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**Implications of semi-intensive managment  
on the breeding of Black Rhino (*Diceros  
bicornis*)**

***H. D. Randle and M. Kiley-Worthington***

1997

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**Improved animal husbandry**

Occasional Paper No. 004

## Black Rhino (*Diceros bicornis*)

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### Abstract

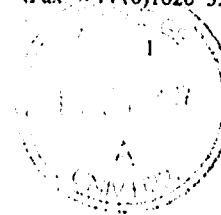
The aim of this study is to examine the lack of breeding in a unique herd of seven rhino, three males and four females kept on a game ranch in Zimbabwe. The herd spent the day on the game ranch browsing under armed guard and the night penned in order to protect them from poachers. All females were showing cycling regularly and showing behavioural signs of oestrous, however only one had produced young. The maintenance activities engaged in by the herd were comparable to those by rhino in the wild. Proximity relations however were compromised (usually 5 to 15m between any two individual), very different from those displayed by 'solitary' or 'semi-solitary' rhino in the wild. Females were significantly more popular as neighbours than males ( $P < 0.05$ ). There was some evidence of alliances between pairs of rhino as seen in the wild. Penning the rhino at night (in order to protect them from poachers) resulted in an increase in aggression. All individuals were more socially involved in the pen than out in the day ( $P < 0.001$ ), whilst the tendency of an individual to be a 'performer' or a 'receiver' remained the same whether in the pen or out in the park (ns). It is suggested that three of the females are suffering from behavioural inhibition of breeding caused by first, confinement (typically only 15m away from another rhino) and second, the breeding female during penning. A number of improvements to the management of these rhino are suggested including, allowing individuals to achieve larger distances between each other when out in the day and physical improvements to the pen.

**Keywords:** Black Rhino; Behaviour; Breeding; Management

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## Introduction

In 1963 Ritchie noted the dramatic depletion of the Black Rhinoceros (*Diceros bicornis*) population in Africa. Despite the 1989 moratorium on ivory trade the African black rhino population continued to decline (Berger, 1993; Thorne and Whale, 1996) unlike some other rhino populations (see Tudge, 1991). Tudge (1991) reported that 40,000 individuals were killed between 1970 and 1987 in order to provide in excess of 100 tonnes of rhino horn. Western (1982) believes that it is easier to obtain horn from a solitary rhino than ivory from an elephant. Most of the remaining black rhino are located in Southern Africa (Estes, 1995), mainly Botswana and Zimbabwe. In 1996 the African black rhino population numbered around 2,350 individuals (Thorne and Whale, 1996).

Berger (1993) outlined three approaches that were being taken in attempt to secure a sustainable population of African black rhino: attempts to stop illegal trade and markets, dehorning and translocation to safe reserves.

CITES (the Convention on International Trade in Endangered Species), part of the IUCN, banned the trade in ivory and rhino horn, in attempt to prevent poaching of both rhino and elephant. However, in remote areas, it is difficult to prevent poaching since extensive policing is required.

It has been suggested that rhino in the wild should be dehorned in order to discourage poachers (Leader-Williams, 1989). There are however a number of difficulties associated with this approach. First, the dehorning procedure is very costly, and despite a considerable amount of World Wildlife Fund money spent on these projects.

poaching of rhino did not cease (Leader-Williams, 1989). This could in part be due to the rapid regeneration of rhino horn (on average 9cm of horn/individual/year). Second, there is evidence that poaching is indiscriminate, since a substantial number of rhinos with only small horn nubs have been killed. Third, on examining the outcomes of a long term dehorning project in Namibia, it was concluded that whilst the demographic effects of dehorning were unclear, it was possible that dehorning had a serious effect on the long term survival of rhino (Berger, 1993). Furthermore, Berger (1993) suggested that the survival of young rhino (*i.e.* individuals less than 3 years of age) is likely to be compromised by dehorning their mothers, who would be less able to protect them from predators such as hyaena (see Western, 1982).

Another approach is the setting up of reserves in which to keep the rhino safe from poachers and to develop a sustainable source of horn, which can then either be harvested from the live animals, or recovered when the rhino die of natural causes. An additional advantage to 'controlled rhino ranching' in which rhino horn can be obtained legally, is the assurance of the survival of the rhino (Wells, 1997). There is however a major disadvantage to keeping rhino in captivity, they have a poor breeding success rate. Kock *et al.* (1991) attribute the failure of captive rhinos to breed to a haemolytic syndrome about which very little is known.

There has been no work done on the behavioural inhibition of breeding, that is, where some individuals may inhibit the breeding behaviour of others. Clearly the African Black rhino currently kept in reserves and in captivity must continue to breed to at least, maintain the current population. To date successful breeding of rhino kept in zoos (Thorne and Whale, 1996 state 208 individuals around the world) and wildlife

parks is poor (Gould, personal communication). It is therefore essential to understand both their social and sexual behaviour in the wild in order to manage them appropriately, to facilitate successful breeding.

Female black rhino tend to be solitary (Goddard, 1967) although sometimes associate 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), and have small home ranges (Mukinya, 1973; Estes, 1995). Rhino reproduce slowly with an annual birth rate of 6.8 to 10.9 percent (Goddard, 1970). They are both polygamous and polyandrous (Goddard, 1966). Males reach sexual maturity by 7 to 8 years, although individuals have been seen covering females at the age of 4, whilst females reach sexual maturity any time after 3.8 years (Estes, 1995). The oestrous cycle lasts between one and six days, and as Kock *et al.* (1991, citing Rowland and Weir, 1984) point out, there is little visual evidence of oestrous, apart from a slight prominence of the vulva. Mating can take place at any time of the year (Ritchie, 1963) and gestation lasts approximately 15 months.

Since there are relatively few rhino left the establishment of small breeding herds under guard could be an important way forward. One of these has been established at Imire Game Ranch in Zimbabwe, however only one of the four females has produced young. The aim of this study therefore, was to examine the lack of breeding in this herd by carrying out a detailed assessment of the maintenance activity, proximity relations and social interaction exhibited by the individual rhino.

#### Animals, materials and methods

#### *Animals and study site*

Seven black rhino belonging to the Zimbabwe Department of National Parks and Wildlife Management were involved in this study: 4 females (Cuckoo, D.J., Mvu and Amber) and 3 males (Sprinter, Noddy and Fumbi). All were born in the wild between April 1987 and June 1987 and were orphaned as a result of poaching. One of the females Mvu had no outer ears since they were eaten by Jackal after she was orphaned. They were brought to Imire Game Ranch between 2 and 6 months, and thereafter lived in a single group. Imire Game Ranch is a 1500ha park in Zimbabwe (30° latitude and 20° longitude). It has *Brachystasia* woodland and coppice, with open grassland, and supports populations of various antelope, elephants, buffalo, but no large predators. The game ranch is run in conjunction with a commercial farm.

#### *Rhino husbandry*

The rhino were kept in a single group all of the time for security reasons. They spent the night in the 'rhino boma', a secure pen, surrounded by sand bags within an electrified compound (Fig. 1). The males and females were separated into two groups on entry to the boma (Fig. 1). At 08:00 h they were let out into the game park under the close surveillance of at least three scouts armed with shot guns and carrying wire whips to discourage individual rhino from straying from the group (Fig. 2). During the course of this study individuals were never observed to be more than approximately 200m from the rest of the group. At 13:30 h the rhino were herded to a pre-arranged

site and fed a small quantity of cattle cubes (approximately 1.5 kg each) in order to enable visitors to the Ranch on a 'wildlife observation drive' to view the rhino at close range. At this time the rhino typically met up with the group of 6 elephants who were also in the game park browsing and grazing during the day. The rhino spent the remainder of the afternoon browsing before being herded back to the rhino boma between 16.30 and 17.00 h. At 17.30h they each suckled 5l of a milky solution from a teated container from the positions indicated with a x on Fig. 1. This was done daily in order to be able to administer any necessary medication easily.

The rhino in this study did not have their horn routinely harvested, although six of them (all, apart from one non breeding female, Amber) had the first 10 cm of their anterior horn removed in 1995, in order to prevent injury when penned at night. If necessary, antibiotics were given in their daily milky feed to treat any infections. Pregnancy testing was carried out by testing faecal hormone levels. One female, D.J., had a prolapsed uterus as a result of vaginal injury which was treated by antibiotics, and was unlikely to breed. At no time had the rhino been put through a crush.

#### *Observations*

The head rhino scout had kept notes on the sexual activity of the rhino since January 1995. He noted the dates and frequency of chasing, mounting without copulation and mounting with copulation for each individual as behavioural indicators of oestrous.

Behavioural observations were made between 7 and 31 January 1996 (inclusive). The rhino were observed between 08.00h and 16.30h when browsing and grazing in

the park by the two authors and three trained scouts. They were then observed for a further hour immediately after penning between 17.30 and 18.30 h by the two authors. The three scouts each received 12 hours of training on how to record maintenance activity and proximity relations onto check sheets. Two of the scouts received a further 8 hours training on how to record social interactions onto a dictaphone.

#### *Observations carried out during the day*

Three aspects of the rhinos behaviour were recorded during the day: maintenance activity, proximity relations and social interactions.

The maintenance activities of all of the rhino were recorded onto a check sheet every 15 minutes using scan sampling. Maintenance activity was divided into browsing, walking, standing, drinking, lying resting, engaging in social activity or eliminating (urinating and defecating).

Proximity relations were also recorded every 15 minutes using scan sampling. The identity of each rhino's nearest neighbour, and the distance to the nearest neighbour was noted onto a check sheet. Distances were coded as follows: 1=Touching; 2=up to 5 m; 3=5 to 15m; 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, 1994, on cattle).

Social interactions between the rhino were observed instantaneously, *i.e.* as and when they occurred (see Altman, 1974). The identities of the 'Performer' and the 'Receiver', and the behaviours that they engaged in were either recorded using a

programme ('Social') written by Lea and Randle for a Psion 3a organiser, or a dictaphone. Table 1 lists the specific behaviours that were identified and recorded. It can be seen that for the purposes of this study, social activity was divided into four broad categories: aggression, withdrawing, affiliation and 'other'. The 'other' category contained behaviours for which the meaning was not clear from the 'Receivers' response (see Kiley-Worthington and Randle, in prep.).

#### *Observations carried out after penning*

The rhino were also observed for a further hour after penning. During this time the social interactions occurring within the male group were observed instantaneously by one author, whilst the other observed the social interactions within the female group. The two authors alternated which group they observed on a daily basis. Any changes of location (i.e. A, B, C and D, see Fig. 1) made by the females were also recorded instantaneously.

#### *Data downloading and statistical analysis*

The maintenance and proximity data were transcribed from the checksheets directly into the Minitab statistical package v8.2, for Mackintosh. The social interaction data was transcribed directly from dictaphone into Minitab (MAC v8.2). The social interaction data obtained on the Psion 3a was also downloaded directly into Minitab

(MAC v8.2) worksheets. The completed Minitab worksheets were then transferred into Minitab v for Windows for statistical analysis.

The data analysis was largely qualitative, and where quantitative, mainly of a non parametric nature because of the small sample size.

#### **Results**

The rhino were observed for 407 rhino hours during the day and 105 rhino hours in the pen.

#### *Breeding*

Only one female calved at the game park. Cuckoo calved in 1993 then again on 23/01/96. The other three females all showed behavioural evidence of oestrous between 01/01/95 and 01/01/96. D.J. was observed being chased by a male 14 times, mounted without copulation 10 times and with copulation 6 times. Nvu was chased by a male 43 times, mounted without copulation 8 times and with copulation 11 times. Amber was chased by a male 12 times, mounted without copulation twice and with copulation once. At the time of the study the exact pregnancy status of the three non calving females was unknown.

#### *Maintenance activity*

Fig 3 shows that the black rhino spent the majority of their time browsing, walking and standing respectively

#### *Proximity relations*

Fig. 4 shows that all of the males and two of the females were typically 5 to 15m from their nearest neighbour. Two of the non breeding females (DJ and Mvu) however maintained smaller distances of between 0 to 5m to their nearest neighbour

Table 2 summarises the proximal relations between the 7 individual rhino. Both males and females preferred females as their nearest neighbours (Chi-squared, with Yale's correction, = 5.84, d.f.=1,  $P < 0.05$ ). There were two obvious alliances, one between two of the females (Cuckoo and Amber), and a slightly weaker one between a female (D.J.) and a male (Noddy).

An index of 'popularity' (based on ranks of the number of times an individual is the nearest neighbour of any other rhino) is also shown in Table 2. The females were significantly more 'popular' than the males (Mann-Whitney  $W = 10.0$ ;  $P < 0.05$ ).

#### *Social interaction*

Fig 5a shows the types of social behaviour engaged in by the group of rhino during the day. Fig 5b shows the types of social activity engaged in by the group of males and the group of females during the first hour of penning. Further analysis of the social activity (both occurring during the day and in the boma during the first hour of

penning), established whether an individual tended to be a 'Performer' (i.e. perform more than he/she received) or a 'Receiver' (i.e. receive more than he/she performed) (Fig. 6.), and how socially involved he/she was overall (Fig. 7). Whilst, there was no significant difference in the Performing/Receiving tendency when out in the day and being penned at night (Wilcoxon  $T = 12$ ; d.f.= ns), there was significantly more total social involvement (TSI) exhibited during the first hour of penning (2.18 interactions/h  $\pm 0.34$ ) than during the day (1.12 interactions/h  $\pm 0.16$ ) ( $t_6 = 7.24$ ;  $P < 0.0001$ ).

The amounts of aggression, withdrawing and affiliation performed and received by each of the four females during the first hour of penning at night are shown in Fig. 8.

The female pen was subdivided into four areas, three smaller pens (A, B and C) and a common loafing area (D) (see. Fig. 1). Table 3 shows the number of times each female occupied each of the three small pens (A, B and C), and the number of changes of location made by each female. A Chi-squared test revealed an association between pen (A, B or C) and the frequency with which each female was in occupation (Chi-squared=29.5; d.f.=6;  $P < 0.001$ ). Standardised residuals revealed that Cuckoo occupied pen A more than expected and pen C less than expected. D.J. occupied pen A less than expected, whilst Mvu occupied pen B less than expected. Amber on the other hand occupied pen B more than expected. It is interesting to note that in the 105 rhino hours observed the breeding female (Cuckoo) changed location most frequently (81 changes in all) in comparison with the non breeding females (Mvu 76, D.J. 58 and Amber 52).

## Discussion

All of the non breeding females showed behavioural evidence of regular oestrous cycling, and therefore they should have been breeding, given the multi-male, multi-female structure of the group, suitable for their polyandrous and polygamous breeding habits (Goddard, 1966). Since the maintenance activities they engaged in were typical of wild individuals (Estes, 1995) there was no evidence of disruption of this behaviour.

Ritchie (1963) states that black rhino in the wild are mainly solitary, however the rhino in this study maintained a distance of 5 and 15m between themselves and their nearest neighbour. However the close distance between individuals is likely to be due to the scouts herding them together to protect them from poachers. This close herding is one possible cause of the lack of breeding. Analysis of the proximity relations during the day indicated that females were the preferred nearest neighbours of both males and females, and furthermore that females were more popular as neighbours. Closer examination revealed two alliances, one between two females and one between a male and a non breeding female. The former demonstrates that even with such close proximities due to herding by scouts, alliances typical of truly wild rhino populations occur (*i.e.* between two females) (see Ritchie, 1963), whilst the latter demonstrates that there was opportunity to mate.

It is difficult to assess the social behaviour exhibited by this herd of black rhino, since very little has been published for wild Black Rhino. Nevertheless, the amounts of the four categories of social behaviour used in this study (aggression, withdrawing, affiliation and other) were similar to those exhibited by other large mammals (see

Kiley-Worthington, 1987 for horses; Randle, 1994 for cattle), both when out in the park during the day as a mixed sex group and when in single sex groups at night in the boma. It can be argued that the lack of breeding is not caused by disrupted social activity within this herd.

The penning of the rhino at night is a likely cause of behavioural inhibition of breeding. All individuals were significantly more socially involved when penned than during the day, and more specifically, there was an increase in aggression on penning, a phenomenon seen in other species *e.g.* pigs (Mount and Seabrook, 1993). Given the size of the female pen (15x25m in total, with 3 internal pens -A, B and C; see Fig. 1.) each female may not always have been able to achieve even a distance of 5m from her nearest neighbour. This confinement, coupled with the increase in aggressive activity and decrease in affiliative activity in the pen could exacerbate the tendency of some females to be 'performers' and others to be 'receivers'. It is possible that the three non breeding females are suffering from 'psychological castration' a phenomenon observed in farm animal species, defined as 'conditioned inhibition of sexual behaviour' (Hurnik *et al.*, 1995), as a result of first, not being able to maintain decent distances from their nearest neighbour(s) and second, the presence of the 'domineering' breeding female, Cuckoo. Detailed analysis of the social activity within the herd showed that the breeding female is a definite 'performer', being involved in most of the social interaction within the female pen, especially aggression, whilst the three non breeding females are 'receivers', receiving most of the aggression. These tendencies are the same when out in the herd during the day.



In summary it is suggested that the lack of breeding in this small group of Black Rhino is caused by their management, necessitated by protecting them from poaching. This relates not only to the fact that they are herded, but also that they are being forced too close together. Whilst it is realised that this cannot be changed and that they must remain both heavily guarded by day and confined at night, some changes may be made in order to facilitate breeding. Individual or pairs of rhinos should be allowed to achieve a semi-solitary status, maintaining considerable distance(s) of at least 200m from the rest of the herd. In order to achieve this guards should be instructed to follow different groups of rhino or single rhino.

It is also important to reduce the amount of aggressive interactions occurring during penning, especially between the females. The non breeding females need 'protecting' from the breeding female. This could easily be achieved in the short term by gating off the existing sub pens (locations A, B and C) in order to separate individuals and allow them privacy. There is already some evidence that individuals prefer different sub pens (see Table 3). In the long term it would be appropriate to construct a larger pen with individual areas that individual females could withdraw into and achieve isolation from the others. A gate between the male and female pen would also be advisable for transfer of individuals for breeding purposes. It would also be advisable to construct a creep area for any future calves to allow them to be handled and become accustomed to humans. Fig. 9. illustrates suggested long term improvements to the rhino boma.

#### Acknowledgements

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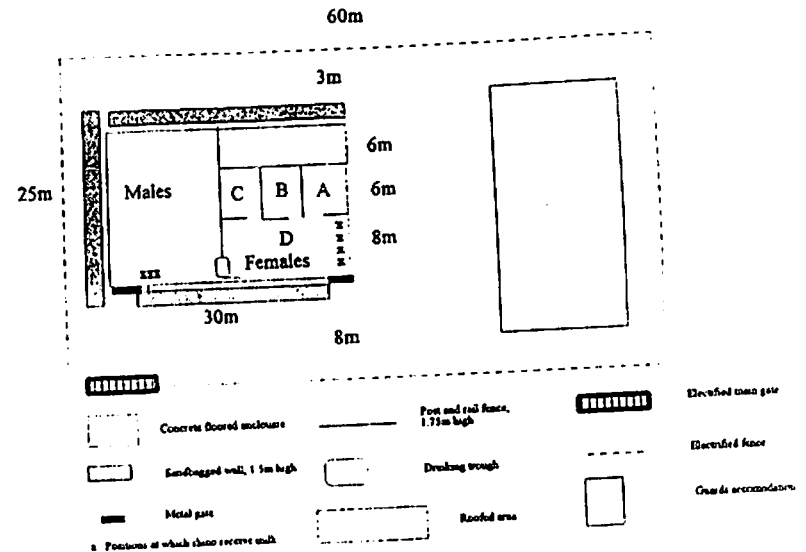


Fig 1. Layout of the Rhino boma (pen). The boma is situated within an electrified enclosure, also containing the guards houses.



Fig. 2. Rhino being herded through the game park by scouts with shotguns and wire whips

Table 1

Behaviours comprising the four categories of social interaction

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

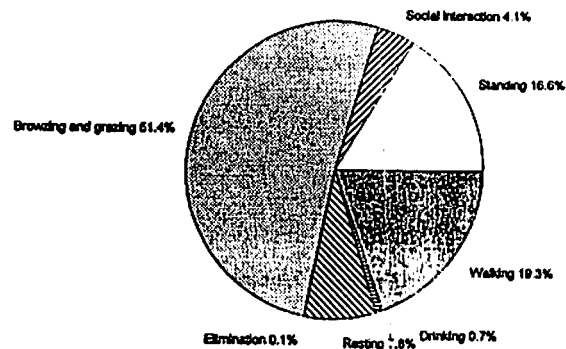


Fig. 3. Black rhino maintenance activity occurring between 08.00 and 16.30h. (Based on 1752 observations, 251 per rhino, made over a 3 week period.)

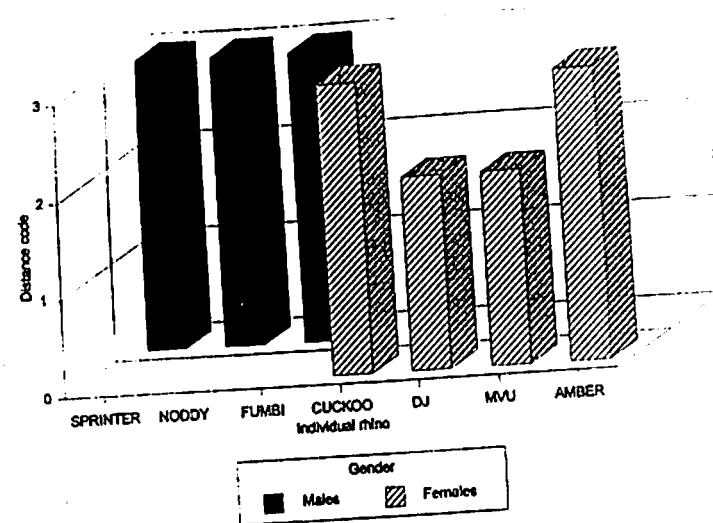


Fig. 4. The preferred distance kept to his/her nearest neighbour by individual rhinos (Based on 1725 observations, 251 per rhino, taken over a 3 week period ) Distance codes used are: 1: touching; 2: up to 5m; 3: between 5 and 15m

Table 2.  
Summary of the proximity relations between the seven individual Black rhino<sup>1</sup>.

| Focal individual                | Nearest Neighbour |     |                 |         |                 |     |                 |
|---------------------------------|-------------------|-----|-----------------|---------|-----------------|-----|-----------------|
|                                 | Males             |     |                 | Females |                 |     |                 |
|                                 | SPR               | NOD | FUM             | CUC     | DJ              | MVU | AMB             |
| Males                           | SPR               | --- | 33              | 31      | 50              | 43  | 22              |
|                                 | NOD               | 35  | ---             | 18      | 81 <sup>2</sup> | 33  | 14              |
|                                 | FUM               | 41  | 47              | 22      | 43              | 31  | 32              |
| Females                         | CUC               | 19  | 25              | 22      | ---             | 30  | 89 <sup>3</sup> |
|                                 | DJ                | 33  | 57 <sup>2</sup> | 37      | 32              | --- | 31              |
|                                 | MVU               | 32  | 36              | 39      | 37              | 41  | ---             |
|                                 | AMB               | 27  | 19              | 24      | 90 <sup>3</sup> | 18  | 37              |
| Total times a nearest neighbour |                   |     |                 |         |                 |     |                 |
| Rank 'popularity' <sup>4</sup>  |                   |     |                 |         |                 |     |                 |
| 7 5 6 2 1 4 3                   |                   |     |                 |         |                 |     |                 |

<sup>1</sup> (Based on 1752 observations, 251 per rhino, made over a 3 week period.)  
SPR: Sprinter; NOD: Noddy; FUM: Fumbi; CUC: Cuckoo; DJ: DJ; MVU: Mvu; AMB: Amber.

<sup>2,3</sup> indicate alliances based on analysis of standardised residuals subsequent to a significant Chi-squared test. Obvious alliances are evident between <sup>2</sup> a male and a female (DJ and Noddy) and <sup>3</sup> two females (Cuckoo and Amber).

<sup>4</sup> The 'Popularity' of each individual is derived from the number of times that he/she is the nearest neighbour of other individuals. DJ is the most popular and Sprinter is the least popular.

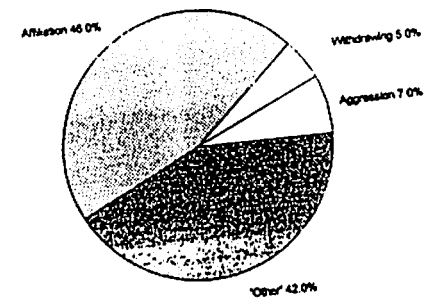


Fig. 5a. Types of black rhino social interaction occurring during the day. (Based on 1778 interactions, observed over 405 rhino hours.)

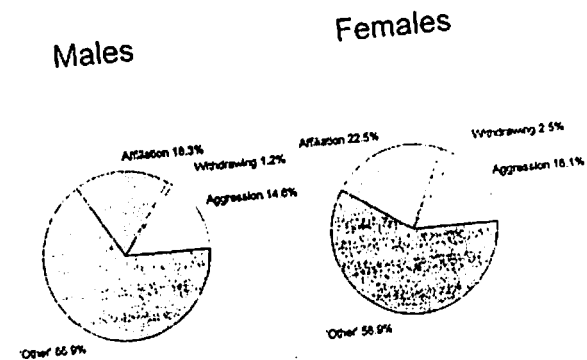


Fig. 5b. Types of black rhino social interaction occurring during the first hour of penning (Based on 476 interactions, observed over 105 rhino hours.)

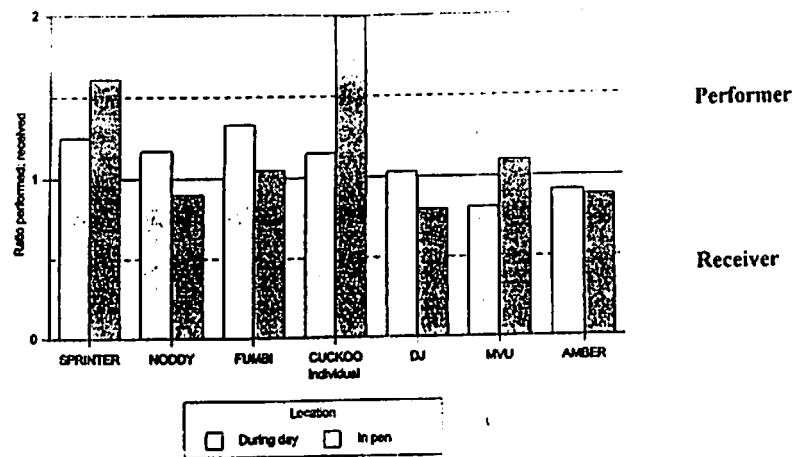


Fig. 6. The tendencies of individual rhino to be 'performers' or 'receivers' during the day and the first hour of penning at night. (Based on 1778 interactions, observed over 405 rhino hours during the day and 476 interactions, observed over 105 rhino hours during penning at night, *i.e.* 2254 interactions in all over 510 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', whilst a ratio of  $<1$  indicates that an individual is a 'receiver'. There was no significant difference between the tendency to be a performer or a receiver during the day and during the first hour of penning at night (Wilcoxon  $T=12$ ; ns.).

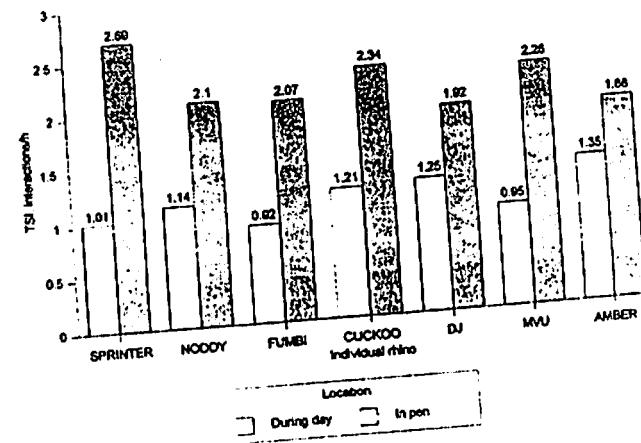


Fig. 7 The TSI (total social involvement) occurring per hour during the day and the first hour of penning at night. (Based on 1778 interactions, observed over 405 rhino hours during the day and 476 interactions, observed over 105 rhino hours during penning at night.) TSI consists of the total number of interactions an individual is involved in (irrespective of whether as a performer or a receiver.) Overall rhinos exhibited significantly more social involvement during the first hour of penning than during the day ( $t_6=7.24$ ;  $P<0.0001$ ).

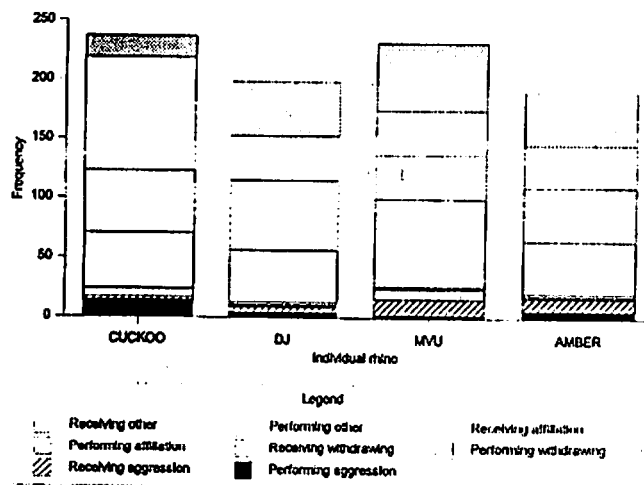


Fig. 8. The frequencies of aggression, withdrawing, affiliation and 'other' behaviour performed and received by the four females when penned together in the boma. (Based on 476 interactions, observed over 105 rhino hours during penning at night.) The solid blocks represent performed frequencies, and the patterned blocks represent received frequencies.

Table 3  
Summary of the occupation of pens within the female side of the rhino boma

|                         | Pen A           | B               | C               | Total number of changes made |
|-------------------------|-----------------|-----------------|-----------------|------------------------------|
| Cuckoo                  | 39 <sup>1</sup> | 21              | 21 <sup>2</sup> | 81                           |
| DJ                      | 11 <sup>2</sup> | 20              | 27              | 58                           |
| Mvu                     | 26              | 10 <sup>2</sup> | 40              | 76                           |
| Amber                   | 13              | 22 <sup>1</sup> | 17              | 32                           |
| Total occupation of pen | 89              | 73              | 105             | 267                          |

There is an association between which pens were occupied by which individuals (Chi-squared<sub>6</sub>=29.5,  $P<0.001$ ).

<sup>1</sup> a high, positive standardised residual indicated that this individual occupied this pen more than would be expected by chance.

<sup>2</sup> a high, negative standardised residual indicated that this individual occupied this pen less than would be expected by chance.

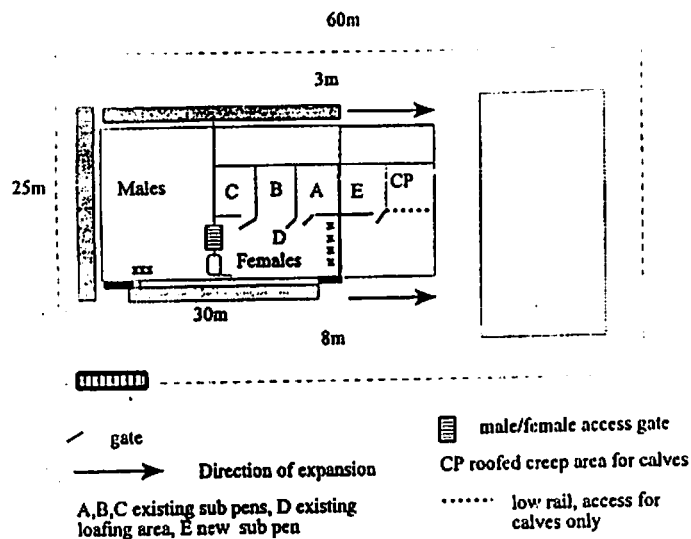


Fig 9. Layout of the suggested improvements to the rhino boma (pen). These are 1. addition of gates to the existing sub pens (A, B and C). 2. the enlargement of the female side of the pen, 3. the provision of an access gate between the males and females and 4. the provision of a creep area for calves.