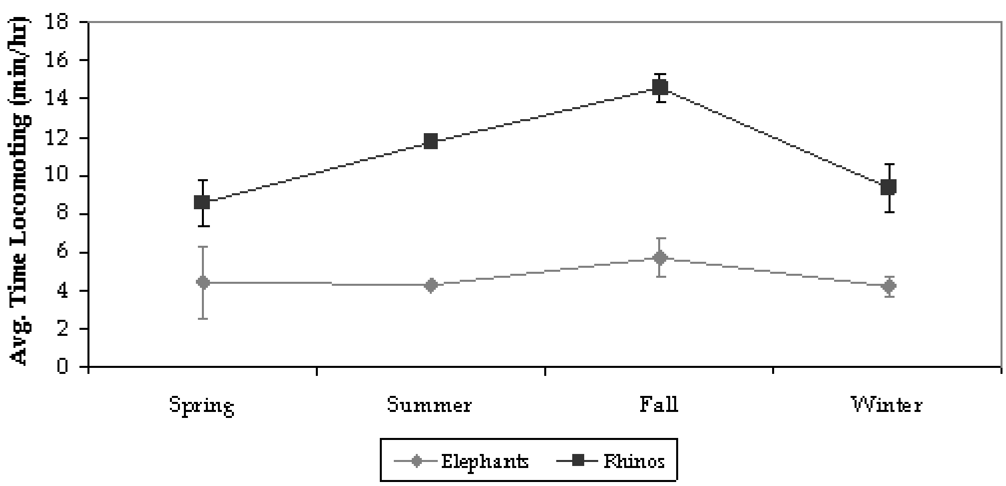

Figure 4. Seasonal differences in locomotor behavior in elephants and rhinos.

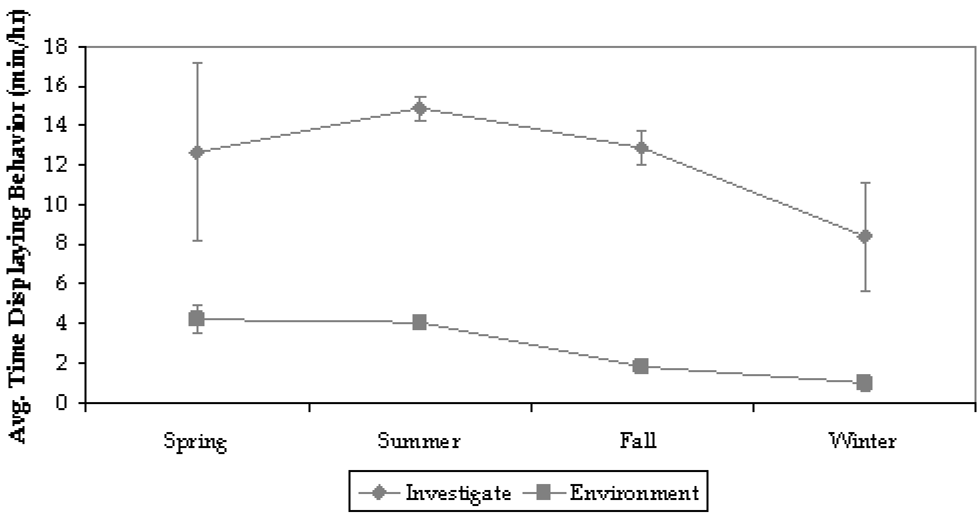

Figure 5. Mean time (min/hr) elephants spent investigating objects and attending to environment through rubbing, digging, dusting, and wallowing.

Temperature and Weather Trends

The only behavior correlated to ambient temperature in elephants was dusting. From 0-30°C there was a linear rise in dusting behavior ($y = 0.1451x - 1.295$, $R^2 = 0.962$) that increased exponentially once temperatures exceeded 30°C (Figure 6). Rhinos increased resting behavior with increasing temperatures, which was not seen in the elephants (Figure 7).

Effects of weather condition, independent of temperature, on behavior were also examined. Each species showed the following trends in activity: with increasing amounts of sun, the elephants decreased object investigation and rhinos increased rest, bathe/wallow, and dig.

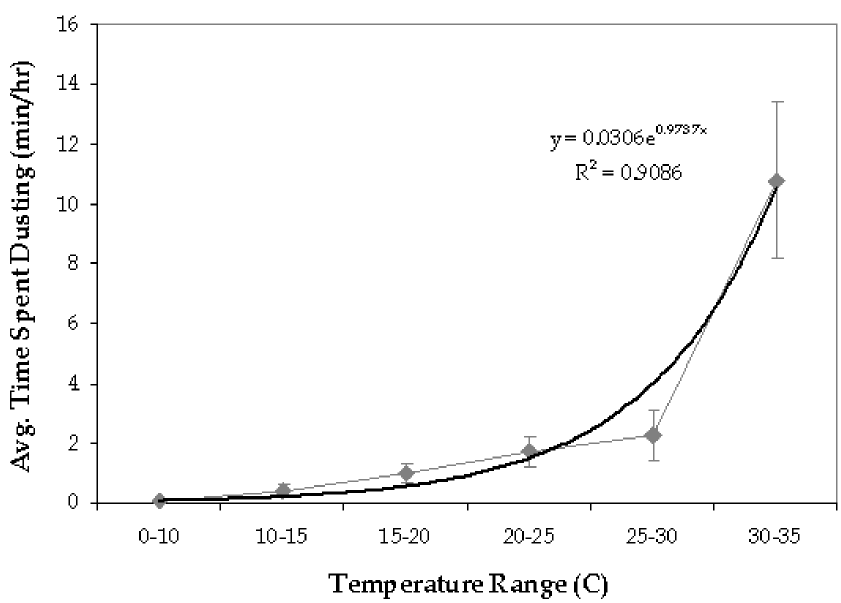

Figure 6. Relationship between ambient temperature (ºC) and dusting behaviors in elephants.

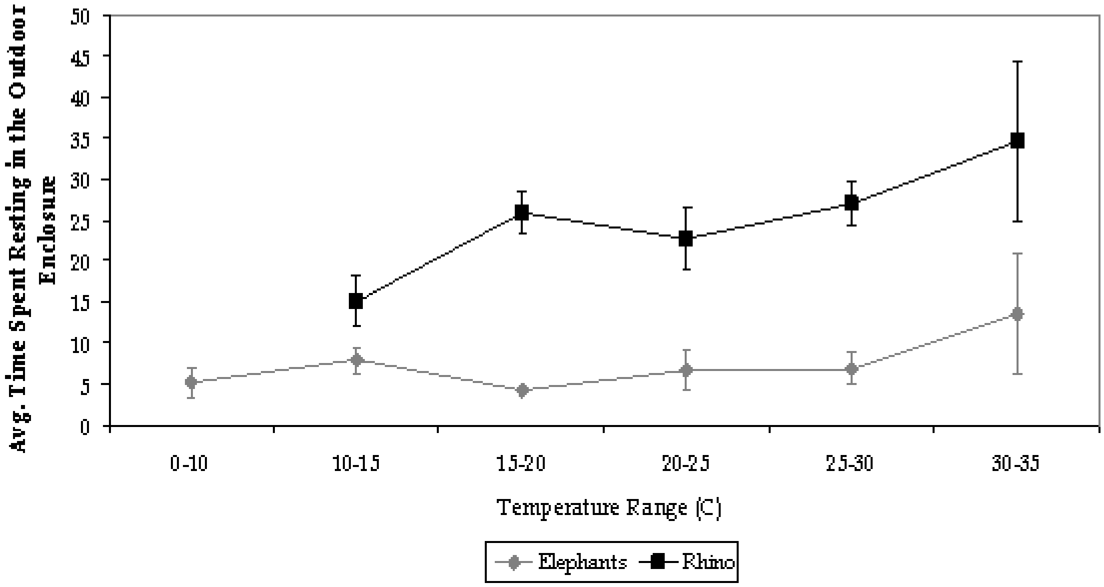

Figure 7. Relationship between ambient temperature (ºC) and resting behavior on both elephants and rhinos.

Social Proximity and Social Behavior

Proximity data include only outdoor observations (to ensure no forced proximity) and do not include the male rhino, who was housed alone. Both species were distant (more than one body length) from conspecifics more often than proximate (within one body length, Figure 8). Moreover, both species spent a similar amount of time distant to conspecifics. Elephants were within a body length of a conspecific more often than rhinos and averaged longer proximity bout lengths. Average time spent in proximity did not change with time of day, temperature, weather, or season for either species.

Elephants did not differ in time spent exhibiting social behavior between enclosures (inside: 0.87±0.19, outside: 0.64±0.12 min/hr, Figure 9). The female rhinos had a larger variation, with more total social behavior inside (1.59±0.25 min/hr) than outside (0.37±0.02 min/hr). The rhinos displayed very few agonistic and other social behaviors outside.

In the elephants total social behavior was greater during PM hours (0.94±0.04 vs. 0.43±0.01 min/hr AM), with large increases in affiliative and other interactions (Figure 10). The rhinos also had higher levels of social behavior during PM hours (1.87±0.30 vs. 0.98±0.39 min/hr AM), with the largest increase in other behavior. No trends in social behavior in either species were evident in relation to season, temperature, or weather.

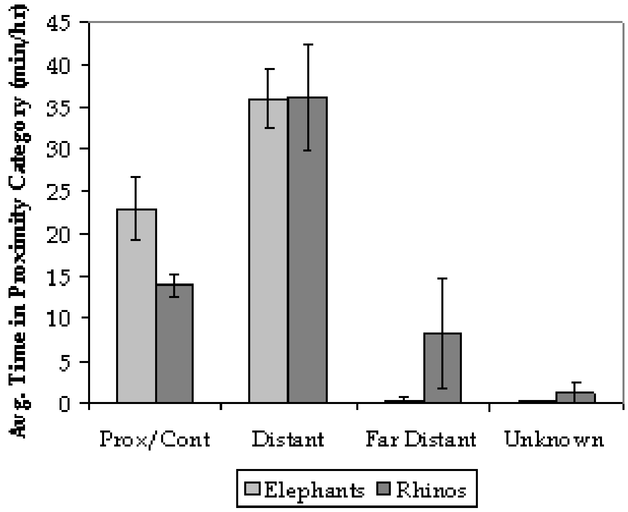

Figure 8. Average time (min/hr) elephants and rhinos spent in defined proximity categories.

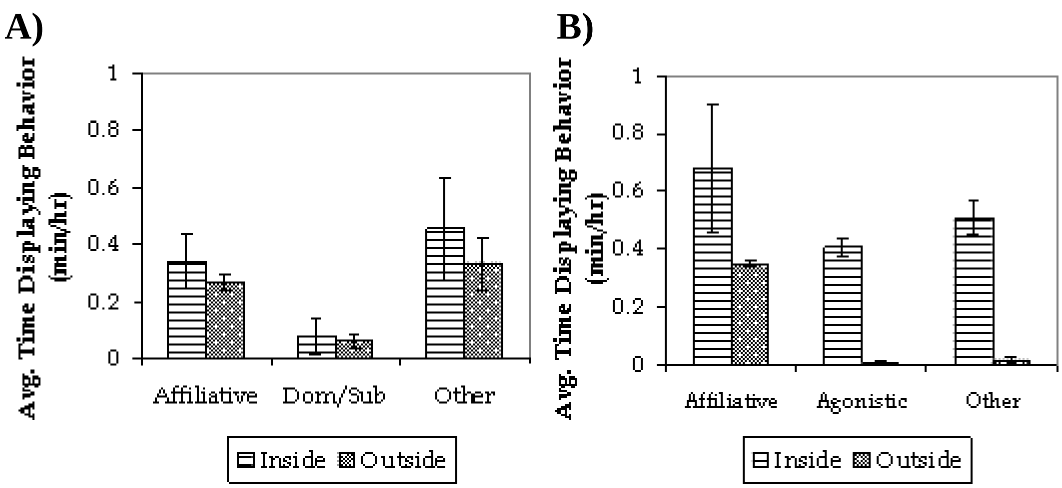

Figure 9. Affiliative, Dominant/Submissive, Agonistic, and Other social behavior observed indoors vs. outdoors in **A)** elephants and **B)** rhinos.

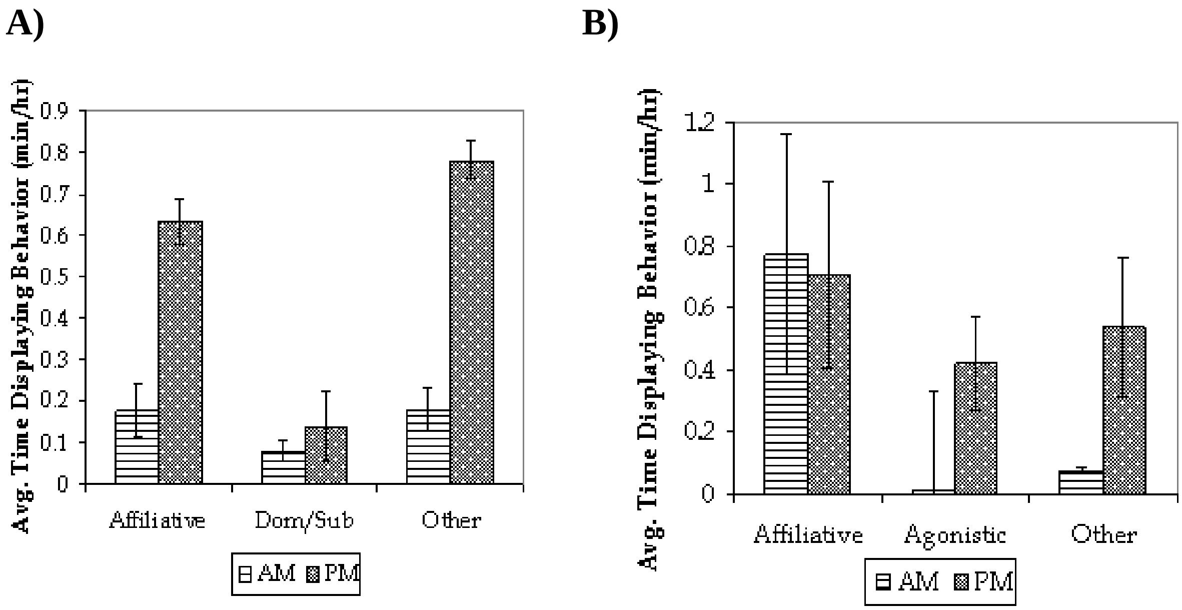

Figure 10. Social behavior observed AM hours vs PM hours in **A)** elephants and **B)** rhinos.

Discussion

Overall Activity

As expected, the elephants were more active than the rhinos. In the wild, elephants rest for only four to six hours each day, with the majority of time spent feeding and foraging (Estes, 1991; Spinage, 1994). The data from this study reflect time spent on exhibit during the day; longer bouts of sleeping typically happened in the early morning hours before data collection began and are therefore not reflected in the results. Rhinos in the wild spend up to half the day sleeping and wallowing (Kiwia, 1986); although this study did not group wallowing into the resting behaviors, it accounted for less than 1.5 min/hr of activity in each individual and was only seen outside. The rhinos rested most in the early afternoon, while the elephants did not show differences in the behavior throughout the day. These different trends correspond to differences in natural behavior: elephants rest for short periods of time throughout the day as they move and forage, whereas rhinos are inactive for long stretches during the late morning and early afternoon when temperatures are highest (Estes, 1991; Hutchins & Kreger, 2006; Kiwia, 1986; Spinage, 1994; Tatman et al., 2000). Resting behavior and patterns in both species were therefore similar to expected values based upon natural activity budgets.

Time elephants spent locomoting in the current study was comparable to what was reported for three female elephants at Zoo Atlanta (Stoinski et al., 2000). Comparisons of daily walking rates to wild populations of elephants and rhinos are more difficult and require additional data collection measures such as GPS ankle bracelets or collars. In the wild, elephant herds typically walk while foraging, moving at a consistent and slow pace of about 0.5 km/hr with the overall amount of locomotion depending upon multiple factors such as habitat quality, population size, and season (Estes, 1991; Spinage, 1994). Leighty et al. (2009) and Miller et al. (2012) reported similar daytime travel rates at two southern zoos where GPS technology revealed elephants walked 0.409 kph and 0.537 kph, respectively. When browse is plentiful herds may walk only 10-15 km in a day, and during the dry season when food is scarcer herds have been reported to travel as much as 80 km in a day (Hutchins, 2006; Spinage, 1994). Rhinos also vary their movement patterns, walking primarily to find food, water, and sites for wallowing or resting (Tatman et al., 2000). The rhinos locomoted more often than the elephants, averaging approximately 19.32% of their total activity budget. Kiwia (1986) documented wild black rhinos as walking 14.2% of their total activity budget during the wet season and 22.1% during the dry season, rates similar to those found in this study.

Resource availability is clearly a factor in the daily activity patterns both species in the wild, and other influences include season, geographical location, and even activities of other herds and individuals (Estes, 1991; Hutchins, 2006; Hutchins & Kreger, 2006; Tatman et al., 2000). In captivity, however, resources are presented to the animals and condensed within a small area, and environmental and social variables are relatively static. Eliminating the primary reasons for elephants and rhinos to move could result in lower locomotion rates than what is seen in the wild, but this does not necessarily mean the animals need to compensate by increasing their movement. Adequate exercise is necessary to maintain physical and psychological health and provided these needs are met it may not be necessary for animals to locomote any more than is required. Determining appropriate amounts of exercise should therefore not be based solely upon movement levels of wild animals but rather a combination of natural behavior and measures of individual health, such as overall behavioral repertoires, obesity, arthritis, and hormone levels. Future work at multiple institutions that incorporates both behavioral and physiological data is necessary to characterize healthy activity level ranges forthese species.

Feeding

Feeding was the most common behavior observed in the elephants. Little data are available regarding time elephants spend feeding in zoos. Separate studies of one captive elephant group found feeding rates between 20% and 50% of total activity depending on time of day (Brockett, Stoinski, Black, Markowitz, & Maple, 1999; Stoinski et al., 2000; Wilson, Bashaw, Fountain, Kieschnick, & Maple, 2006). Reported feeding rates of wild elephants range from 74.2% to 90% (Estes, 1991; Shannon et al., 2008; Spinage, 1994). The rhinos in this study spent considerably less time feeding. Few wild or captive studies have examined rhino feeding behavior, but Kiwia (1986) found average feeding rates of black rhinos in Tanzania ranging from 15.8% in the dry season to 31.7% in the rainy season. Feeding times of both the elephants and rhinos were therefore less than average rates in the wild. This decrease is likely due to the different food sources of wild elephants and rhinos: both species are browsers, and the leaves, sticks, and bark they feed upon in the wild take longer to manipulate and eat than does the hay and grain commonly fed in captivity. Stoinski et al. (2000) found that an equal amount of browse instead of hay increased feeding time in zoo-housed African elephants from 50% to 80%, and additionally increased overall activity and public visibility. Feeding and foraging are basic needs and animals are often highly stimulated to perform the behaviors even if not nutritionally required to do so (Veasey, 2006). The time an animal spends feeding in captivity should therefore be similar to that of wild counterparts (Morimura & Ueno, 1999), and for African elephants and black rhinos this is dependent upon providing more natural food sources. Increasing the amount of browse in captivity can help to increase natural foraging and feeding behaviors and as a result may decrease the amount of time spent inactive or performing abnormal behaviors. Feeding a diet of exclusively browse is not practicable in captivity, but supplementing some of the traditional hay rations with equal amounts of browse encourages natural levels of feeding and foraging without increasing daily food allowances.

Heat Dissipation

African elephants and black rhinos are large mammals that inhabit warm environments, and each species has various methods of dissipating body heat. In elephants this is done via dusting, or using the trunk to toss dirt and other substrates onto an individual's back and sides. Dusting was the only temperature-correlated behavior in elephants; the behavior increased with increasing temperatures but was seen in all temperature ranges. Although an elephant's skin is thick the blood vessels and nerves are relatively close to the skin and they have few sweat glands for heat dissipation (Adams & Berg, 1980; Rees, 2002). Dusting and mudding help to protect the skin from sun and insects, assist with temperature regulation, and encourage the shedding of dead skin cells (Rees, 2002). Adams & Berg (1980) reported that captive elephants performed the behavior more frequently when the temperature was greater than 27°C; Rees (2002) found the frequency of dusting in captive Asian elephants was linearly correlated with increasing temperatures, and as in this study there was no difference in individual rates based on age, mass, or reproductive condition. The temperature correlation found in this and other studies support the idea that the primary reason for dusting is reducing body heat, but dusting is also considered a comfort behavior and is often performed after bathing, during social situations, and when anxious (Adams & Berg, 1980; Schmid, 1995). Elephants should therefore have the option of dusting not only when temperatures are high but at all times and in both outdoor and indoor enclosures.

Like elephants, rhinos have a large mass and only a small number of sweat glands and necessitate ulterior means of reducing body heat. They do not have the ability to throw substrates onto themselves and thus their method of dissipating body heat, gaining sun protection, and reducing insects is wallowing in mud (Hutchins & Kreger, 2006). Wallowing was not correlated with temperature, but was seen more with increasing amounts of sunlight. Increased temperatures were associated with increased resting behavior, and resting was also highest during hotter hours of the day; this behavior is likely used in conjunction with wallowing to reduce body heat. These results suggest that rhinos adapt their overall activity budgets to temperature and weather conditions more so than elephants and rhino enclosures should provide enough mud wallows, resting sites, and shade structures for all individuals, and the conditions of mud wallows should be monitored at higher temperatures to assure rhinos have the option of wallowing.

Seasonality

Locomotion was the most commonly observed active behavior in rhinos, and investigatory/environmental behaviors were the most common active behavior in elephants next to eating. Rhinos locomoted least in the winter, which suggests that increased time in the indoor enclosure due to colder weather was associated with decreased locomotion. This trend was not seen in the elephants, but object investigation and environment-directed behaviors were lowest in winter. Each species therefore showed a different behavior that was most affected by indoor housing. Housing animals in northern climates often necessitates increased time inside during colder months and ideally this should not affect average activity budgets. Research at multiple institutions is needed to determine if these patterns are seen in other captive elephants and rhinos, including comparisons of northern and southern climates to clarify the effect of indoor housing. If rhinos in fact have a tendency to decrease locomotion when housed inside they may benefit from managerial changes designed to increase motivation to move, such as larger indoor exhibit areas, scattered food, or exercise programs implemented by keepers. Elephants may necessitate increased environmental complexity and variability to encourage investigatory behaviors, as well as substrates that allow digging, dusting, and manipulation. This does not negate the need for appropriately designed rhino enclosures or adequately spacious elephant enclosures, but merely highlights how the two factors may not impact each species to the same degree.

Social Behavior

Fighting was never seen amongst the elephants at CMZ, and low rates of female aggression are common in both captive and wild groups of elephants (e.g., Archie et al., 2006; Adams & Berg, 1980; Brockett et al., 1999; Garaï, 1992; Rees, 2009; Wilson et al., 2006). In fact, little social interaction was seen between the CMZ elephants compared to what has been reported in other studies of female elephants in zoos (Freeman et al., 2010b). Frézard and LePape (2003) reported a captive group of three female wolves that had been housed together for years and displayed little social behavior. Although not closely related to elephants, wolves have a similar social system: they generally live in related groups, have an intricate repertoire of social behaviors, and rely on conspecifics for survival. Like elephants, wolves often must adapt to small, unrelated social groups in captivity and those with established dominance hierarchies may interact less extensively than those with weaker social hierarchies. As stable dominance hierarchies may also reduce aggression in elephants (Meyer, Goodwin, & Schulte, 2008; Wittemyer & Getz, 2007) and other social species (Magana, Alonso, & Palacin, 2011; Rowell, 1974; Willisch & Neuhaus, 2010) Although it is possible that the small amount of social behavior seen in the CMZ elephants was simply due to a lack of relatedness, it is also possible that the social stability of the group may have contributed to a lack of overt social behavior.

Small amounts of social behavior were also characteristic of a group of three elephants housed at Zoo Atlanta (e.g., Brockett et al., 1999; Stoinski et al., 2000; Wilson et al., 2006). Wilson et al. (2006) suggested it may also be due to age, as other species of ungulates decrease social interaction with age. It could also be a factor of the captive environment. Most of the factors that enhance social relationships among wild elephants are not present in captivity, such as entering a new environment, searching for food, or defending calves against predators, and thus individuals may decrease social behavior (Schulte, 2000; Wittemyer & Getz, 2007). Each of these reasons suggests that captive elephant groups may have less immediate need to interact as compared to their wild counterparts. This may also explain the elephants most often remaining socially distant in the outdoor enclosure, which has been reported in other captive groups (e.g., Brockett et al., 1999; Wilson et al., 2006). Lack of need to interact, however, does not counteract the importance of conspecific companionship in this species. Social proximity and physical contact are vital components of elephant societies both in the wild and in captivity (Adams & Berg, 1980; Garaï, 1992), even if displayed for small amounts of time, and captive elephants should always be housed in social groups to provide opportunities for social interaction.

Black rhinos are not a social species but inhabit territories shared by many conspecifics; thus they do not have the intricate social relationships of African elephants but still maintain methods of interacting with other rhinos. Kiwia (1986) found that black rhinos in Tanzania engaged in social behavior for only 1-2% of the total activity budget. The female rhinos at CMZ had similar levels. Although the increase seen in the indoor enclosure may not be biologically significant due to the small values (Swaisgood, Dickman, & White, 2006), it is possible that it is due to environmental and/or social factors. There was less available space and fewer behavioral options inside and the rhinos may have used social behaviors as a form of enrichment. It is also possible that the increased social density of the indoor enclosure is stressful to this naturally solitary species, even when individuals are related. When housed outside the females most often remained distant from one another, but inside the rhinos had less control over their social proximity. Additionally, agonistic behaviors were seen more often inside, which may suggest increased tension between the females. Metrione, Penfold, and Waring (2007) reported white rhinos at two zoological facilities developed dominance hierarchies and accompanying indicators of social stress that were potentially exacerbated by crowding. The aggression observed in the present study, however, was still relatively rare and never resulted in injury. Although black rhinos are naturally solitary, individuals can likely be housed together provided they have ample space to control social proximity and aggression rates are low. Black rhinos housed socially would also benefit from the inclusion of enrichment or environmental objects to provide additional behavioral options.

Maintaining functional social groups in captivity is a primary welfare concern (Frézard & LePape, 2003; Veasey, 2006). Social groups are an effective and long-term form of enrichment that can provide captive animals with increased behavioral opportunities and a more dynamic environment (Veasey, 2006). Most ungulate species can adapt to various social situations (Veasey, 2006), but if group structures differ from what is seen in the wild, behavioral research can help determine whether those groups are providing animals with their social needs while allowing for low levels of social tension. Groups should be engaged in primarily affiliative behavior and show little aggression, which signifies stable social relationships (Hutchins, 2006; Veasey, 2006; Wilson et al., 2006); the results support this in both the elephants and rhinos. Zoos should strive to evaluate social groupings of these species in an effort to ensure compatibility. A better understanding of how African elephants and black rhinos interact with conspecifics in captivity will result in more informed decisions regarding social housing and management.

In conclusion, we found average resting levels of African elephants and black rhinos were similar to expected values based on data from wild and captive studies. Both species adapted their behavior to cope with high temperatures and increased sun exposure. Increased time spent inside during winter months was associated with decreased investigatory behaviors in elephants and decreased locomotion in rhinos. To increase species-typical behaviors, exhibits should include substrates for dusting, mud wallows, shade structures, and resting sites for all individuals. Time spent feeding may be increased through natural food items such as browse. Indoor exhibits should include environmental variation, enrichment, and adequate space so as to encourage these behaviors. In addition to behavior assessments, physiological and health measurements might be measured to determine sufficient levels of exercise for zoo-housed elephants and rhinos.

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Appendix A: African Elephant Ethogram

Solitary Behaviors

Rest	Stationary with eyes open or closed and no other simultaneous behaviors; may include ear flapping; may be upright or lying on side
Drink	Ingestion of water
Eat	Ingestion of food
Elimination	urination and/or defecation
Locomotion	Movement in either a forward or backward direction at any speed
Self-Directed	Touching/rubbing/grooming own body with mouth, trunk or appendages; does not include self-suck
Object Rub	Rubbing body against any object or substrate; does not include object manipulation
Bathe/Wallow	Submerging all or part of body in water or mud and/or using trunk to toss water or mud onto body
Dust	Using trunk to too sand/dirt/dust onto body
Dig	Manipulating/moving substrate with foot or tusk
Investigate Object	Sniffing and/or manipulating environment (branches, rocks, etc); does not include enrichment items
Investigate Enrichment	Sniffing and /or manipulating enrichment items
Pace	Repeated locomotion across the same route for at least 10 s
Sway	Repeated shifting of weight from one foreleg to the other for at least 5 s
Head Bob	Repeated nodding of head up and down for at least 5 s; may include non-locomotive movement of feet/legs
Head Bang	Forcibly hitting front or side of head against object or substrate
Self-Suck	Using mouth or trunk to suck on specific area of own body
Solitary Aggression	Aggression aimed at environment, such as tusking, head butting, ripping up vegetation or throwing objects
Other Solitary	Any solitary behavior not listed
Not Visible	Individual and/or its behavior cannot be seen by the observer

Social Behaviors

Affiliative	Greet	Ears held high and folded against body, trunk placed in conspecific's mouth
	Caress	Rubbing trunk over body of conspecific
	Trunk Tangle	Gently entwining trunks with conspecific; score focal subject as Mod1
	Play	Energetic social affiliative behaviors such as sparring, trunk wrestling, chasing, and rolling; typically seen only in calves; score focal subject as Mod1
Dominant	Threat	Ears wide, trunk forward, head raised; may include scraping the ground with forelegs, twitching the tail, or weaving
	Charge: Mock	Ears wide and trunk raised while rushing toward conspecific; no contact is made
	Charge: Serious	Ears wide, trunk held against body and tusks aimed at conspecific while rushing toward the individual; contact is made
	Fight	Aggressive interaction that may include head butting, trunk wrestling, and tusk stabbing, often preceded by serious charge
Submissive	Submission	Ears back, head lowered, back arched and trunk curled inward; individual may present rump and/or back into dominant conspecific
Maintain Proximity	Approach	Individual moves to within proximity of conspecific
	Leave	Individual moves out of proximity of conspecific
	Displace	Individual approaches and overtakes position of conspecific

	Other Social	Any social behavior not listed

Social Proximity

Contact/Proximate	Within one body length of or in contact with another individual
Distant	Greater than one body length from another individual, but still within view
Far Distant	Out of view of other individuals
Unknown	Proximity cannot be determined

Outdoor Exhibit Area

Building
Door
Water Source
Mud Wallow
Trees
Public View Area

Substrate

Cement
Water
Mud
Dirt/Sand
Grass

Appendix B: Black Rhinoceros Ethogram

Solitary Behaviors

Rest	Stationary with eyes open or closed and no other simultaneous behaviors; may be upright or lying on side
Drink	Ingestion of water
Eat	Ingestion of food
Elimination	urination and/or defecation
Footscrape	Rapidly alternating hind feet across ground, typically associated with defecation
Urine Spray	Marking objects in environment with bursts of urine
Locomotion	Movement in either a forward or backward direction at any speed
Self-Directed	Touching/rubbing/grooming own body with mouth, or appendages
Object Rub	Rubbing body or horn against any object or substrate; does not include object manipulation
Bathe/Wallow	Submerging all or part of body in water or mud
Dig	Manipulating/moving substrate with foot or nose
Flehmen	Curling up underside of lip, typically with head raised
Investigate Object	Sniffing and/or manipulating environment (branches, rocks, etc); does not include enrichment items
Investigate Enrichment	Sniffing and /or manipulating enrichment items
Pace	Repetitive locomotion across the same route for at least 10 seconds
Sway	Repeated shifting of weight from one foreleg to the other for at least 5 s
Head Bang	Forcibly hitting front or side of head against object or substrate
Mouthing	Repetitive open-mouthed chewing motion not associated with eating for at least 5 s
Solitary Aggression	Aggression aimed at environment, such as ripping up vegetation or throwing objects
Other Solitary	Any solitary behavior not listed
Not Visible	Individual and/or its behavior cannot be seen by the observer

Social Behaviors

Affiliative	Greet	Individual approaches and touches noses with conspecific
	Affiliation	Gentle non-sexual social contact, including nudging heads or horns
	Follow	Traveling behind or next to a conspecifics, within one body length
	Anogenital Investigation	Individual sniffs anogenital region of conspecifics
	Sexual	Any courtship or copulatory behavior
Agonistic	Threat	Turning head from side to side or repeatedly jerking it upward; broadside displays; short, mincing charge-like steps
	Charge: Mock	Head lowered, ears pricked, tail raised and upper lip curled while rushing toward conspecifics; no contact is made
	Charge: Serious	Similar to mock charge but with contact; includes chasing
	Fight	Aggressive interaction, such as horn butting, jousting or stabbing
Submissive	Submission	Head low while backing away from dominant conspecifics
Maintain Proximity	Approach	Individual moves to within proximity of conspecific
	Leave	Individual moves out of proximity of conspecific
	Displace	Individual approaches and overtakes position of conspecific
	Other Social	Any social behavior not listed

Social Proximity

Contact/Proximate	Within one body length of or in contact with another individual
Distant	Greater than one body length from another individual, but still within view
Far Distant	Out of view of other individuals
Unknown	Proximity cannot be determined

Outdoor Exhibit Area

Building
Door
Water Source
Mud Wallow
Trees
Public View Area
Rear Perimeter
Other

Substrate

Cement
Water
Mud
Dirt/Sand
Grass