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Population dynamics and future conservation of a free-ranging black rhinoceros (*Diceros bicornis*) population in Kenya

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Abstract

The black rhinoceros has declined throughout its range since the 1960s as a result of illegal killing to supply the international trade in rhino horn. However, in recent years the decline has been halted and reversed as a result of the protection and management of rhinos in a small number of key areas. This paper assesses population recovery in one such area, the Masai Mara, since the mid 1980s, using data from daily surveillance patrols. Although a partial recovery to 35 individuals at a growth rate of 9.8% per annum took place until 1994, the population then appeared to decline to 23 individuals by 1999. At no point did the population size or density approach that of the population prior to poaching. The apparent decline could be a result of death, dispersal or an increased reclusiveness amongst some individuals. Evidence suggests that this population extends beyond both protected area and international borders within the Serengeti-Mara ecosystem, and a comparison of the age and sex structure of present versus disappeared rhinos implies that dispersal of sub-adult individuals may partly explain the recent decline. Intensive monitoring with regular assessment of rhino population performance is vital to avoid complacency and identify potential problems quickly. It is recommended that cross-border monitoring is implemented to identify and protect the full range of this population, and to try to ascertain the fate of individuals that have disappeared. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Black rhinos; Population recovery; Dispersal; Serengeti-Mara ecosystem; Kenya

1. Introduction

The black rhinoceros (*Diceros bicornis* L.) has declined throughout its range throughout the 20th century, but most significantly since the 1960s as a result of illegal killing to supply the high international demand in rhino horn (Martin and Martin, 1982; Martin, 1983; Leader-Williams, 1992; Nowell et al., 1992; Martin et al., 1997; Mills, 1997). The decline continued throughout the 1980s, and it is estimated that over 95% of the population that existed in the 1960s was eliminated (Western, 1982; Leader-Williams, 1988; Milliken et al., 1993).

Recently the situation has improved as a result of the concentration of the majority of wild rhinos into well protected areas administered by both government and private owners, and by intensifying anti-poaching efforts (Dublin and Wilson, 1998; Emslie and Brooks, 1999). Many populations have stabilised or recovered, and the continental population now numbers ca. 2600 rhinos (Emslie and Brooks, 1999). However, there is still a need to maintain continuous biological and security monitoring of all populations, to ensure that poaching does not recur and that populations are meeting recovery targets and maintaining demographic and genetic viability (Emslie and Brooks, 1999).

This paper uses daily monitoring data to assess the recovery and performance of a key Kenyan black rhino population. Kenya, along with South Africa, Namibia and Zimbabwe, is one of the major strongholds of the black rhino, and currently protects around 430 individuals, or 16% of the estimated continental population (Emslie and Brooks, 1999). Many of these are in fenced sanctuaries, but some are free-ranging, of which the most significant population is that of the Masai Mara

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National Reserve (MMNR). This comprises a relatively large contiguous area of rhino habitat, and is unusual in remaining unfenced and under the management of local councils within Kenya. This paper analyses temporal trends in a number of demographic parameters over a 12-year period of continuous monitoring that has taken place after a period of severe poaching. Population recovery is measured by comparison of current data with those gathered almost three decades ago, prior to the onset of severe poaching. Reasons for the observed trends are considered, and recommendations for improving population monitoring to ensure optimum recovery are offered.

2. Methods

2.1. Study area

The MMNR is a 1510 km^2 unfenced protected area in the south-west of Kenya on the border with Tanzania, lying between 34° 45′–35°25′ E and 1°13′–1°45′ S (Fig. 1). It is an area of undulating grassland savanna intersected by numerous drainage lines and three rivers, the Mara river, Sand river and Talek river. To the west it is bordered by the Olololo (Siria) Escarpment, and to the east it extends into a range of bushed hills. Mean elevation on the plains is 1600 m. Thickets dominated by Croton dichogamus are widespread especially on hill

Fig. 1. Map of Masai Mara National Reserve.

slopes, whilst some remnant Acacia woodland remains in places. Mature stands of riverine woodland are associated with the major rivers. Rainfall is normally within the range of 800–1200 mm/year (Dublin, 1991). MMNR is the northernmost extension of the world-famous Serengeti-Mara ecosystem which supports an extremely high diversity and biomass of large mammals, including a range of ungulate and large carnivore species (Sinclair and Norton-Griffiths, 1979; Dublin, 1984; Broten and Said, 1995; Sinclair, 1995).

MMNR is a key refuge for the black rhinoceros. In the 1960s, it contained a large population of ca. 150 black rhinos (Brett, 1993). Furthermore, in the Serengeti National Park and Ngorongoro Conservation Area which are contiguous with MMNR, a further 700 and 108 rhinos, respectively, were known to reside (Goddard, 1967, Frame, 1980). A study in the early 1970s identified 108 different individuals in MMNR (Mukinya, 1973). However, throughout the 1970s and early 1980s, the population was decimated by poaching to supply the illegal trade in rhino horn, and declined to fewer than 15 individuals. There were similar declines in Serengeti, where the population remains unknown, and Ngorongoro which currently holds 18 rhinos (Haywood, 1995; Morgan-Davies, 1996). Since the mid 1980s security in MMNR has increased and the population has begun to recover.

The MMNR black rhinoceros population is important for a number of reasons. It remains the only indigenous, unfenced and free-ranging population of the lowland race of the sub-species D. b. michaeli in Kenya. No inward translocations have affected the genetic purity of the founder stock (Brett, 1993). With a large potential range across the whole of the Serengeti-Mara ecosystem, it has the capacity to become one of the largest populations in Africa. Furthermore, it is one of the only populations of black rhinoceros to reside on land owned and managed by local Maasai communities. As a key visitor attraction in one of Africa's most visited areas (Gakahu, 1992), it has the potential to generate significant tourism revenues for the local communities. The recovery of the population is therefore of paramount importance from both biological and socio-economic perspectives.

2.2. Population size and individual recognition of rhinos

Since the mid-1980s, twice-daily vehicle-based monitoring of the population has been carried out within MMNR by a team of Narok County Council (NCC) rangers, led for the past 6 years by one of the authors (PB). Over 90% of patrols took place in Keekorok sector (Fig. 1), with occasional patrols in Musiara and Triangle sectors where only one rhino is currently known to reside. Patrols usually took place between 0600 and 1100 h in the morning and between 1600 and
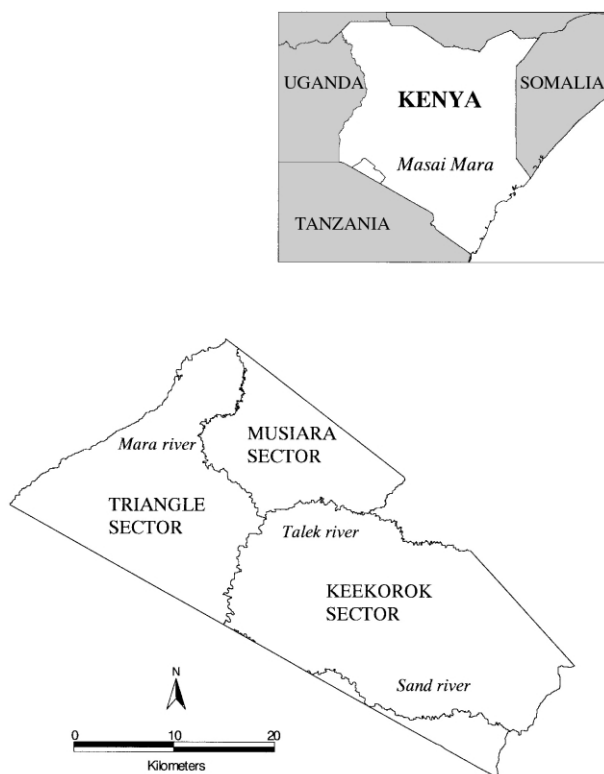
2000 h in the afternoon. Individual rhinos were recognised by a number of features (age, sex, horn size and shape, ear notches, body shape and nose wrinkle patterns), as have been widely used elsewhere (Klingel and Klingel 1966; Hitchins 1968; Hamilton and King, 1969; Western and Sindiyo, 1972; Makacha et al., 1979; Kiwia, 1989). For each sighting, the individual(s) encountered and general area of sighting were recorded. For each patrol, regardless of whether a sighting was made, the date, start and end times, personnel involved and areas traversed were recorded.

Previous estimates of population size in MMNR have taken the total number of individuals seen during a period of continuous monitoring and subtracted those individuals known to have died (Mukinya, 1973; Morgan-Davies, 1996). This method is acceptable for short studies but it risks overestimating the population size over longer periods since it may include individuals last seen several years previously, which may have either died or emigrated from the area. Initially this method was used in this study, adding each successive year of observations from 1988, to generate annual estimates of 'maximum' population size. The method was then refined to generate a second series of estimates. Population estimates were made for 2-year periods beginning every January from 1988 to 1998. Every rhino recorded over each 2-year period was added to the population estimate for that period. This method takes into account unverified 'disappearances' because only rhinos seen within each 2-year period are counted (cf. Leader-Williams, 1988). Based on the flattening off of monthly cumulative totals of new rhinos sighted, 2 years of observation was enough to be confident that all rhinos remaining in the study area had been recorded (Fig. 2). This matches the Kenyan black rhino management strategy which considers only those rhinos seen within the past 2 years to be 'definite' members of a population (T.Oloo, pers. commun.).

The number of sightings per unit effort during patrols was also calculated, as a separate measure of changing population size. Effort-based indices have been used previously to assess spatial differences in rhino density, based on the assumption that a smaller population in the same area will yield a lower rate of sightings, and vice versa (Leader-Williams, 1985). In this study, both total number of patrols and hours on patrol each year from 1993 to 1999 were used as measures of effort to assess temporal changes in the population in Keekorok sector only.

2.3. Population structure and inter-calving interval

Due to the long continuous period of monitoring it was possible to age all animals accurately up to 12 years old by reference to their month of birth. Individuals were classified into six sex and age categories; calf $\leqslant 3$ years old (male or female), sub-adult male (4–7 years), sub-adult female (4–5 years) and adult (male or female). A number of commonly used population parameters (sex ratio, adult:calf ratio, proportion of females with calves, and inter-calving interval) were calculated for comparison with earlier studies both in MMNR (Mukinya, 1973) and elsewhere. Changes in population structure between 1988/1989 and 1998/1999 were assessed, and the age and sex composition of the group of 'disappeared' rhinos was compared with that of the remaining population in 1998/1999. In both cases the Chi-squared test was used.

2.4. Density and distribution

Between 1992 and 1999, three of us (MMD 1992–1995, SM 1997–1998, and MJW 1998–1999) worked alongside the NCC rhino surveillance team, using GPS technology to record accurate locations of individual rhinos encountered. These data were entered into IDRISI, a GIS computer software package, to create rhino distribution maps for the three periods of GPS monitoring. For each rhino, a polygon was created within IDRISI by linking the outermost locations of sightings of that individual. Polygons were overlaid to create a total distribution map, from which the area of distribution was calculated as that area containing at least one rhino. Density estimates were made for each period by dividing population estimates by the appropriate area of distribution. Comparisons were made with density and distribution estimates from an earlier study (Mukinya, 1973).

3. Results

3.1. Trends in population size and growth

In 1988, 20 rhinos were observed in MMNR. Considering only known births ($n=25$), deaths ($n=7$) and
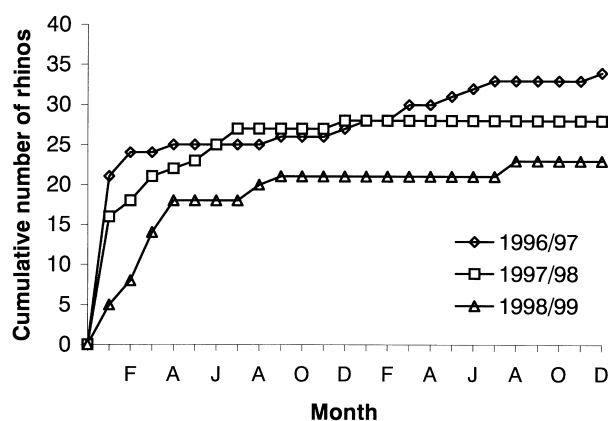

Fig. 2. Cumulative total of new rhinos seen each month in each of three seasons.

immigrations ($n = 5$), the population grew to 43 individuals by 1999, at a mean annual growth rate of 7.2% (Fig. 3). However, using the two-year count method, the population only reached a peak of 35 in 1993/1994 before declining to 23 in 1998/1999 (Fig. 3). This represents a mean annual growth rate of 9.8% (1988/1998–1993/1994) followed by a mean annual decline of 7.5% (1994/1995–1998/1999). This apparent decline is a result of 16 'disappearances' between 1994 and 1999, compared with only four 'disappearances' between 1988 and 1994. An independent aerial census in 1999 revealed no additional rhinos (Walpole and Bett, 1999).

The decline in population size since the mid 1990s was mirrored in a decline in both observations per patrol and observations per patrol hour between 1993 and 1999 in Keekorok sector (Fig. 4).
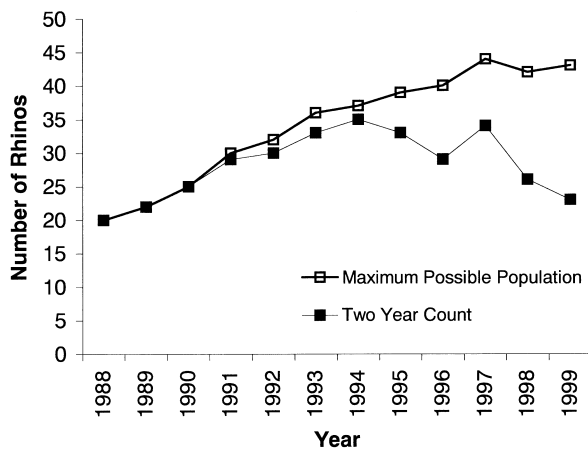
3.2. Trends in population structure

The ratio of males:females in the population was 1:1.2 in 1998/1999 and 1.2:1 in 1971/1972. Both are within the range of values found in other populations in east Africa (Frame, 1980). Some 61% of the population was more than 4 years old, whilst 67% of adult females were accompanied by calves, compared with values of 73 and 75% respectively in 1971/1972. The mean intercalving interval was 35 months ($n = 18$), which is slightly longer than average (Adcock et al., 1999). However, this figure is skewed by a few very long intercalving intervals (Fig. 5), which may mask intermediate foetal or infant deaths.

Between 1988/1989 and 1998/1999 there was no significant change in the population sex ratio or age structure ($P > 0.5$ in both cases), with an average of 58%

Fig. 3. Biennial and 'maximum possible' population estimates for black rhinos in the Masai Mara National Reserve, 1988–1999.

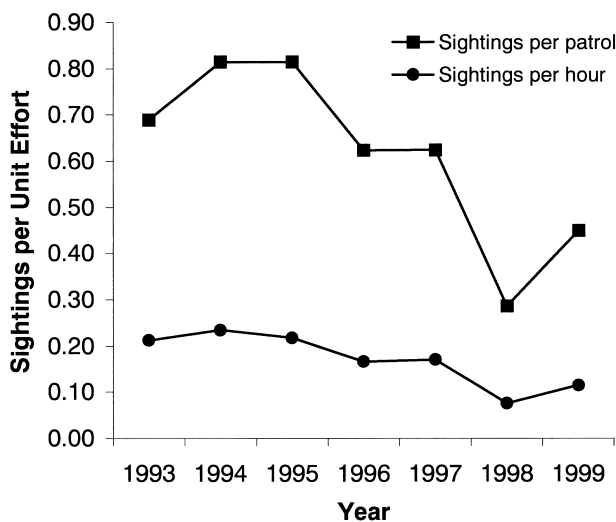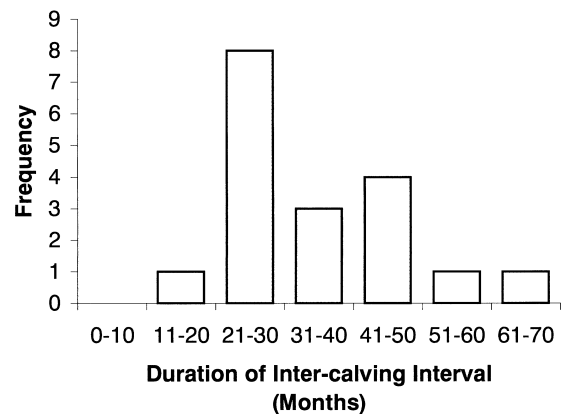Fig. 5. Frequency distribution of intercalving intervals.

Fig. 4. Rhino sightings per unit effort, 1993–1999, based on 1796 sightings in 10,806 h of patrol on 2910 patrols.
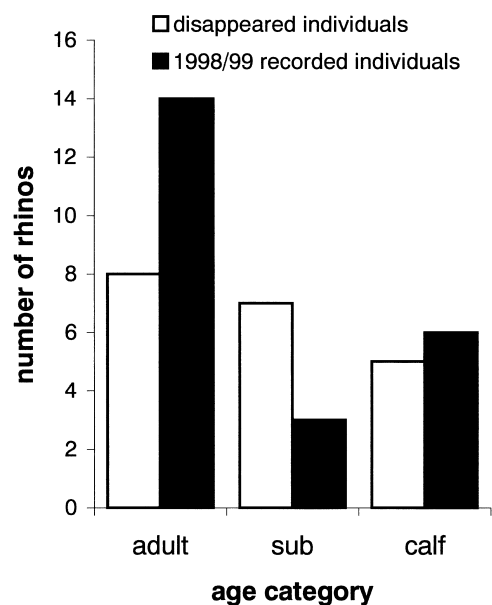

Fig. 6. Age structure of individuals recorded in 1998/1999 and disappeared individuals.

Table 1
Distribution and density of black rhinos in MMNR, 1971/1972–1998/1999 (1971/72 data from Mukinya, 1973)

Time period	Area (km^2)	Number of rhinos	Density (rhinos/km^2)
1971/1972 (Total)	749	108	0.144
1971/1972 (Keekorok)	395	72	0.182
1994/1995	345	31	0.090
1997/1998	370	27	0.073
1998/1999	254	22	0.087

Fig. 7. Age and sex structure of disappeared individuals.

adults, 13% sub-adults and 29% calves. This differed from the age composition of 'disappeared' animals ($\chi^2 = 8.83$, d.f. = 1, $P < 0.05$), which was 40% adults, 35% sub-adults and 25% calves (Fig. 6). This result suggests that more than expected sub-adults have disappeared from the population. Among the disappearances, most of the adults (75%) were female and most of the sub-adults and calves (58%) were male (Fig. 7).

3.3. Trends in population distribution and density

During the 1990s, population density varied between 0.07 and 0.09 rhinos/km^2, covering an area of 254–370 km^2 within Keekorok sector (Table 1). By comparison, the density in a similar-sized area of Keekorok sector in 1971/1972 was 0.18 rhinos/km^2, whilst the population density as a whole in MMNR during that period was 0.14 rhinos/km^2 (Table 1, data from Mukinya, 1973).

4. Discussion

The Mara rhino population made a partial recovery until the mid 1990s after a decline of >80% due to poaching. Although a growth rate of 9.8% between 1988 and 1994 is relatively productive for this species, at no time during its recovery did the population approach the size and density that it attained prior to the onset of severe poaching. Although population structure and breeding performance throughout the 1990s appeared normal, population density was at the low end of the range for black rhinos, and was considerably lower than the expected density for this population (Brett, 1993).

The recent apparent decline in the population has arisen because 20 individuals seen during the period of surveillance could no longer be accounted for at the end of 1999. There are three possible explanations for these disappearances. Firstly, these animals may still be present but have become either more shy or more nocturnal and are thus evading observation. Secondly, they may have died, naturally or unnaturally, within MMNR. Thirdly, they may have moved out of MMNR into adjacent areas both north and south of the international border with Tanzania, beyond the range of the surveillance team.
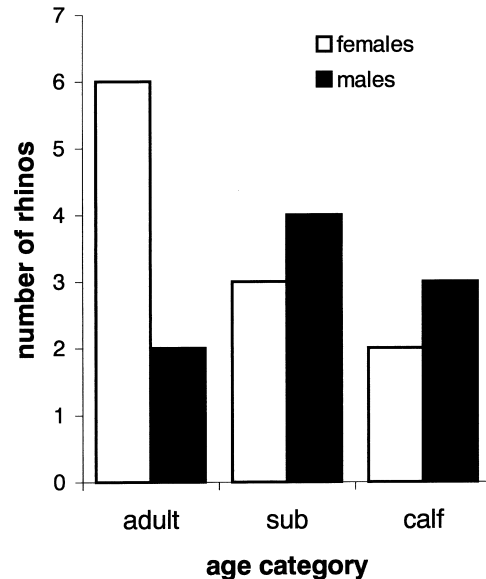
It seems unlikely that hitherto regularly recorded individuals should suddenly become so elusive as to evade observation over periods spanning several years, although this possibility cannot be ruled out entirely. It would however seem more likely that these individuals have either died or moved out of MMNR. The relatively balanced age structure of the disappeared individuals (Fig. 6) adheres more closely to recorded patterns of illegal killing than to natural mortality (Leader-Williams, 1988), although with either explanation one would expect to have found more carcasses. Again, this explanation cannot be ruled out given that patrols are conducted by vehicle and so do not penetrate areas of thicker bush where carcasses may be hidden.

The high proportion of younger animals that had disappeared suggests that dispersal in search of suitable less-occupied habitat elsewhere could be contributing to the disappearances, and anecdotal evidence supports this. There have been numerous observations of known and unknown rhinos south of the border in Tanzania, suggesting some cross-over between these areas. Equally, there is indirect evidence of rhino presence to the east of MMNR (N. Martin, pers. commun.). The rhino populations of the Serengeti-Mara ecosystem appear to constitute a continuous population, and movement between Ngorongoro and Serengeti has been recorded (Haywood, 1995). Taken together, this evidence suggests that rhinos range over an area that extends beyond the borders of MMNR and current surveillance. Given this scenario it is reasonable to assume that many of the disappeared individuals may have moved out of MMNR, either temporarily or permanently.

The relatively low population density within MMNR in comparison with pre-decline estimates raises the question as to why individuals would need to disperse out of the reserve. It is thought that rhino carrying capacity in MMNR may have declined as a result of declining woodland (Dublin, 1991, 1995), increased competition and disturbance from other herbivores, particularly elephant, and increased human pressure in terms of tourism and cattle encroachment. If this is the case, these factors would make the less disturbed, lower density areas of the northern Serengeti more favourable for dispersing individuals.

The small size of the population raises concerns regarding long-term genetic viability. If the Mara rhinos are a sub-population of a larger group ranging into Maasai communal areas and northern Serengeti, then inbreeding and genetic viability may not be a problem. However, if the population is isolated, at its present size it is below estimates of minimum effective population size (Franklin, 1980; Conway and Goodman, 1989). This is not unusual for rhino populations, and management strategies for the species include provision for metapopulation management by creating genetic links with other populations (Brett, 1993; Foose et al., 1993; Emslie and Brooks, 1999). However, the Mara rhinos constitute a genetically pure population of the lowland race that is immune to the tsetse-born disease tripanosomiasis (Brett, 1993), and that has never been mixed with highland strains through the introduction of translocated individuals. As such inward translocation may not be a favourable option for this population.

4.1. Recommendations

A number of recommendations can be made with regard to clarifying the situation with this population and improving surveillance. Firstly, it would be valuable to implement foot patrols within MMNR, to ascertain whether more individuals, alive or dead, are present in thicker bush within MMNR.

Secondly, it is imperative that monitoring on foot and in vehicles be extended beyond the borders of MMNR. Currently a team of Maasai community scouts undertakes foot patrols in hills to the east of MMNR, and they have been successful in locating indirect signs of rhino presence (middens, footprints and browse points, N.Martin personal communication). However, no methodical monitoring takes place in northern Tanzania where some of the Mara rhinos are known to spend part of their time. There is currently no means either of protecting or of ascertaining the status of dispersed individuals. At a workshop in Tanzania in 1998, the potential importance of rhinos in the northern Serengeti to the national rhino conservation effort was highlighted. The need for coordinated surveillance by trained and equipped personnel in collaboration with Kenyan counterparts was

recognised, and included in a new draft of the Policy and Management Plan for Black Rhinos in Tanzania (Emslie and Brooks, 1999). It is hoped that such plans can be realised and implemented with expedience.

Thirdly, reasons for the sub-optimal performance of the population within MMNR, and in particular the reasons for any confirmed emigrations, must be identified to allow for appropriate management intervention where necessary. Potential explanatory factors (see above) are currently being investigated by MJW and NLW.

Finally, there is the question of the genetic viability of the population. The debate regarding the link between genetic variance and population viability, particularly where rhinos are concerned, continues (Ashley et al., 1990; Soulé, 1990; Caughley, 1994; Frankham, 1995). In the case of the Mara rhinos, it would be advisable to: (1) ascertain the actual effective population size through wider monitoring; (2) ensure adequate protection of the population across its entire range; and (3) be sure of the effects of small population size on long term population viability in rhinos, before the translocation of individuals in or out of the population is considered.

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