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IMPLICATIONS OF SEMI-INTENSIVE MANAGEMENT FOR THE BREEDING OF BLACK RHINOCEROS

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Introduction

Despite the black rhinoceros (*Diceros bicornis*) population in Africa numbering over 100,000 individuals in the 1960s (Ritchie, 1963), poaching for horn (Tudge, 1991) and inadequate protection (Thorne and Whalen, 1996) resulted in a serious decline to only 2,410 individuals in 1995. The IUCN SSC African Rhino Specialist Group (AfRSG) reported an increase to 2,600 individuals by the end of the 1990s. Latest figures suggest that the African wild population (which accounts for 97.6% of the worldwide population) has increased to 3,100 individuals (IUCN Red List, 15 May 2004). Since its dramatic decline, a number of measures have been taken in order to conserve the black rhino, not least a trade ban (the species was listed on CITES Appendix II in 1975, and moved onto Appendix I in 1977, Berger, 1993). Other 'in range' (see Emslie and Brooks, 1999, for definition) measures included protection *in situ*, translocation to Intensive Protection Zones, dehorning of wild rhinos in order to discourage poaching (see Leader-Williams, 1989, and Western, 1992, for debate), development of informer networks and specialised investigation outside reserves, sustainable harvesting of horn and the use of radiocollars for tracking purposes (see Alibhai and Jewell, 2001, and Alibhai *et al.*, 2001, for further discussion). Other 'out of range' measures included keeping black rhinos in captivity in order to maintain a genetic and demographic 'reserve' for strengthening wild populations (Serow *et al.*, 2002). Despite Balmford *et al.*'s (1995) demonstration that *in situ* conservation costs considerably less than *ex situ* conservation, but is equally productive, many conservation studies and projects during the 1980s and 1990s focused on *ex situ* black rhinos (Linklater, 2003).

Successful conservation will result in an increase in the number of individuals in the wild and can be achieved through actions to decrease the number killed and increase population growth. The current AfRSG Conservation Action Plan maintains that conservation effort should be directed towards 'key' and 'important' *in situ* rhino populations and the use of metapopulation management. However, the importance of existing *ex situ* captive breeding groups is also acknowledged – especially with regard to the acquisition of knowledge about the biology of the species.

At present many of the remaining black rhinos in the wild are to be found in sanctuaries, conservation areas and intensive protection zones where they are afforded effective protection. These may be considered to be kept under a 'wild' system or a 'semi-wild' system, both of which differ from a 'captive system' –

largely in relation to breeding (natural or manipulated) (Emslie and Brooks, 1999). It is important to note, however, that about 250 black rhinos are held in captivity worldwide. These individuals are clearly important since they represent approximately 8% of the worldwide population.

Data from captive-breeding programmes can be used to support field-based studies (Emslie and Brooks, 1999). For example, the International Rhino Foundation provides knowledgeable rangers for wild rhinos, who have gained knowledge from their experience of captive rhinos. Moreover, correct management of 'captive' populations can provide the opportunity for the production of surplus individuals who can be translocated into wild populations to help to increase their size.

It should be noted, however, that there may be problems with breeding in rhinos kept in semi-wild or captive conditions (Blumer, 1996; Mehrdadfar, 1997). The basic reproductive biology of the black rhino is still not clearly understood (Schaffer *et al.*, 2001). Studies have suggested that black rhinos suffer from haemolytic anaemia syndrome (Kock *et al.*, 1991) caused by the spirochaete bacterium *Leptospira interrogans* (Miller, 1993; Neiffer *et al.*, 2001), which is a relative of *L. hardjo*, known to cause subfertility in dairy cattle (Peters and Ball, 1995). The captive diet may contribute to health problems (Grant *et al.*, 2002) including breeding difficulties. As a selective browser in the wild, the black rhino feeds on many different plant species all containing low levels of phenols, alkaloids (Muya and Oguge, 2000) and iron (Beutler *et al.*, 2001). Beutler *et al.* (2001) suggested that browsing black rhinos have very efficient iron-absorptive mechanisms, so when they are given supplementary feedstuffs they may become iron 'overloaded'.

In the wild, female black rhinos have home ranges (Mukinya, 1973) which vary enormously in size (Tatman *et al.*, 2000). The black rhino is either solitary (Goddard, 1967) or semi-solitary – associating in pairs (typically a cow and her calf, or a male and a female) or in groups of three (typically a cow and two calves) (Ritchie, 1963). Rhinos are polygamous (Goddard, 1967), reproducing slowly with a typical annual birth rate of 6.8 to 10.9 percent (Goddard, 1970). Males reach sexual maturity by eight years (Garnier *et al.*, 2001), whilst females reach sexual maturity any time after 3.8 years (Estes, 1991). The oestrous cycle lasts between one and six days with little visual evidence (Kock *et al., 1991).* Mating can occur at any time of the year (Ritchie, 1963) and if successful is followed by a 15-month gestation period. Over the past decade it has become easier to monitor the reproductive status of individuals, especially those in captivity, by ascertaining hormone levels from salivary (Czekala and Callison, 1996), faecal (Garnier *et al.*, 1998; Lance *et al.*, 2001; Garnier *et al.*, 2002) and serum (Berkeley *et al.*, 1997; Graham *et al.*, 2001) samples.

One particular aspect of breeding in captivity which has received very little research attention in black rhinos is 'behavioural inhibition of breeding', whereby the behaviour of some individuals may inhibit others from reproducing. It has been demonstrated that levels of reproductive hormones in an individual may be influenced by aspects of the social system in which it lives. See Bennett *et al.* (1996), Arnold and Dittami (1997), and Saltzman *et al.* (1998) for cases of reproductive suppression (reduced luteinizing hormone levels) in Damaraland mole-rats (*Cryptomys damarensis*), alpine marmots (*Marmota marmota*) and common marmosets (*Callithrix jacchus*) respectively.

It is important to understand social behaviour in any 'managed' species, whether kept in semi-wild conditions or in captivity, in order to minimise

'stress' and to ultimately encourage breeding (Mehrdadfar, 1997; Carlstead *et al.*, 1999a, b) and promote conservation (Komdeur and Deerenberg, 1997).

Although black rhino numbers are slowly increasing, mainly through prioritising effective, scientific *in situ* conservation projects and studies (Linklater, 2003), the management of captive black rhino breeding groups can continue to contribute to their conservation, particularly through providing more thorough biological (and behavioural) knowledge about the species in general. In 1987 a small (n = 7) herd was established at the privately-owned Imire Game Ranch in Zimbabwe and managed on a custodial basis for the State. According to the AfRSG (Emslie and Brooks, 1999) classification system this herd was 'semi-wild' (kept in an area of less than 10 km^2, under 'compressed' conditions, with a high stocking density at times, regular food supplementation and housing, subject to veterinary procedures when necessary, and allowed to breed naturally). The herd was also kept under 'sanctuary' conditions (continuously protected by armed guard). The herd was neither 'key' nor 'important' according to the AfRSG classifications of conservation importance.

The custodian of the herd was concerned that after nine years as a herd only one of the four females had produced a calf, despite there being physiological evidence that all females were cycling regularly. The purpose of the present study was to examine the apparent lack of breeding through a detailed assessment of the behaviour exhibited by the seven individuals in order to provide a basis for improving their management and, subsequently, their breeding. The analysis of social activity displayed by the individuals was not limited to the use of the oversimplified 'dominance hierarchy concept' (Syme and Syme, 1979), but also considered proximity relations, physical and social associations and individual attributes (Kiley-Worthington, 1977; Carlstead *et al.*, 1999a, b) such as 'Total Social Involvement' and 'Performer' or 'Receiver' Tendency (Kiley-Worthington, 1978; Randle, 1995).

As long as the black rhino remains Critically Endangered, every single individual, including those kept in *ex situ* conditions, matters. These individuals must be managed in the best way possible in order to facilitate breeding, and ultimately to promote their conservation (either directly by translocation to the wild or indirectly by providing valuable biological information about the species).

On the completion of this study a number of changes to the housing and management of these rhinos were implemented immediately. Although it was not possible to obtain behavioural data for the period after the changes were made, the three non-breeding females rapidly became pregnant and bred successfully. This study aims to demonstrate the potential usefulness and importance of simple behavioural observations for the management of *ex situ* rhinos.

Methods

Animals and study site

Seven nine-year-old black rhinos belonging to the Zimbabwe Department of National Parks and Wildlife Management were involved in this study: four females (Cuckoo, D.J., Mvu and Amber) and three males (Sprinter, Noddy and Fumbi). All were born in the wild between April and June 1987 and had been separated from their dams shortly after birth due to the dams being killed by poachers. They were brought to Imire Game Ranch at between two and six months of age, and thereafter kept as a single herd. Imire Game Ranch is a

1500-ha park in Zimbabwe (30° latitude and 20° longitude). It has *Brachystegia* woodland and *Eucalyptus* coppice, and *Themeda* dominated grassland. Imire supports populations of various antelope, elephants and buffalo, but there are no large predators. The game ranch is run in conjunction with a commercial farm producing cattle, tobacco and maize.

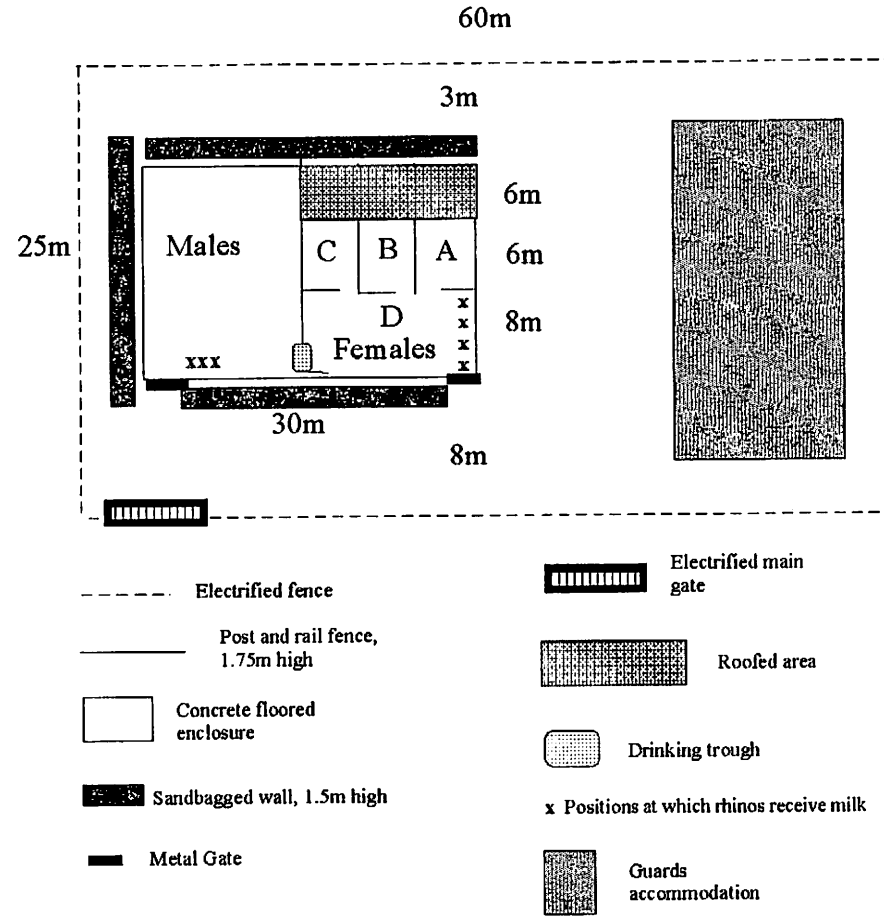

Figure 1. Layout of the rhino boma (pen). The boma is situated within an electrified enclosure, also containing the guards' houses.

Husbandry

The rhinos were kept as a single herd all of the time for security reasons. They spent the night in the 'rhino *boma*' (pen), surrounded by a 2.5-metre-high wall of sand bags within an electrified compound (Fig. 1). The males and females

were separated on entry to the boma. Overnight the females occupied a total area of 15 m × 8 m (with three smaller sub-pens each measuring 5 m × 4 m which they could go into if they wished), whilst the males occupied an adjacent, similar-sized area (15 m × 8 m). At 08.00 hours all the rhinos were let out into the game park under the close surveillance of at least three armed scouts/guards. Hand-held wire whips were used to discourage individual rhinos from straying from the herd. At 13.30 the rhinos were herded to a pre-arranged site and fed a small quantity of cattle cubes (approximately 1.5 kg each) to enable visitors participating in a 'wildlife observation drive' to view them at close range. At this time the rhinos typically met up with a group of six elephants. The rhinos spent the remainder of the afternoon browsing before being herded back to the boma between 16.30 and 17.00, where they received *ad libitum* hay, minerals and water. At 17.30 they each suckled five litres of a milky solution from a teated container from the positions marked 'x' on Fig. 1. This was done daily in order to facilitate the administration of medication at any time. The rhinos in this study did not have their horn routinely harvested, although six of them (all, except one non-breeding female, Amber) had 10 cm of their anterior horn removed in 1995, to prevent injuries when penned at night.

Regular pregnancy testing was carried out on faecal hormone levels.

Observations

The head rhino scout had notes on the 'sexual activity' displayed by the rhinos since January 1995, which included the dates and frequency of chasing, mounting without copulation and mounting with copulation for each individual (all of which were considered to be behavioural indicators of oestrus).

The authors and three trained scouts conducted behavioural observations for three weeks, from 7 to 31 January 1996 (inclusive). The rhinos were observed between 08.00 and 16.30 when out in the game park and for a further hour immediately after penning between 17.30 and 18.30. Three aspects of the rhinos' behaviour were recorded during the day: maintenance activity, proximity relations and social interactions. (Only proximity and social data are discussed in this paper.)

Proximity relations were also recorded every 15 minutes using the focal scan sampling method (Altmann, 1974). The identity of each rhino's nearest neighbour, and the distance to the nearest neighbour, were noted onto a check sheet. Distances were coded: 1 = touching; 2 = up to 5 m; 3 = 5 to 15 m; 4 = 15 to 30 m; 5 = 30 to 50 m; 6 = 50 to 100 m; and 7 = over 100 m (adapted from similar work by Kiley-Worthington and de la Plain, 1983, and Randle, 1995, on beef cattle).

Social interactions between the rhinos were observed using 'all-occurrences' sampling (Martin and Bateson, 1986), as and when they occurred (see Altmann, 1974). The identities of the 'Performer' and the 'Receiver', and the behaviours that they engaged in, were recorded onto check sheets. For the purposes of this study, social activity was divided into four broad categories: aggression, withdrawing, affiliation and 'other' (Table 1). The 'other' category contained behaviours for which the meaning was not clear from the Receivers response (see Kiley-Worthington and Randle, in prep.). During the hour directly after penning, the social interactions occurring in the male group were recorded by one author, while those in the female group were recorded by the other. (The two authors alternated between the male and female groups on a daily basis.)

Changes of location (i.e. A, B, C and D on Fig. 1) made by the females were also recorded using 'all-occurrences' sampling.

Table 1. Behaviours comprising the four categories of social interaction.

Aggression	Withdrawing	Affiliation	Other
Head down – chin in	Tail withdraw	Head extend	Head up
Push body	Back off	Rub against	Head lower
Push head	Leap away	Rub body	Head toss
Push side	Run away	Rub head	Head nod
Push rump	Avoid	Rub neck	Head throw
Horn body		Rub side	Horn ground
Horn face		Head rest	Smell ground
Horn head		Chin rest	Ear(s) forward
Horn body		Neck rest	Ear(s) back
Horn side		Smell another	Ear(s) flick
Horn rump		Smell body	Ear(s) prick
Growl		Smell side	Open mouth
		Smell face	Close mouth
		Smell rump	Chew
		Nose-to-nose	Puff
		Squeak	Sigh
		Approach	Yawn
		Contact make	Call
		Contact stand	Rest leg
		Contact walk	Kick own body
		Contact lie	Kick dung
		Follow	Stamp
		Touch	Paw
		Stand over	Shake body
		Nudge	Turn body to
			Turn head to
			Blink
			Close eyes
			Tail wag
			Tail swish
			Tail up
			Tail down
			Contact break
			Sexual actions

Data analysis

The raw data were transcribed into the MINITAB statistical package v12. The Total Social Involvement measure (TSI) represented the total number of interactions an individual was involved in. The Performing to Receiving Tendency measure (P/R) was derived from the number of interactions performed divided by the number of interactions received. (A Performer would have a ratio of >1, whilst a Receiver would have a ratio of <1.) Quantitative data analysis was mainly non-parametric due to the small sample size.

Results

The rhinos were observed for 407 rhino hours during the day and 119 rhino hours in the pen, i.e. 526 rhino hours in all.

Behaviour associated with breeding

Only one female, Cuckoo, calved at the game park, first in 1993, then again on 23 January 1996. At the time of the study none of the other three females were pregnant; however, all showed regular behavioural signs of oestrus between 1 January 1995 and 1 January 1996. D.J. was observed being chased by a male 14 times, mounted without copulation ten times and with copulation six times. Mvu was chased by a male 43 times, mounted without copulation eight times and with copulation 11 times. Amber was chased by a male 12 times, mounted without copulation twice and with copulation once.

Proximity relations

During this study individuals were never permitted to be more than 200 m from the remainder of the herd. Five of the rhinos were typically seen between 5 and 15 m from their nearest neighbour. The remaining two, the non-breeding females D.J. and Mvu, were only ever between 0 and 5 m of their nearest neighbour. Table 2 summarises the occurrence of each individual being the nearest neighbour of another individual. Females were the preferred neighbours of both males and females (Chi-squared$_1$, with Yate's correction, = 5.84, $P <$ 0.05). There were two obvious alliances, one between two females (Cuckoo and Amber), and a slightly weaker one between a female (D.J.) and a male (Noddy).

Table 2. Summary of the proximity relations between the seven individual black rhinos.[1]

	Focal individual	Nearest Neighbour: Males			Females			
		SPR	NOD	FUM	CUC	DJ	MVU	AMB
Males	SPR	–	33	39	31	50	43	22
	NOD	35	–	33	18	81[2]	33	14
	FUM	41	47	–	22	43	31	32
Females	CUC	19	25	22	–	30	30	89[3]
	DJ	33	57[2]	37	32	–	31	24
	MVU	32	36	39	37	41	–	31
	AMB	27	19	24	90[3]	18	37	–

[1] Based on 1752 observations, approx. 251 per rhino, made over a three-week period. The data are the number of times each rhino is another's neighbour. SPR: Sprinter; NOD: Noddy; FUM: Fumbi; CUC: Cuckoo; DJ: D.J.; MVU: Mvu; AMB: Amber.

[2,3] indicate alliances based on analysis of standardised residuals subsequent to a significant Chi-squared test. Obvious alliances are evident between [2] a male and a female (D.J. and Noddy) and [3] two females (Cuckoo and Amber).

Social interaction

During the day, 1,778 interactions were observed over 405 rhino hours. Of these, 46% were of an affiliative nature, 7% aggressive and 5% withdrawing. The remaining 42% were classified as 'other' since their nature was unclear. During the first hour of penning, 867 interactions were observed over 119 rhino hours. The penned males exhibited slightly more interactions/individual/hour (7.67) than the penned females (7, P > 0.05). There were no significant differences between the genders in the amounts of the different types of interactions occurring within the single-sex groups (all Chi-squared P > 0.05; see Figure 2).

There was significantly more TSI (interactions/rhino/hour) exhibited during the first hour of penning (2.18 ± 0.28) than during the day (1.12 ± 0.17) (Wilcoxon T = 0.0; N = 7; $P < 0.05$; Fig. 3). However, there was no significant difference in the Performing/Receiving tendency when out in the day and penned at night (Wilcoxon T = 12; N = 7; $P > 0.05$; Fig. 4).

The total amounts of aggression displayed by each of the four females and three males within the single-sex groups during the first hour of penning at night were derived (Table 3).

The female pen was subdivided into four areas, three smaller pens (A, B and C) and a communal loafing area (D) (see Fig. 1). Table 4 summarises the number of times each female occupied each of the sub-pens and the number of changes of location made by each female. There was a significant association between sub-pen and individual female occupation (Chi-squared$_6$ = 29.5; $P <$ 0.001). Standardised residuals revealed that Cuckoo clearly preferred pen, whilst D.J. and Mvu were prevented from using pen A and B respectively. The breeding female (Cuckoo) changed location more frequently (81 changes in all) than any of the non-breeding females (Mvu 76, D.J. 58 and Amber 52).

Breeding after implementation of suggested changes

A number of changes were suggested regarding both the physical design of the pen and the herding of the rhinos during the day. These were implemented in spring 1996, and by the end of 1998 a further four calves had been born. The breeding female (Cuckoo) had her third calf (a female), while the three previously non-breeding females (Amber, Mvu, D.J.) each had a male calf. Furthermore, in 2002 all four females had calved again, and were pregnant again.

Discussion

If, as a result of this study, just one individual of this Critically Endangered species breeds successfully, that is an important result. (It may not be in statistical terms, but clearly is in terms of international importance.) Since all of the non-breeding females actually exhibited behaviour typical of individuals in oestrus prior to the study, it was reasonable to expect some breeding given the polygamous structure of the herd (Goddard, 1967).

Their environment was deemed to be appropriate in terms of plant species present (Muya and Oguge, 2000; Tatman *et al.*, 2000). However, given that their environment consisted of mainly lowveld with some *Brachystegia* woodland, it could be suggested that the ecological carrying capacity would be in the region of one rhino per 1000 to 1500 ha. Consequently seven rhinos/1500 ha constitutes a very high stocking density. It could be argued that a lack of palatable browse

Table 3. Amount of aggression occurring between individuals within the single-sex groups. Data are frequencies and consist of the sum of number of times aggression is performed by the initiator of an interaction (the 'Performer') and the number of times that aggression is performed by a recipient as a 'Recipient Response'.

Females

	Receiver				
Performer	Cuckoo	DJ	Mvu	Amber	**Total**
Cuckoo	–	6	11	15	**32**
DJ	2	–	4	5	**11**
Mvu	0	2	–	6	**8**
Amber	3	7	13	–	**23**

Males

	Receiver			
Performer	Sprinter	Noddy	Fumbi	**Total**
Sprinter	–	15	17	**32**
Noddy	9	–	2	**11**
Fumbi	6	1	–	**7**

Table 4. Summary of the occupation of pens within the female side of the rhino boma.

	Sub-pen			
	A	B	C	**Total number of changes made**
Cuckoo	39 [1]	21	21 [2]	**81**
DJ	11 [2]	20	27	**58**
Mvu	26	10 [2]	40	**76**
Amber	13	22 [1]	17	**32**
Total occupation of pen	**89**	**73**	**105**	**267**

[1] a high, positive standardised residual indicated that this individual occupied this pen more than would be expected by chance.

[2] a high, negative standardised residual indicated that this individual occupied this pen less than would be expected by chance.

could lead to a vitamin and/or mineral deficiency, which may have resulted in the observed extended delay to first calving. While these are possible contributing factors to the apparent lack of breeding in the females, it must be argued that the land the rhinos were grazing/browsing was part of a farmed system, achieving more growth than that of typical unmanaged lowveld. Furthermore,

there were no visual signs of poor condition, and the rhinos were fed balanced concentrates (cattle cubes) and had access to *ad libitum* hay and mineral supplements when penned at night.

It was considered more likely that the factors contributing to the lack of successful breeding were behavioural (Serow, 2002), in particular, social. As Ritchie (1963) stated, black rhinos in the wild tend to be solitary, or at most semi-solitary. The rhinos in this study were typically only 5 to 15 m from their nearest neighbour, some only 0 to 5 m. Such enforced proximity between individuals (caused by the scouts herding them together in order to protect them from poachers) must therefore be considered as a possible cause of the lack of breeding. The fact that females were the preferred nearest neighbours of both males and females, and that there were two clear alliances, demonstrates that there was opportunity to mate (male and female alliance) and that associations typical of truly wild rhino populations occurred (i.e. between two females; see Ritchie, 1963, and Carlstead *et al*, 1999a, b).

It is difficult to determine if the social behaviour exhibited by this herd of black rhinos was typical of truly wild individuals, since very little detailed information has been published. All individuals were significantly more socially involved when penned than during the day, and more specifically, there was a substantial increase in aggression on penning (at least doubled), a phenomenon seen in other species, e.g. pigs (Mount and Seabrook, 1993). It is likely that penning the rhinos at night was also a major contributing factor to the lack of breeding. Given the size of the females' pen (15 × 25 m in total, with three internal pens), it was not possible for each female to maintain a distance of more than 5 m from her nearest neighbour. Such confinement, coupled with the increase in aggressive activity, could exacerbate the tendency of some females to be Performers and others to be Receivers. Indeed, both when penned at night and herded during the day, the breeding female was clearly a Performer, involved in most of the social interaction occurring in the female pen (particularly aggression), while the three non-breeding females tended to be Receivers, especially of aggression. While the amount of aggression occurring did not appear to result in obvious physical damage, it might very well have had a psychological effect on breeding. It may be argued that the high levels of aggression exhibited by the breeding female were due to her imminent calving. But the reason why is not as important as the fact that she was by nature an aggressive individual and was having an inhibiting effect on the other three females.

In conclusion, it is suggested that the three non-breeding females were being inhibited from breeding by a number of behavioural factors: first, enforced close proximity with other individuals when herded during the day and confined with other females in the pen at night; second, increased levels of aggression from the breeding female; and third, disruption of position within the pen caused by the breeding female preventing them from settling. It appears that the lack of breeding in this small group of black rhinos was caused by their management. While it was acknowledged that the herding by day and penning by night had to continue (in order to protect them from poaching), some changes to procedure were suggested. The armed guards were asked to allow individuals or pairs of rhinos to achieve a solitary or at least semi-solitary status by letting them move at least 200 m away from the rest of the herd. As Kiley-Worthington (1977) pointed out, wild female and male ungulates need to spend a considerable amount of time together in pairs in order to achieve a prolonged courtship,

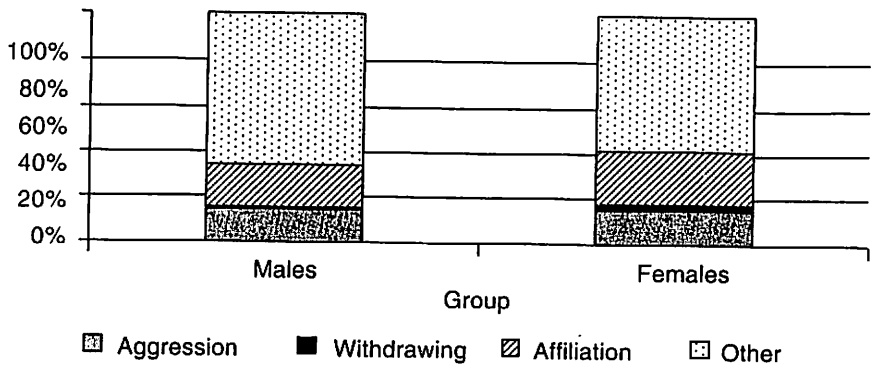

Figure 2. Types of interaction within single sex groups during penning at night.

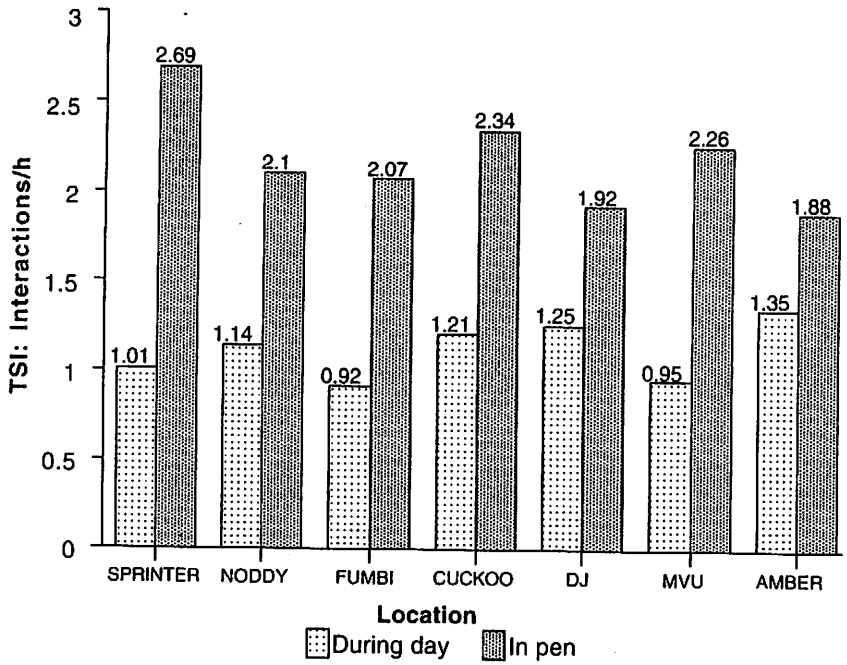

Figure 3. TSI occurring per hour during the day and the first hour of penning at night.
Based on 1778 interactions, observed over 405 rhino hours during the day and 867 interactions observed over 119 rhino hours during penning at night. TSI consists of the total number of interactions an individual is involved in (irrespective of whether as a 'Performer' or a 'Receiver'.)

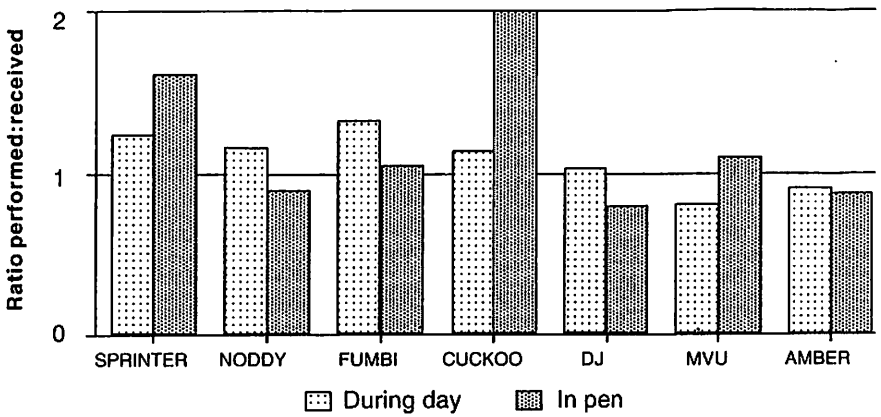

Figure 4. The tendencies of individual rhinos to be 'Performers' or 'Receivers' during the day and the first hour of penning at night.
Based on 1778 interactions, observed over 405 rhino hours during the day and 867 interactions observed over 119 rhino hours during penning at night, i.e. 2645 interactions in all over 524 rhino hours. This measure is the ratio of the number of interactions performed to the number of interactions received. A ratio of >1 indicates that an individual is a Performer, while a ratio of <1 indicates that an individual is a Receiver.

and consequently successful mating. In the reported situation it was likely that the herding was disrupting courtship. Measures were also suggested to reduce the aggressive interactions occurring during penning, especially between the females. This could be achieved in the short term by gating off the existing sub-pens (A, B and C) in order to separate individuals and allow them privacy. Indeed, there was already some evidence that individuals preferred different sub-pens (see Table 4). In the long term it was suggested that a larger pen should be constructed where individual females could withdraw and isolate themselves; the provision of four sub-pens would be an advantage. A gate between the male and female pen would also be advisable for transfer of individuals for breeding purposes.

It has been found that hand-rearing individuals and raising white rhino siblings together leads to a failure in breeding in captivity. This could be avoided in this herd of black rhinos by allowing voluntary separation of individuals within the herd. There may be more flexibility in such a semi-intensive system, as in the game park; however, such considerations should also be included in the environmental design in the urban zoo.

Breeding and conservation implications

It is imperative that such groups of rhinos are subject to appropriate biological management (Walpole, 2002) – and that this includes providing an appropriate social environment (in addition to the more focused-on physical environment). The improvements to the management of this herd of black

rhinos were implemented in 1996, subsequent to the breeding female having her second offspring in January 1996. To date (July 2003) the breeding female has had another four calves, and all three of the previously non-breeding females have successfully bred on more than one occasion. This successful breeding group has helped to facilitate the re-establishment of black rhinos in the wild (under surveillance) and is contributing to the apparent stabilisation of black rhino numbers reported in Zimbabwe (IUCN, Feb. 2003).

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References

Alibhai, S.K., and Jewell, Z.C. (2001): Hot under the collar: the failure of radio collars on black rhinoceros (*Diceros bicornis*). *Oryx* 35: 284–288.

Alibhai, S.K., Jewell, Z.C., and Towindo, S.S. (2001): Effects of immobilisation on fertility in female black rhino (*Diceros bicornis*). *Journal of Zoology* 253: 333–345.

Altmann, J. (1974): Observational study of behavior. *Behaviour* 49: 227–267.

Arnold, W., and Dittami, J. (1997): Reproductive suppression in male alpine marmots. *Animal Behavior* 53: 53–66.

Balmford, A., Leader-Williams, N., and Green, M.J.B. (1995): Parks or arks – where to conserve threatened animals. *Biodiversity and Conservation* 4: 595–607.

Bennett, N.C., Faulks, C.G., and Molteno, A.J. (1996): Reproductive suppression in subordinate, non-breeding female Damaraland mole-rats: two components to a lifetime of socially induced infertility. *Proceedings of the Royal Society of London* (Series B) 263: 1599–1603.

Berger, J. (1993): Rhino conservation tactics. *Nature* 361: 1215.

Berkeley, E.V., Kirkpatrick, J.F., Schaffer, N.E., Bryant, W.M., and Threlfall, W.R. (1997): Serum and fecal steroid analysis of ovulation, pregnancy, and parturition in the black rhinoceros (*Diceros bicornis*). *Zoo Biology* 16: 121–132.

Beutler, E., West, C., Speir, J.A., Wilson, I.A., and Worley, M. (2001): The HFE gene of browsing and grazing rhinoceroses: a possible site of adaptation to a low-iron diet. *Blood Cells, Molecules and Diseases* 27: 342–350.

Blumer, E. (1996): Research. In *Rhinoceros Husbandry Resource Manual* (eds. M. Fouraker and T. Wagener), pp. 56–60. Fort Worth Zoological Park, Texas.

Carlstead, K., Mellen, J., and Kleiman, D.G. (1999a): Black rhinoceros (*Diceros bicornis*) in US zoos: I. Individual behaviour profiles and their relationship to breeding success. *Zoo Biology* 18: 17–34.

Carlstead, K., Fraser, J., Bennett, C., and Kleiman, D.G. (1999b): Black rhinoceros (*Diceros bicornis*) in US zoos: II. Behaviour, breeding success, and mortality in relation to housing facilities. *Zoo Biology* 18: 35–52.

Czekala, N.M., and Callison, L. (1996): Pregnancy diagnosis in the black rhinoceros (*Diceros bicornis*) by salivary hormone analysis. *Zoo Biology* 15: 37–44.

Emslie, R., and Brooks, M. (1999): *African Rhino Status Survey and Conservation Action Plan*. IUCN Publications Services Unit, Cambridge, U.K.

Estes, R.D. (1991): *The Behavior Guide to African Mammals*. University of California Press, Berkeley.

Garnier, J.N., Bruford, M.W., and Goossens, B. (2001): Mating system and reproductive skew in the black rhinoceros. *Molecular Ecology* 10: 2031–2041.

Garnier, J.N., Green, D.I., Pickard, A.R., Shaw, H.J., and Holt, W.V. (1998): Non-invasive diagnosis of pregnancy in wild black rhinoceroses (*Diceros bicornis minor*) by faecal steroid analysis. *Reproduction, Fertility and Development* 10: 451–458.

Garnier, J.N., Holt, W.V., and Watson, P.F. (2002): Non-invasive assessment of oestrous cycles and evaluation of reproductive seasonality in the female wild black rhinoceros (*Diceros bicornis minor*). *Reproduction* 123: 877–889.

Goddard, J. (1967): Mating and courtship of the black rhinoceros (*Diceros bicornis* L.). *East African Wildlife Journal* 4: 69–75.

Goddard, J. (1970): Age criteria and vital statistics of a black rhinoceros population. *East African Wildlife Journal* 8: 105–122.

Graham, L., Schwarzenberger, F., Mostl, E., Galama, W., and Savage, A. (2001): A versatile enzyme immunoassay for the determination of progesterones in feces and serum. *Zoo Biology* 20: 227–236.

Grant, J.B., Brown, D.L., and Dierenfeld, E.S. (2002): Essential fatty acid profiles differ across diets and browse of black rhinoceros. *Journal of Wildlife Diseases* 38: 132–142.

Kiley-Worthington, M. (1977): *Behavioral Problems of Farm Animals*. Oriel Press, London.

Kiley-Worthington, M. (1978): The social organisation of a small captive group of eland, oryx and roan antelope with an analysis of personality profiles. *Behavior* 66: 33–55.

Kiley-Worthington, M., and de la Plain, S. (1983): *The Behavior of Beef Suckler Cattle* (Bos taurus). Birkhäuser Verlag, Basel.

Kiley-Worthington, M., and Randle, H.D. (in prep.): Communication in black rhino.

Kock, N., Morton, D., and Kock, M. (1991): Reproductive parameters in free-ranging female black rhinoceroses (*Diceros bicornis*) in Zimbabwe. *Onderstepoort Journal of Veterinary Research* 58: 55–57.

Komdeur, J., and Deerenberg, C. (1997): The importance of social behaviour studies for conservation. In *Behavioural Approaches to Conservation in the Wild* (eds. J.R. Clemmons and R. Buchholz), pp. 262–276. Cambridge University Press, U.K.

Lance, V.A., Patton, M.L., and Hagey, L.R. (2001): Identification of a series of C2102 pregnanes from fecal extracts of a pregnant black rhinoceros (*Diceros bicornis minor*). *Steroids* 66: 875–881.

Leader-Williams, N. (1989): Desert rhinos dehorned. *Nature* 340: 599–600.

Linklater, W.L. (2003): Science and management in a conservation crisis: a case study with rhinoceros. Conservation *Biology* 17: 968–975.

Martin, P., and Bateson, P. (1986): *Measuring Behavior: an Introductory Guide*. Cambridge University Press, U.K.

Mehrdadfar, F. (1997): Detecting estrus in black rhinoceros by behavioral observations. *International Zoo News* 44: 272–280.
Miller, E. (1993): Hemolytic anemia in the black rhinoceros. In *Zoo and Wild Animal Medicine – Current Therapy 3* (ed. M.E. Fowler), pp. 455–459. W.B. Saunders, Philadelphia.
Mount, N., and Seabrook, M. (1993): A study of aggression when group housed sows are mixed. *Applied Animal Behavior Science* 36: 377–383.
Mukinya, J.G. (1973): Density, distribution, population structure and social organisation of the black rhinoceros in the Masai Mara Game Reserve. *East African Wildlife Journal* 11: 385–400.
Muya, S.M., and Oguge, N.O. (2000): Effects of browse availability and quality on black rhino (*Diceros bicornis michaeli* Groves 1967) diet in Nairobi National Park, Kenya. *African Journal of Ecology* 38: 62–71.
Neiffer, D.L., Klein, E.C., and Wallace-Switalski, C. (2001): Leptospira infection in two black rhinoceroses (*Diceros bicornis michaeli*). *Journal of Zoo and Wildlife Medicine* 32: 476–486.
Peters, A.R., and Ball, P.J.H. (1995): *Reproduction in Cattle* (2nd ed.). Blackwell Science, Oxford.
Randle, H. (1995): 'Adoption and Personality in Cattle'. Ph.D. thesis, University of Exeter, U.K.
Ritchie, A.T.A. (1963): The black rhinoceros (*Diceros bicornis* L.). *East African Wildlife Journal* 1: 54–62.
Saltzman, W., Schultzdarken, N.J., Wegner, F.H., Wittwer, D.J., and Abbott, D.H. (1998): Suppression of cortisol levels in subordinate female marmosets: reproductive and social contributions. *Hormones and Behavior* 33: 58–74.
Schaffer, N.E., Foley, G.L., Gill, S., and Pope, C.E. (2001): Clinical implications of rhinoceros reproductive tract anatomy and histology. *Journal of Zoo and Wildlife Medicine* 32: 31–46.
Serow, B., Zorovsky, Y., Terkel, A., and Katcoff, D.J. (2002): Genetic kinship and social structure in a herd of square-lipped rhinoceroses (*Ceratotherium simum simum*) at the Zoological Centre, Tel Aviv/Ramat-Gan, Israel. *Zoo Biology* 21: 561–571.
Syme, G.J., and Syme, L.A. (1979): *Social Structure in Farm Animals*. Elsevier, Amsterdam.
Tatman, S.C., Stevens-Wood, B., and Smith, V.B.T. (2000): Ranging behaviour and habitat usage in black rhinoceros, *Diceros bicornis*, in a Kenyan habitat. *African Journal of Ecology* 38: 163–172.
Thorne, A.R., and Whalen, P.J. (1996): Conditioning of black rhinoceros for reproductive manipulation. *International Zoo News* 43 (4): 214–220.
Tudge, C. (1991): Can we end rhino poaching? *New Scientist* 132: 34–37.
Walpole, M.J. (2002): Factors affecting black rhino monitoring in Masai Mara National Reserve, Kenya. *African Journal of Ecology* 40: 18–25.
Western, D. (1982): Patterns of depletion in a Kenya rhino population and the conservation implications. *Biological Conservation* 24: 147–156.

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