# MORTALITY FACTORS AND BREEDING PERFORMANCE OF TRANSLOCATED BLACK RHINOS IN KENYA: 1984-1995

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## ABSTRACT

Between 1984 and 1995, 118 black rhinos *(Diceros bicornis michaeli)* were translocated into, and between, rhino sanctuaries in Kenya The majority of these were surplus animals removed from existing sanctuaries, with fewer stragglers 'rescued' from non-viable situations. There was high mortality after release from non-human causes (16% of rhinos translocated), with intraspecific fighting being the major mortality factor (53% of all deaths). Immature females and adult males had lower survival rates and suffered higher fighting mortality than other age/ sex categories, and fighting mortality was confined to animals introduced singly to new reserves, or in small groups. The total translocated sample showed a growth rate of 4% per year following translocation, increasing by 12% by the end of 1995. This was well below the potential rate of increase, with the breeding performance of translocated females being less than 50% of reasonable expectation. Several females were slow to calve after introduction, or had not yet done so. Female stragglers translocated to sanctuaries were slow to produce their first calves relative to animals moved from sanctuaries, but had similar breeding rates overall. A population-level analysis of a larger sample of translocated rhinos is needed to determine the main causes of poor breeding performance, and thus to help promote enhanced growth rates of new populations.

## RESUME

Entre 1984 et 1995, 118 rhinos noirs *(Diceros bicornis michaeli)* ont été transloqués à l'intérieur et entre les sanctuaire de rhino au Kenya La majorité d'entre eux était constituée de surplus d'animaux retirés des sanctuaires existants, avec moins de traînards sauvé de situations non viables. Après le lâché, il y avait une forte mortalité(16% des rhinos transloqués) liée à des causes non - humaines, les conflits spécifiques internes ayant été le facteur potentiel de mortalité (53% de tous les décès). Les femelles immatures et les mâles adultes avaient un taux de survie inférieur et ont souffert des mortalités liées au grands conflits par rapport aux autres catégories d'âge et de sexe. Aussi, la mortalité portait sur les animaux introduits, particulièrement dans les nouvelles réserves ou en petits groupes. L'échantillon du total transloqué présentait un taux de croissance de 4% par an suivant la translocation, une augmentation de 12% avant la fin de 1995. Cela a été bien en dessous du taux d' augmentation avec une performance de reproduction des femelles déplacées qui a douné moins de 50% du résultat raisonnable. Plusieurs femelles étaient lentes à vêler ou n'étaient pas eneore dans cette situation. Les femelles traînards déplacées dans les sanctuaires étaient lentes dans la production de leur première vêler en relation avec les animaux déplacés des sanctuaires, mais avaient dans 1'ensemble, un taux de reproduction similaire. Une analyse du niveau de la population d'un grand échantillon de rhinos déplacés est nécessaire pour déterminer les principales causes de la pauvre performance de reproduction en vue d'aider à promouvoir l'accroissement du taux de croissance des nouvelles populations.

## INTRODUCTION

Translocation has been a key component of successful rhinoceros conservation programmes in Afirica (Hitchins *et al.* 1972; Cumming *et al.* 1989; Brooks 1989). Together with adequate security and protection, the translocation and successful introduction of black rhinos *(Diceros bicornis)* to new reserves have proved essential to developing viable populations of this species. Since 1984, Kenya has focused its rhino conservation effort on the intensive protection and breeding of its remaining animals in relatively small protected areas, or sanctuaries (Jenkins, 1983; Brett, 1990; KWS, 1993; Leader-Williams *et al*, 1997). The goal is to breed up and maintain a minimum total population of 2,000 black rhinos *(Dr b. michaeli)* in their natural habitat, currently accepted as a minimum number required for a genetically viable metapopulation of this subspecies (Du Toit *et al.*, 1987; Brooks, 1989). Kenya's present rhino conservation plan (KWS, 1993) has four objectives:

- to secure and protect all remaining rhinos;
- to capture and translocate all isolated, non-breeding or non-viable rhinos or rhino groups into sanctuaries for their own protection and to contribute to breeding;
- to remove any recognised surplus of rhinos in sanctuaries approaching or exceeding their carrying capacities on a basis of maximum sustainable yield;
- to translocate surplus rhinos to stock new sanctuaries and unfenced release areas located in larger areas of secure habitat.

Kenya's total population of about 440 black rhinos is fragmented into more than 15 sub-populations, none numbering more than 70 animals (Brett, 1994; Oloo, 1996). Without intensive management involving the continuous monitoring of population size and structure, and the periodic introduction and exchange of unrelated rhinos, most or all of the these populations are not viable in the long term (Dobson *et al.*, 1991). The recommendations of a Population and Habitat Viability Analysis (PHVA: Foose *et al.*, 1993) and additional population modelling (Lacy, 1987; Dobson *et al.*, 1991) sanctuaries by the end of 1995.

Translocation was originally used in Kenya largely for the removal or rescue of individual rhinos from non-viable locations for subsequent introduction into protected areas (eg. Hamilton & King, 1969). Over 100 black rhinos were translocated to reserves in Kenya between 1959 and 1984, all animals which had been captured in areas vulnerable to poaching and/or being occupied by human settlement. More than half of these rhinos were used to stock two small reserves (Nairobi National Park(114km$^2$) and Solio ranch (56 km$^2$) with rhinos between 1963 and 1980 (Hamilton and King, 1969; KWS, 1993). These populations prospered, and after 1986 each had substantial surplus numbers available for subsequent translocation and progressive stocking of newly developed sanctuaries, for which each had been such successful models. The Nairobi and Solio populations have now produced three and five times their respective founder populations (Table 1). Consequently, since 1984, most rhinos translocated have originated from these sanctuaries. Increasingly, the management of remaining wild populations for improved population performance is now based upon translocation between protected areas (KWS, 1993). The Kenya rhino programme has shown some success: between 1986 and 1990 rhino numbers in sanctuaries increased at

*Table 1. Supply of Rhinos for translocation (1984-1995), with (a), surplus Rhinos from sanctuaries, and with (b), strggler/outlier Rhinos (isolated, non-breeding and/or vulnerable animals*

| Source | Number of founders of donor populations (years of stocking) | Number of rhinos translocated | Population total (1995) | Population change: number of Rhinos | Population change: multiple |
|---|---|---|---|---|---|
| (a)Surplus from sanctuaries | | | | | |
| Solio Ranch | 22(1970-80) | 61 | 50 | +81 | 5.05 |
| Nairobi NP | 37(1963-80) | 26 | 64 | +53 | 2.43 |
| Exchanges (between sanctuaries) | 10 | | | | |
| Subtotal | | 97 | | | |
| b) Stragglers* | | 21 | | | |
| Total | | 118 | | | |

* Captured in remote areas of Samburu, Laikipia and Nyeri Districts and the periphery of Tsavo National Park.

approximately 5% annually (Brett, 1990,1991; Gakahu, provided the basis for the adoption of 20 rhinos as the minimum number of founders of new populations, the managed migration of one **to** two unrelated rhinos between populations per generation, and a short-term translocation programme to complete the minimum stocking of existing 1989; KWS, 1993).

This paper reviews the results of Kenya's recent 12-year translocation programme (1984-1995) and examines the performance of source and translocated sanctuary populations. It determines the major causes of mortality in translocated populations, and makes a preliminary assessment of the breeding performance of translocated individuals. The aim is to identify factors affecting the survival and breeding output of translocated individuals which could be used to derive criteria or guidelines on translocations for wildlife managers implementing rhino conservation plans.

## METHODS

### Supply and destination of translocated rhinos

A total of 121 rhinos were captured for translocation during the 12 year period under examination. Of these 111 different rhinos were introduced into new reserves (118 translocations completed). Eight rhinos died during the capture or translocation process (6.6% of all captures) and consequently were never released into a new reserve, and two others were moved to isolation in paddocks. The majority of rhinos translocated over this time (82%) were surplus animals from sanctuaries exceeding their respective estimated Ecological Carrying Capacities (eECC) (Table 1), the majority originating from Solio ranch and Nairobi NP The remaining rhinos translocated (18%) were captured in situations where they were isolated, vulnerable to poaching and/or out of breeding contact with other rhinos (termed ‘stragglers’ or ‘outliers’: Leader-Williams *et al.*, 1997). There was no significant bias of the sample of translocated rhinos with respect to sex (57 males: 61 females), and there were similar numbers of adult and immature animals moved (61:57).

The rhinos supplied were translocated to nine different reserves (Table 2). With the exception of eight animals added to three already existing rhino populations, all rhinos were translocated as founder stock for six new populations (five rhino sanctuaries and one intensive protection zone (IPZ: Leader-Williams *et al.,* 1997), all developed after 1984. Each of these areas received a minimum of 20 founders, with the exception of the ill-fated 4km$^2$ sanctuary in Meru NP Here, the first two rhinos translocated were poached within a year of introduction, and the sanctuary was abandoned soon afterwards.

Approximately one quarter of all rhinos were translocated and released singly (including most of the 21 straggler rhinos captured). Others were released in pairs, and groups of three, four, seven and eight. A group release was made if all rhinos were released into the recipient reserve from holding bomas in as many days (eg. seven rhinos released within one week) Translocations to all recipient reserves were spread over the 12-year period (Figure 1), largely due to the lack of resources needed to carry out expensive operations, and other logistic constraints. All rhinos were captured by chemical immobilisation, and either moved immediately to destination reserves, held at the capture site in holding bomas and/or held in bomas at the release site in the recipient reserve prior to release. Holding periods at capture or release sites varied from a few days to over 12 months.

Long term daily monitoring of sanctuary populations provided life history data on all individually identified rhinos and the sex/age composition of each rhino population, including all births, deaths and causes of mortality. All translocated rhinos were ear-notched at capture to assist subsequent individual identification. Where precise ages were not known from life history records, ages of translocated animals were estimated at capture by examination of tooth wear (Hitchins, 1978; Du Toit, 1986), or judged adult or immature using the field criteria developed by Hitchins (1970), and modified by Emslie *et al.* (1993), where females become adult at seven years of age, and males at eight. All rhinos translocated were subject to intensified surveillance in the first few months after release.

In order to examine individual and collective mortality and breeding of rhinos after translocation, data were compiled into a database for all black rhinos which were introduced to new reserves between January 1984 and December 1995. The database comprised a matrix with row entries for each individual rhino for each year following their translocation, a total of 543 rhino years. Data on mortalities and births were entered for each rhino, including the causes of mortality, and the sex and survivorship of calves born. Additional column entries were data selected as possible factors influencing translocation success, including attributes of the individual rhino selected (eg. sex and age), of time elapsed after translocation, and of the translocation procedure (eg. size of group of rhinos released together).

## RESULTS

### Performance of recipient populations

The total sample of translocated rhinos had increasedby 11.7% at the end of the 12-year study period, equivalent to a 4.1% increase per year following translocation. At the end of 1995, there were 88 survivors (79%) out of the original 111 rhinos introduced to new reserves. Breeding performance was highly variable, with only

*Table 2. Reserves receiving translocated rhinos (1984-95) in (a), stocking of new rhino sanctuaries, or (b), reinforcing existing rhino populations.*

[a] Intensive Protection Zone (unfenced area of high security for Rhinos within a protected area (eg. Tsavo East NP))
[b] The Lewa downs sanctuary was extended to 40 $km^2$ in 1987, and further enlarged to cover the entire ranch and a neighbouring forest reserve in 1984
[c] Kenya Wildlife Service (National Park)
[d] The Ngulia sanctuaty was extended to 20 $km^2$ in 1987 and to 65$km^2$ in 1990 -91
[a] Estimated Ecological Carrying Capacity of reserve for Rhinos (Foose et al., 1983; KWS, 1993)
[f] Excludes one Rhino removed from Lake Nakuru NP and four from Lewa Downs

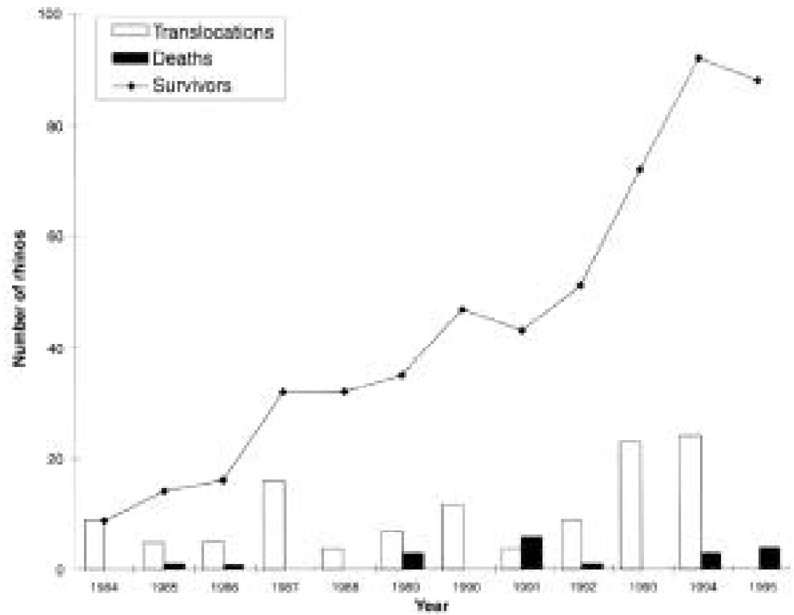



*Figure 1. Distribution of the number of rhinos translocated, and the number of deaths and survivors among translocated rhinos by year (1984-1995).*

two populations (Lake Nakuru and Ngulia) showing significant population growth (41% and 45% respectively), while two reserves (Lewa Downs and Ol Pejeta) have had significant mortality, equalling two populations (Lake Nakuru and Ngulia) showingor exceeding the number of calves born (Table 2). The Tsavo East IPZ has had insufficient time since minimum stocking to show appreciable population growth, and the founder stock has since been doubled by further translocations of surplus rhinos from Nairobi NP since 1995.

## Causes and timing of mortality

Intraspecific fighting with resident rhinos was the major cause of mortality among translocated rhinos, accounting for 12 out of 23 deaths, and more than half of the 19 'natural' deaths (those not directly caused by humans) (Figure 2). The next most common cause of death was falling over cliffs, accounting for three rhinos in the Lewa Downs reserve. Other 'natural' deaths included one rhino that fell over a fallen tree trunk, one killed by an elephant (Figure 2), and another death from old age. Three other deaths were from unknown causes; in two of these cases, fighting was suspected.

Most 'natural' deaths occurred in the first five years after introduction (Figure 3), particularly in the case of fighting mortality, which was restricted to the first two years. Closer examination of the timing of fighting mortality after release (Figure 4) revealed an initial peak of deaths within the first three months (25%) related to the translocation process, and another peak between six and 12 months in residence. In all cases where combatants were identified (eight out of 12), resident adult males killed translocated rhinos.

There was a slight bias of all deaths in the translocated sample towards adult males and immature females ($X^2$=7.83 df=3, p<0.05). A similar, but not significant bias was found with deaths from fighting (Figure 5). The sex and age composition of groups of rhinos released in new reserves, and the incidence of mortality with group size show that most deaths occurred **to** rhinos released in small groups (four rhinos or less). Fighting deaths were only found in small groups, particularly with rhinos released singly (Figure 6). Although it appears that there was a sex and age bias in mortality of small groups (eg. all adult males killed in fights were released singly: Figure 6) this was due to a significant bias in the sex/age composition of small groups translocated towards adult males and immature females (eg. singles and pairs of rhinos: $X^2$=8.44, df=3, p<0.05).

## Breeding performance of females

A total of 44 calves were born to translocated females, of which 36 survived **to** the end of 1995 (Table 1 and Figure *7)*. Of the 59 females translocated (30 adult, 29

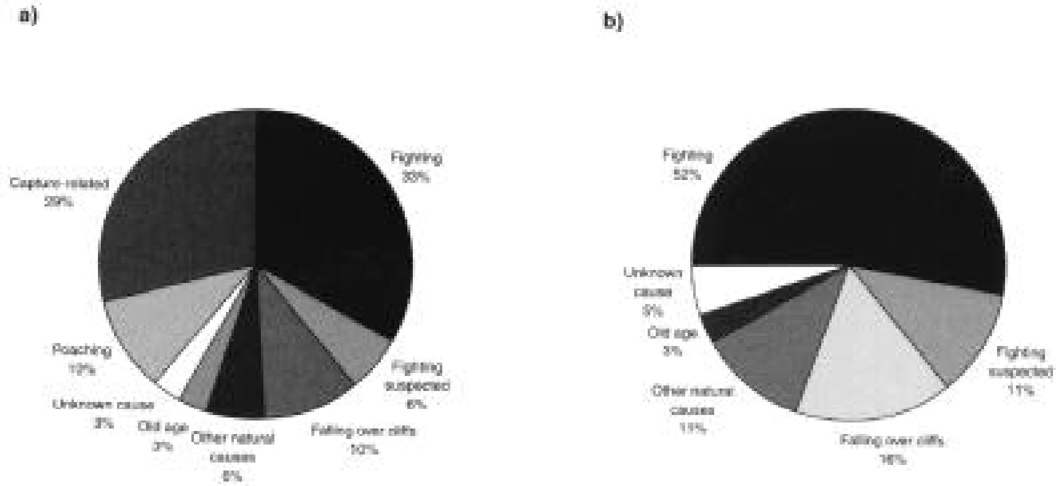



*Figure 2. Relative proportion of causes of mortality Figure 2. Relative proportion of causes of mortality to rhinos which were captured, translocated and introduced to new reserves:*
*(a) all deaths (n=23);*
*(b) 'natural' deaths (n=19, excludes human-related deaths: 3 poached, 1 during capture).*

immatures), 33 had sufficient time in residence in recipient reserves to produce at least one calf (ie. more than one gestation period of 16 months: Goddard, 1967, and assuming that on average young females produce their first calves at the age of seven), a total of 227 rhino years of potential breeding. Four females had calved out of the 12 immature rhinos which became adults after translocation. Seven of the latter had sufficient time in residence to have calved.

A total of 25 females had calved by the end of 1995(76% of potential mothers), of which 21 were translocated as adults, and four as immatures. The mean time spent by females as adults after introduction to new reserves was 6.9 ±3.2 years. The distribution of calves born within a year after their mothers' introduction is shown in Figure 8. Eight calves were conceived in donor reserves (ie. before translocation), and their mothers were pregnant when released.

Adult females (including animals pregnant at translocation) took an average of 3.4 ±2.2 years to produce their first calves in the new reserve (n=21), with non pregnant animals calving 4.6±2.1 years on average after translocation (n=13). At the end of 1995, eight females had spent an average of 3.6 ±1.6 years as adults in residence, and had still not calved. Of these, two appear to be infertile (no calf after 6 years). Only a small number of females were of known age at translocation, and of those which had calved, the mean age at first calving was 8.7 ±1.0 years (n=6, range 7-10).

Adult, not pregnant females who were translocated had similar calving rates in recipient reserves whether they were captured as stragglers (0.18 calves/year, n=7) or as surplus rhinos moved from other sanctuaries (0.19 calves/ year, n=6), with a comparable proportion of females breeding (80 vs. 67%) in each case. However, stragglers took significantly longer than ex-sanctuary females to have their first calf (5.4 vs. 3.6 years; z=l.71, $p<0.05$).

There was poor survivorship of calves whose mothers were translocated while pregnant (ie. calves conceived in previous locations). Of all four calves dying in the first week after birth, three were born to mothers translocated while pregnant. Half of the eight calves conceived before translocation of their mothers did not survive their first year.

Overall there was no bias in the sex ratio of calves born to translocated rhinos (22 males, 21 females, 1 unsexed). However, sex ratios of calves born in particular sanctuaries did show a marked, but not consistent bias. For example, male calves exceeded female calves by approximately 2:1 in the Ngulia and Lake Nakuru sanctuaries (6:3 and 9:5 respectively) but the reverse was found for calves born at Lewa Downs (4 males: 8 females).

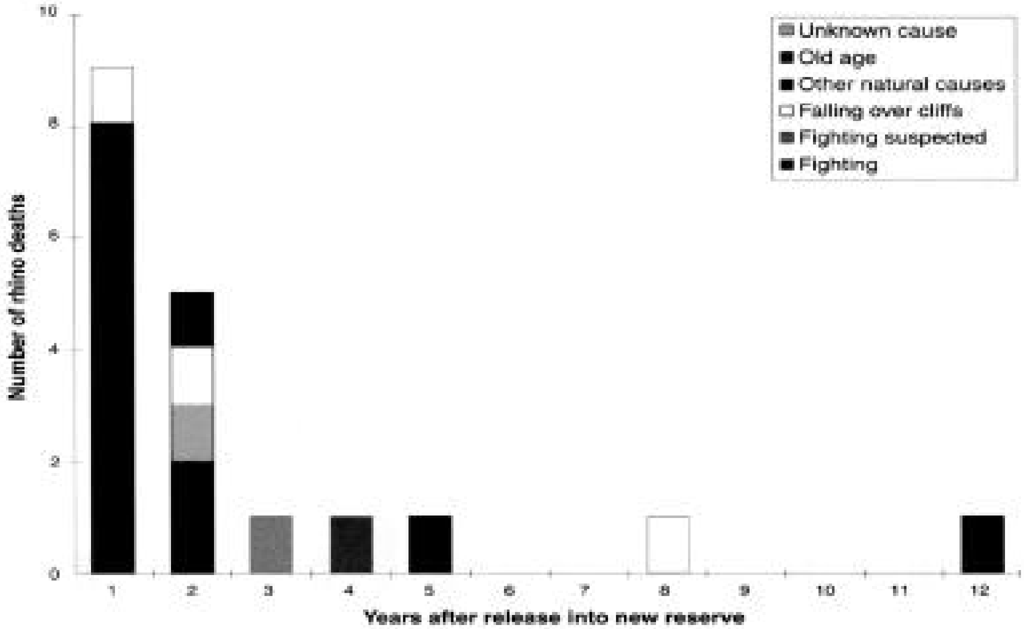



*Figure 3. Distribution of mortality of rhinos with number of years after introduction to new reserves and cause of death.*

## DISCUSSION

### Mortality factors

Intraspecific fighting of translocated rhinos in the first two years after introduction to new reserves in Kenya was the major mortality factor affecting all sex and age groups. High levels of fighting mortality in translocated populations have also been recorded in southern African populations since 1989 (Adcock, 1995,1996), accounting for 4l% of natural deaths. Overall mortality of translocated rhinos has been similar (24% of 148 translocated rhinos vs. 21% for Kenya: 1984-95). Intraspecific fighting is clearly a major problem facing rhino managers in translocating animals **to** form new populations, and in particular, in introducing rhinos **to** established populations. This factor clearly needs to be reduced in order to promote the rapid growth of translocated populations.

In past rhino translocation programmes in Africa, mortality related to disease, dispersal, capture and stress was more prevalent (Clausen, 1981; McCulloch and Achard, 1969; Hamilton and King, 1969; Booth *et al.*, 1981), and these have now been much reduced through improved capture methodology and translocation management (Kock, 1993; Rogers, 1993). However, accidental death, the other significant mortality factor identified in this study, may be an inevitable toll on rhinos, translocated or otherwise. The black rhino's vulnerability **to** falling over cliffs and getting stuck in water holes was always a feature of former, very large wild populations. For example, after poaching, these were the major mortality factors in over 700 rhino mortalities recorded by Tsavo East NP wardens D.LW. Sheldrick and F.W. Woodley between 1949 and 1974 (KNP, 1949-74; see also Hitchins, 1962; Hitchins & Anderson, 1983). A further two cliff deaths occurred on Lewa Downs in **1995,** involving the calf and grand-calf of one of the first adult females translocated from Solio in 1984. Published accounts of predation by lions *(Panthera leo)* and spotted hyaenas *(Crocuta crocuta)* on black rhino and their calves have been little more than anecdotal (Sillero-Zubiri & Gotelli, 1991; Goddard, 1967; Berger *et al.*, 1993); no cases of predation have been reported on this translocated sample, or their calves.

Mortality of rhinos during capture and translocation in Kenya during 1984-95 was relatively low (<10% of translocations; compare with McCulloch and Achard, 1969; Hitchins *et al.,* 1972; Hall-Martin, 1982; Hall-Martin & Hillman, 1983; Hitchins, 1984), but difficult to compare with recent figures for other range states (eg. South Africa, Namibia and Zimbabwe: Adcock, 1995, 1996; Kock, 1993), where fighting mortality within the first three months after introduction ('post-release fighting') is judged to be 'translocation-related', and

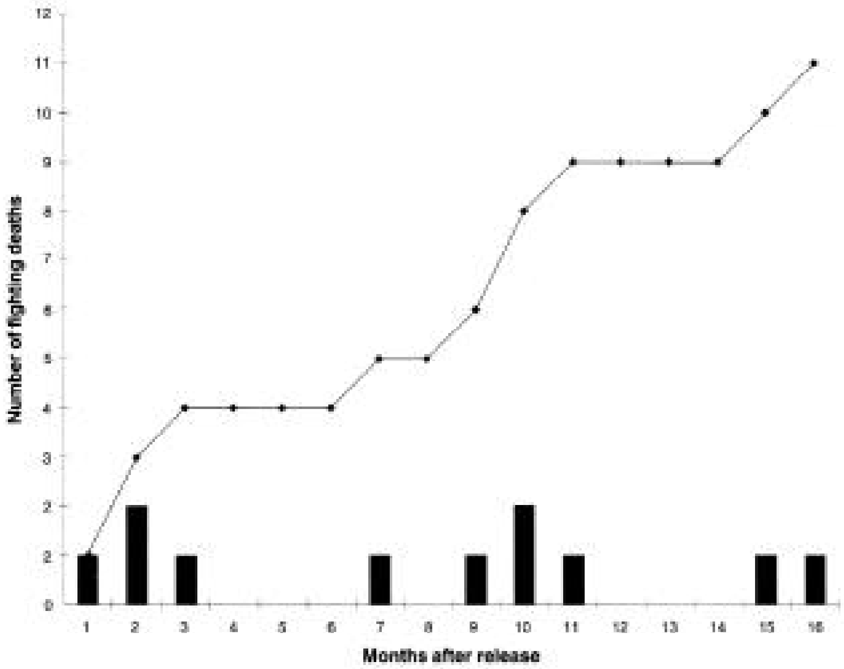
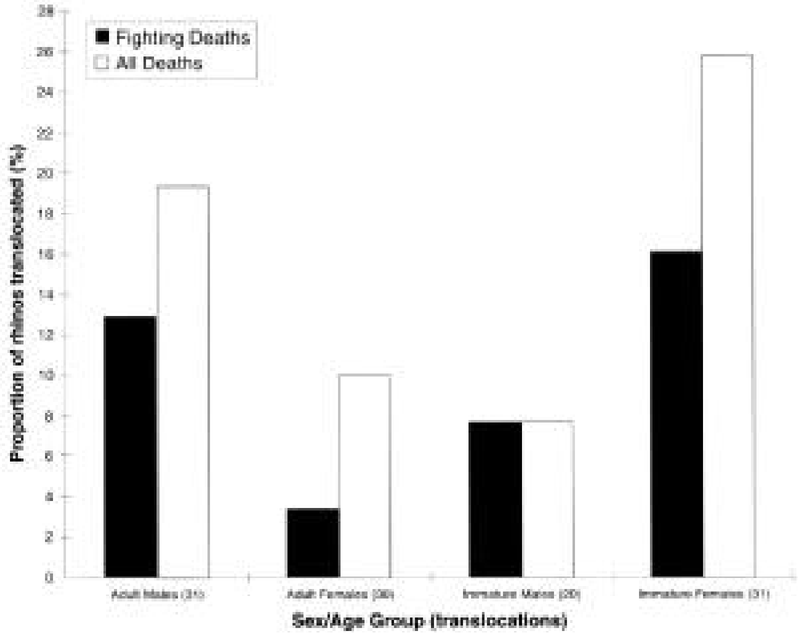



*Figure 4. Distribution of individual and cumulative fighting mortalities in the first 16 months after introduction to new reserves.*

subsequent fighting mortality recorded as 'natural'. Although a quarter of all fighting deaths to translocated rhinos in Kenya were recorded within the first three months of residence (Figure 4), fighting mortality occurred through the first 16 months of residence, indicating that it may take some time before the repercussions of the introduction of a strange rhino are felt in terms of the probability of a potentially lethal encounter with a resident

A recent statistical analysis of this data set (Brett *et al.*, unpubl) examined the effects of 30 different explanatory variables on the probability of individual survival and fighting mortality after translocation, using generalised linear modelling. The explanatory variables tested included attributes of the rhino translocated (eg. sex), of the recipient rhino population (eg. rhino density), of the recipient reserve (eg. estimated Ecological Carrying Capacity (eECC)), of time (eg. years since release) and of the translocation procedure (eg. release group size). Although individual survival was found **to** be primarily related to attributes of the recipient reserve (eg. reserve eECC) with some effect of the age group of the introduced rhino), the best model of the probability of fighting mortality was related to one factor: the size of the group of rhinos introduced together. It was expected that rhino density, in absolute terms and as a proporton of eECC, would have a strong effect on post-translocation mortality, perhaps associated with overstocking in some recipient areas. These attributes, however, were found to be of secondary importance. Clear recommendations for rhino managers were derived from this analysis: to improve individual survival after translocation; move rhinos to reserves with excellent habitat (high eECC density) at a relatively low rhino density, and in large groups; and, select adults for translocation, and adult females if available.

In Kenya and elsewhere in Africa, sub-adult rhinos (four to seven years old) have often been selected preferentially for translocation, and younger animals (two to three years old) still with their mothers have also been included. Forty two percent of the translocated sample studied here were of the sub-adult category; these rhinos are more convenient to move (since they have no dependants), would normally be dispersing in order to establish themselves in a new range in the natal area, and have their whole breeding life ahead of them. These results suggest that immature rhinos (particularly females) are least likely to survive after translocation (Figure 5). This may be because they are least able to look after themselves after release into an unfamiliar area and population, often seeking out the company of other rhinos, which can get them into dangerous situations if they approach an adult male. The




*Figures. Relative proportion of mortalities and fighting deaths suffered by different sex and age groups translocated.*

poor survival of immature females in Kenya and southern Africa (where one to four year olds were at highest risk: Adcock, 1995, 1996) may also be linked to lethal encounters with resident males who try **to** mate with them.

Another clear finding of this study and of Brett *et al.* (unpubl) was the preponderance of deaths (including all fighting deaths) suffered by animals released singly, or in small groups (four or less: Figure 6). The consensus of rhino managers in eastern and southern Africa is that large numbers of rhinos should be moved into a vacant reserve area within a relatively smalltime, giving little opportunity for any resident animals to assert themselves, or to become aggressive to newcomers (Brooks, 1989; Zimbabwe DNPWLM, 1992; KWS, 1993). Due to financial and other constraints, it is rarely possible to stock anew reserve with more than 20 rhinos in one operation, and thus other variables (eg. the age and sex of translocated rhinos, the density and eECC of recipient reserves) may assume increased importance in translocation decisions.

## Population performance and breeding output in females

The translocation of black rhinos into sanctuaries over the last 12 years has resulted in a small overall population increase, and has also fulfilled the guidelines adopted for genetic and demographic management of the Kenya black rhino metapopulation (KWS, 1993; Foose *et al.*, 1993). In itself, the removal of 21 stragglers from highly vulnerable situations, and of 87 surplus rhinos from overstocked sanctuaries (Table 1) was essential for the immediate survival of those stragglers (and any future breeding on their part) and the future health of key breeding populations (eg. Solio and Nairobi NP).

However, the reproductive performance of this translocated sample was below expectation. Compared with a modest prediction of each adult female having a mean calving interval of three years (Goddard, 1967, Hall-Martin, 1986), the conception and calving output in recipient reserves was less than half (45%) of an expected minimum total (78 calves). The overall annual growth rate of translocated populations (mean of 2.9%) was well below that of the two source populations Solio (4-10% annual growth) and Nairobi (10% annual growth; KWS, 1993; Leader-Williams, unpubl). Reduced performance of translocated rhinos has also been noted with similar sizes of translocated samples, populations and reserves in southern Africa (Adcock, 1995,1996).

Responsibility for at least some of the relatively poor initial performance of these translocated populations lies with the low output of some adult females, with around a quarter not having calved, and two animals with nothing to show after six years in residence. Even those that did calve

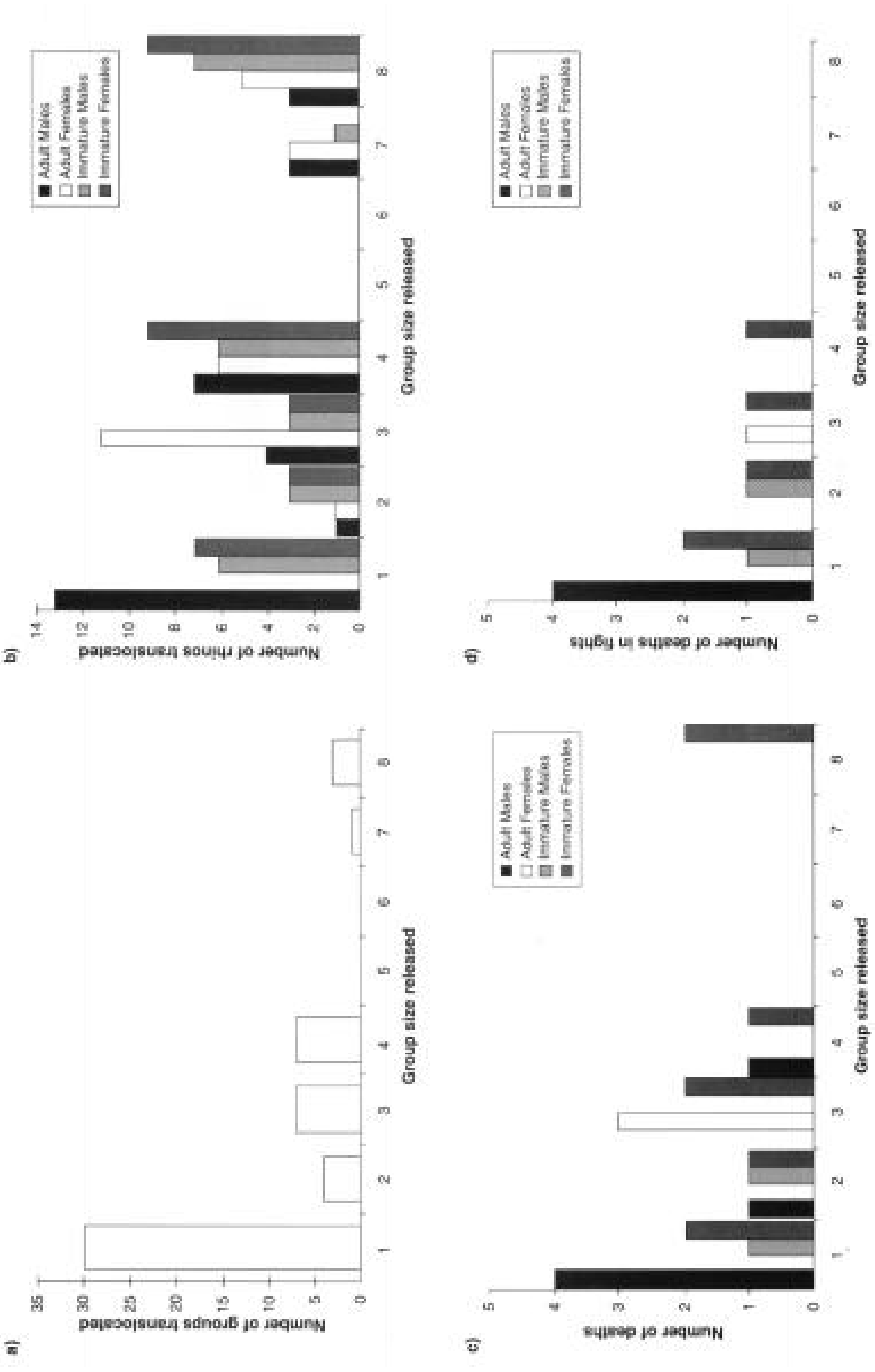



*Figure 6. Sizes of groups of rhinos translocated and released into new reserves: (a), frequency, (b), sex and age group composition of groups, (c), mortality by sex and age group; (d), fighting mortality by sex and age group.*

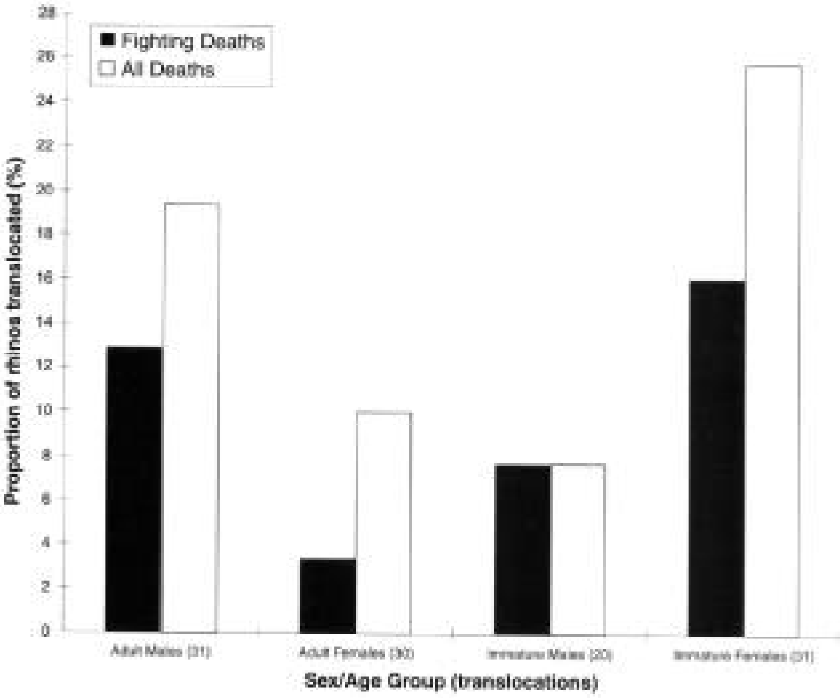



*Figure 7. Distribution of the number of calves born to translocated rhinos, and cumulative surving calves by year (1984-1995).*

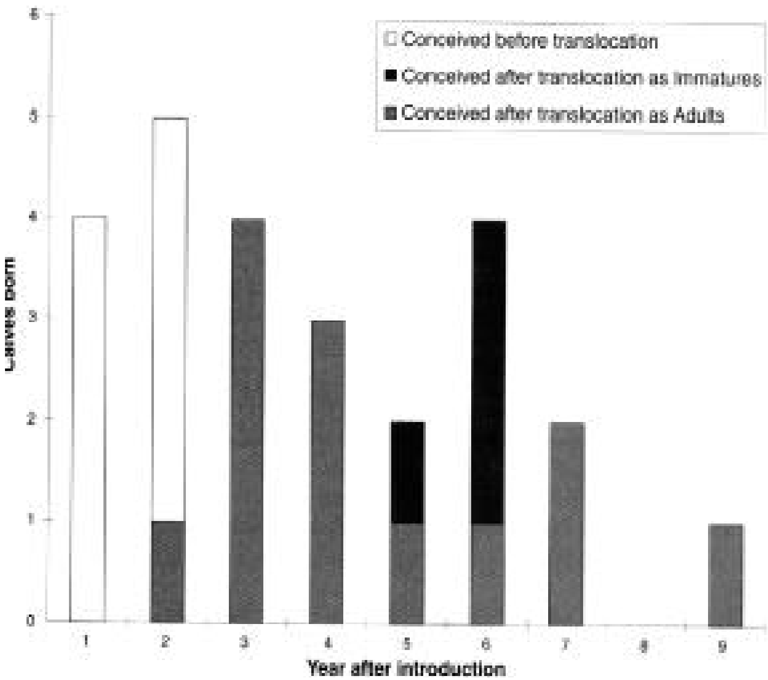



*Figure 8. Distribution of calves born with the number of years after introduction of their mothers to new reserves.*

after translocation (when not in calf) took around 40 months to conceive. In addition, young known-age females were slow to conceive for the first time, doing so well after the earliest possible time (4-5 years old: Goddard, 1967, 1970). It is possible that stress and lowered nutrition status after introduction to a new reserve, and disruption of established relationships of adult females with breeding males in previous reserves have some effect in delaying conceptions after translocation. The relative delay in production of first calves in a new reserve for straggler females, compared with ex-sanctuary animals, is also understandable, particularly considering the long periods of isolation that some straggler females have endured as the last remnants of formerly large populations which had been severely reduced through poaching (eg. Tsavo NP). However, lack of breeding (or any) contact with other rhinos, does not necessarily result in reduced subsequent fertility. The last animal captured in the southern area of Tsavo West NP in 1993, a particularly aggressive female which had probably been isolated for at least six years, took only a year to conceive after introduction to Ngulia sanctuary, and calved in 1995.

Although the sample was small, the indication that there was reduced survival of calves whose mothers had been translocated while pregnant gives cause for some concern about the wisdom of routinely translocating pregnant females. This was evident in poor calf survival rather than early abortion, perhaps due to lowered nutritional status and reduced milk production of lactating cows. Visual diagnosis of pregnancy is problematic in black rhinos, with only the presence of a swollen udder just prior to parturition giving a reliable (but not early) warning. If additional data to these confirm that the translocation of pregnant females constitutes a significant risk to unborn calves, a reliable field-based test of diagnosis of pregnancy using urine or faeces could assist selection of females for translocation and thus improve overall calf survival.

The marked bias in sex ratio of calves born in some sanctuaries demonstrates the potential for early demographic upset in small breeding groups of rhinos. Extreme sex ratio bias in the Lewa Downs population prior to 1992, and the loss of single adult breeding males resulted in complete cessation of breeding for several years. The results of recent simulations of Kenya rhino populations *(Dobson et al.,* 1991, Foose *et al.*, 1993), found that demographic instability is more of an initial problem for small populations than loss of genetic variation or inbreeding in causing early extinction.

Using this data set and the same methodology as that of Brett *et al.* (unpubl), an additional analysis of potential effects on the probability of conception and calving in individual females found that none of 30 explanatory variables tested had any effect except calendar year. The sex/age composition of founder stock for new reserves may bean important influence on breeding output in the first five years after introduction. Obviously a bias in adult sex ratio of founder stock towards females should result in an early high yield of calves. The founder stock of the Solio reserve was strongly female-biased (8 males:14 females) and early and rapid population growth resulted (Table 1). Recent modelling of southern African black rhino populations (Hearne & Swart, 1991) has suggested that translocating adults is also more favourable to total population growth due to the immediate enhancement of fecundity in a new lower density reserve; these authors recommended the translocation of as many adults from the source population as it can tolerate. Clearly the selection of the age and sex composition of translocated founder groups of rhinos should be adapted to the sex/ age composition of donor populations and should avoid any negative effect on the future breeding potential or viability of the latter.

This study is a first step in finding factors which may promote early and fast growth of translocated populations. A population-based analysis is now required, looking at the composition and subsequent performance of different founder populations, and the reasons why some populations perform much better than others (Table 2). Pooling of data on translocated rhino populations in Kenya with those from other range states (eg. Zimbabwe, Namibia, South Africa) would clearly improve such a study. Meanwhile, the survival of individuals in the few years after release into new populations provides a useful advance assessment of translocation procedure, in particular the choice of rhinos for translocation to suit conditions in recipient reserves (Brett *et al.*, unpubl). Given the relatively short post-release periods examined here (an average of 4.9 years per translocated rhinoceros), the overall success of the 1984-95 translocation programme awaits future evaluation in terms of the sustainability of translocated populations.

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