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RESEARCH ARTICLE

Neonatal Milestones, Behavior and Growth Rate of Sumatran Rhinoceros (*Dicerorhinus sumatrensis*) Calves Born and Bred in Captivity

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The birth of Sumatran rhino calves at the Cincinnati Zoo and Botanical Garden offered a unique opportunity to study early development and cow–calf behavior in this elusive, critically endangered species. Study goals were to: (1) record developmental milestones of newborn calves; (2) characterize cow and calf behavior during the first year following birth; (3) compare trends in the behavioral development of a male vs. female calf; and (4) record weight gain and footprint size throughout the first year. In addition to recording eight neonatal milestones, more than 450 hr of behavioral data were collected on each of the two calves (one male and one female) and their dam during the first 12 months of life. Neonatal milestones were achieved within 24 hr of birth with the exception of first defecation, which occurred at 16–18 days. Although nursing bouts decreased slightly in the second half of the year (from once every 90 min to once every 2 hr), they continued to occur frequently throughout the day and night. Therefore, calves grew rapidly from approximately 33 kg at birth to 400 kg at 12 months. Average daily weight gain for the first week was approximately 2.0 kg, whereas average daily weight gain for the remaining 12 months was slight (<1 kg) and did not differ between calves. Eating and resting occupied 70–80% of the Sumatran rhino cow and calves' time and no gender biases in either maternal investment or developmental parameters were noted. Finally, footprint measurements proved valuable for estimating calf age. Zoo Biol 30:1–15, 2011. © 2011 Wiley-Liss, Inc.

Keywords: nursing; activity budget; footprints; maternal investment; neonatal development

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INTRODUCTION

The Sumatran rhinoceros (*Dicerorhinus sumatrensis*) is one of the most endangered species on earth with a global population now estimated at just 200 animals, a 50% reduction over the last 15 years (http://www.rhinos-irf.org/sumatran/). Today, most of the rhinos exist in a few fragmented forests of Indonesia on the island of Sumatra, with a subset of less than 40 rhinos in Sabah Malaysia on the island of Borneo [Clements et al., 2010]. Although these rhinos are intensively protected from poachers by Rhino Protection Units, they are rarely seen because the species is so secretive and inhabits tropical and mountain moss forests that are difficult for humans to navigate. Therefore, directly studying the behavior of wild Sumatran rhinos is virtually impossible, but some progress has been made by indirectly studying rhino "signs" in the forests (i.e., footprints, broken branches, feces, etc.) and extrapolating to behavior.

Perhaps, the most extensive study of Sumatran rhino behavior was conducted by Van Strien [1986], who recorded signs of rhinos in the forests of Gunung Leuser National Park on Sumatra over a 5-year period. Through his in-depth study and that of several other field researchers, there is now a general understanding of the species' behavior. Sumatran rhinos wallow in mud during the day and feed mainly at night browsing on more than 150 species of trees and shrubs. They are solitary, except when a female is rearing her calf. Females live in stable "home ranges," whereas males are more nomadic, wandering along streambeds and game trails and visiting the female's territory to mate. It has been suggested that females can produce one calf every 3–4 years in the wild and that calves nurse for 16–17 months, but beyond these estimates from Van Strien's study, nothing else is really known about calf development and behavior.

Arguably, one of the values of keeping endangered species in captivity is that scientists are able to study and learn more about them than if the species only existed in the wild. The Sumatran rhino has become a case in point. Although the captive breeding program for Sumatran rhinos was at first considered a failure [Rabinowitz, 1995], scientists were able to study the rhinos intensively and eventually unravel the unusual reproductive physiology of this species [Roth et al., 2001], which led to successful propagation in captivity [Roth, 2006; Roth et al., 2004]. Similarly, the birth of these Sumatran rhino calves in a zoo provided a unique opportunity to study the behavior and early development of this species' calves in a manner that would never be possible with wild rhinos. Furthermore, by studying the behavior of these critically endangered animals in a captive setting, we gain valuable information that helps us improve their level of care and welfare.

The specific goals of this study were to: (1) record developmental milestones of newborn calves; (2) characterize cow and calf behavior during the first year following birth; (3) compare trends in the behavioral development of a male vs. female calf; and (4) record weight gain and footprint size throughout the first year.

METHODS

Animal Care

A female Sumatran rhinoceros was captured as a subadult in 1991 on the island of Sumatra and grew up at the Los Angeles Zoo. She was sent to the Cincinnati Zoo and Botanical Garden in 1995 at the estimated age of seven. She gave birth to a male calf at

the age of 13 and a female calf at the age of 16 [Roth et al., 2004]. The calves had the same sire and both were born in the summer season (September 13 and July 31).

Housing and husbandry conditions were similar following the birth of each calf. The cow and calf were maintained together in two stalls, each measuring 3.66×4.27 m, within a heated barn with concrete flooring. A rubber mat, approximately 1.83×1.22 m, was placed in one of the barns where the cow and calf usually slept. The barn was maintained at 21°C and the animals were exposed to artificial lighting from 07:00 hr to 18:00 hr and dim lighting from 18:00 hr to 07:00 hr. During the summer months, the cow and calf spent several hours each day outside on display to the public in an exhibit approximately 2,000–2,500 m^2, where they had access to a mud wallow and pool. During the winter months, outdoor access was more limited and weather dependent. The male calf was weaned and moved to another zoological facility before the female calf was born.

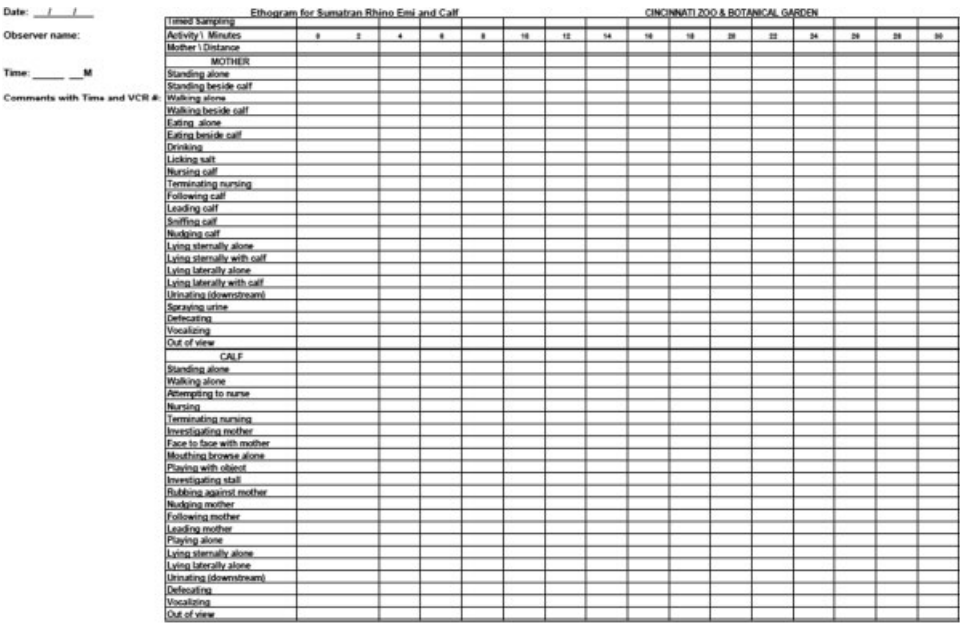
The cow and calf were provided a diet consisting primarily of fresh ficus (30–50 kg per day of up to 10 types of ficus and occasional Kaffir plum), supplemented with 1–2 flakes of hay (40% alfalfa, 60% orchard grass) and 1.8 kg of grain (ADF 16; Mazuri, St. Louis, MO). A variety of fresh fruits (apples and bananas) and vegetables (sweet potatoes and carrots) were hand fed to the cow until the calf was old enough (6–8 weeks) that choking on the fruit and vegetables was not a concern. They both had unlimited access to fresh water and iodized salt blocks. Each morning, the cow received 6 ml of a vitamin E supplement (Emcelle Tocopherol; 500 U/ml; Stuart Products., Bedford, TX) fed in a banana.

Behavioral Observations

Two remote surveillance cameras were strategically located in each of the two stalls occupied by the cow and calf. Cables ran from the cameras in the barn to the Center for Conservation and Research of Endangered Wildlife, allowing Zoo Volunteer Observers (ZVOs) to monitor the animals remotely without disrupting them. The cameras included both audio and video output, so that ZVOs could hear the rhinos while monitoring them. A behavioral ethogram was developed to monitor the cow and calf's behavior immediately following parturition (Fig. 1), and a milestone data sheet was used to record the timing of key behavioral and physiological achievements.

After the birth, behavioral observations were recorded continuously for 7 consecutive days. Mean values for the first 24 hr period on day 1 represented month 1 data for all monthly comparisons of time budget activities. Following this intensive monitoring period, a 24 hr watch was conducted once each month (every 4–5 weeks) for the next 11 consecutive months, with the exception of months 2 and 3 for the male calf and month 11 for the female (owing to conflicts with animal management requirements). During these intensive monitoring periods, the cow and calf remained indoors in their two stalls equipped with cameras. Nursing frequency and duration data were also recorded separately during the first week and at each monthly 24 hr watch.

Time sampling was the methodology employed for all behavioral observations using 2 min instantaneous scans. Therefore, 15 instantaneous scan samples were taken during each 30 min observation period. Each scan involved recording the behavior of the cow and calf at the instant the scan was conducted. Two ZVOs sharing a 4 hr shift would alternate for each 30-min observation period. Each behavioral watch was backed by video recordings, so that the PI could review behaviors when ZVOs had questions. The PI conducted small group training



Date: __/__/__
Observer name:
Time: _____ __M
Comments with Time and VCR #:

Ethogram for Sumatran Rhino Emi and Calf — CINCINNATI ZOO & BOTANICAL GARDEN

Timed Sampling																
Activity \ Minutes	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Mother \ Distance																
MOTHER																
Standing alone																
Standing beside calf																
Walking alone																
Walking beside calf																
Eating alone																
Eating beside calf																
Drinking																
Licking salt																
Nursing calf																
Terminating nursing																
Following calf																
Leading calf																
Sniffing calf																
Nudging calf																
Lying sternally alone																
Lying sternally with calf																
Lying laterally alone																
Lying laterally with calf																
Urinating (downstream)																
Spraying urine																
Defecating																
Vocalizing																
Out of view																
CALF																
Standing alone																
Walking alone																
Attempting to nurse																
Nursing																
Terminating nursing																
Investigating mother																
Face to face with mother																
Mouthing browse alone																
Playing with object																
Investigating stall																
Rubbing against mother																
Nudging mother																
Following mother																
Leading mother																
Playing alone																
Lying sternally alone																
Lying laterally alone																
Urinating (downstream)																
Defecating																
Vocalizing																
Out of view																

Fig. 1. Detailed Sumatran rhino cow-calf behavioral ethogram.

sessions with the ZVOs and observed them in pairs during data collection to ensure behaviors were interpreted correctly by all participating ZVOs.

Although the ethogram included numerous behaviors for both cow and calf (Fig. 1) and the ZVOs recorded data for all of these behaviors, to address the primary objectives of the study, data were collapsed into the following three broad categories: (1) nursing frequency and duration; (2) time spent eating; and (3) time spent resting (lying down sternal or lateral).

Developmental Data

Calf weight

Except for the first weight of the male calf which was obtained on a portable scale, daily weights for both calves and the dam were obtained by walking the animals onto a floor scale about the same time each morning.

Footprints

Weight-bearing footprints left by the female calf in the mud near the wallow were used to obtain footprint molds (Fig. 2). Molds were obtained opportunistically at several ages beginning at 5 weeks and ending at 58 weeks. Plaster of Paris (DAP Inc., Baltimore, MD) was poured into the footprint depression in the mud and allowed to set just long enough that it would retain its shape once removed. Back at the lab, the molds were allowed to harden completely and then three measurements were taken: (1) length from the top of the middle digit to the heel; (2) maximum width of the middle digit; and (3) distance from the outer edges of the inner and outer toe. On one occasion (week 22), in the absence of mud, a footprint impression in snow was used.

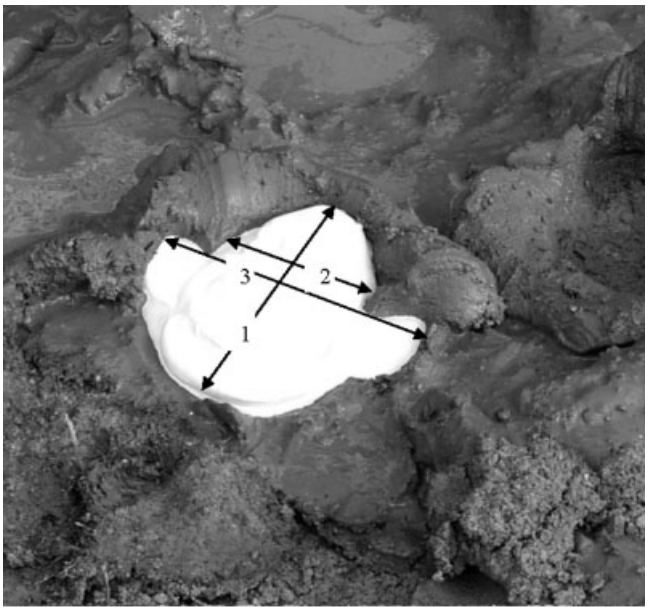


Fig. 2. Sumatran rhino footprint mold originating from a weight bearing footprint left in the mud near the wallow. Molds of each footprint were used to measure the distance from the top of the middle digit to the heel (1), the diameter of the middle digit (2) and the distance between the outer edges of the inner and outer digits (3).

Data analysis

Data collected on the two calves are primarily descriptive. Data in Figures 3 and 4 represent means ± SEM for each 24 hr observational period. Data in Figures 7–10 represent total percentage of time during the 24 hr observational period. A correlation coefficient was calculated for the growth curves of the two calves.

RESULTS

Calf Milestones

Although the cow's behavior clearly changed 12–24 hr before giving birth [Roth et al., 2004], true labor was uncomplicated and quick, lasting just 2–3 hr. The mother oriented toward the calf quickly and began licking the calf between 5 and 28 min after birth. Both calves attempted to stand within 60 min of delivery and succeeded in standing and walking within 2 hr and 10 min of delivery (Table 1). The calves attempted to nurse shortly after walking and succeeded in nursing within 3½ hr after birth. Each calf urinated for the first time within the first 24 hr observation period, but first defecation occurred more than 2 weeks later. The cow expelled the placenta 7–8 hr after parturition following each delivery.

Nursing

Nursing was monitored around the clock during the first 7 days for each calf. Nursing was initiated by the cow, but she did not approach the calf. Instead, she adopted a "nursing stance" with one hind leg extended backwards and waited for the

TABLE 1. Newborn Sumatran Rhino Calf Behavioral and Physiological Milestones

Milestone	Male calf (time after delivery)	Female calf (time after delivery)
Attempt to stand	59 min	15 min
Successful stand	90 min	57 min
Attempt to walk	1 hr and 58 min	59 min
Successful coordinated walk	2 hr and 10 min	1 hr and 33 min
Attempt to nurse	2 hr and 31 min	1 hr and 37 min
Successful nurse	3 hr and 19 min	2 hr and 15 min
First urination	23 hr	20 hr
First defecation	18 days	16 days

calf to nurse. The cow did not aid the calf in finding the teat. She stood still so the calf could search, finding it by trial and error. Successful nursing was evident when the calf began wagging its tail. The first rhino calf suckled from one teat only during each nursing bout, whereas the second calf suckled on alternate teats during the same nursing bout. The cow simply walked away when she wished to terminate suckling. Occasionally, the rhino calf terminated suckling. Because nursing frequency and duration each month were similar between calves and there were no diurnal differences, data collected during the entire 24 hr observation period were combined for each calf for monthly comparisons.

Nursing Duration

Once the teat was found, the first nursing bout lasted 6 min for both calves. A nursing bout was defined as the moment the calf began suckling until it physically released the teat. During the first 24 hr, the male calf nursed 8.54% of the time (123 min), whereas the female calf nursed 7.64% (110 min). There was no observed difference in time spent nursing during the day vs. night for either calf. Therefore, the data were pooled for each 24 hr observation period during the first 7 days and the daily mean used for comparisons. The most notable variation in the duration of nursing bouts between each calf during the first week occurred on day 4 (Fig. 3A). Nursing bout means ($\pm$SEM) for male and female calves were 4.86 ± 0.39 min and 2.73 ± 0.34 min, respectively. Duration of nursing bouts was similar for female and male calves by day 7 (4.25 ± 0.41 and 4.38 ± 0.56 min, respectively).

Overall, nursing duration varied throughout the 12-month period, without a distinct trend when data for both calves were combined (Fig. 3B). The shortest mean nursing duration was recorded in month 2 at 3.4 ± 0.20 min and the longest duration was recorded in month 9 at 4.7 ± 0.31 min.

Nursing Frequency

During the first week, the interval between nursing bouts did not vary substantially between male and female calves, except on day 3 when the male calf nursed every 0.63 ± 0.59 hr and the female calf nursed every 3.39 ± 0.12 hr (Fig. 4A). By day 7, the time between nursing bouts was similar for the female and male calves (2.83 ± 0.34 and 2.82 ± 0.53 hr, respectively) and they continued to nurse at similar frequencies throughout the 12-month study (Fig. 4B).

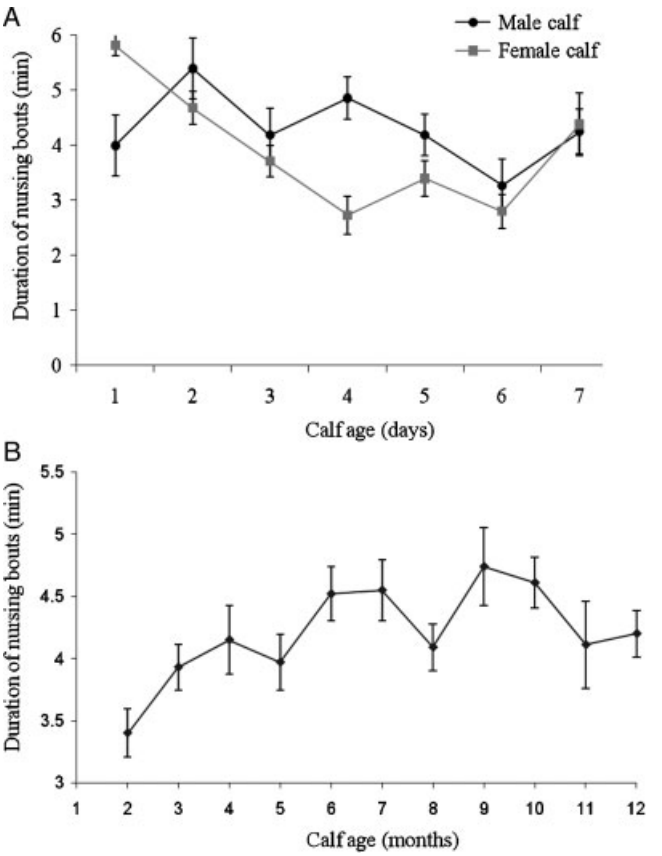


Fig. 3. Mean duration of nursing bouts for male (black circles) and female (gray squares) Sumatran rhino calves during the first seven days after birth (**A**) and the mean nursing bout duration for both calves combined in each of the remaining 11 months of the first year (**B**).

Both calves nursed more frequently during their first 6 months, with the interval between nursing bouts ranging from 1.57 ± 0.17 to 1.79 ± 0.17 hr. Nursing frequency decreased during months 7–12, with the interval between bouts ranging from 2.19 ± 0.27 to 2.10 ± 0.21 hr.

Growth Rate

When first weighed on the day after birth, the male and female calves weighed 32.9 kg and 34.0 kg, respectively. During the first week, the male calf gained an average of 2.0 kg per day, whereas the female calf gained 2.12 kg per day (Fig. 5). Although more variable, the average daily weight gain by month for each calf was similar over the 12-month period (Fig. 6). There was a strong, positive correlation in the growth rate of the calves throughout the first 12 months ($R = 0.99$; Fig. 6). During the first year, the male and female calves gained an average of 0.98 and 1.01 kg/day, respectively. Based on the average weight of the dam during the 7 days following parturition and the last 7 days of the 12-month study, she lost 52.7 and 63.5 kg during the lactation period for the male and female calf, respectively.

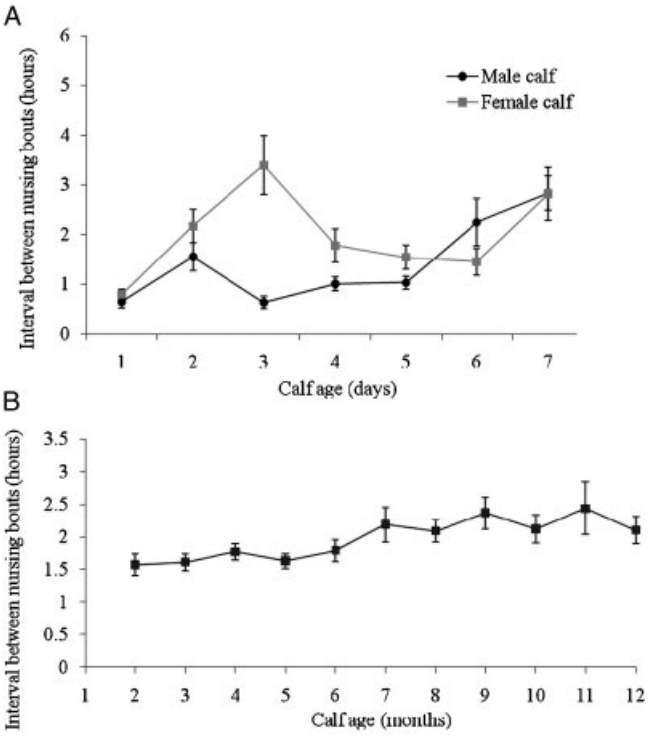


Fig. 4. Mean interval between nursing bouts for male (black circles) and female (gray squares). Sumatran rhino calves during the first seven days after birth (**A**) and mean nursing interval combined for both calves during the remaining 11 months of the first year (**B**).

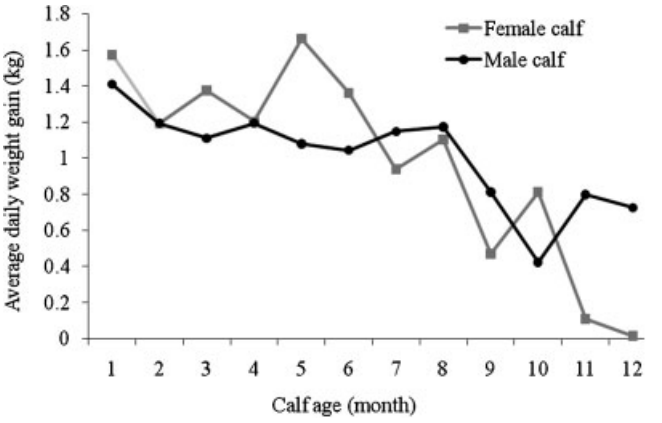


Fig. 5. Average daily weight gain by month for male (black circles) and female (gray squares) calves.

Footprint Measurements

The footprints made by the female calf almost doubled in size between weeks 5 and 58 (Table 2). However, the size did not increase in a linear fashion. Instead, the distance between inner and outer digits increased rapidly (4.41 mm/week) between

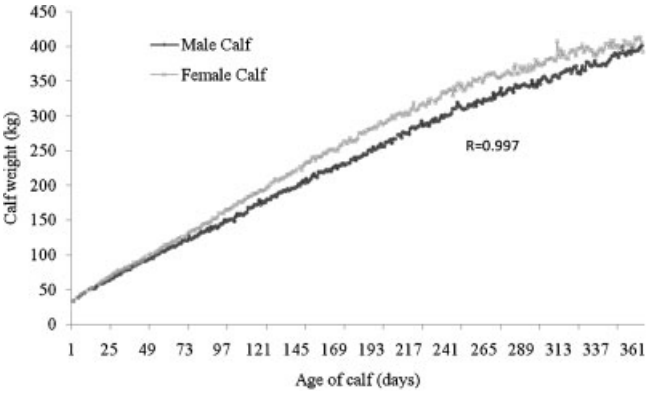


Fig. 6. Sumatran rhino calf body weight during the first year of life. The black line represents data from the male calf and the gray line represents data from the female calf. R = the correlation coefficient for the two data sets.

TABLE 2. Female Sumatran Rhino Calf Weight Bearing Footprint Measurements

	Measurement (mm)		
Calf age (weeks)	Middle digit	Inner to outer toe	Middle digit to heel
5	40	115	115
6	40	130	130
10[a]	45	135	135
10[b]	45	135	125
22 (snow)[a]	70	190	170
22 (snow)[b]	70	190	190
28[a]	75	195	195
28[b]	75	195	195
43	75	200	200
49	75	210	210
58	75	220	225

[a,b]Indicate two different prints.

weeks 5 and 22 and much more gradually (0.83 mm/week) between weeks 22 and 58. The difference was likely owing to the flexing of the toes that occurs during the early months after birth, because the Sumatran rhino calf is born with very compact feet and contracted toes. Compared with her adult mother's footprint measurements, at 58 weeks the female's middle digit, inner to outer toe, and middle digit to heel measurements were still 25, 11, and 17% smaller, respectively.

Time Budgets

All rhinos (cow and calves) spent 70–80% of their time eating and resting. Time spent eating increased from approximately 2 to 20% between week 1 and month 4 for both calves, and then remained relatively consistent ranging from 14 to 26% during the next 8 months (Fig. 7). The time that the cow spent eating did not differ much with each calf, except in month 9 when she appeared to spend more time

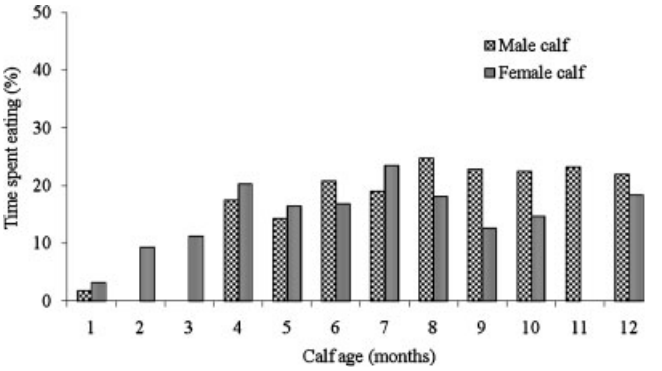


Fig. 7. Mean time spent eating by the male calf (checkered column) and female calf (striped column) on day 1 and each 24-hour observation period during the next 11 months.

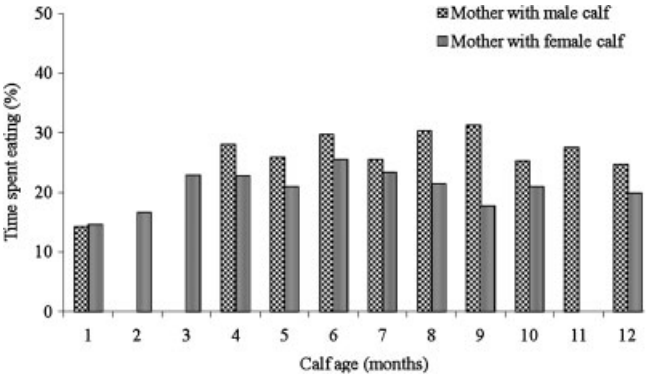


Fig. 8. Mean time cow spent eating while rearing the male calf (checkered column) and female calf (striped column) on day 1 and each 24-hour observation period during the next 11 months.

eating with the male calf than with the female calf (Fig. 8). Both calves spent 50–70% of the time resting throughout the 12-month observation period (Fig. 9). The time that the cow spent resting decreased slightly from more than 60% in week 1 to 45–50% during months 3–12 with each calf (Fig. 10).

DISCUSSION

This study provides the first detailed data on newborn Sumatran rhinos and their first year of behavioral and developmental progress. Such detailed information has to this point been impossible to document on wild Sumatran rhinos. Although a few results are likely influenced by the captive environment and associated animal management practices, many findings are relevant to the species as a whole, wild or captive.

The newborn Sumatran rhino calves took relatively little time to stand, walk, and nurse after birth. Although it appeared that the female calf achieved these milestones quicker than the male calf, some of this difference was likely an artifact of changes in management strategies. With the birth of the first calf (the male), the staff

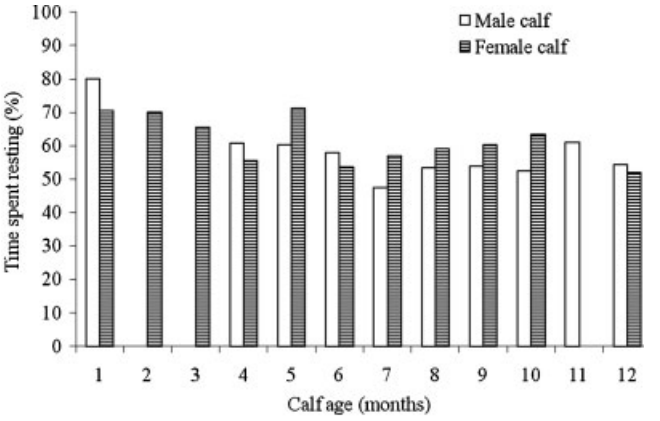


Fig. 9. Mean time spent resting by the male calf (clear column) and female calf (striped column) on day 1 and each 24-hour observation period during the next 11 months.

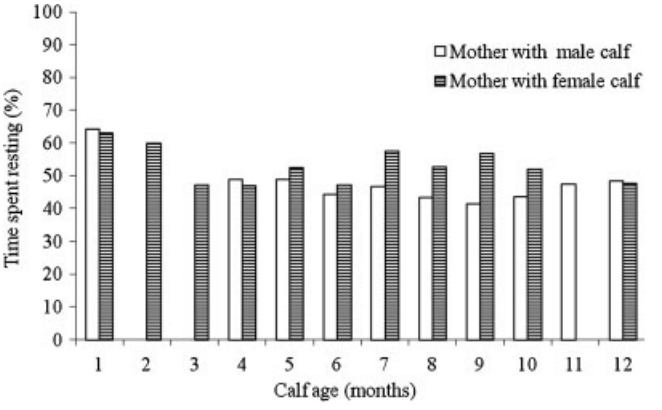


Fig. 10. Mean time cow spent resting while rearing the male calf (clear column) and female calf (striped column) on day 1 and each 24-hour observation period during the next 11 months.

was hesitant to disturb the first-time mother and waited much longer before entering the stall. Therefore, the stall floor was slick with amniotic fluid and blood, making it difficult for the calf to stand. The calf was able to stand fairly quickly after the staff cleaned and bedded the stall with fresh, dry straw. With the birth of the second calf (the female), the animal staff cleaned and bedded the stall very quickly after the calf was delivered. Regardless of this confounding factor, some individual variation could be expected. Overall, the two calves achieved these early milestones in a timely manner, similar to that reported for domestic horse foals [Waring, 2003]. The only surprising finding was the length of time from birth to first defecation. In horses, first defecation is often stimulated by nursing and can occur within less than 2 hr of birth and then every 10 hr on average throughout the foals first week of life [Waring, 2003]. Another large pachyderm, the elephant, defecates within 24 hr of birth [Bercovitch and Andrews, 2010; Kowalski et al., 2010]. In contrast, the Sumatran

rhino calves did not defecate for more than 2 weeks. However, other forest dwelling species' calves are also known to delay their first defecation. For example, first defecation in healthy okapi calves is typically 4–8 weeks after birth [Bennett and Lindsey, 1992]. Whether this physiological phenomenon reflects an evolutionary strategy to avoid predation or an exceptionally efficient utilization of milk nutrients is unknown, but it likely has some adaptive value.

Nursing is one of the most important behaviors to monitor because it is directly linked to neonatal well being. Therefore, it is useful to develop species' "norms" so that it is possible to identify when a neonate requires assistance. This study has established such a normative data set for the Sumatran rhino. During the first week, a very critical time for the neonate, nursing bouts ranged on average between every 1/2 hr on day 1 to every 2½ hr by day 7. Interestingly, intervals between nursing bouts remained relatively short (1½–1 3/4 hr) and similar throughout the day and night during the first 6 months. These data suggest that the Sumatran rhino calf is not a "hider" species, as hider calves typically go without nursing for much longer intervals while their mothers are off in search of food [Lent, 1974]. "Hiding" by calves is thought to be a method of avoiding predation. Because Sumatran rhino calves have very few predators, it is not surprising that they do not exhibit classical hiding behavior.

The frequency of nursing also suggests that the cow's territory may be reduced during the first few weeks following the birth of a calf, because she needs to be close enough to nurse her calf every 1–2 hr until the calf is capable of traveling longer distances. Alternatively, it is possible that enforced proximity of mother and infant owing to captive conditions influenced nursing behavior. Van Strien [1986] noted that, in the wild, rhino mothers with calves walk considerable distances without stopping to feed, but the age of the calf was not specified and could only have been estimated.

Surprisingly, the nursing interval increased only slightly as the calf became older and much more dependent on solid food. Even throughout months 6–12, Sumatran rhino nursing bouts occurred almost every 2 hr around the clock, whereas in many other species, including caribou, muskox, and the domestic horse, nursing intervals increase significantly as the offspring become more dependent on solid food [Lent, 1966, 1970; Crowell-Davis, 1985].

High nursing frequency throughout the first 12 months of life likely contributes to the rapid growth the calf experiences in its first year. Body weight increased more than 10-fold during the first 12 months, giving the calf the size it needs to become independent of its mother by the time it is 16–18 months of age [Van Strien, 1986]. For herd species, such as elephants and horses, rapid growth is less important because offspring will continue to find protection within their dam's social group even after weaning; but for the solitary Sumatran rhino, it is more important for calves to grow quickly while the dam is lactating, because they will be on their own as soon as they are weaned.

Because growth is so accelerated during that first year of life, footprint measurements provide excellent data for estimating the age of wild calves. These data are beneficial to rangers patrolling the forests and conducting wildlife surveys because they rarely see the rhinos themselves. Although there will always be individual variation, estimates can be relatively accurate given how quickly footprint size increases with age during those first 12 months. In particular, there is a sharp

increase in foot width that occurs during the first 6 months of life when the foot truly uncurls and flattens out, thereby providing a milestone for distinguishing very young calves from calves 6 months old or older. A similar pattern of foot growth has been recorded for Indian rhinos [Schenkel and Schenkel-Hulliger, 1969] and is likely a common trait across all rhino species.

Not surprisingly, the rhinos (both cow and calves) spent most of their time eating and resting. The increase in the percent of time calves spent eating between week 1 and month 4 was owing to increased solid intake and not increased nursing. Calves began mouthing leaves during their first week of life and were eating solids shortly thereafter. Frequently, the calves chewed on the leaves of twigs hanging from the cow's mouth as she fed. This behavior potentially teaches the calf what floral species it should seek in the forest [King, 1999], a lesson critical for the survival of a solitary browser species. Because there were no notable differences in time spent eating, nursing, or resting between male and female calves, it was not surprising that they gained weight similarly during their first 12 months.

In some species, maternal investment is greater for male vs. female offspring. For example, colts spend more time nursing than fillies [Duncan et al., 1984]. In bison, sex-skewed maternal investment is even more profound. Not only do cows nurse male calves more than females, but they often do not reproduce at all the year following a male calf, and if they do, they only produce female calves, whereas cows raising female calves produce male or female calves the following year [Wolff, 1988]. Similarly, free-ranging elephant mothers seem to invest more in male vs. female calves and also experience longer interbirth intervals following the rearing of a male calf [Lee and Moss, 1986]. In contrast, this study revealed no gender bias in Sumatran rhino maternal investment in captivity. However, we cannot exclude the possibility that gender bias is displayed in the wild under increased pressures and with restricted resources.

Both the horse and the bison are herd animals and males must fight for and defend a harem of females to propagate. Therefore, robust males are more likely to succeed and it is understandable that investment in male offspring would be substantially greater than that for females. In contrast, both male and female Sumatran rhinos are solitary with large overlapping territories [Van Strien, 1986], so propagation of this species relies more on the odds of a male and female being in close proximity when the female comes into estrus than on the outcome of a battle between competing bulls. Therefore, selection pressures on male rhinos are likely targeting other attributes besides size and physical vigor. Furthermore, the lifestyle and survival challenges of male and female Sumatran rhinos appear similar. Therefore, it makes sense that neither maternal investment nor calf behavior would differ based on the gender of the offspring.

One benefit of maintaining animals in zoos is the ability to study and learn about them using methodologies that cannot be applied to wild populations. This study is a perfect example of putting that theory into practice. Although one must use caution when extrapolating from captive animal behavior to that expected from wild animals, nevertheless, results from studying captive Sumatran rhinos do provide valuable insight and significantly enhance our understanding of the species. In addition, learning more about a species' general behavior and needs typically leads to improved animal care and welfare in captivity.

CONCLUSIONS

1. After birth, Sumatran rhino calves achieved developmental milestones quickly with the exception of defecation, which only occurred after approximately 2½ weeks.
2. Male and female calves were similar in size at birth, nursed at the same frequency, and gained weight comparably during the first 12 months of life.
3. Eating and resting occupied 70–80% of the Sumatran rhino cow and calves' time.
4. Footprint measurements are good indicators of the calf's age.
5. Maternal investment and calf development appeared similar regardless of calf gender.

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