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Nursing behaviours of black rhinoceros *Diceros bicornis* in a zoological park: a case report

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Abstract
The black rhinoceros *Diceros bicornis* is a Critically Endangered species for which detailed information on mother–immature offspring relationships in the wild is scarce. Furthermore, no longitudinal data on development of immatures are available, even in captivity. At Hiroshima City Asa Zoological Park, Japan, nursing behaviours of one adult female rhinoceros were quantitatively examined with her fourth offspring (a female) over the entire 25-month period of lactation, and with her fifth calf (also female) over the first 21 months. The mother accepted over half of all suckling attempts by the calves and actively terminated fewer suckling bouts than the calves did during most of the lactation period. The average durations of mother- and offspring-terminated suckling bouts were similar, and bout durations increased with offspring age. These findings suggest considerable tolerance of offspring's nursing needs in female black rhinoceros.

Background

This study focused on nursing behaviour of captive black rhinoceros *Diceros bicornis*, a Critically Endangered species according to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species with an estimated 5,500 individuals in the wild in 2017 (Emslie et al. 2019). The world population of captive black rhinoceros was 334 in 2020 (Kern 2020). Males are solitary, as are many females except those rearing calves. Because mothers and their calves usually remain close to each other (Goddard 1967; Lent and Fike 2003; Mukinya 1973), rhinoceros are considered as follower ungulates, in which offspring follow their mothers almost from birth (Langman 1977). However, quantitative data on nursing behaviours in rhinoceros are scarce, both in wild and in captive populations (Greene et al. 2006; Hutchins and Kreger 2006; Plair et al. 2012).

Quantitative data on nursing behaviours of a female black rhinoceros with two consecutive offspring were collected at Hiroshima City Asa Zoological Park (hereafter Asa Zoo), Japan. Even with limited sample size, quantitative and longitudinal data on nursing behaviour can contribute towards a better understanding of mother–offspring relationships in black rhinoceros.

Actions

Study group and subjects

The observations were conducted at Asa Zoo between May 2009 and October 2013, during which time an adult male (Hailstone), an adult female (Saki), and one to three offspring of different ages were housed. Between 0800 and 0900 they usually entered an outdoor, clay-ground enclosure (approximately 1,100 m^2) containing four big trees, some large rocks and a shallow pool (approximately 60 m^2), and stayed there until returning indoors between 1600 and 1630. At night the mother with her youngest calf, her older offspring and the male stayed in separate compartments (approximately 30–35 m^2). While indoors they were fed branches, dicotyledonous weeds, hay cubes, pellets for herbivores and various other food items. They were also fed branches in the outdoor enclosure in the morning.

Observations started when Saki's fourth offspring Coco (female) was born on 23 May 2009. Until shortly before the birth, Saki was in the outdoor enclosure with her 2.5-year-old juvenile son Rocky, 4.5-year-old adolescent daughter Addie, and Hailstone who sired all of Saki's offspring (Table 1). Following the birth, for 1.5 months Saki and Coco stayed in the enclosure during the day, separated from the others. In the second and fourth months after birth, Addie and Rocky, and Hailstone, respectively, were allowed in the enclosure with Saki and Coco. When Coco was 2 years 5 months old, Addie (6 years, 11 months) was removed for transfer to another zoo. One day before Saki gave birth to her fifth offspring (Yuki, female), Coco (2 years 7 months), Rocky (5 years 1 month) and Hailstone were separated from her because she suddenly became aggressive towards Coco and Rocky, as reported in other rhinoceros about to give birth (Hutchins and Kreger 2006; Moss 1975). Starting two months later, Coco and Hailstone were allowed to remain with Saki and Yuki in the enclosure; Rocky was sent to another zoo. Thereafter, Coco remained with Saki, Yuki and Hailstone for 1.5 years until she was shipped to another zoo. Therefore, the total observation period was 4 years and 4 months, spanning the period from the first to the fifty-third month of Coco's life. During this period, nursing behaviours of Saki with Coco across the entire 25-month lactation period, and with Yuki for the first 21 months, were recorded.

Data collection

From the public space adjacent to the enclosure, M.N. collected behavioural data on Saki and Coco using focal animal sampling (Martin and Bateson 1993). Each focal session lasted 10 min; mother and daughter were usually observed in alternation, with no pauses between sessions other than occasional 10-minute breaks every few hours. Whenever the pre-determined observation ended as scheduled or was interrupted, Saki was not nursing. In total, 2,340 10-min focal sessions were conducted over 72 days. The observations were distributed equally across the daytime period (48% between 0800 and 1230, 52% between 1230 and 1630, n=390 hours of observation).

All suckling behaviour by Coco during sessions was recorded. Suckling by Yuki was also recorded even when the focal animal was Coco or Saki, as suckling was a conspicuous behaviour and the latter pair were usually close to each other throughout the study (Nakamichi and Saito, in preparation). To suckle, the calf brought its muzzle close to the mother's inguinal area if she was standing motionless or pushed with its horn against her hindleg or around the udder if she was lying on her side. These behaviours were recorded as a suckling attempt. A successful suckling bout was recorded if the mother remained standing motionless or if she stood up directly after being pushed by the calf and then remained standing while the calf took her teat in its mouth. An unsuccessful suckling attempt was recorded if the mother started to walk, moved her hindquarters or continued lying down despite the calf's attempt or if the mother started to move within 10 sec of the calf taking a teat in its mouth. A suckling bout that ended with the calf voluntarily releasing the teat was recorded as terminated by the calf. Release of the teat due to the mother walking away or moving her hindquarters was recorded as a suckling bout terminated by the mother. When Coco or Yuki released the teat due to pushing by an older sibling, the bout was considered terminated by the latter. No bouts were seen to be terminated by Hailstone. The start and end of suckling bouts were recorded using a digital watch, and calculation of bout durations was to the nearest 1 sec.

Table 1. Profile of black rhinoceros at Hiroshima City Asa Zoological Park during the observation period (May 2009 to Oct 2013).

Name	Sex	Kinship	Birth order among Saki's offspring	Date of birth	Date of departure from group	Birth location
Hailstone	Male	Father		30 Jul 1991		San Francisco Zoo
Saki	Female	Mother		26 Jul 1993		Hiroshima City Asa Zoological Park
Addie	Female	Daughter	Second	16 Nov 2004	Jul 2011	Hiroshima City Asa Zoological Park
Rocky	Male	Son	Third	19 Nov 2006	Nov 2011	Hiroshima City Asa Zoological Park
Coco	Female	Daughter	Fourth	23 May 2009	Oct 2013	Hiroshima City Asa Zoological Park
Yuki	Female	Daughter	Fifth	14 Jan 2012		Hiroshima City Asa Zoological Park

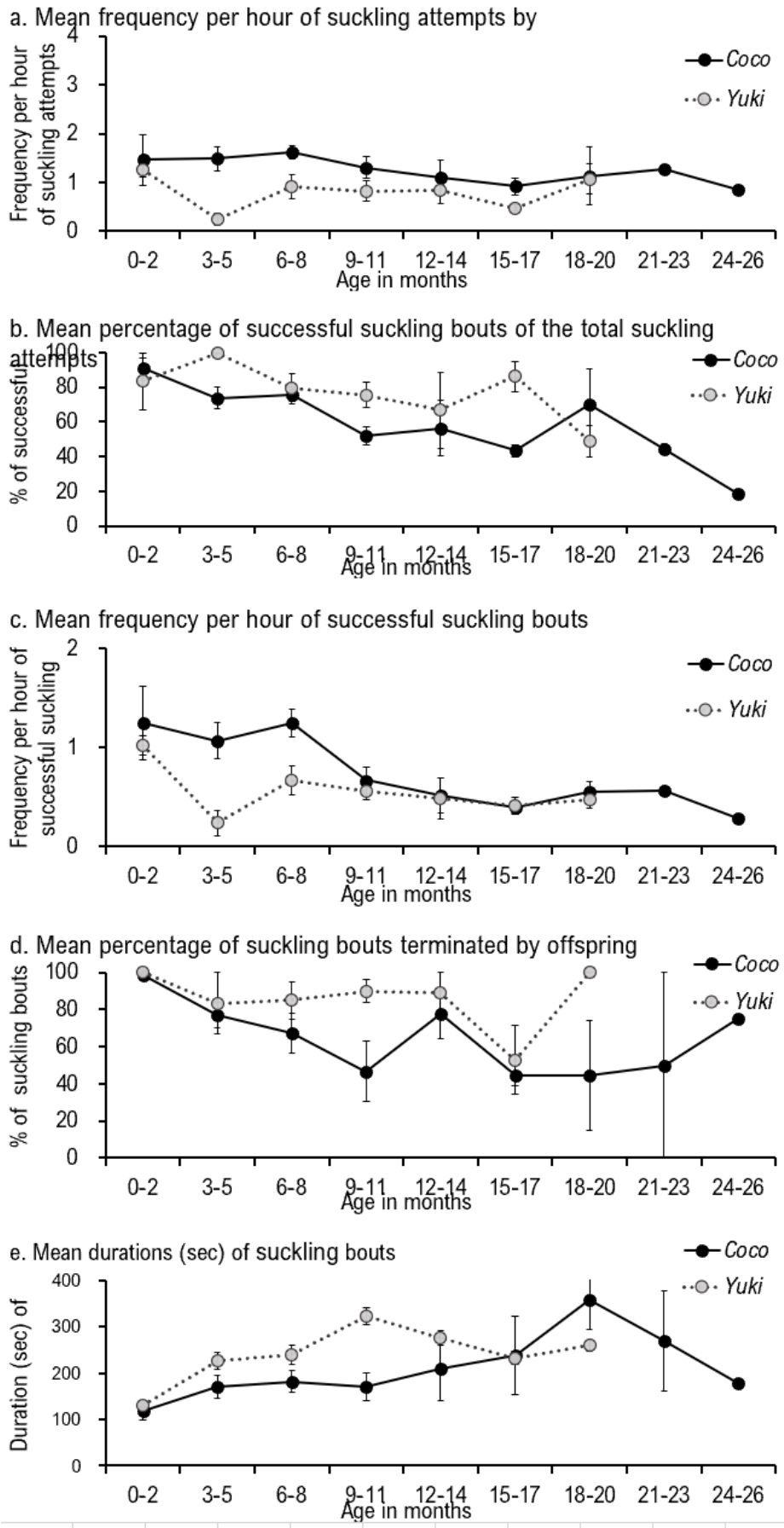

Figure 1. Nursing behaviours toward the fourth offspring Coco and the fifth offspring Yuki. Sample size (observation days per 3-month period) in Figures. 1a and b for Coco (0 to 24 months of age) = 7, 6, 8, 5, 4, 3, 3, 3, and 3, respectively) and for Yuki (0 to 20 months of age) = 2, 3, 5, 5, 3, 6, and 3, respectively). Sample size in Figures. 1c, d, and e for Coco = 7, 6, 8, 5, 4, 3, 3, 3, and 3, respectively, and for Yuki = 2, 2, 5, 5, 3, 6, and 3, respectively. Vertical bars show standard error (SE).

Analyses

Values (frequency or percentage) of each behavioural category for each observation day were calculated taking into account uneven observation time across days, and means of these values were calculated for 3-month periods to control for uneven numbers of observation days. General linear models (GLM) with Poisson distribution and log-link function were used to test whether: (1) frequency of suckling attempts, (2) percentage of successful suckling bouts, (3) frequency of successful bouts and (4) percentage of bouts terminated by the calf varied with age and between the two calves. The log of the total observation time (in minutes) for each day was included as an offset for (1) and (3), and the total number of suckling attempts for each day was included as an offset for (2) and (4). To test whether suckling bout durations differed between the two calves, a GLM with gamma distribution and log-link function (for the number of observation days for each 3-month period, Figure 1) was used. Statistics were performed using data for Coco and Yuki for the first 21 months after birth (i.e. seven 3-month periods). Differences in suckling bout durations based on three terminator categories (offspring, mother and sibling) were examined with the Steel–Dwass test. Data from the first three months were excluded because almost all bouts during this period were terminated by the calf, and the mean duration was notably shorter than in other periods.

All statistical analyses were performed using R software version 4.0.3 (R Core Team 2018). GLMs were run using the R package 'lme4' (Bates et al. 2015). The two-tailed significance level was set at $P<0.05$. All values are reported as mean±standard error (SE) in the text and figure.

Consequences

The total number of suckling attempts and successful suckling bouts were 294 and 187 by Coco and 113 and 79 by Yuki, respectively. The mean frequency of suckling attempts per hour by Coco and Yuki gradually decreased over 25 months, with Yuki making fewer attempts than Coco (Figure 1a: Age, $\chi^2=11.531$, df=6, $P<0.10$; ID, $\chi^2=20.259$, df=1, $P<0.01$; Age×ID, $\chi^2=11.089$, df=6, $P<0.10$). The percentage of successful suckling attempts varied between 50% and 90% in most 3-month periods (Figure 1b: Age, $\chi^2=9.634$, df=6, n.s.; ID, $\chi^2=1.107$, df=1, n.s.; Age×ID, $\chi^2=3.443$, df=6, n.s.). The percentage of successful suckling attempts by Coco was 36% at 24 months of age, when she last successfully suckled. One more attempt was observed in the following month, but it was unsuccessful. The mean frequency per hour of successful suckling bouts for both calves decreased with age (Figure 1c: Age, $\chi^2=26.701$, df=6, $P<0.01$; ID, $\chi^2=7.441$, df=1, $P<0.01$; Age×ID, $\chi^2=6.640$, df=6, n.s.).

The total number of calf-, mother-, and sibling-terminated bouts for Coco were 120, 45 and 22 and for Yuki 54, 15 and 10, respectively. Concerning mother- or calf-terminated suckling bouts (excluding those terminated by an older sibling), both calves terminated almost 100% of bouts in the first three months. Thereafter, Yuki continued to terminate over 80% of bouts, except during the sixth 3-month period, while Coco terminated between 45% and 80% of bouts (Figure 1d: Age, $\chi^2=6.385$, df=6, n.s.; ID, $\chi^2=1.312$, df=1, n.s.; Age×ID, $\chi^2=1,780$, df=6, n.s.). Figure 1e shows the mean duration of all suckling bouts (duration was not recorded for two suckling bouts by Coco and one by Yuki). Coco's bouts became increasingly longer as she got older. Yuki's bouts became longer during the first 12 months (Figure 1e: Age, $F(6, 48)=4.391$, $P<0.01$; ID, $F(1, 48)=4.491$, $P<0.05$; Age×ID, $F(6, 48)=1.537$, n.s.). The shortest and longest suckling bouts for Coco were 11 and 655 sec, and for Yuki, 45 and 410 sec, respectively.

The mean duration of suckling bouts terminated by Coco, her mother and older siblings (Addie or Rocky) were 195±16 (n=84), 204±23 (n=43) and 141±34 (n=22) sec, respectively, with no significant differences (Coco versus mother, t=0.357, n.s.; Coco versus older sibling, t=2.100, n.s.; mother versus older sibling, t=2.059, n.s.). This was also the case for Yuki: the mean durations of bouts terminated by herself, her mother and her older sibling (Coco) were 268±9 (n=49), 260±25 (n=15), and 185±44 (n=9) sec, respectively (Yuki versus mother, t=0.903, n.s.; Yuki versus other, t=1.686, n.s.; mother versus older sibling, t=1.252, n.s.).

Evaluation

These longitudinal, quantitative data on one captive black rhinoceros mother with two calves show that she accepted more than half of their suckling attempts and actively terminated fewer suckling bouts than the calves during most of the lactation period. Average durations of mother- and offspring-terminated suckling bouts were similar and bout durations increased with offspring age. These findings indicate considerable maternal tolerance of calves' suckling behaviour.

In contrast to hider species, in which young offspring remain hidden in vegetation until their mothers return and which show a pattern of infrequent but long suckling bouts, follower species' nursing is characterised by frequent but short suckling bouts (Carl and Robbins 1988; Lent 1974). Based on the observations of the black rhinoceros mother in this study and a literature survey, two general behavioural tendencies of follower species are proposed: mothers accept more than half of their infants' suckling attempts, and they terminate less than half of suckling bouts during most of the lactation period. Several follower species, such as feral horses *Equus caballus* (Cameron et al. 2003), common hippopotamus *Hippopotamus amphibius* (Pluháček and Bartošová 2011) and zebra *Equus grevyi, E. quagga* and *E. zebra*, (Bartoš et al. 2012) exhibit both of these characteristics, while others, such as Alpine chamois *Rupicapra rupicapra* (Rucksstuhl and Ingold 1994) and bighorn sheep *Ovis canadensis* (Festa-Bianchet 1988) exhibit the first characteristic.

In this study there was no clear difference between suckling bouts terminated by the mother or her calves (although the limited sample size should be noted). Suckling bout duration commonly decreases with increasing offspring age in some follower species (bison *Bison bison*, Green et al. 1993; plains zebra *E. quagga*, Pluháček et al. 2010), whereas both calves in our study showed longer bout durations with increasing age (Figure 1e). This pattern has also been reported for Sumatran rhinoceros *Dicerorhinus sumatrensis* (Plair et at. 2012) and common hippopotamus (Pluháček and Bartošová, 2011). In short, the black rhinoceros mother almost always tolerated her calves' suckling until they were satisfied.

Just before, and after giving birth, rhinoceros mothers often behave aggressively towards their older offspring, thus promoting the latter's independence (Hutchins and Kreger 2006; Moss 1975). Something similar was simulated in the present study: due to the mother's aggression, the older offspring was separated from her and the new infant for two months, before reintroduction and co-occupation of the enclosure. It seems that black rhinoceros mothers may live peacefully with older, non-adult offspring, except for a short time just before and up to a few months after giving birth. Living together could be advantageous for mother, infant and older offspring in the wild, for example in defence against predators. According to Moss (1975), such groups have been seen in the wild; conceivably, the older immature in such cases is the mother's previous offspring. However, the continued presence of older siblings may have costs for unweaned, younger calves. Some suckling bouts by Coco and Yuki were interrupted by an older sibling. Moreover, while the mother was lactating for

Coco, she also allowed two older, weaned offspring (Addie and Rocky) to suckle, albeit infrequently (Nakamichi unpublished data). This uncommon behaviour was also seen in another black rhinoceros mother (Hiroshima City Asa Zoological Park 1995). Such interruptions by older siblings could restrict milk intake by the younger calf.

This study quantitatively demonstrates a captive black rhinoceros's high maternal tolerance of two consecutive offspring, by using nursing-related behavioural measures including successful suckling bout ratio and ratio of bouts terminated by the mother. These measures could be useful for comparative studies of tolerance across ungulates. More behavioural studies with larger sample sizes are needed to confirm the present findings and clarify behavioural adaptability in captivity.

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