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BRIEF REPORT

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Daytime spatial relationships in a family group of black rhinoceros *Diceros bicornis* at the Hiroshima City Asa Zoological Park, Japan

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Abstract

Although black rhinoceros *Diceros bicornis* are mostly solitary in the wild, the Hiroshima City Asa Zoological Park (Asa Zoo) has kept a family group together during the daytime, with good reproductive performance over five decades. Management procedures at the zoo include temporary single housing of the mother before and after giving birth, which facilitates maintenance of a compatible family group. We recorded intra-group spatial relationships for 4 years and 4 months, during which time an adult female reared two consecutive calves. During daytime she remained in an enclosure with her new calf, one or two older offspring, and an adult male, the sire of all her offspring. Proximity (within two adult body-lengths) scores between the mother and her two calves were especially high during the first year after birth, and only slightly lower for her older offspring. The adult male had the lowest proximity scores. The spatial relationships were visualized by applying multidimensional scaling (MDS) to the proximity scores. Mother and calves were plotted close to each other, with older offspring slightly farther apart on the two-dimensional MDS representation; the adult male was more distant from the other group members. These findings indicate clear follower-type characteristics in the mother–calf pair and also older immature offspring, albeit to a lesser degree. Although black rhinoceros are generally solitary in the wild, our results duplicate observations of some wild black rhinoceros groups containing an adult female, her calf, and an older immature, with adult males being largely solitary.

KEYWORDS

follower-type, mother–calf relationship, mother–older offspring relationships, multidimensional scaling (MDS), proximity

1 | INTRODUCTION

Black rhinoceros *Diceros bicornis* is a critically endangered species according to the International Union for Conservation of Nature Red list of Threatened Species, with an estimated 5630 individuals in the wild in 2018 (Emslie, 2020) and 334 individuals in captivity in 2020 (Kern, 2020). Adult males and females are solitary in the wild, except when mothers rear their calves (Goddard, 1967; Lent & Fike, 2003; Moss, 1975). Therefore, keeping adult black rhinoceros together is not generally

recommended, although offspring can be kept with their mothers until they reach puberty (Hutchins & Kreger, 2006). The Hiroshima City Asa Zoological Park (hereafter Asa Zoo) has housed a family group including one adult male, one adult female and their one to four offspring of various ages in an enclosure during the daytime for around five decades, during which period two females successfully reared 18 calves (Hatase, personal communication).

Black rhinoceros is considered a follower species, in which young offspring remain close to their mother (Lent, 1974), and some groups consisting of an adult female, her calf, and an older immature (probably her older offspring) have been seen in the wild (Moss, 1975; Penny, 1987). However, quantitative information both in the wild and in captivity is limited not only about social relationships between a mother and her offspring of different ages, including proximity (Berger, 1993; Greene et al., 2006; Law et al., 2019). We observed the Asa Zoo family group of black rhinoceros for 4 years and 4 months, during which time one female reared two consecutive calves and showed tolerance of her offspring's nursing needs (Nakamichi & Saito, 2022). Here, we report changes in spatial relationships among the group members over time, as interindividual proximity is known to be fundamental to intimate social relationships in many species (e.g., giraffes, *Giraffa cameloparadalis*, Bashaw et al., 2007; Nakamichi et al., 2015; tigers *Panthera tigris*, Miller & Kuhar, 2008; gorilla *Gorilla gorilla*, Nakamichi et al., 2014).

2 | METHODS

Author M. N. conducted observations on black rhinoceros at Asa Zoo between May 2009 and October 2013, during which time an adult female (*Saki*) reared two calves. After entering the open enclosure (approximately 1100 m^2, Figure 1) between 08:00 and 09:00, she remained there with one or two older offspring and an adult male, the sire of all the offspring, until returning indoors for the night between 16:00 and 16:30. As *Saki* suddenly began to behave aggressively toward her two offspring on the day before giving birth (see Section 3), she was separated from them and the adult male, and then a few months later she and her new calf were again allowed to remain in the enclosure with her one older offspring and the adult male. See Table 1 and Figure 1 for information on the enclosure, management routine, and group members.

When they were in the enclosure, M. N. collected behavioral data including nursing on *Saki* and her female offspring *Coco* using 10 min focal animal sampling sessions (Martin & Bateson, 1993) during the period from *Coco*'s birth to leaving the zoo at the age of 4 years and 4 months. They were observed in alternation, usually with no pauses between sessions. At precisely 5 and 10 min after the start of the session, M. N. used scan sampling to record proximity among all rhinoceros. When animal A was within two-adult body-lengths (approximately 6 m) of animal B, this was scored as proximity between A and B. Three animals are sometimes lined up in an almost straight line and four animals gathered together (Figure 2). As it

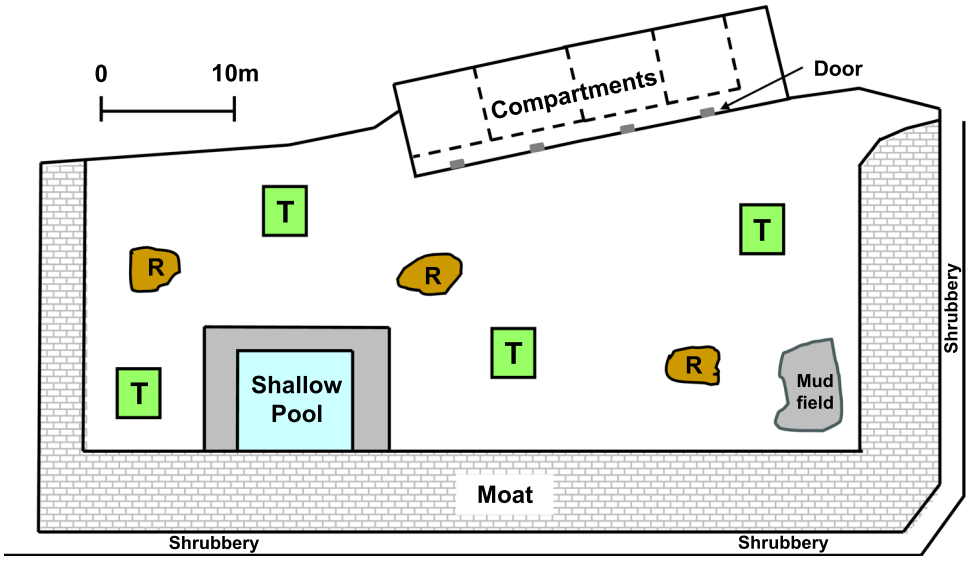

FIGURE 1 Rhinoceros' facilities at the Hiroshima City Asa Zoological Park (Asa Zoo). The outdoor, clay-ground enclosure (approximately 1100 m^2; width, 55 m; the left side, 20 m) contains four big trees (T), which are each framed on all four sides by wooden fence 2.3 m wide and 1.6 m high, three large rocks (R) approximately 2–3 m wide and 1–2 m high, and a shallow pool (approximately 60 m^2). After rain or water is poured in the mud field, rhinoceros can play in the mud. The house has four compartments (approximately 25–35 m^2) with concreate floors, separated from each other by iron pipes. Rhinoceros entered the enclosure between 08:00 and 09:00, and remained there until returning the house between 16:00 and 16:30. At night, the mother with her calf, her older offspring, and the adult male stayed in separate compartments, where they could see, hear, and smell each other and those in adjacent compartments could make muzzle contact between iron pipe fences. While staying in compartments, rhinoceros were fed branches, dicotyledonous food items, hay cubes, pellets for herbivores and various vegetables. They were also fed branches in the enclosure usually in the morning. The figure was depicted based on the ground plan described in the Hiroshima City Asa Zoological Park (1995). [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Profiles of black rhinoceros at Hiroshima City Asa Zoological Park during the observation period from May 2009 to October 2013.

Name	Sex	Kinship	Birth order among *Saki*'s offspring	Date of birth	Age in years and months when individuals left the group
Hailstone[a]	Male	Father		July 30, 1991	
Saki	Female	Mother		July 26, 1993	
Addie[b]	Female	Daughter	Second	November 16, 2004	6 years and 11 months
Rocky[c]	Male	Son	Third	November 19, 2006	5 years and 1 month
Coco[d]	Female	Daughter	Fourth	May 23, 2009	4 years and 3 months
Yuki	Female	Daughter	Fifth	January 14, 2012	

[a]Separated from the other animals shortly before *Saki* gave birth to *Coco* and *Yuki*, and reunited with them 3 and 2 months after they were born, respectively.

[b]Separated from the other animals shortly before *Saki* gave birth to *Coco*, and reunited with *Saki* and *Coco* 1 and a 1/2 months after *Coco* was born. Removed from the group for transfer to another zoo 3 months before *Yuki* was born.

[c]Separated from the other animals shortly before *Saki* gave birth to *Coco*, and reunited with *Saki* and *Coco* 1 and a 1/2 months after *Coco* was born. Since *Saki* suddenly started repeatedly rushing toward and chasing *Rocky* and *Coco 1 day before* Saki *gave birth to Yuki*, he was separated from *Saki*, and then he was transferred to another zoo.

[d]Separated from *Saki* 1 day before *Saki* gave birth to *Yuki*, and reunited with *Saki* and *Yuki* 2 months after *Yuki* was born. Transferred 1 year and 6 months later to another zoo.

FIGURE 2 The black rhinoceros female *Saki* standing together with her three offspring of different ages (from the left: *Rocky* at 2.5 years of age, *Saki* at 16 years of age, *Coco* at 2 months of age, and *Addie* at 4.5 years of age). [Color figure can be viewed at wileyonlinelibrary.com]

seems to be appropriate to consider the first and last animals and those at each end of the four side by side, respectively, as proximity, within two-adult body-lengths was used as the criterion for proximity. The total number of 10 min sessions was 2340 (giving a total observation time of 390 h), over 72 days (mean observation time of 5.4 h per day). The total number of scans was 4680, of which 78 lacked proximity scores.

Proximity scores (%) for each pair of rhinoceros for each observational day were calculated taking into account uneven observation time across days, and mean scores were calculated for 3-month periods to control for uneven numbers of observation days. To test whether frequency of proximity with *Saki* differed among individuals (ID) and as a function of age (in months), we used generalized linear models (GLM) with Poisson distribution and log-link function. GLM was run using the R package "lme4" (Bates et al., 2015). The statistics were performed using data from when *Coco* was between 3 and 26 months old (Period I) and between 33 and 54 months old (Period II); during these periods all five and four

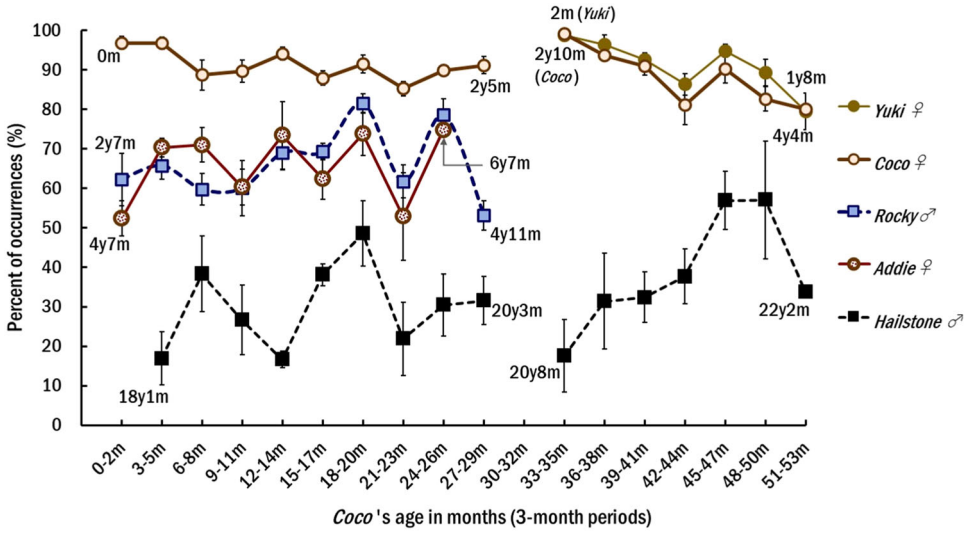

FIGURE 3 Proximity values (within two adult-body-lengths) between adult female *Saki* and other group members: her offspring (*Addie*, *Rocky*, *Coco*, and *Yuki*) and the adult male, *Hailstone*. Numbers with "y" and "m" represent ages in years and months. Vertical bars show standard error (SE). Sample size (observation days per 3-month period) (from the left): 7, 6, 8, 5, 4, 3, 3, 3, 3, 2, 0, 4, 2, 5, 5, 7, 3, and 2, respectively. When *Coco* was 27 months old, *Addie* was transferred to another zoo. When *Coco* was 30 months old, *Hailstone* was not allowed into the enclosure with the other group members because *Saki* would give birth soon. *Coco* and *Rocky* were separated from their mother (*Saki)* the day before she gave birth to *Yuki* because of *Saki's* aggression toward them. Thereafter, *Rocky* was transferred to another zoo. Around 2 months after *Yuki*'s birth, *Coco* and *Hailstone* again started to stay with *Saki* and *Yuki* in the enclosure. Therefore, no values are presented for *Addie* and *Rocky* after the periods when *Coco* was 27–29 months and 30–32 months old, respectively, or for *Coco* and *Hailstone* when *Coco* was 30–32 months old. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Statistical analyses on proximity between adult female *Saki* and the other group members, using generalized linear models (GLM).

Period	Factor	χ^2	*Df*	*p*	Post hoc analyses Factor	Estimate	SE	z	*p*	Nagelkerke R^2
Period I	ID	671.73	3	<.01						0.993
					Intercept (ID: *Addie*)	−0.382	0.025	−14.969	<.001	
					ID: *Coco*	0.285	0.033	8.512	<.001	
					ID: *Hailstone*	−0.786	0.047	−16.724	<.001	
					ID: *Rocky*	−0.007	0.036	−0.185	.854	
	Age: *Coco*	3.23	7	.86						0.305
	Age: *Rocky*	15.92	7	.03						0.506
	Age: *Addie*	12.06	7	.10						0.358
	Age: *Hailstone*	3.23	7	.86						0.979
Period II	ID	400.78	2	<.01						0.992
					Intercept (ID: *Coco*)	−0.130	0.025	−5.117	<.001	
					ID: *Hailstone*	−0.748	0.045	−16.573	<.001	
					ID: *Yuki*	0.037	0.036	1.050	.294	
	Age: *Yuki*	4.36	6	.63						0.548
	Age: *Coco*	6.51	6	.37						0.434
	Age: *Hailstone*	68.31	6	<.01						0.921

Note: The overall model included the number of in proximity with *Saki* as a fixed effect. The log of the total number of scan sampling of each observation day set as an offset.

family members, respectively, stayed together in the enclosure. When *Coco* was 27–32 months old, her older siblings were transferred to other zoos and when she was 30–32 months old, the adult male was not allowed into the enclosure with the other group members. Second, we applied multidimensional scaling (MDS) (Kruskal, 1964a, 1964b) to proximity scores between all rhinoceros pairs, as MDS has been successfully used to visualize spatial relationships among group members (Corradino, 1990; Nakamichi & Kato, 2001). In MDS, animals that spend relatively more time near each other are plotted relatively close together, while those with the lowest proximity scores are plotted farthest apart (Morgan et al., 1976; Nakamichi & Kato, 2001).

TABLE 3 Proximity (within two adult body lengths) scores (%) between rhinoceros during Periods I and II, which were applied to multidimensional scaling (MDS).

Period I[a]	*Saki*	*Coco*	*Rocky*	*Addie*	*Hailstone*
Saki					
Coco	90.5				
Rocky	68.2	66.4			
Addie	67.4	64.9	53.8		
Hailstone	29.7	30.2	29.7	26.6	
Period II[b]	***Saki***	***Yuki***	***Coco***	***Hailstone***	
Saki					
Yuki	91.2				
Coco	88.3	82.9			
Hailstone	38.1	39.3	39.5		

[a]Period 1: from 3 to 26 months of *Coco*'s age.

[b]Period II: from 33 to 54 months of *Coco*'s age.

3 | RESULTS

Proximity scores between *Saki* and *Coco* remained around 90% through the first 2.5 years after *Coco*'s birth, and those between *Saki* and *Yuki* remained above 80% for *Yuki*'s first 1.5 years. By contrast, proximity scores between *Saki* and *Hailstone* were consistently the lowest throughout the study (Figure 3). Proximity scores of the older offspring (*Rocky* and *Addie*) to *Saki* were slightly lower than those of the youngest, or almost same (*Coco*). For results of statistical analyses, see Table 2.

To apply MDS, we calculated mean proximity scores between all pairs of rhinoceros for Periods I and II, respectively, based on 3-month periods, and then constructed the proximity matrix for each Period (Table 3). Figure 4 shows visual representations of the two-dimensional solutions; the stress values of less than 0.001 indicate that the two-dimensional MDS solutions appropriately reflect the proximity values. During Period I, the five rhinoceros were plotted such that *Saki* and *Coco* remained close to each other, *Addie* and *Rocky* remained relatively near *Saki* but away from each other, and *Hailstone* remained far away from any individual. During Period II, *Saki*, *Yuki*, and *Coco* were plotted in clusters and *Hailstone* remained distant from them.

On the day before giving birth to *Yuki*, *Saki* rushed toward *Coco* (three times) and *Rocky* (nine times) during 10 10 min sessions (i.e., over a

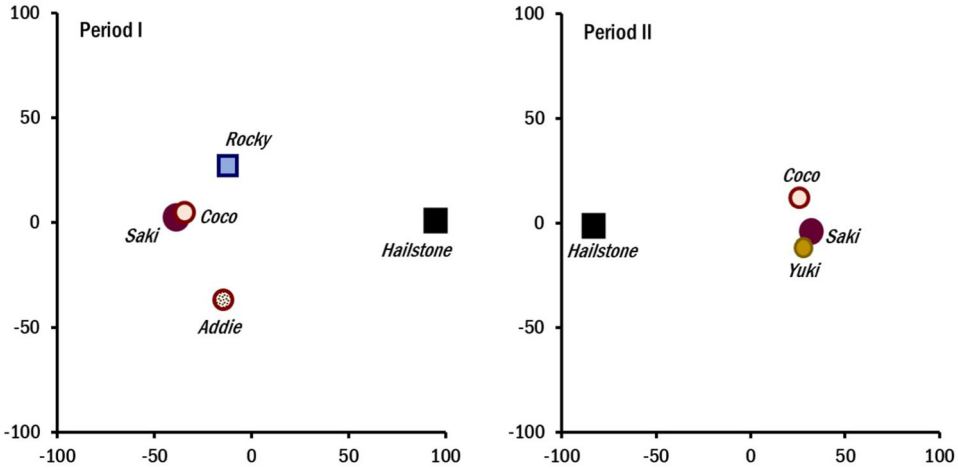

FIGURE 4 Two-dimensional multidimentional scaling (MDS) solutions for proximity values among black rhinoceros in a family group at Asa Zoo in Periods I (*Coco* from 3 to 26 months of age: the group consisted of *Coco*, her mother *Saki*, her older siblings *Addie* and Rocky, and the adult male *Hailstone*) and II (*Coco* from 33 to 54 months: the group consisted of *Coco*, *Saki*, her younger sibling *Yuki*, and *Hailstone*). In MDS, two animals with the highest proximity value are plotted closest, and those with the lowest value are plotted farthest apart. In the MDS procedure, how well a configuration in a given dimensional space represents the data is provided by the stress value. The two stress values for the Periods I and II for two dimensions were each less than 0.001. According to Kruskal (1964a), a stress of 0.1 is fair and a stress of 0.05 is good, which means that the two-dimensional MDS solutions for Periods I and II appropriately reflect the proximity values. As social network analyses appear especially powerful when applied to larger groups than in the present study (we had only 4 or 5 rhinoceros), they were not used in this study. [Color figure can be viewed at wileyonlinelibrary.com]

period of 100 min). Thus, she was separated from the other group members. No severe aggressive behaviors involving physical contacts were observed in the group during the 390 h of observations, although relatively mild aggression such as snorting sometimes occurred.

4 | DISCUSSION

As wild rhinoceros mothers and their calves usually remain close to each other (Goddard, 1967; Moss, 1975), rhinoceros are considered follower ungulates (Langman, 1977). The present quantitative study confirmed that spatial relationships between a black rhinoceros mother *Saki* and two consecutive calves in captivity were consistent with qualitatively described mother–calf relationships in their wild counterparts. Moreover, this study found that juvenile and adolescent offspring also showed this follower-type tendency, to a lesser degree. However, wild rhinoceros mothers commonly chase away their offspring around the time of birth of a new calf (Moss, 1975). This was also the case in the present study. Although *Saki* was therefore separated from the group on the day before giving birth, within a few months after the birth, she with her newborn calf, older offspring, and the adult male resumed living together with no serious aggressive episodes. This means that in their captive environment where older offspring and the adult male cannot disperse, they seem to adapt not by acting aggressively, but by peaceful association and maintaining appropriate interindividual distance. That is, the adult male, adult female, and their offspring of different ages lived compatibly together in the family group, in which she successfully reared her two consecutive calves (Nakamichi & Saito, 2022) and the adult male remained distant from the other individuals. Asa Zoo's successful maintenance of rhinoceros in a family group during daytime requires appropriate management procedures, including temporary separation of the mother from the other animals before and after giving birth.

Although black rhinoceros are essentially solitary, groups of three to five adult females and females with their calf and older immature are occasionally observed in the wild (Penny, 1987; Schenkel & Schenkel-Hullinger, 1969, referred from Hutchins & Kreger, 2006). It is important to continue accumulating behavioral data on any captive family groups and their management, as this can provide guidance for captive management of this species. At the same time, care should be taken to avoid the misleading perception that black rhinoceros commonly live in families.

AUTHOR CONTRIBUTIONS

Conceptualization, design, and sample collection: Masayuki Nakamichi. *Data analysis and interpretation*: All authors. *Writing*: Masayuki Nakamichi. *Reviewing and editing of manuscript*: All authors.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study was approved by the Animal Research Committee of the Graduate School of Human Sciences, Osaka University.

REFERENCES

Bashaw, M. J., Bloomsmith, M. A., Maple, T. L., & Bercovitch, F. B. (2007). The structure of social relationships among captive female giraffe (*Giraffa camelopardalis*). *Journal of Comparative Psychology*, *121*, 46–53.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*, 1–48.

Berger, J. (1993). Disassociations between black rhinoceros mothers and young calves: Ecologically variable or, as yet, undetected behaviour? *African Journal of Ecology*, *31*, 261–364.

Corradino, C. (1990). Proximity structure in a captive colony of Japanese monkeys (*Macaca fuscata fuscata*): An application of multidimensional scaling. *Primates*, *31*, 351–362.

Emslie, R. (2020). *Diceros bicornis*. The IUCN red list of threatened species 2020: e.T6557A152728945. Retreived February 23, 2022, from: https://doi.org/10.2305/IUCN.UK.2020-.RLTS.T6557A152728945.en

Goddard, J. (1967). Home range, behaviour, and recruitment rates of two black rhinoceros populations. *African Journal of Ecology*, *5*, 133–150.

Greene, T. V., Manne, S. P., & Reiter, L. M. (2006). Developing models for mother–infant behaviour in black rhinoceros and reticulated giraffe *Diceros bicornis michaeli* and *Giraffa camelopardalis reticulata* at Brookfield Zoo, Illinois. *International Zoo Yearbook*, *40*, 372–378.

Hutchins, M., & Kreger, M. D. (2006). Rhinoceros behaviour: Implications for captive management and conservation. *International Zoo Yearbook*, *40*, 150–173.

Kern, C. (2020). *ZIMS for Studbooks for World Association of Zoos and Aquariums//Diceros bicornis. Species360 Zoological Information Management System*. Retreived July 12, 2021, from: http://zims.Species360.org/

Kruskal, J. B. (1964a). Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika*, *29*, 1–27.

Kruskal, J. B. (1964b). Nonmetric multidimensional scaling: A numerical method. *Psychometrika*, *29*, 115–129.

Langman, V. A. (1977). Cow–calf relationships in giraffe (*Giraffa camelopardalis giraffa*). *Zeitschrift für Tierpsychologie*, *43*, 264–286.

Law, P. R., Jewell, Z. C., & Alibhai, S. K. (2019). Disassociation between black rhinoceros (*Diceros bicornis*) mothers and their calves. *African Journal of Ecology*, *57*, 268–269.

Lent, P. C. (1974). Mother–infant relationships in ungulates. In V. Geist & F. Walther (Eds.), *The behavior of ungulates and its relation to management* (24, pp. 14–55). International Union for the Conservation of Nature and Natural Resources (IUCN).

Lent, P. C., & Fike, B. (2003). Home ranges, movements and spatial relationships in an expanding population of black rhinoceros in the Great Fish River Reserve, South Africa. *South African Journal of Wildlife Research*, *33*, 109–118.

Martin, P., & Bateson, P. (1993). *Measuring behavior*. Cambridge University Press.

Miller, A., & Kuhar, C. W. (2008). Long-term monitoring of social behavior in a grouping of six female tigers (*Panthera tigris*). *Zoo Biology*, *27*, 89–99.

Morgan, B. J. T., Simpson, M. J. A., Hanby, J. P., & Hall-Craggs, J. (1976). Visualizing interaction and sequential data in animal behaviour: Theory and application of cluster-analysis methods. *Behaviour*, *56*, 1–43.

Moss, C. (1975). *Portraits in the wild: Behavior studies of east African mammals*. The University of Chicago Press.

Nakamichi, M., & Kato, E. (2001). Long-term proximity relationships in a captive social group of Western lowland gorillas (*Gorilla gorilla gorilla*). *Zoo Biology*, *20*, 197–209.

Nakamichi, M., Murata, C., Eto, R., Takagi, N., & Yamada, K. (2015). Daytime mother–calf relationships in reticulated giraffes (*Giraffa cameloparadalis reticulate*) at the Kyoto City Zoo. *Zoo Biology*, *34*, 110–117.

Nakamichi, M., Onishi, K., Silldorf, A., & Sexton, P. (2014). Twelve-year proximity relationships in a captive group of Western lowland gorillas (*Gorilla gorilla gorilla*) at the San Diego Wild Animal Park, California, USA: Proximity relationships among gorillas. *Zoo Biology*, *33*, 173–183.

Nakamichi, M., & Saito, M. (2022). Nursing behaviors of black rhinoceros (*Diceros bicornis*) in a zoological park: A case report. *Journal of Zoo and Aquarium Research*, *10*, 158–162.

Penny, M. (1987). *Rhinos: Endangered species*. Christopher Helm Publishers.

Schenkel, M., & Schenkel-Hullinger, L. (1969). *Ecology and behaviour of the black rhinoceros* (Diceros bicornis *L.): A field study*. Paul Parney.

The Hiroshima City Asa Zoological Park. (1995). *Black rhinoceros: The third research report*. The Hiroshima City Zoological Association.

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