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# PRELIMINARY ANALYSES OF THE FREE-RELEASE AND SCENT-BROADCASTING STRATEGIES FOR BLACK RHINOCEROS REINTRODUCTION

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## Abstract

Translocation has been key to Black Rhinoceros (*Diceros bicornis*) meta-population recovery. However, translocation can in some instances result in poor post-release survival and reproduction. The post-release behaviour of rhinoceros is little studied but might provide insights with utility for improving translocation success. We examined the influence of sex, age (young- or full-adult), time and physiological state in captivity, and the drugs regime administered for transport and release on the first 6 days of post-release movements by 15 black rhino (*D. b. minor*) translocated to Mun-ya-Wana Game Reserve (GR). We also conducted an experimental trial on the effect of scent broadcasting on their post-release behaviour. Rhino were captured at Ezemvelo KwaZulu-Natal Wildlife reserves, held in individual iMfolozi GR enclosures (bomas) for from 31 to 61 days, fitted with horn-implant radio transmitters, and released near-simultaneously over 3 days at different individual locations spaced throughout Mun-ya-Wana GR. This release strategy appeared to have benefits compared with translocation techniques that instead release rhinoceros from boma at the same site but separately over many days. Before release the dung and urine soaked substrate from the boma of 7 rhinos (treatment group) was collected and spread within 2km of their future release site. The control group, comprising 8 rhinos, did not have scent broadcast about their release site. We hypothesised that the presence of a rhino's scent would reduce its post-release movement and that they would settle around or near their own scent. Contrary to our hypothesis, individuals in the treatment group moved significantly farther than those from the control group. Although we attempted to hold all factors constant between the two groups, retrospective hormone analyses showed that the control rhinos had higher levels of reproductive hormones; faecal androgens for males and progestins for females. Despite this potential confound, we discuss the possible meaning of these results towards understanding black rhino behavioural ecology and improving translocation strategies.

## Introduction

Meta-population management by translocation has been key to the conservation of Black Rhinoceros *Diceros bicornis*. Translocations for reintroduction and population supplementation (IUCN, 1998) are used in range-expansion and to support populations not large enough to be genetically or demographically self-sustaining. By initially stabilising and then beginning the recovery of the species, translocation has largely been applied successfully to black rhino meta-population management (Linklater, 2003). However, the performance of individual rhino after translocation and release varies tremendously (Hofmeyr *et al*, 1975; Hall-Martin & Penzhorn, 1977; Hitchins, 1984; Adcock *et al*, 1998; Brett, 1998). Survival and post-release breeding after some translocations is poor in ways that might relate to the characteristics of the rhino involved, how they were translocated and released, or the context into which they were released. Improving rhino survival and breeding after release depends on choosing correctly between potential reserves to receive rhino and the rhino

to capture for translocation as well as how and where to release them. Making decisions in this context where many factors influence the success of a translocation might be improved by a better understanding of how rhinoceros behave after release, particularly how much they move relative to their release site and their pattern of movement about the landscape during the early stages of establishing a home-range, what factors influence that behaviour, and experimental trials of ways to modify that behaviour if necessary.

Although translocation has been a common tool in black rhino conservation for several decades (Emslie, 2001), there are surprisingly few reports that describe the daily movements of black rhino after their release. Monitoring by Hillman (1982-84, *unpubl. data*) and Hansen and Lindemann (1989-95, *unpubl. data*) provided early home-ranges in Pilanesberg National Park (Adcock *et al*, 1998) and others have reported on the behaviour of individual rhino as they leave the enclosure (boma) or crate at the

release site and before they disappear from view (Hitchins *et al*, 1972; Hall-Martin & Penzhorn, 1977) but detailed daily movements after release have not been reported.

Reintroductions of black rhino have largely adopted two release methods; boma- or free-releases. In boma-releases the rhino are transported to, and held in a group of individual bomas at the release site. They are subsequently released one at a time during a sequence of evenings from those bomas. Boma-releases are more common and currently regarded 'best practice'. Free-releases, on the other hand, involve the transport of individual rhino to their own separate release sites that are spaced throughout the new reserve. The key difference between boma- and free-releases is that the rhino are either released at the same site or different sites respectively. While boma-releases have become more common in recent years our concern is that when releasing large numbers of rhino their release at the same place increases encounter rates between them and therefore the potential for conflict. Fighting is one of the leading causes of injury and death in black rhinoceros after release (see: Brett, 1998). In larger reserves the release of individual rhino at different sites spaced throughout the reserve might reduce post-release encounter rates and conflict.

Olfactory communication via dung and urine appear to have an important role in black rhino social, mating and spatial relationships (Goddard, 1967; Schenkel & Schenkel-Hulliger, 1969; Joubert & Eloff, 1971; Kiyasu & Kohshima, 2002) thus influencing where and in what associations rhino live. Moreover, of the senses, scent is the one that is easiest to collect and it persists in the environment making it more amenable to manipulation. For this reason we identified the use of dung and urine to manipulate the post-release behaviour of black rhino and the potential to develop broadcasting scent via dung and urine as a behavioural management technique (Linklater *et al*, 2003; Linklater, 2004). Others have considered the idea that dung broadcasting might modify a rhino's behaviour after release, and even spread dung at release sites (see: Hitchins *et al*, 1972), but have not designed and monitored their efforts as scientific experiments to test hypotheses about the influence that scent might have or to test its potential utility as a management tool. Other influences on the post-release behaviour of black rhino include their age, sex and physiological and reproductive state at release. Here we describe a preliminary trial of scent broadcasting to modify black rhino behaviour after release and investigate the influence of those other factors on the post-release behaviour of black rhino. We hypothesised that the presence of a rhino's own scent about a release site might encourage it to move less and settle at or near their release site.

## Methods

### *Capture, transmitter installation, translocation and release*

The capture, transportation, veterinary care and husbandry of black rhino by Ezemvelo KwaZulu-Natal Wildlife (EKZNW) Game Capture have been described previously (Hitchins *et al*, 1972; Hitchins, 1984; Galli & Flamand, 1995) and conformed to standard procedures (Rogers & McKenzie, 2001) similarly applied elsewhere (Hofmeyr *et al*, 1975; Kock, 1992; Morkel, 1994). All rhino received a MOD-80 or the larger MOD-125 horn-implant transmitter (Telonics, Inc., 932 E. Impala Avenue, Mesa, AZ, 85204-6699. [www.telonics.com](http://www.telonics.com)) depending on the size of their horn. We were able to install the larger transmitter in larger horns. The installation of horn-implant transmitters occurred either while the rhino was immobilised at the capture site or while in the boma, and conformed to procedures described previously (Pienaar & Hall-Martin, 1991; Schrader & Beauchamp, 2001).

The 15 black rhinos for translocation (Table 1) were captured from EKZNW Reserves, transported and housed in individual boma (approximately 80m<sup>2</sup>) at iMfolozi Game Reserve (GR) for from 31 to 61 days depending on the timing of their capture and release. Before and during their loading into transport crates for release, each rhino was administered with 0.35 to 0.6mg etorphine hydrochloride (M99, Novartis, Isando, South Africa), 250 to 550mg zuclopenthixol acetate (Acuphase, Clopixol Acuphase, H. Lundbeck, North Riding, South Africa) and 80 or 100mg azaperone (Stresnil, Janssen Pharmaceutica, Halfway House, South Africa). Quantities varied between individuals depending on their size and behaviour during captivity and translocation. One individual (Rhino 300, Umkhandi wensimbi, Table 1) received 2.5mg etorphine hydrochloride to completely immobilise it for installing an horn-implant transmitter prior to loading and was loaded into its transport crate as it recovered. Mun-ya-Wana GR, the reserve where the rhino were released, is approximately 150km from the boma in iMfolozi GR and the journey between boma to each release site within the reserve took around 2 hours. A further dose of between 80 and 220mg azaperone was administered to most, but not all, rhino at the release site before each rhino's crate door was opened to allow them to leave. Releases were conducted mid-morning or late afternoon.

### *Scent broadcasting experimental design*

The 15 rhino were separated into two groups; treatment (7 rhino) and control (8 rhino). Care was taken to ensure that treatment and control groups were representative of age and sex classes (Table 1). Each rhino's boma was cleaned daily by EKZNW staff and the dung and urine-wetted substrate (largely sand) removed. For treatment rhino we gathered this material containing the rhinos scent, into individual black polyethylene drums and transported them to Mun-ya-Wana GR for spreading (i.e. scent broadcasting). Each rhino was assigned their own drums and a different release site. Release sites were located in a clearing that allowed the positioning of release equipment (i.e. truck and rhino transport crate) near dams or waterholes with

thick vegetation nearby to ensure that released rhino located cover and drinking water soon after release. The clearings near dams and waterholes that served as release sites were spaced across the reserve, in so much as road access and transport time would allow, to maximise the distance between them, particularly for the adult males who posed the greatest risk to other rhino (Figure 1). For each treatment rhino, between 10 and 15 approximately

110 litre drums of its scent rich boma substrate were spread up to 2 km from its release site in the 4 weeks before their release (Figure 1). The scent material was spread by shovel from the back of a truck along and beside the roads around each release site. Piles of material were spaced 50 or 100 metres apart and consisted of from 2 shovels to one-third of each 110l drum.

Group <sup>a</sup>	ID# <sup>b</sup>	Name	Sex <sup>c</sup>	Age class <sup>d</sup>	Date captured	Captured from <sup>e</sup>	Date ear notched	Date transmitter installed	Date released
T	1	Nqogotshane	F	F	27 Aug	iMfolozi GR - Mbuzane	30/11/88	At capture	15/10/04
C	7	Stuquza Jnr	F	E	15 Aug	Ithala GR - Kwasambane	15/08/04	At capture	14/10/04
C	14	Paris	F	F	2 Sept	Tembe EP – north	nd	At capture	16/10/04
T	147	iMfolozi female	F	E	30 Aug	iMfolozi GR – Masinda	4/11/03	At capture	15/10/04
T	170	Harriet	F	F	1 Sept	Hluhluwe GR – Nqumeni	3/11/00	At capture	15/10/04
T	243	Ngenisa	F	E	28 Aug	Hluhluwe GR – Manzibomvu	4/11/00	At capture	14/10/04
C	251	Betty	F	F	13 Sept	iMfolozi GR - Masinda	9/11/00	At capture	15/10/04
T	10	Godweni	M	E	29 Aug	Eastern Shores	29/08/04	At capture	15/10/04
T	72	Ntshonilanga	M	F	16 Aug	Ithala GR – Thalu	2/03/00	At capture	15/10/04
T	75	Amadodamabili	M	E	16 Aug	Ithala GR -	14/10/01	7/10/04	16/10/04
C	76	Jaluka	M	E	14 Aug	Ithala GR – Thalu	15/10/01	At capture	14/10/04
C	131	Dougal	M	F	26 Aug	iMfolozi GR – Makhamisa	3/11/00 <sup>f</sup>	7/10/04	16/10/04
C	136	Tembe	M	F	5 Sept	Tembe EP – north	2003 <sup>f</sup>	7/10/04	16/10/04
C	146	Potty	M	F	26 Aug	iMfolozi GR - Mbuzane	6/11/88 <sup>f</sup>	7/10/04	16/10/04
C	300	Umkhandi wensimbi	M	E	28 Aug	Hluhluwe GR - Manzibomvu	28/08/04	16/10/04	16/10/04

<sup>a</sup> denotes whether the rhino was part of the treatment (T) or control (C) group.  
<sup>b</sup> refers to the number described by the configuration of ear notches for identification.  
<sup>c</sup> denotes female (F) and male (M) rhino.  
<sup>d</sup> denotes rhino as young adult (age class E; Hitchins 1978) or fully adult (age class F).  
<sup>e</sup> GR = game reserve, EP = elephant park.  
<sup>f</sup> Original earlier ear notch configuration was modified before release.

Table 1: Summary of black rhino released in the Mun-ya-Wana Game Reserve, October 2004

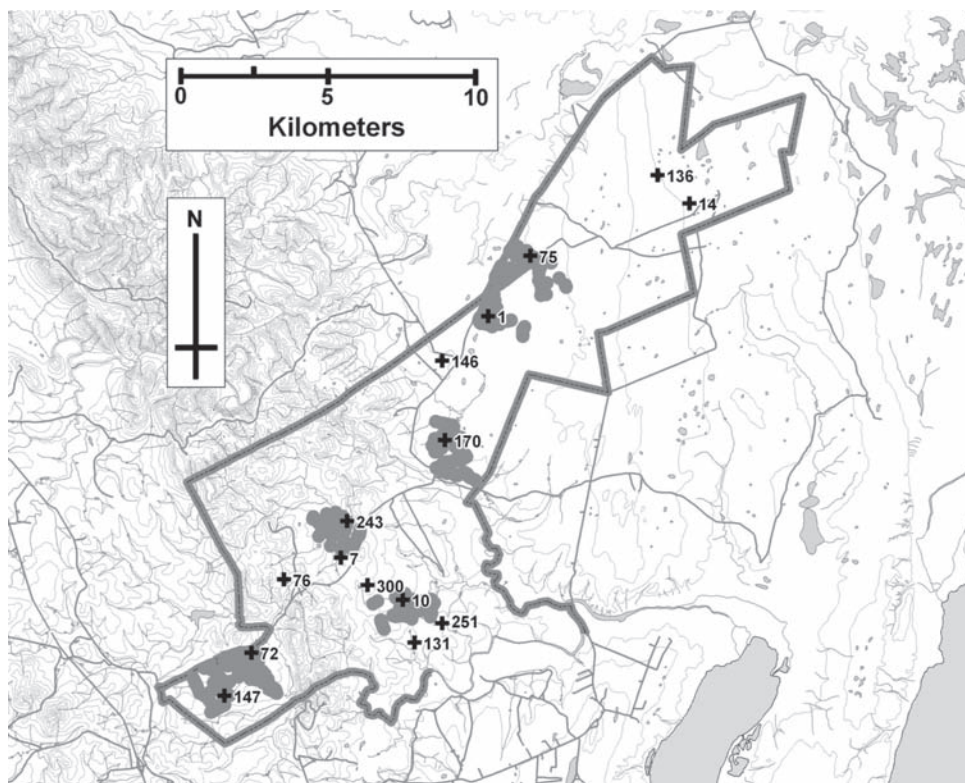


Figure 1: Topographical map showing Mun-ya-Wana Game Reserve (delineated by the thick grey and dashed boundary line). The location of release sites and the individual rhino released at each are shown by the + symbol with associated individual ID number (refer Table 1, ID#). The spread of treatment rhino scent about their release sites is shown by the clump of grey dots with a dot at the location that each pile of dung and urine soaked boma substrate was placed.

### *Faecal sampling and corticoid, progestin and androgen assays*

Samples of fresh and still wet faeces from each rhino were collected at least twice weekly during their captivity in screw-top plastic bottles (80ml). Samples were collected from the middle of faecal boli while each rhino's boma was being cleaned. Samples were stored by freezing soon after and shipped on ice to the Conservation and Research for Endangered Species centre of the San Diego Zoo for quantitative assay of their corticoid and reproductive hormone concentrations; progestins for females and androgens for males. Laboratory techniques and procedures for these assays are described elsewhere (Patton *et al*, 1996; Schwarzenberger *et al*, 1996; Schwarzenberger, 2000; Brown *et al*, 2001). Average values of corticoid and reproductive hormones in faeces were used as a measure of physiological stress and reproductive status, respectively (Linklater & Swaisgood, 2005; Linklater *et al*, 2005).

### *Post-release monitoring*

Each rhino was located daily after release to determine their post-release movements. We present here just the first 6 days of movement after release. Movements during the first 6 days after release are more likely to be influenced by the rhinos' physiological state at release and early analyses of movement data indicate that rhino entered the area defined by their subsequent home range within 3 days of release and variance in daily movement declined substantially after the 6th day (*unpubl. data*).

The locations of rhino during the first six days after release were determined by triangulation rather than by visual sighting to limit the influence of observers on the rhinos movements (i.e. to reduce disturbance). Rhinos' triangulated locations were estimated using Locate II software (version 1.82, Nams, 2000). Some locations derived by triangulations were immediately outside of the reserve due to measurement errors in the technique. In these cases the true position was estimated as the closest point within the reserves boundary to the estimated location.

Average daily displacement was the average of the 6 distances between the 7 sequential locations, including the release site, over the first 6 days post-release. Cumulative 6-day displacement was estimated from the shortest distance between the sequence of points and constrained by movement within the reserves fence.

### *Statistical analyses*

We used the non-parametric Mann Whitney-U (2 independent samples, SPSS Inc., Version 12.0, 4 September 2003) to test for the differences in the movements of rhino between the control and treatment groups, and between young adult and fully adult rhino. Mann Whitney-U tests were also conducted to test whether the rhino in treatment and control groups differed in their levels of stress-related

and reproductive hormones. Spearman rank correlations were used to test for the relationship between faecal reproductive hormone concentrations (androgens for male and progestins for females) and the movement of rhino after release. Non-parametric tests were used because the small sample size does not provide certainty about the normal distribution of group data. Small sample sizes but multiple factors also make it important to set up *a priori* criteria for judging the biological significance of effects. We considered test statistics that generated P values >0.1 as not significant and P<0.05 as significant tests. Where the P-values fell between 0.05 and 0.1 we consider the possibility that sample size, and therefore poor statistical power, may be masking a biologically significant result.

### **Results**

Rhinos whose dung was spread at their release site (treatment group) moved more than those whose dung was not spread (control group) during the first 6 days after their release (Figure 2A: Mann Whitney-U test; Average daily displacement, P<0.005; Cumulative 6-day displacement, P<0.01; for examples see Figure 3).

Treatment and control groups consisted of similar rhino also treated similarly. Dosages of etorphine, zuclopenthixol, and azaperone during translocation from boma to the release sites were not different between treatment and control groups (Figure 4). The higher average dose of etorphine hydrochloride for the control group is attributable to one individual (i.e. Rhino 300, Umkhandi wensimbi, Table 1) who was immobilised prior to loading for transport in order to install a horn-implant transmitter. All other rhino received between 0.35 and 0.6mg etorphine hydrochloride. Nevertheless, the movements of Rhino 300 after release (i.e. an average daily displacement of 2.7km and cumulative 6-day displacement of 21.0km) were within the range (i.e. 1.5 – 2.9km and 10.3 – 24.4km, respectively) of other rhino in the control group. The rhinos in each group also spent a similar time in boma between capture and release (Average  $\pm$  1SE: control, 48.5  $\pm$  3.4 days; treatment, 50.6  $\pm$  2.6). The concentrations of corticoids in faeces taken weekly from individuals during captivity were slightly higher in the control group (Average  $\pm$  1SE: control, 18.7  $\pm$  1.7 days; treatment 15.9  $\pm$  0.7) but not statistically different (Mann Whitney-U test, P>0.1). The small difference between the two figures can be attributed to one individual in the control group (i.e. Rhino 136, Tembe, Table 1) whose corticoid levels were 10 and 11 ng.g<sup>-1</sup> higher than other rhinos of the control and treatment groups respectively. However, Rhino 136's movements after release (i.e. average daily displacement of 2.1km and cumulative 6-day displacement of 14.8km) were typical, if not slightly more conservative, than others in the control group (range 1.6 – 2.9km and 10.3 – 24.4km, respectively).

Two characteristics of individual rhinoceros appeared to influence the distance they travelled during the first 6-

days after release; age and reproductive hormone levels. No juvenile rhino were released (Table 1) but individuals classified as young adults (age class E; Hitchins, 1978) tended to travel more than mature adults (age class F, Figure 2B). However, the difference in distances travelled by the two age classes was not statistically significant (Mann Whitney-U test: average daily displacement,  $P > 0.1$ ; cumulative 6-day displacement,  $P > 0.1$ ). The levels of reproductive hormones in males and females, as judged from the concentration of androgens and progestins respectively in their faeces during captivity, varied considerably. Males and females with low levels of reproductive hormone moved greater distances after release than those with high reproductive hormone levels (Figure 5; Spearman rank correlation: females,  $r_s = -0.82$ ,  $P < 0.05$ ; males,  $r_s = -0.79$ ,  $P < 0.05$ ). The sexes did not differ significantly in their mobility after release (Average  $\pm$  1SE: average daily displacement, male  $3.9 \pm 0.9$ , female  $3.6 \pm 0.5$ ; cumulative 6-day displacement, male  $24.3 \pm 4.7$ , female  $23.0 \pm 2.8$ , Mann Whitney-U test,  $P > 0.1$ ). Of the two factors, age and reproductive hormone levels, only reproductive hormone levels has the potential to also explain the difference in movements between the control and treatment groups because the groups were evenly balanced for young and mature adults (Table 1). Although treatment and control groups were also balanced for their number of males and females, individuals of both sexes with higher levels of reproductive hormones were retrospectively found to contribute disproportionately to the control group (Figure 5).

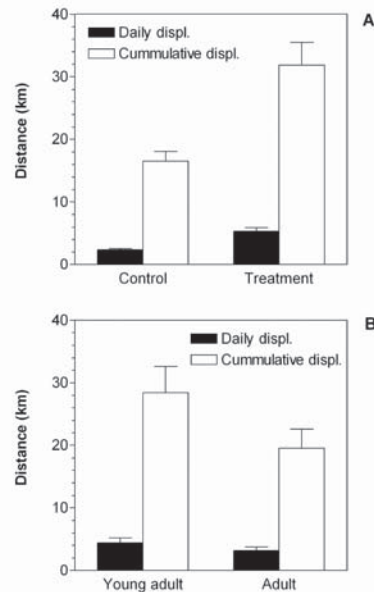


Figure 2. Movement during the first 6 days after release by black rhino that were in (A) treatment (scent broadcast) and control (scent not broadcast) groups and (B) young adult (i.e., E; Hitchins, 1978) compared with fully-adult (i.e., F) age classes. Mobility is expressed as the average daily displacement and cumulative displacement during the first 6 days post-release (Average  $\pm$  1SE).

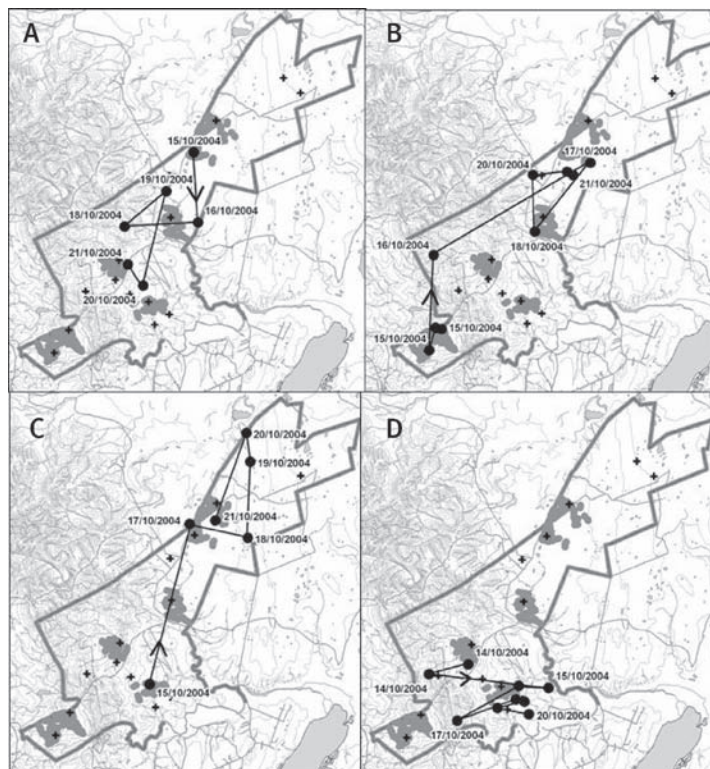


Figure 3. Examples of the movements during the first 6 days after release by four of the 15 released rhino; (A) female 1, (B) male 72, (C) male 10, and (D) female 7 (refer Table 1, ID#). Daily locations are shown by black dots and their sequence by associated dates and connecting lines. Topographical map features are as in Figure 1. Note the tendency for centrality in the movements of rhino towards the end of the first 6 days.

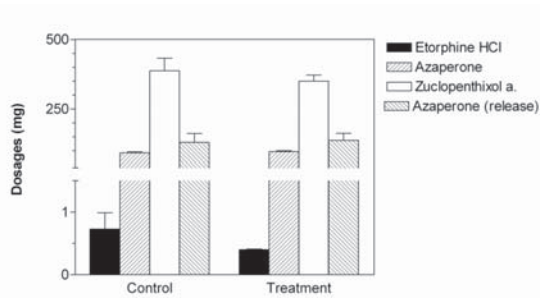


Figure 4. The average ( $\pm 1SE$ ) drugs regime during transportation and release for rhino in the treatment (scent broadcast) and control (scent not broadcast) groups.

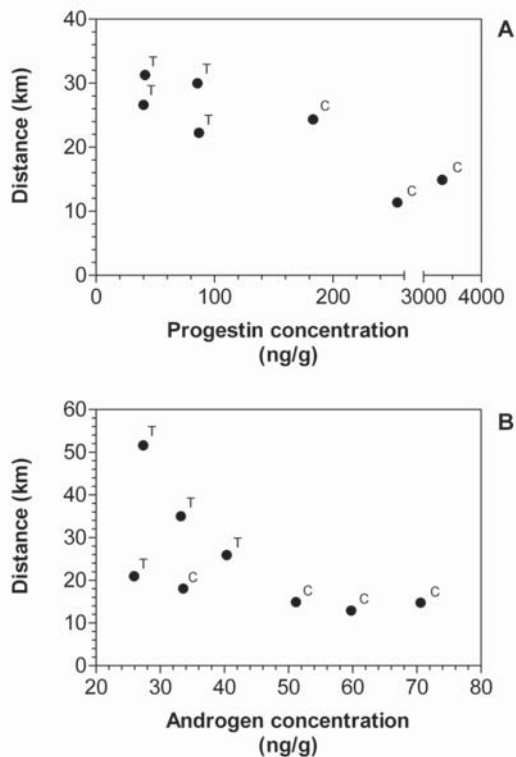


Figure 5. The relationship between average faecal (A) progesterin concentration in females and (B) androgen concentration in males and their cumulative 6-day displacement after release. Each dot represents 1 rhino of the 15 released and the associated letter indicates whether they were part of the treatment (T) of control (C) group of the scent broadcasting experiment.

**Discussion**

*Free- versus boma-release*

This is the first time that detailed daily movements have been reported for black rhinos after their translocation and release for reintroduction. For this reason we do not know how the movements reported here after ‘free-releasing’ 15 black rhino at individual sites compare with similar releases from boma. However, Raath and Hall-Martin (1989) remark that after a boma release on Vaalbos National Park individuals walked up to 24km on the first

day before resting. This distance exceeds any of the values reported here after the Mun-ya-Wana GR release where the largest first-day distances travelled from the release site was 6.7km, although Vaalbos National Park at 18 120ha was a similar size to Mun-ya-Wana GR (18 626ha).

The rationale for free-releasing black rhinos at individual sites that are spaced across the reserve for reintroductions (IUCN, 1998) is based on the expectation that this release structure reduces the encounter rates between rhinos after release, therefore reducing the probability of potentially aggressive interactions and the injuries and mortalities that have been associated with other translocations (Hall-Martin & Penzhorn, 1977; Brett, 1998). Free-releasing rhino achieves this in 2 ways:

(1) It allows many more rhino to be released each day and for the entire cohort to be released over a shorter period (in this case 15 rhino over 3 days) than would be possible if the rhino were released from a boma complex. This is because boma releases require that the rhino are released at different times and that there be sufficient time between each release to prevent interactions that might result in conflict. Therefore, the common procedure is to release one rhino at dusk on subsequent days until all have left the boma. On Mun-ya-Wana GR a boma release would have required 15 days. Even if 2 rhino a day were released from boma the release period would have been over twice as long as the 3 days required for a free-release scheme. The time that it takes to release all individuals is a potentially important consideration because our expectation from rhinoceros home range or territorial behaviour (Goddard, 1967; Conway & Goodman, 1989; Kiwia, 1989; Tatman *et al*, 2000; Lent & Fike, 2003) is that once having established themselves a rhino is more likely to respond to a newcomer aggressively. Thus, shortening the time from the first to the last release means that the rhino are more equally uncertain about their home and thus less inclined to defend it. On Mun-ya-Wana GR rhinos began to demonstrate site loyalty through central tendency in their movements with the first 6 days. The entire release occurring over just 3 days ensured that the rhino released first had not established themselves before the last rhino was released.

(2) Free-releasing allows rhino release sites to be spaced across the reserve thus further limiting the probability of rhino encountering one-another during the critical period when they are recovering from the drugs and experience of boma, transportation and release. Boma releasing, on-the-other-hand, means that each subsequent rhino that is released is likely to encounter the rhino released earlier and the rates of encounter might increase as the release schedule proceeds. The problem is exacerbated if rhino initially do not move far from the boma after release. Some rhino are reluctant to leave bomas, do not travel far in the initial few days and may return to boma after release (Linklater & Swaisgood, 2004). For

the largely solitary-living black rhinos these interactions may stimulate greater movement as they try to avoid one another and establish their own relatively independent home ranges. It is possible that boma-release may result in a *domino effect* every time another rhino is released as rhino encounter, interact and displace one another away from their release site and about the reserve.

The higher maximum distance travelled during the first day after release by rhino reintroduced to Vaalbos National Park (Raath & Hall-Martin, 1989) compared with Mun-ya-Wana GR might indicate that this *domino effect* was occurring on Vaalbos. Certainly, multiple releases at single sites for other re-introductions have resulted in significant conflict between the released rhino during the first few days (Hall-Martin & Penzhorn, 1977). In the reintroduction described here, although the distances travelled by the rhino after release were large relative to the space between release sites and they had the occasion and opportunity to encounter and interact with each other (Figures 1 & 3), there was no evidence of aggression or fighting during the first few days after release. Indeed the rhinos' movements appear to indicate that they actively and successfully avoided each other, or at least conflict with each other, during this critical period. Free-releasing, such that the release occurs over as short a time period as possible and the rhino are spaced throughout the reserve appears to have facilitated this process.

This is not the first time that the free-release of a large number of rhino for reintroduction has been successfully conducted. Although Hillman (unpublished report quoted in: Adcock *et al*, 1998) thought that free-releasing black rhinos on Pilanesberg National Park meant that they were highly disturbed (these rhino were transported and released immediately after capture and without a period in boma at the donor reserve) the first Pilanesberg release of 19 black rhinoceros stands out as one of the most successful reintroductions with no mortalities while releases from boma at several different sites over the subsequent 20 years have resulted in average mortalities ranging from 6 to 16% (Hitchins, 1984; Adcock *et al*, 1998; Brett, 1998). Although, boma-releases are recommended best practice, it is conceivable that the suitability of either the boma- versus free-release strategy depends on the context. Where the release cohort is large and the reserve is large enough to support individual release sites spaced several kilometres apart, free-releasing might be the more successful strategy. Free-releasing also probably reduces additional stress to the rhinoceros of acclimating to another captive environment that inevitably includes new staff and routines, and reduces the infrastructure costs and disturbance of building boma at release sites. Building bomas adds considerably to the cost of translocation.

#### *Scent broadcasting experiment*

The rhino moved about the landscape immediately after release and individuals varied considerably in the

distances they moved (Figure 3). The discussion above notwithstanding, such movements are a concern where they might increase encounter rates after release. The spreading of a rhino's own dung at and around its release site appeared to stimulate greater movement by those rhinoceros and the tendency for them to leave the release area. This effect was contrary to our *a priori* hypothesis that a rhino would choose to settle where its own scent was broadcast and that this might prove a useful tool in controlling movements or encouraging local settlement after release. However, the effect is confounded by the control group being dominated by males with higher androgen levels and females with higher progesterin levels. Thus, we are not sure at this stage whether the effect we observed was a consequence of scent broadcasting or some other, as yet unknown, effect on behaviour of elevated hormone levels.

The potential effect of reproductive hormone levels is an interesting one. Rhino that were older (Figure 2B) and had higher reproductive hormone levels (Figure 5) moved less. Perhaps males with higher androgen levels are reproductively ready mates and more quickly identify opportunities to defend females, territories or home-ranges and thus were inclined to move less? The effect for females is less easy to rationalise since the effect could be in different directions depending on whether her elevated progesterin levels were due to pregnancy or oestrus. Perhaps during oestrous or pregnancy a female is more selective of habitat as an aid to attracting or avoiding males, respectively? Currently our understanding of black rhino behavioural ecology is not well enough developed to understand this result. Future studies of individuals in different reproductive states, such as those in white rhinoceros (Rachlow, 1997), would be an important contribution.

If reproductive status was not a confounding influence on rhino movements after release then there are two possible explanations for the effect observed. Either:

- (1) when a rhino encounters its own scent while moving around and away from the release site it is encouraged to move and explore further afield. This might be because its scent imparts confidence; that is the rhino is fooled into believing it has 'territorial' precedence, or
- (2) the rhino is avoiding the broadcast scent because it associates the smell with its largely negative experience in boma over the previous few weeks of captivity after capture. Indeed, when gathering rhino dung and urine from the boma we inevitably collect the scent of that environment that will likely include the smells of the teams that cleaned the boma each day, the chemicals and detergents used, vehicles and artificial foods. Moreover, during capture and captivity the physiological status of the rhino changes (Kock *et al*, 1999; Linklater *et al*, 2005). Changes in rhino physiology will be reflected in their dung and urine. Those changes might even act like an alarm signal if metabolites resulting from the activation of the



stress-response system alter dung and urine chemistry. We suspect that it is the former (i.e. 1) that is true because ongoing, but as yet unpublished analysis of the longer term dataset, show that although rhino moved away from their own scent (e.g. Figure 3), 13 of the 15 rhino established initial home ranges that included or were immediately adjacent to areas that had been spread with the scent of another rhino. If rhino were avoiding their dung and urine because it also included smells that they associated with their negative experience of the boma then one might expect them to avoid all the other rhinos' dung as well because it too would incorporate boma scents. That rhino did not avoid the dung from other rhino, and appear to have even been attracted by it, indicates that conspecific scent might play a role in black rhinoceros movements after release and be a tool for managing home range establishment. Improving our understanding of this effect will depend on studies of black rhinoceros olfactory behaviour, scent chemistry, and further experimental trials of the scent broadcasting technique.

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