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ARTICLE

Behavioral and Physical Development of Captive–Born Eastern Black Rhinoceros (*Diceros bicornis michaeli*) Calves

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ABSTRACT

The birth of two eastern black rhinoceros (*Diceros bicornis michaeli*) calves (0.2) at the Blank Park Zoo in Des Moines, IA offered an opportunity to collect normative data for the first six months of calf development. Both calves successfully stood within 76 minutes of birth. Nursing first occurred at approximately 130 minutes. First defecation occurred within 1-2 days. Body weight increased by approximately 1.2 kg/day. Activity budgets for the first six months of the calves' lives revealed that they spent a substantial proportion of their time resting, followed by standing, walking, and eating, respectively. Nursing duration increased gradually over the study period. Calves spent the majority of their time throughout the first six months in close proximity to the cow. Interactions with inanimate features of the environment began early, and no clear developmental pattern was evident in the data. These data can serve as the initial entry in a public record of developmental information for this species and as a reference point for other zoos, assisting them in monitoring the health and proper development of black rhinoceros calves and maximizing their welfare.

KEYWORDS

Black rhinoceros; neonatal development; time budget; proximity; nursing duration

The eastern black rhinoceros (*Diceros bicornis michaeli*), one of three extant subspecies of black rhinoceros (*Diceros bicornis*), has been listed as critically endangered by the IUCN since 2000 (Emslie, 2020). Due to increased protection throughout its main range in Kenya and Tanzania, the population is currently increasing, with a most recent census count of 583 individuals (Emslie, 2020). However, poaching is still problematic, and the demand for rhinoceros horn, which is use in traditional medicine and ornaments in Southeast Asia, continues to pose the most serious threat to the survival of the species (Emslie, 2020; Pilgrim & Biddle, 2014).

Given the precarious status of the wild population, maintaining a viable *ex situ* population is more important than ever. *Ex situ* populations can serve as genetic reserves to prevent the extinction of critically endangered species, and to provide stock for future reintroduction programs. Captive populations, particularly those in zoos, can also serve to raise public awareness and support for conservation efforts. Data from captive animals can provide knowledge of the species' biological and behavioral traits, which can be applied to conservation in the field (Edwards et al., 2015).

Zoos must have successful breeding programs in order to maintain genetically healthy captive populations. Unfortunately, captive breeding efforts for the eastern black rhinoceros have historically met with limited success. In North American facilities, an average of only two black rhinoceros calves are born each year (Taylor, 2019). More than 40% of sexually mature captive individuals have never reproduced, and captive females exhibit later initial reproduction as well as longer intercalving intervals than wild females (Edwards et al., 2015). First-year mortality is 24% for female

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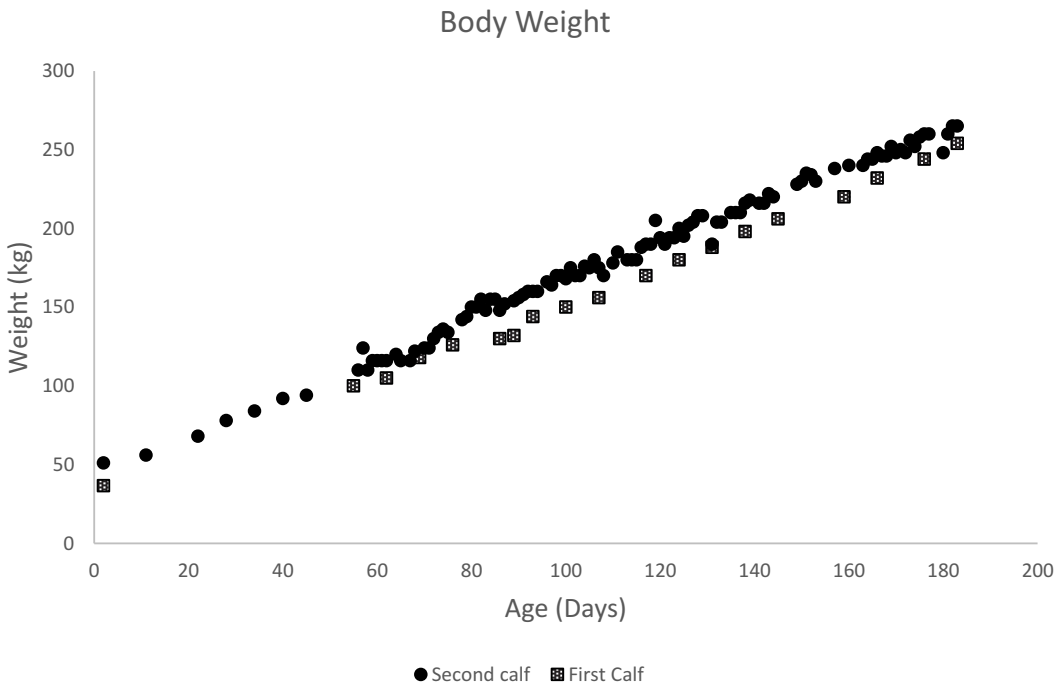

Figure 1. Body weight for the first six months.

calves and 25% for male calves (Smith & Ferrie, 2018). There are approximately 152 individuals in zoos throughout the world (Species360, 2020), including only 60 in AZA-accredited zoos throughout North America (Ferrie, 2020).

Although there are reports including limited information on perinatal characteristics of eastern black rhinoceros neonates (Greene, Manne, & Reiter, 2006; Pilgrim & Biddle, 2014), there is very little published data available on typical developmental patterns for this species. A more complete account exists for the Sumatran rhinoceros (Plair, Reinhart, & Roth, 2012); this project is intended to create a similar resource for the eastern black rhinoceros. Knowledge of developmental patterns can help inform population management and conservation decisions. The existence of reference values for various physical and behavioral measurements can help animal care staff monitor infants' development and make better-informed decisions about when intervention is, and is not, warranted. Recent best-practices proposals promote a combination of behavioral, physiological, and biological measures to assess the welfare of captive animals (Whitham & Wielebnowski, 2013). Data on neonatal milestones, nursing, and time budgets of healthy calves can provide a baseline of behavioral and physiological development to which the welfare of future individuals can be compared.

This study will report the normal progression of physiological and behavioral development for two captive-born eastern black rhinoceros calves during the first six months of postnatal life.

Methods

Subjects

Two female calves were born at the Blank Park Zoo in Des Moines, IA: "Tumani" (October 11 2016) and "Kamara" (April 5 2019). Both calves are the offspring of "Ayana" (0.1, born August 23 2010 at Zoo Miami, Florida; primiparous for the first calf) and "Kiano" (1.0, born October 7 2010 at Great

Plains Zoo in Sioux Falls, South Dakota). Both adults were transferred to the Blank Park Zoo in 2013, matched as a breeding pair by the Species Survival Plan.

Animal care

The Blank Park Zoo rhinoceroses are housed in a purpose-built facility consisting of a barn with six stalls (four square stalls of 24 m^2 and rectangular stalls of 47 and 97 m^2). Stalls have heated floors; 3 have rubber-padded surfaces, and 3 have concrete surfaces. Mulch and straw are available as substrate during cold-weather months. Two outdoor yards of approximately 800 m^2 each and an outdoor-holding yard of 240 m^2 are used when outdoor temperature is 10°C or above. The substrate is dirt, and each outdoor enclosure is furnished with logs, boulders, a wallow, a pulley system for attaching enrichment items and slow feeders, and a concrete pad for food distribution. Visitors view the rhinoceroses from minimum distances of approximately two meters during indoor viewing, and three meters during outdoor viewing.

Each calf was born inside the rhinoceros barn while the cow was housed singly in an off-exhibit 24 m^2 stall. The birthing stall was deeply bedded with straw. Barn temperature was maintained at 18° C; internal barn lighting was scheduled to conform to the local day/night cycle. The cow was unattended during the final stages of labor and during birth to minimize disturbance; observations were conducted via video monitoring.

For both calves, neonatal examinations were performed 2 days after birth and weights were obtained with a portable scale at that time. Blood collection did not occur during these examinations due to the robust nature of both calves and concerns for stressful separation from the dam. Following the neonatal examinations animal care and veterinary staff performed tactile examinations and daily visual checks to monitor general health. Veterinarians and technicians practiced minimal interventions except if indicated by clinical signs. Fecal examinations were performed when feces appeared abnormal, but there were no significant abnormalities noted. Because both calves appeared healthy, veterinary interventions did not occur and no other physiological data were collected.

Neither calf was visible for public viewing for the first month postpartum. The cow and calf were housed together, separately from the sire. Cow and calf had access to outside yards as weather permitted. During the second pregnancy, the first calf was separated from the cow at 2 years of age, approximately 5 months prior to the birth of the second calf. The separation process was gradual, with increasing periods of separation over several days.

Once weaned, the calves were fed with the cow. Their diet consisted of grass hay, alfalfa hay, and Mazuri browser rhino cube, supplemented with produce for training and enrichment. Animal care staff followed an environmental enrichment program, furnishing the enclosure with at least two enrichment items at all times. Enrichment items are designed for investigative play (e.g., boomer balls, hanging logs) and resource acquisition (slow feeders); these were replaced with new items every other day.

Behavioral observations and data collection

This study used a combination of continuous and all-occurrence behavior sampling methods for observations. Observers used a general-purpose ethogram designed for ungulates. The same ethogram (Table 1) was used for both calves, except that nursing was recorded separately from other forms of ingestion for the second calf. After observers completed training and inter-observer reliability of at least 90% had been established, data were recorded in real time using tablets with specialized software. Because the calves were born 3 years apart, the available data collection technology had evolved in the intervening time. This was a descriptive study, and so the advantages of implementing available improvements in data collection technology were judged to justify the resulting differences between the data sets. As a result, data collection methods varied slightly for the

Table 1. Ethogram used to categorize eastern black rhinoceros behavior. The ethogram was identical for the two calves, except that nursing and other forms of ingestion were separate only for the second calf.

BEHAVIOR	DESCRIPTION
Base Behaviors	
Stand	Body is held above the substrate; subject is in a single location, not engaged in locomotion. All four feet are typically on the substrate.
Walk	Locomotion characterized by at least one foot being on the ground at all times.
Run	Rapid locomotion; may include instants where all four feet leave the ground at the same time.
Alert	Head up, eyes open; head may scan left and right or be still.
Pace	Repeated locomotion between or among two or more locations, continued beyond a single circuit.
Lie Down	Ventral or lateral surface of torso is in contact with substrate (other than mud); head may be elevated or in contact with substrate.
Wallow	Focal animal lies or rolls in a muddy area of substrate.
Not Visible	Focal animal is not within visible area of enclosure, or is obscured by another animal or object in enclosure.
All Occurrence Behaviors	
Urinate	Release of liquid from the anogenital region. Stream is typically directed toward the substrate.
Defecate	Release of fecal material from the anus.
Mark or Spray	Release of liquid from the anogenital region upon or toward nearby objects such as walls, gates, or tree stumps.
Eat	Placing objects in the mouth and consuming them; may be accompanied by slow locomotion on the ground, picking through substrate, locating objects for ingestion.
Drink	Face in contact with liquid, apparently ingesting.
Nurse	Mouth in contact with teats of lactating adult female; apparent ingestion.
Vocalize	Emission of sound from the subject's head and neck area.
Gambol	A gait with distinct vertical components unrelated to change of location through locomotion. May include play-bowing. May seem to resemble dancing.
Flehmen	A distinctive contortion of the upper lip, used to draw air to the vomeronasal organ for detection of airborne chemicals
Play Bow	Forelimbs on substrate, hind limbs straight or bent, head directed toward another individual; may include bouncing.
Mount	Placing the ventral surface on the dorsal surface of another animal, as in copulation.
Head to Head Contact	Contact between the subject's head and the head of another individual.
Non-Head Contact with Other	Contact between the subject and another animal with a body part other than the head.
Head to Body Contact	Contact between the subject's head and any body part of another individual other than then the head.
Manipulate Edible Object	Handling (contact via mouth or foot) inanimate objects that are not primarily food (e.g., enrichment objects) but which include components that could be eaten. Behavior may or may not include ingestion. Includes breaking, turning, shaking. Does not include social interaction in which the object is the central focus.
Manipulate Non-Edible Object	Handling (contact via mouth or foot) inanimate objects that are not typically eaten, without ingestion; may include breaking, turning, shaking. Does not include social interaction in which the object is the central focus.
Climb or Stand on Object	Placing one or more feet, and some portion of body weight, upon an object in the environment.
Manipulate Scat	Nose, kick or walk on fecal material.
Dig or Paw at Ground	Repeated motion of foot against ground or substrate; substrate may be moved, deformed, or rearranged as a result.
Rub on Fixed Object	Body contact with movement against an object that is anchored or too large to easily move.
Horn Rubbing	Horn is repeatedly rubbed against enclosure structure (e.g., indoor bars, feeders, drink trough). Must exceed 5 seconds duration.
Human Contact	The focal animal makes contact with a human across the barrier.

two calves. For the first calf, an independently created software program was used. Observations were made for the second calf using ZooMonitor, a cloud-based platform (Wark et al., 2019).

Observation sessions were 30 minutes for the first calf and 20 minutes for the second calf. For the first calf, all behaviors were recorded as continuous durations. For the second calf, duration of behavioral state listed in the ethogram was recorded (Table 1, designated as "Base Behaviors"), while certain behaviors were recorded as time-stamped events (designated as "All Occurrence Behaviors") when they occurred. For the second calf, proximity to the cow was also recorded continuously, in five categories (touch proximity, <1 m, 1–3 m, 3–5 m, and >5 m). (Proximity data collection did not

begin for the first calf until the fifth months and so these data are not included here.) All forms of ingestion (nursing and eating solid food) were recorded together for the first calf; nursing and eating were recorded separately for the second calf. Observations on the first calf began at 24 days of age. The second calf was observed daily for the first eight days postpartum and then at least four times per week subsequently until the calf was 6 months of age. All observations occurred during daylight hours.

Results

Birth weight

At the initial examination (two days postpartum), the first calf weighed 36.6 kg, and second calf weighed 51.0 kg. Although veterinary staff had estimated a range of likely delivery dates based on observed mating and prenatal ultrasound examination, gestation time in the eastern black rhinoceros appears to be variable. The first calf was born near the beginning of this estimated delivery range; the second calf was born near the end of the estimated range. Changes in husbandry procedures between births resulted in more–frequent weight records for the second calf. At six months of age, the first calf weighed 254 kg, the second calf 265 kg, as shown in Figure 1. The slope of the linear regression of the each calf's weight data indicates weight gain of approximately 1.2 kg/day during the first 6 months (first calf 1.19 kg/day; second calf 1.21 kg/day).

Postpartum milestones

Table 2 outlines the elapsed time to reach behavioral milestones after birth. Calves varied in elapsed time to the first successful quadrupedal stand, 35 minutes for the first calf and 76 minutes for the second calf. Both calves began nursing approximately 130 minutes after birth, with subsequent frequent short periods of nursing. The first calf had her first defecation on or before two days postpartum, with no feces being expelled in the following 3 days. Care staff identified infant feces one-day postpartum for the second calf, but the exact time of the first defecation could not be determined.

Both calves were observed shivering intermittently beginning one-day postpartum (both while standing and laying down). This continued for approximately 7–10 days. On the working hypothesis that this reflected immature thermoregulation, the barn temperature was increased to approximately 24°C; this did not result in the end of shivering. The second calf's body temperature was 38°C at seven days postpartum but decreased to 37.4°C at 8 days; it remained at 37.4°C at 11 days. The decrease in body temperature coincided with the end of trembling bouts. Trembling was more common when there was environmental change or the introduction of unfamiliar people, so it is also possible that the trembling was arousal-related.

Behavioral observations

Observers completed a total of 26 hours of observation for the first calf and 70 hours for the second calf within the first six months postpartum. Data for the two calves are combined when possible; some results reflect only those data collected from the second calf. Behaviors in the ethogram that

Table 2. Newborn eastern black rhinoceros calf behavioral milestones.

Milestone	First calf	Second calf
Successful stand	35 minutes	76 minutes
Nursing	129 minutes	131 minutes
First defecation	2 days	Approximately 1 day

were not observed in either of the calves in the first six months postpartum do not appear in the analysis.

Nursing

Nursing was not recorded separately from other forms of ingestion for the first calf, so nursing data comes only from the second calf. Nursing was frequent within the first 24 hours after birth, with nursing bouts varying from 1 to 9 minutes in duration. After the first 24 hours, nursing about duration decreased, with a mean bout duration of 38.4 seconds in month one. However, the duration of nusing bouts generally increased over the first six months of life, to a monthly mean of 110.9 seconds in month six (Figure 2). Both calves began mouthing their cow's hay and pelleted food within two weeks of birth.

Time budget

Time budgets for the two calves are shown in Figure 3, with monthly averages for resting (lying down) shown in Figure 4. The second calf spent more time lying down overall than the first calf. The calves spent 11.7% and 6.6% of the time eating or nursing. Time spent walking and standing were similar (Figure 3). The remaining time (7.3–19.5%) was occupied in the aggregate by all other activities listed in the ethogram (Table 1); non occurred frequently enough to permit separate analysis.

Proximity data are reported only for the second calf. The calf's proximity to the cow was relatively consistent throughout the study. Throughout the first six months, the second calf spent between 57.2% and 93.1% of her time within 1 m of the cow (Figure 5). Conversely, she spent 1.3% of her time more than 5 m from the cow.

Environmental interactions were assessed by the rate (number of interactions per hour) at which the calves engaged in physical manipulation of some element of the environment without ingestion. Seven behaviors were recorded (manipulate edible object without ingestion, manipulate non-edible object, climb/stand on object, rub on fixed object, horn rubbing, manipulate scat, and dig/paw at ground); each is described in the ethogram (Table 1). The frequency of these different behaviors varied considerably and so could not be analyzed separately; the aggregate rate of occurrences over the six months was 7.1 occurrences per hour (Figure 6) and did not show a clear developmental trend.

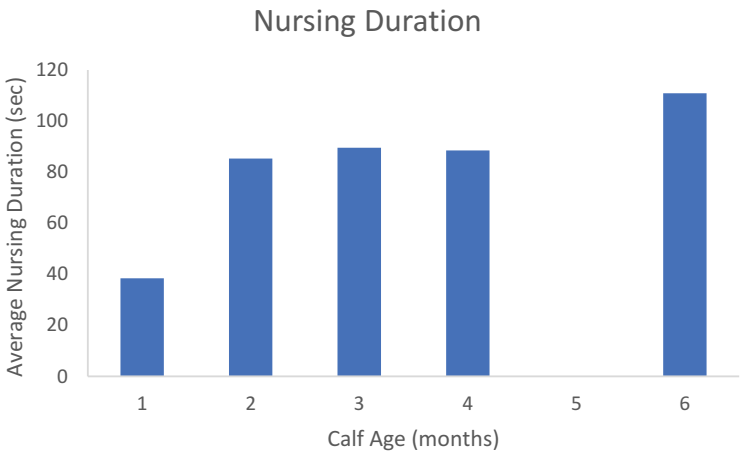

Figure 2. Mean duration of nursing bouts over the first six months of life. Data is for second calf only (There is no data point for month five; nursing was not observed during this month and so average duration could not be calculated.).

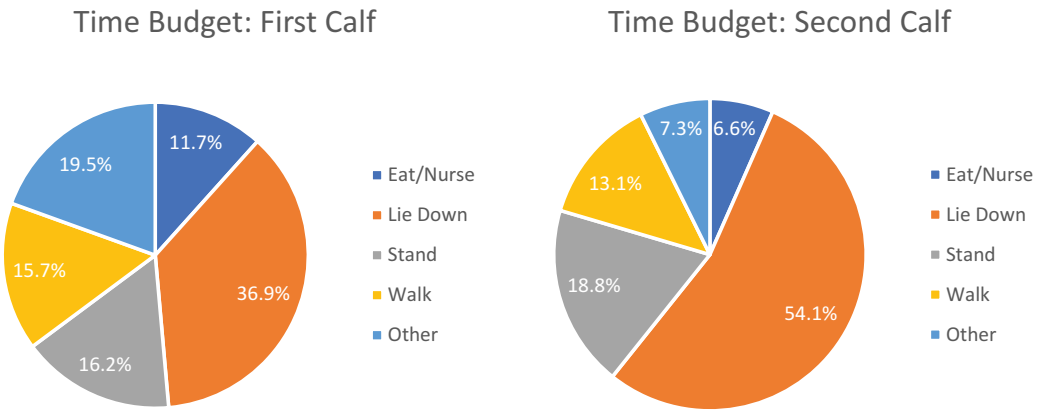

Figure 3. Time budgets for Eastern Black Rhinoceros calves during the first six months of life. Observations for the first calf began at 24 days postpartum; observations for the second calf began two days postpartum.

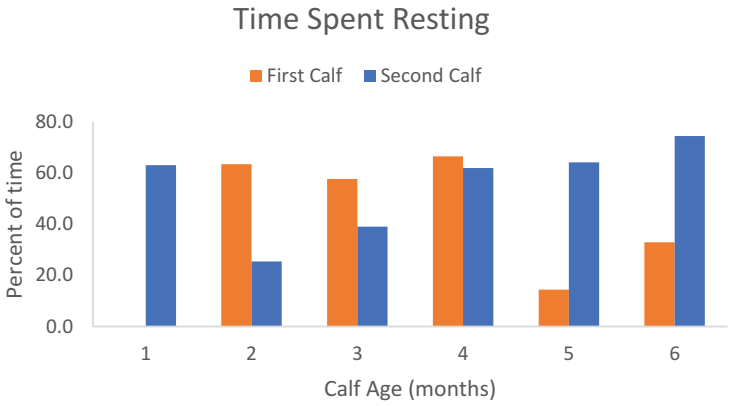

Figure 4. Total percent of time spent resting ("lie down" in ethogram) over the first six months of life.

Discussion

This study provides baseline information about perinatal development in the eastern black rhinoceros, including neonatal milestones, long-term time budgets, and nursing behavior. Knowledge of a species' typical behavior patterns results in better care and welfare for captive animals (Plair et al., 2012). Having this information and developmental trends available for reference can help zoo staff more effectively monitor health and welfare. This information will be useful for comparison in the case of future births, and may assist staff in recognizing when a developmental pattern indicates a deviation from optimal welfare that requires intervention to ensure healthy physiological and behavioral development.

The calves reached infant milestones at very similar rates on most measures, and followed similar developmental patterns as other rhinoceros species in the existing literature. Rhinoceros calves of other species also typically stand between 30 – 60 minutes after birth and begin nursing one to two hours after that (Hutchins & Kreger, 2006). Previous studies on neonatal milestones reveal that calves first stand within 15 minutes to one or two hours after birth and should begin to suckle within the first five hours (Pilgrim & Biddle, 2014). Our findings are consistent with these values. Unlike Sumatran rhinoceros calves, who did not defecate for more than 2 weeks after birth (Plair et al., 2012), both calves in this study defecated within 2 days after birth. This suggests that eastern black

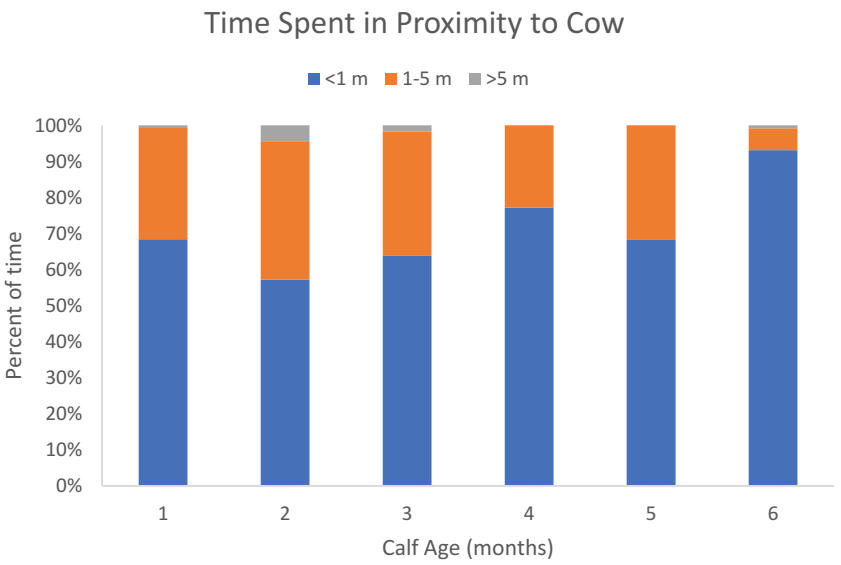

Figure 5. Percentage of time spent within one meter, one to five meters, and five or more meters from the cow over the first six months of life. Data is for second calf only.

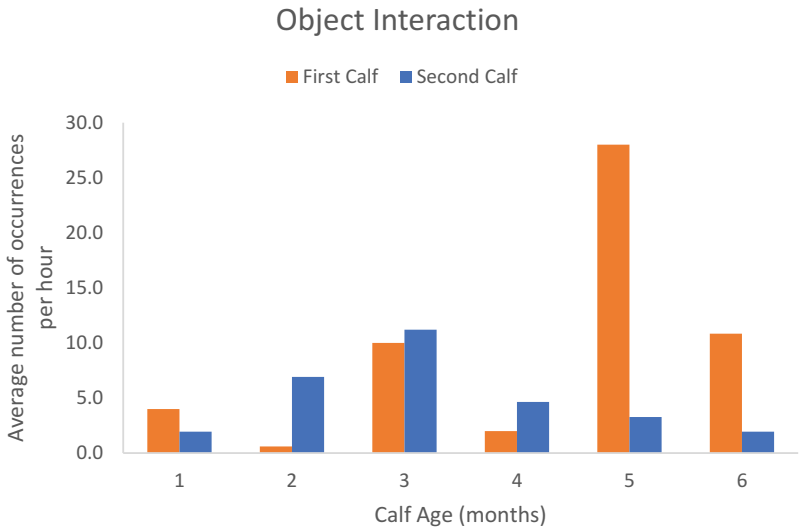

Figure 6. Mean number of occurrences of object/environment interaction per hour over the first six months of life.

rhinoceroses follow a typical schedule for ungulate calves' first defecation rather than displaying delayed defecation like the Sumatran species (Plair et al., 2012).

Birth weight is another important marker for neonate health. According to the existing literature, other sources indicate that black rhinoceros calves weigh approximately 35–45 kg at birth (Pilgrim & Biddle, 2014; Read, 2020; Robbins & Robbins, 1979; Wagner, Edwards, & Escondido, 1999). In this study, the first calf's birth weight was at the low end of this range, the second calf's was above it, which corresponds with animal care staff estimates that the first calf was born early in the range of gestation periods and the second calf was born near the end of the range; this could account for the difference in neonatal weights. It is common in hoofstock such as cows for primiparous females to

bear calves of lower than average weight (Swali & Wathes, 2007); it is also possible that the first calf's lower birth weight was a concomitant of primiparity.

There is very little data on the frequency and duration of nursing for wild calves of any rhinoceros species, but there is evidence that wild calves begin to eat grass around two to three months of age while continuing to suckle throughout the first year of life (Hutchins & Kreger, 2006). Both calves' behavior is consistent with this: Both began mouthing solid food before the end of their first month and consumed both milk and solid foods throughout their first six months. For the Sumatran rhinoceros (*Dicerorhinus sumatrensis*), calves' average monthly nursing duration ranged from 3.4 min–4.7 min (Plair et al., 2012). In a study of one Indian rhinoceros (*Rhinoceros unicornis*) calf, over three days the mean nursing bout lasted 5.32 minutes (Hutchins & Kreger, 2006). In this study, the second calf (for which we have data) had much shorter average nursing durations, with mean values ranging from 0.64 minutes to 1.9 minutes over the first six months. It is important to note that all of these studies are essentially case studies: the Sumatran rhinoceros study included only two calves, and both the Indian rhinoceros study and this report collected nursing data on only one calf. In the absence of additional evidence, it is impossible to determine whether the observed variation can be attributed to species differences.

Time spent resting is also similar across species. According to the Sumatran rhinoceros development study, calves spent 50–70% of the time resting over the first year and 14–26% of time eating (Plair et al., 2012). A preliminary study of five black rhinoceros calves, reporting a single value for data aggregated over the first six weeks postpartum, also found that calves spent the majority of the time (about 55%) resting (Greene et al., 2006). These previous studies are consistent with our findings that both eastern black rhinoceros calves spent most of their time resting, followed by standing, walking, and eating. In this study, the two calves' time budgets were similar.

Both calves spent the bulk of their time in close proximity to their cow for the first six months postpartum. Black rhinoceros juveniles in the wild remain in close vicinity to their mothers, as they are vulnerable to predation by lions and hyenas (Hutchins & Kreger, 2006).

The evidence presented here provides a descriptive account of the first six months of development for captive eastern black rhinoceros calves. These data can serve as the initial entry in a public record of developmental information for this species and as a reference point for other zoos, assisting them in monitoring the health and proper development of black rhinoceros calves. This type of information can contribute to the development of animal care practices to optimize the welfare of this species in captivity.

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