

Research article

Uncommon behaviours observed in a family group of captive black rhinoceros *Diceros bicornis*: nursing of older offspring and redirected aggression

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Abstract

Black rhinoceros *Diceros bicornis* is considered solitary in the wild, but the Hiroshima City Asa Zoological Park, Japan, has housed a family group with good reproductive outcomes over five decades. Together as a group during the daytime, the members are separated at night. During quantitative observations on this group over more than 4 years, focusing on maternal behaviours and social relationships among individuals, we recorded two unexpected behaviours previously reported in some mammal species that live in well-organized social groups such as primates and elephants, but not in black rhinoceros nor, to our knowledge, any other ungulates: 1) A mother sometimes allowed her two older offspring to suckle repeatedly after she again gave birth, but she accepted their suckling attempts less frequently and terminated their suckling bouts more frequently than those of her new calf, suggesting at least partial satisfaction of unusual suckling demands of older offspring, and differential responding to suckling demands by offspring of different ages. 2) Directly following an unfulfilled suckling demand, one older offspring sometimes displayed aggression toward their younger siblings, similar to redirected aggression seen in animals living in social groups when the victim of a conflict then threatens or attacks a third party. These findings show that black rhinoceros living in a family group in captivity can maintain stable dominance relations, with behavioural tolerance and sociality sufficient for coping with various demands and agonistic situations.

Introduction

Both male and female black rhinoceros *Diceros bicornis* are considered solitary in the wild except for females rearing calves (Goddard 1967; Lent and Fike 2003); therefore, keeping adult black rhinoceros together is not generally recommended (Hutchins and Kreger 2006; Pilgrim and Biddle 2020). However, the Hiroshima City Asa Zoological Park, Japan (hereafter, Asa Zoo) has housed a family group of one adult male, one adult female and their one to four offspring of various ages in an enclosure during the daytime, but separating them at night, for around five decades. During this period three

females successfully reared 18 calves (Hatase, personal communication).

Mammal mothers usually nurse their youngest infant but not older offspring, although nursing of older siblings in addition to the youngest has been reported in African elephants *Loxodonta africana* (Lee and Moss 1986). Redirected aggression has been observed in some mammalian species forming stable, well-organized social groups (e.g., primates: Aureli and van Schaik 1991, spotted hyenas *Crocuta crocuta*: Engh et al. 2005). However, to our knowledge, neither concurrent nursing of offspring of different ages nor redirected aggression have been reported in black rhinoceros or other ungulates. Here,

we report nursing by a black rhinoceros mother toward offspring of different ages and redirected aggression among offspring, indicating previously undocumented behavioural flexibility in black rhinoceros.

Methods

Study groups, subjects, and data collection

Asa Zoo has housed black rhinoceros in a family group of one adult male, one adult female and one to four offspring of various ages in an enclosure (approximately 1,100 m²) during daylight hours. M.N. observed the family group during the period from when adult female Saki gave birth to Coco (May 2009) until Coco's departure to another zoo (October 2013). During this observation period Saki gave birth to another calf (Yuki), but the data used in this study are from the time of Coco's birth to one day before Yuki's birth (January 2012), as unlike her older siblings Addie and Rocky, Coco never attempted to suckle after the birth of a new calf (see Table 1).

Like black rhinoceros females in the wild (Pilgrim and Biddle 2020), shortly before giving birth to Coco, Saki became aggressive toward her offspring (Addie and Rocky). Therefore, these two were separated from Saki; the resident adult male, Hailstone, had been separated around one month earlier. Addie and Rocky were reunited in the enclosure with Saki and Coco 1.5 months after Coco's birth, and Hailstone, 3 months after (Table 1). Such separation and reunion procedures have been carried out every

time a female gives birth, paying due attention to the behaviour of group members (Hatase, personal communication).

M.N. used 10-min focal animal sampling sessions (Martin and Bateson 1993) to observe Saki and Coco when they were in the enclosure during the day (08:00-09:00 to 16:00-16:30; see Nakamichi and Saito (2022) for detailed observation methods). In total, 1,448 10-min sessions were conducted over 45 observation days, totaling 241 h 20 min of observation. All suckling episodes by Coco and her two older siblings Addie and Rocky were recorded regardless of whether the focal animal was Coco or Saki, as suckling behaviour was conspicuous (Nakamichi and Saito 2022) and Saki and Coco were usually close to each other (Nakamichi et al. 2024). Agonistic interactions between group members that were observed during the 10-min sessions were also recorded. Definitions of the behaviours recorded are detailed in Table 2.

Data analyses

Values for each behavioural category recorded during the daily 10-min observation sessions were calculated taking into account uneven numbers of sessions across days, and means of these values were calculated for 3-month periods. Sample sizes (observation days per 3-month period) are shown in Figure 1. To test for possible differences in frequency and percentage of suckling-related activities at different ages and each offspring pair (i.e., Coco vs Addie, and Coco vs Rocky), we used a Generalized Linear Model (GLM) with a Poisson distribution and log-link function. The number of total suckling attempts was included as

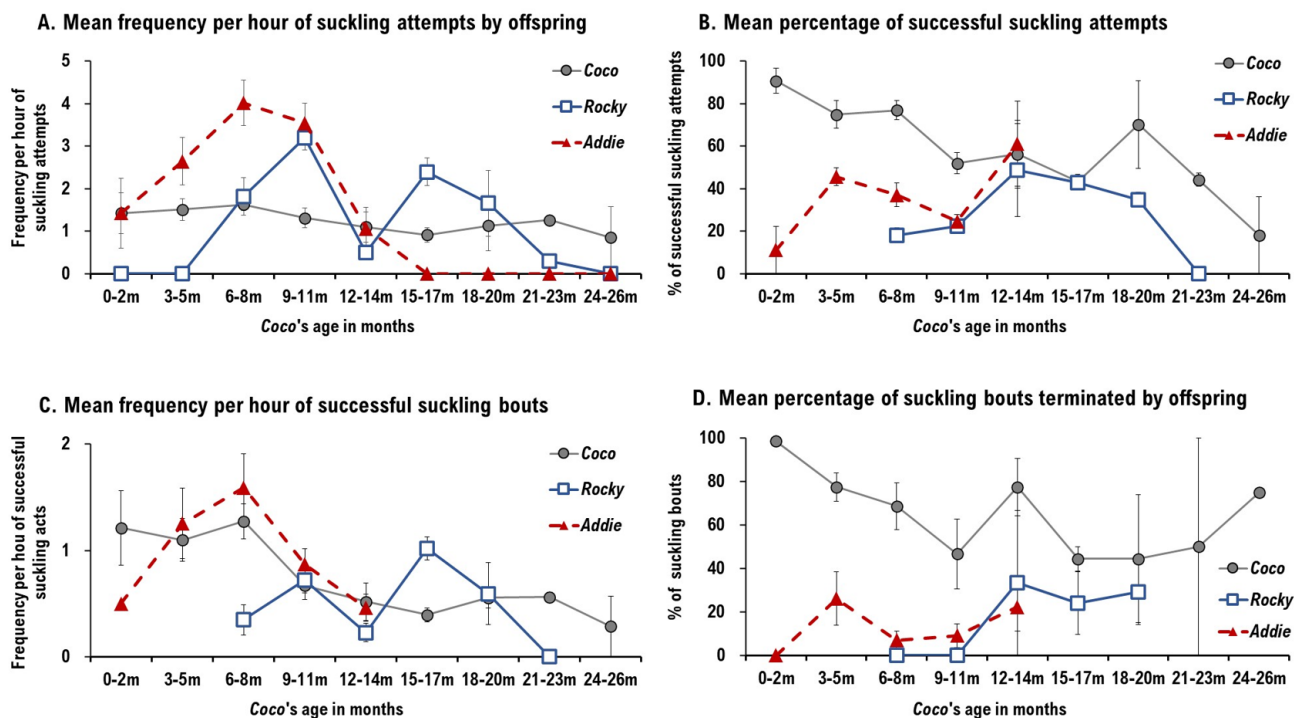


Figure 1. The mean frequency and percentage of suckling-related behaviours by the mother's fourth offspring (Coco, female), third offspring (Rocky, male), and second offspring (Addie, female). Sample sizes (observation days per 3-month period) in Figures 1A and 1B (0 to 24 months of age) are 7, 6, 8, 5, 4, 3, 3, 3, and 3, respectively. Sample sizes in Figures 1C and 1D are 7, 6, 8, 5, 4, 3, 3, 3, and 3, respectively. Vertical bars show standard error (SE).

Table 1. Information on the black rhinoceros family group at Hiroshima City Asa Zoological Park

Name	Kinship	Date of birth	Age during the observation period from May 2009 to January 2012	Age of rhinoceros that was observed to attempt suckling	Period of actual suckling
Hailstone	Father	30 July 1991	18 years 1 month to 19 years 3 months		
Saki	Mother	26 July 1993	15 years 10 months to 17 years 5 months		
Addie	Daughter	16 November 2004	4 years 7 months to 6 years 11 months	4 years 7 months to 5 years 8 months	14 months
Rocky	Son	19 November 2006	2 years 7 months to 5 years 1 months	3 years 2 months to 4 years 5 months	13 months
Coco	Daughter	23 May 2009	1 week to 2 years 7 months	0 months to 2 years 1 month	25 months
Yuki ¹	Daughter	14 January 2012			

¹Behavioural data on Yuki were not included in this study (see text)

the response variable for Test 1, the number of successful suckling bouts was included as the response variable for Tests 2 and 3, and the number of successful suckling bouts terminated by offspring was included as the response variable for Test 4. The log of the observation time (in min) was included as an offset for Tests 1 and 3. The total number of suckling attempts was included as an offset for Tests 2 and 4. Age period (Age) and offspring identity (ID) were included as explanatory variables. The values used for Coco were from Nakamichi and Saito (2022). All statistical analyses were performed using R software version 4.3.2 (R Core Team 2023). GLM was run using the R package 'lme4' (Bates et al. 2015). The two-tailed significance level was set at $P < 0.05$. Multicollinearity

was assessed using variance inflation factors, and all values were below 4.

Results

Suckling-related behaviours

From the second month after Coco's birth, her older siblings Addie (4.5 years old) and Rocky (2.5 years old) were housed with their mother Saki and Coco in the enclosure during the day. Addie started trying to suckle within one week, and Rocky did so after six months. Both of them stopped suckling before Coco was weaned, at 24 months of age (Fig. 1A, Table 1). Addie and Rocky attempted

Table 2. Behaviours and their definitions

Behaviour	Definition
Suckling-related activities	
Suckling attempt	An offspring brings its muzzle close to the mother's inguinal area if she is standing motionless, or it pushes with its horn or touches with its foreleg against her hindleg around the udder while she lying on one side
Successful suckling attempt	An offspring takes the mother's teat in its mouth
Unsuccessful suckling attempt	When an offspring attempts to suckle, its mother starts to walk, moves her hindquarters, continues lying down, or starts to move within 10 sec after an offspring takes a teat in its mouth
Suckling bout terminated by offspring	An offspring voluntarily releases the teat
Suckling bout terminated by mother	Release of the teat from an offspring's mouth resulting from the mother walking away or moving her hindquarters
Aggressive behaviours	
Snort	Make a sound by breathing air noisily through the nose toward the target animal
Head swing	Swing the head rapidly toward a target animal
Push with horn(s)	Using the horns to push the body of another individual
Rush	Run short distance of up to 10 m toward a target animal
Chase	Run over 10 m to chase a fleeing target animal
Submissive behaviours	
Stop approaching	Stop approaching an individual as soon as an aggressive behaviour is performed
Walk away	Walk away from an individual performing an aggressive behaviour
Run away	Run away from an individual performing an aggressive behaviour

to suckle more frequently than Coco (Fig. 1A: Addie, top-ranked model (AIC=336.3, ΔAIC=0), Age × ID ($\chi^2=20.513$, df=4, P<0.01), Age ($\chi^2=36.386$, df=4, P<0.01), ID ($\chi^2=54.485$, df=1, P<0.01); Rocky, top-ranked model (AIC=313.7, ΔAIC=0), Age × ID ($\chi^2=39.381$, df=5, P<0.01), Age ($\chi^2=37.989$, df=5, P<0.01), ID ($\chi^2=13.455$, df=1, P<0.01)), but with significantly lower proportions of successful bouts than Coco (Fig. 1B: Addie, top-ranked model (AIC=207.6, ΔAIC=0), ID ($\chi^2=27.615$, df=1, P<0.01); Rocky, top-ranked model (AIC=159.3, ΔAIC=0), ID ($\chi^2=17.534$, df=1, P<0.01)). The mean hourly rate of successful suckling bouts did not differ between Coco and either of her older siblings (Fig. 1C: Addie, top-ranked model (AIC=254.7, ΔAIC=0), Age ($\chi^2=31.263$, df=4, P<0.01), Rocky, top-ranked model (AIC=179.1, ΔAIC=0), Age × ID ($\chi^2=27.960$, df=5, P<0.01), Age ($\chi^2=18.208$, df=5, P<0.01), ID ($\chi^2=1.400$, df=1, P<0.01)). Unlike Coco’s suckling bouts, most of those by Addie and Rocky were terminated by the mother (Fig. 1D: Addie, top-ranked model (AIC=145.9, ΔAIC=0), ID ($\chi^2=72.067$, df=1, P<0.01); Rocky, top-ranked model (AIC=98.7, ΔAIC=0), ID ($\chi^2=18.383$, df=1, P<0.01)).

Agonistic interactions and redirected aggression

We observed 209 agonistic interactions; none was severe, i.e., wound-inducing aggression, and 208 (99.5%) of them were unidirectional. As shown in Figure 2, Saki was consistently

dominant over the other individuals, and Addie dominated the other three. Hailstone showed aggression only toward Coco and Rocky. Throughout Coco’s first 2.5 years, her dominance relation with her older brother Rocky was unclear. These observations indicate that the dominance rank order among adult and older immature rhinoceros is linear, with females outranking males.

Soon after 22 of 216 of unsuccessful attempts by to suckle (approximately 10%), Addie displayed redirected aggression to her two younger siblings. She also did this after 9 of 114 (8%) of her suckling bouts were terminated by Saki. In 5 of Addie’s 25 aggressive responses toward Coco, Saki displayed aggression toward Addie (i.e., Saki aided Coco); however, Saki never intervened when Addie was aggressive toward Rocky (6 times).

Another two episodes of redirected aggression appeared to be independent of suckling attempts: (1) Soon after being chased by Addie (cause unknown), Coco chased Rocky. (2) In response to head-swinging by Saki toward Addie (cause unknown), the latter chased Coco.

Discussion

Mothers of “follower” ungulate species tend to be more tolerant of their calves’ suckling than those of “hider” species, and black rhinoceros mothers may be among the more tolerant than others

		Recipients of aggressive behavior				
		Saki ♀ Mother	Addie ♀ 2nd offspring	Coco ♀ 4th offspring	Rocky ♂ 3rd offspring	Hailstone ♂ Father
Aggressors	Saki		13	4	24	68
	Addie	0		42	20	1
	Coco	0	0		18	0
	Rocky	0	0	10		0
	Hailstone	0	0	2	6	

Figure 2. Dominance matrix among five black rhinoceros, based on 208 unidirectional agonistic interactions in which one individual exhibited an aggressive behaviour such as snorting, rushing, chasing and the victim responded submissively by walking or running away. Twenty-four agonistic interactions were excluded: one which was bidirectional, and 23 in which the observer (M.N.) failed to record the victim’s response. In 47 of 68 (69%) aggressive behaviours by Saki toward Hailstone, she snorted (69%) when he approached or remained near her, indicating that she tried to keep greater distance between them.

(Nakamichi and Saito 2022). Rhinoceros maternal tolerance may even permit older, weaned offspring to attempt suckling, at least in a food-rich, captive situation. In fact, Saki's mother had also allowed older offspring to suckle (Hatase, personal communication). However, it remains unclear why some older offspring, such as Addie and Rocky, seek nursing, while others, such as Coco, do not.

Tolerance-related permission of suckling attempts appears consistent with black rhinoceros mothers allowing their older, non-fully adult offspring to remain close to them, even in the wild. Some mothers reportedly remained close to their youngest calf and older immatures (Goddard 1967; Pilgrim and Biddle 2020). As predatory attacks on calves by lion *Panthera leo* and spotted hyena are a potential danger (Brain et al. 1999; Plotz and Linklater 2009), the high tolerance of black rhinoceros mothers likely provides protection for older immatures not yet able to effectively defend themselves from predators. Despite this prolonged protection, however, mothers behave aggressively toward their offspring just before giving birth.

We reported the black rhinoceros mother allowed suckling attempts by older offspring at different ages, although she was more tolerant of attempts by her youngest offspring. We also recorded instances of redirected aggression. Moreover, we found that the captive family group of black rhinoceros maintained stable dominance relations, with females outranking males. To conclude, despite being considered solitary in the wild, black rhinoceros living in a family group appear capable of previously unknown behavioural flexibility and greater sociality than previously thought. It is essential to continuously accumulate behavioural data on rhinoceros in wild and captivity, which could lead to a comprehensive understanding of this species and improved management in captivity. At the same time, care should be taken not to mislead the public about their lives.

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