SADC Regional Programme for Rhino Conservation

INVESTIGATION OF BLACK RHINO MORTALITIES AT NGORONGORO CRATER, TANZANIA:

BLACK RHINO HABITAT AND ECOLOGICAL REQUIREMENTS

Rob Brett

Coordination with National and Continental Rhino Conservation

Semester 4 Task 1.3-1.3

COOPERAZIONE ITALIANA
ITALIAN COOPERATION
AID 5064

CESVI cooperazione e sviluppo

SADC

IUCN The World Conservation Union

WWF

SPECIES SURVIVAL COMMISSION
AFRICAN RHINO SPECIALIST GROUP

PUBLICATION CREDITS:

Title:	Investigation of Black Rhino Mortalities at Ngorongoro Crater, Tanzania: Black Rhino Habitat and Ecological Requirements
Author:	Rob Brett
Date:	August 2001
Special acknowledgements:	Johan Robinson, Paula Robinson, Ivan Horak, Pete Morkel, Richard Kock, Rian Labuschagne, Joe ole Kwai and Markus Borner

This report is an output from a task of the **SADC Regional Programme for Rhino Conservation**.

ABOUT the SADC Regional Programme for Rhino Conservation:

The Programme is funded by the Italian Ministry of Foreign Affairs, Directorate General for Development Cooperation (Project AID 5064).

The Programme is contracted to CESVI and implemented through a regional consortium which comprises:

- The Secretariat of the Southern Africa Development Community (SADC)
- IUCN-ROSA (The World Conservation Union - Regional Office for Southern Africa)
- The IUCN African Rhino Specialist Group
- WWF-SARPO - (World Wide Fund for Nature - Southern Africa Regional Programme Office)
- CESVI (Cooperazione e Sviluppo)

The ***Programme goal*** is to contribute to maintain viable and well distributed metapopulations of Southern African rhino taxa as flagship species for biodiversity conservation within the SADC region.

The ***Programme objective*** is to implement a pragmatic regional rhino strategy within the SADC region following the acquisition of sound information on, firstly, the constraints and opportunities for rhino conservation within each range state and secondly, the constraints and opportunities for rhino metapopulation management at the regional level.

DISCLAIMER

CONTACT DETAILS FOR THE PROGRAMME:

Dr. Rob Brett
SADC Regional Rhino Programme Coordinator
IUCN-ROSA
6 Lanark Road Belgravia PO Box 745 Harare, Zimbabwe
Tel: 263-4-728266 Fax: 263-4-720738
Email: robb@iucnrosa.org.zw

SADC Secretariat
Directorate of Food, Agriculture and Natural Resources
P O Box 0095 Gaborone Botswana

CESVI Zimbabwe Office
9 Northwood Rise, Mt Pleasant, Harare, Zimbabwe
TEL/ FAX: 263-4-882243, 884492, 850898
EMAIL: cesvi@africaonline.co.zw

Ministero degli Affari Esteri
Direzione Generale per la Cooperazione allo Sviluppo, Unità Tecnica Centrale
Viale Contarini (angolo Viale Farnesina)
00194 ROMA ITALY

PROGRAMME WEB SITE: We invite you to vist our web site : www.rhino-sadc.org

INTRODUCTION

The Ngorongoro Crater Area (NCA) experienced the almost complete failure of the short rains of 1999 and the long rains of 2000. From February 2000 onwards, and before and following the onset of the short rains of 2000, there were significant mortalities of large mammal fauna resident in the crater, including five of the remaining 18 black rhinoceros (*Diceros bicornis michaeli*). Given the major importance of the NCA's wildlife, a multidisciplinary team of local and international experts was tasked by the Ngorongoro Crater Area Authority (NCAA) to investigate the cause of the mortalities and provide recommendations for future management of the NCA and its wildlife to prevent any future problems of this kind and mitigate threats to the future survival of Ngorongoro's black rhino population.

This report provides input on the ecological processes that may have influenced the black rhino mortalities, and gives recommendations for improved future management of the NCA for future health of individual rhinos and population growth, including suggestions for increasing ecological and social carrying capacity for black rhinos. Extracted from the Terms of Reference for the multidisciplinary team, relevant tasks addressed were as follows: (a) understand ecosystem dynamics precipitating the mortalities of rhinos and provide practical recommendations to predict and (where relevant) prevent such problems in future; (b), investigate and make recommendations on certain aspects of the ecology and related disease problems in the crater; and (c), work with rest of team to find solutions.

PROCEDURE

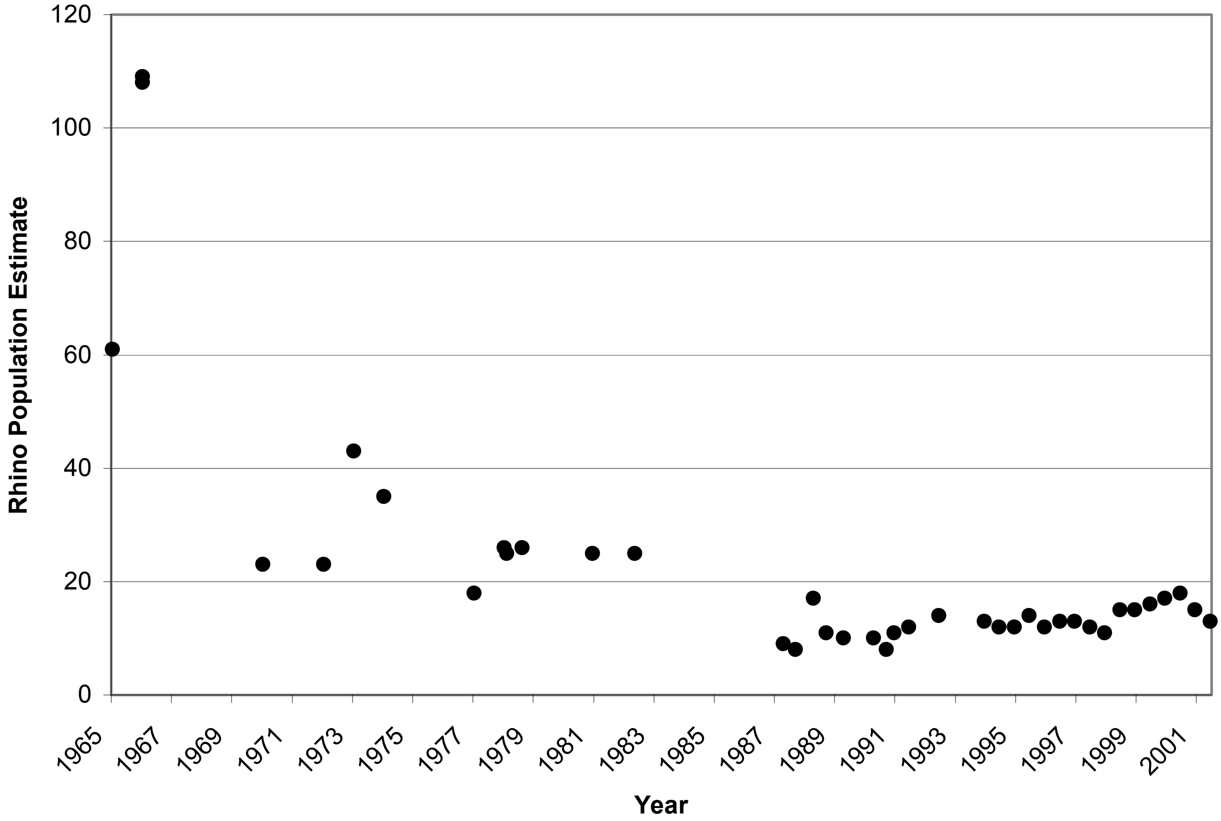
My visit to the NCA was made between 28th and 31st May, 2001, and coincided with that of Professor I G Horak, who investigated the tick populations found on vegetation and roads on the crater floor (Horak 2001). Several of the key rhino range areas of the NCA were visited, and eight of the black rhinos were sighted. The Rhino Project officers of the Frankfurt Zoological Society made available their library of periodic and biannual reports, as well as rhino identification material and photofiles. They also provided for review files of data from wildlife counts made in the crater since the 1960s, and GIS data used by the project since the early 1990s for mapping rhino monitoring data. To assist with future rhino monitoring activities at NCA, the NCA Rhino Unit was provided with rhino database software (WILDb), developed in *MS Access* for the SADC Rhino Programme, for use in storing life history information, key events (e.g. births, mortalities) and sightings information, and for generating population status reports and performance analyses. Materials developed by the AfRSG/RMG for scoring the condition of black rhinos (Adcock *et al* 2001) were also provided. This contribution to the investigation benefited greatly from the reports already filed by other members of the team (Fyumagwa 2001, Morkel 2001, Kock 2001, Mlengeya 2001, Trollope & Trollope 2001), and the cooperation and advice from staff of the Frankfurt Zoological Society working at NCA (Mr J Robinson and Mrs P Robinson).

HISTORICAL OVERVIEW

Black Rhino Numbers

The population of black rhinos resident in the Crater has remained at very low numbers since the late 1980s (Figure 1), and has still not recovered sufficiently to reach the number of animals recommended for establishing new populations (20 unrelated founders). Although poaching was main cause of major depletion of the population from the original numbers of the 1960s recorded by Klingel & Klingel (1965) and Goddard (1967), and there have been minor poaching episodes since the late 1980s, other factors including environmental constraints and other human-related impacts are believed to have had at least as much influence on the lack of recovery of the population to viable levels. Although the 108 individuals (at 0.32 rhinos/km^2) recorded by Goddard were showing healthy recruitment (7% each year) and calving performance of adult females (0.25 calves/year/adult female), the remaining rhino population has struggled to reach these indicators in the last 15 years, even at less than 20% of former density. Although the rhino monitoring and surveillance in the crater have been maintained at a high standard through the work of the FZS/NCAA Rhino Protection Unit, and additional unrelated *D.b.michaeli* have been introduced to the population from South Africa, the mortalities which have prompted this investigation also beg questions about possible ecological changes over the past 2-3 decades that may have influenced key resources and habitats for black rhinos, and consequent carrying capacity for black rhinos in the crater.

Figure 1 - NCA Black Rhino Numbers 1965-2001
(Ground Counts/Indiviudal ID)



Rhino habitat use and distribution

The black rhinos of the NCA distinguish themselves in respect to their very high use of herbaceous plants and forbs found in the plains and forest areas of the crater floor. In particular, their diet and food preferences determined by Goddard (1968) showed strong selection for particular species of legumes in all habitats, during wet and dry seasons; the key species involved (selected from Goddard's (1968) tables) are shown below:

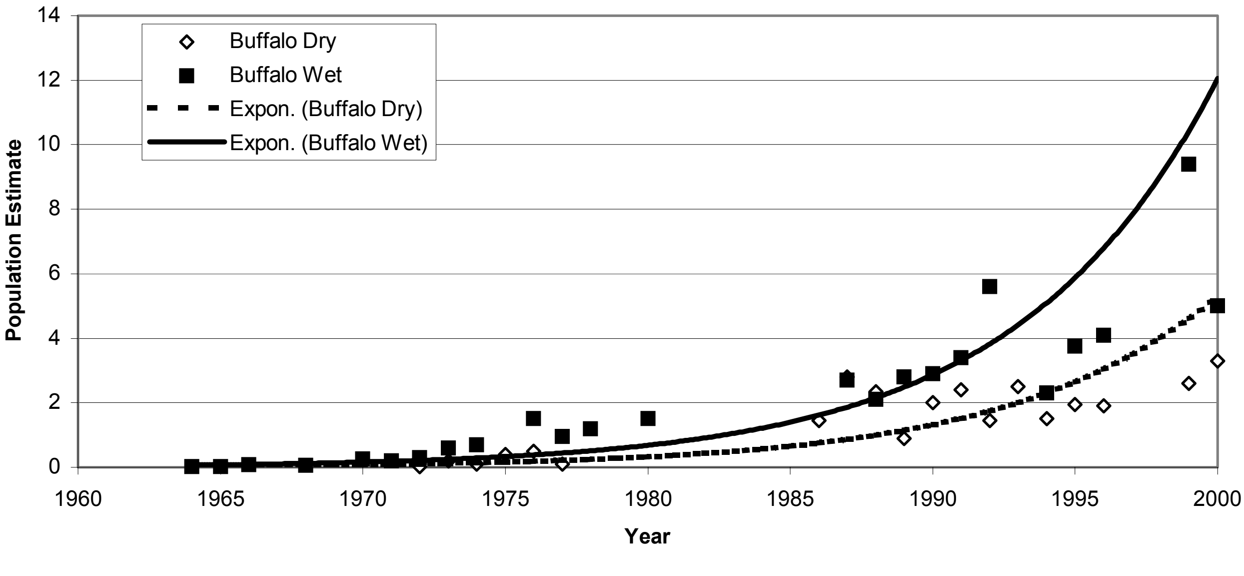
Habitat	**Wet Season**	**Dry Season**
Plains	*Trifolium masaiense (*Papillionaceae*)*	*Indigofera basiflora (*Papillionaceae*)* *Solanum incanum (*Solanaceae*)*
Scrub	*Acacia lahai (*Mimosaeae*))* *Trifolium masaiense (*Papillionaceae*)*	*Indigofera arrecta(*Papillionaceae*)* *Aspilia pluviseta (*Compositae*)*
Swamp	*Cyperus rotundus (*Sedge*)* *Lathyrus hygrophilus (*Papillionaceae*)*	*Aeschynomene schimperi (*Papillionaceae*)*
Forest	*Justicia betonica (*Acanthaceae*)* *Urtica massaica (*Urticaceae*)*	*Justicia betonica*

Table 1. Major food plants preferred by black rhinoceros in Ngorongoro Crater (Goddard 1968)

More than 50% of feeding time/stations of rhinos watched by Goddard on the crater plains in wet seasons was spent feeding on *Trifolium maisaiense* (a clover), and among this list of key species (Table 1), the only woody species recorded was *Acacia lahai* (e.g. 25% of wet season feeding time/stations in scrub habitats). The high availability of preferred forbs in open areas (e.g. plains) partly explains the use of these areas by rhinos during the daytime, and their consequent high visibility. The behaviour of rhinos feeding on these small plants (e.g. *Pluchea monocephala*) in the grassland was well described by Fosbrooke (1970), likening them to "a cricket groundsman engaged in weeding plantains". As recorded by Goddard, and since by Kiwia (1986, 1989b) and others, there is a characteristic movement of animals between night-time areas (e.g. Lerai forest, swamps) and day-time ranges (grassland, plains), which continues to this day, with the *shamba la faru* (plain southeast of Lake Magadi) being by far the main day-time concentration area for rhinos in the crater, and where the majority of rhinos are sighted by the NCAA/FZS Rhino Protection Unit (FZA/NCAA 1998, 1999).

The home ranges of the present rhino population now cover a small proportion of the total area of the crater formerly used by the black rhinos. Although the 61 rhinos recorded by Klingel & Klingel (1965) were mostly found in the central area of the crater, all intervening reports up to the mid-1980's record the rhinos using most of the crater floor, including northern and western sectors (e.g. Seneto) not used in recent years (e.g. Makacha *et al* 1979). The rhino density noted by Kiwia in the early 1980s (Kiwia 1984, 1989a, 1989b) was ca. 20% of that observed by Goddard (1967), but the 25 rhinos resident in 1980-82 were widespread, used most of the crater floor and had larger home range ranges on average. There were four animals resident in Seneto/Manduzi area, including three adult males. Unfortunately, neither Makacha *et al*, nor Kiwia, made much reference to possible ecological changes in the crater since the 1968's that may have influenced rhino numbers and distribution, perhaps as poaching was clearly the major and ongoing threat. There has been no repeat of Goddard's feeding and habitat utilisation study, and insufficient attention paid to habitat deterioration and apparent reduction in the carrying capacity for rhinos in the crater, and susceptibility to drought-related impact, highlighted by the mortalities of 2000-2001.

Figure 2 - NCAA Buffalo numbers 1964-2000
(TWCM/NCAA counts)



Status of other species

As strong indicators or participants in ecological changes to the Crater in the last 30 years there have been some major changes in the numbers of herbivores, particularly the sustained and dramatic increase in buffalo (Figure 2). Although NCAA wildebeest numbers have remained relatively constant (Figure 3), eland numbers have declined (Figure 4). Trollope & Trollope (2001) discuss the possible changes in grass species composition accompanying these changes, the lack of burning of grasslands in the crater since the early 1970s, and, in particular, the effects of isolation of the craters large mammal fauna through increased settlement and recent increase in human population in the NCAA (Figure 5) and numbers of their stock (Figure 6).

Figure 3 - NCAA Eland numbers 1964-2000
(TWCM/NCAA counts)

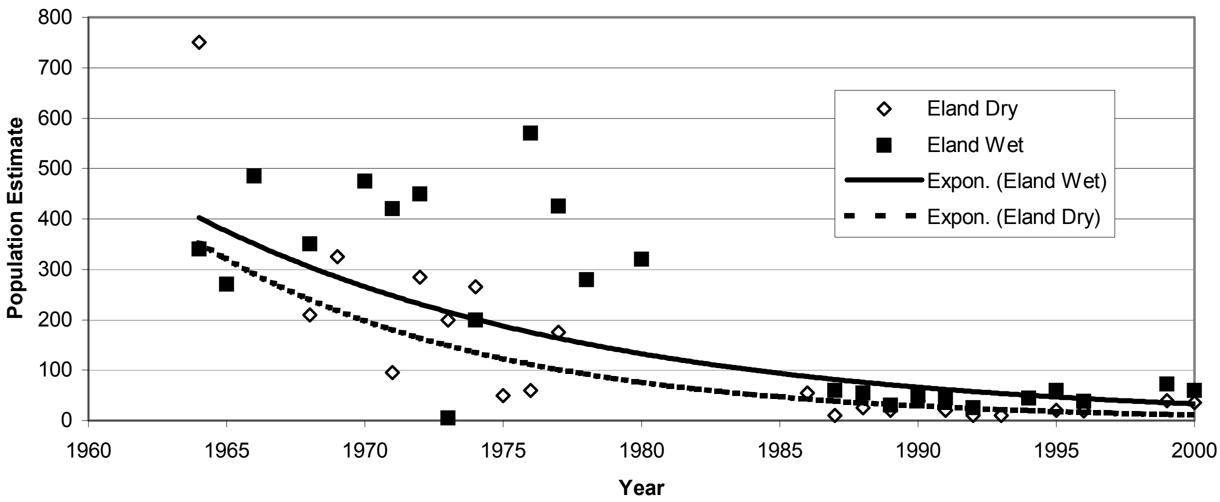


Figure 4 - NCAA Wildebeest numbers 1964-2000
(TWCM/NCAA counts)

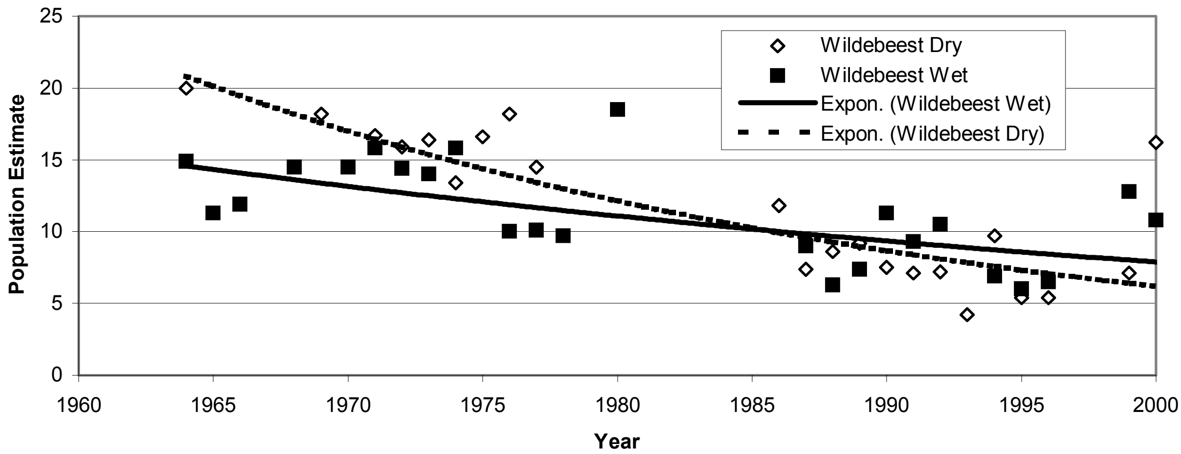


Figure 5 - Numbers of people resident in NCAA 1957-1999
(TWCM/NCAA counts)

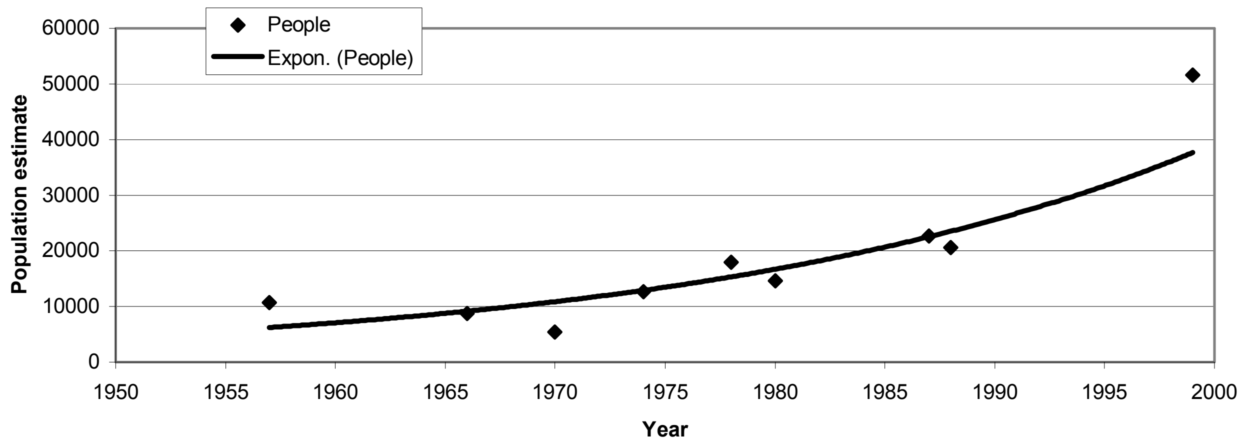
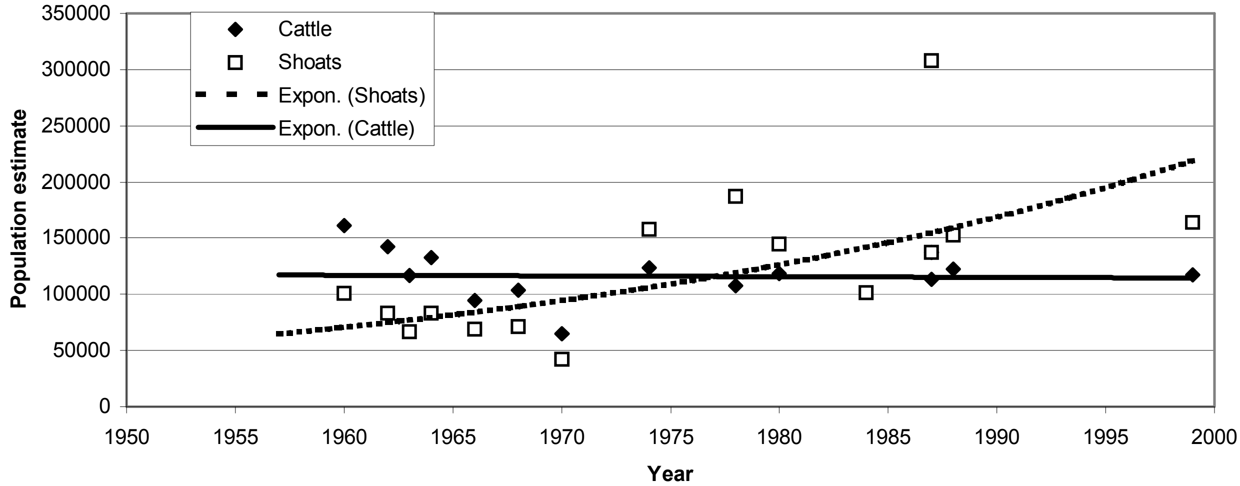


Figure 6 - NCAA Stock numbers 1966-2001
(TWCM/NCAA counts)



ECOLOGICAL CHANGES AND BLACK RHINO HABITAT

The eviction of the Masai from the Ngorongoro Crater in 1974, and the subsequent lack of any burning, controlled or otherwise, of grasslands and plains, is likely to have had a major impact on the overall ecology of the crater, including changes in species composition of grassland, changes in herbivore numbers (including buffalos), and changes in habitat suitability for black rhinos. Changes in the size and extent of the Lerai forest appear to have been cyclical, although the 1999 El Nino event and the consequences of allowing artificial canals to drain the Loitokitok swamp may have a major longer-term effect on this important area for the black rhinos.

As highlighted by other members of the team (Trollope & Trollope, Horak, Fyumagwa, Mlengeya 2001), the lack of burning of grassland has resulted in successive build-up of moribund plant material, which has consequences for habitat suitability for grass species and for the tick species implicated as the hosts for the proximate causes of the mortalities seen in 2000-2001 (protozoan haemoparasites). Moribund vegetation also allows increasing densities of *Stomoxys* flies and ticks, provides ideal habitat for survival of tick eggs, and long-term survival of adults. This reservoir of free-living ticks can then act as source of tick infestation for transmission to other, more open areas (Horak 2001). The areas with tall grass species (*Chloris gayana, Digitaria* spp) and large standing crop (> 4 tons ha^{-1}) have high tick densities (Trollope & Trollope 2001), and controlled burning of these areas, should, as before 1974, result in (a), fewer ticks, (b), less moribund materials for ticks to breed and complete cycles in, (c) less habitat for flies, and (d), improved feedback of nutrients.

Controlled burning also has several positive effects on black rhino habitat, as noted in some detail by Goddard (1968) when he observed the results of burning of grassland, scrub and swamp habitats:

- Firstly, "burning did not appear to have any marked unfavourable effect on the habitat of rhino in Ngorongoro". Six of rhinos observed did not leave burnt home range areas and continued to feed in these same areas. Rhinos continued to eat *Indigofera arrecta* after burn "browsing on charred shrub". This phenomenon has been noted elsewhere in feeding studies, where the stems of some browse plants become more palatable following burning, possibly due to "caramelisation" of the plant sugars and other carbohydrates (Emslie & Adcock, unpubl.)
- Secondly, *Acacia lahai*, the most preferred woody browse species, was observed to increase in regeneration following burning of scrubland areas.
- Finally, "the total burning of the Munge swamp improved the habitat for rhinos", consequent to an increase in *Aeschynomene schimperi* (Leguminosae). Burning removed decaying sedges, and resulted in a ca. 75% coverage of the marsh in this palatable species. In addition, the burning of swamps had a striking effect on rhino movements: after burning, "six rhinos with adjacent home ranges moved in and made extensive use of this habitat". The importance of swamp habitat has also been realised in Solio ranch, Kenya, where it make a major contribution to the high carrying capacity density of this small rhino sanctuary. Also, as noted by Horak (2001), swamps may be important refuge areas where ticks are not found in high densities, and maintenance of these important "tick-free areas", may be threatened by artificial canal drainage.

At the time of my visit, a large proportion of the crater floor, including some of the key range areas for rhinos (e.g. *shamba la faru*), was covered in dead stands of the invasive 'weed' *Erlangea cordifolia* (Oliv) (Compositae) (syn. *Gutenbergia cordifolia*). Although this plant has been prevalent in the past, it appears to have invaded the crater floor following the heavy rains of early 2001 (following the preceding drought). The slopes and walls of the crater also had significant coverage of two species of *Bidens*. The height, density of the *Erlangea* plants, and the total area covered must have had a major interference effect on feeding of rhinos in the plains areas affected. Browsing interference by tall grasses has been noted as an important negative effect on suitability of rhino habitat (Emslie, unpubl), but at Ngorongoro the negative effects of coverage of the crater floor with *Erlangea* will have decreased the resources available to black rhinos, particularly the small legumes found and used in plains habitats. Unless the moribund plants are removed, the interference will have effects on food availability for rhinos in late wet and dry seasons.

Controlled burning in the crater (as recommended by all members of the team cited) could also remove the massive standing crop of dead *Erlangea* (not noted by Trollope & Trollope), and it is interesting that the Seneto area and the north west corner of the Crater (the former having massive *Erlangea* infestation in April/May 2001) were selected as areas for controlled burning. Thus the burning programme recommended is endorsed, but the areas selected for burning should be extended to include dead Erlangea 'thicket' during periods when cool burns can be achieved. The effects of burning regimes on the incidence of the major rhino food plants should be included in the monitoring programme suggested (Trollope & Trollope 2001), including the major areas of *Trifolium* indicated.

RHINO MORTALITIES AND FUTURE MONITORING

The proximate and ultimate causes of the black rhino mortalities have been well and adequately defined by other members of the team (Morkel, Kock, Mlengeya, Fyumagwa 2001), essentially haemoparasitaemia related to drought, stress, increased vector populations (ticks), and reduced immunity to parasites not normally pathogenic. However, although some debility from poor nutrition may have had some effect, the *Theileria/Babesia* and/or its symptoms were only seen in two of the animals that died in January 2001 (Adult females Bahati and Maggie). While elephant attack and lion predation appear to have been the causes of death of two rhinos in May and August 2000 (Adult female Zakhia, and 6-month-old calf), the cause of death of the third animal (Papageno's 11-month-old calf) was not clear. However, it is significant that:

(a) two other adult females (Fausta and Vicky) appeared to have high heavy parasite infection and anaemia (dark red urine, debility) in December 2000, but recovered subsequently.
(b) the two adult females that died did so after onset of the early 2001 rains in January 2001, and associated green flush.
(c) no marked decline was noted in the observable condition of the animals that were affected (*vide* Robinson & Robinson rhino monitoring photographs of November 2000).

Although *Babesia/Theileria* parasites have been found in black rhino populations in East Africa in the past, normally in 'background' or sub lethal levels, in order to rule out the animals translocated from Addo NP as the source of the possible infection it will be necessary to look at the prevalence and species found in other black rhino populations in East Africa, particularly in Kenya (e.g. Nairobi NP, Tsavo NP, Solio ranch) and Tanzania (e.g. Mkomazi GR).

Although the current surveillance and monitoring system operating at the Crater is of a high standard, and all animals are regularly accounted for, mostly within small inter-sighting intervals, it will be vital to maintain this monitoring regime, and if possible, make routine condition assessments (AfRSG/RMG condition scoring system: Adcock *et al* 2001) in order to detect any loss of condition of animals which are vulnerable or under nutritional stress (e.g. pregnant or lactating females, immatures). Human-related impacts on rhinos have clearly been evident in the 'crowding' by tourist vehicles of rhinos during daily movements between forest and plains (e.g. Lerai forest to/from *shamba la faru*). This impact must be minimised in future, both through effective monitoring and/or regulation of numbers and behaviour of tourist vehicles on the crater floor. Clearly management actions that will improve rhino habitat, increase size and number of refuge and feeding areas (e.g. swamps) can also take the pressure of the areas currently favoured by the black rhinos and remove consequent tourist/rhino bottlenecks.

Before the current monitoring regime was established in the mid-1990s, previously well-known animals (e.g. adult male Hamisi, adult female Anna) went missing and cause of their disappearance was never established. Poaching remains the most serious threat to the Ngorongoro rhinos, and attention to the 2000-2001 'natural' mortalities should not detract from the need to provide adequate protection.

CONCLUSIONS

The proximate cause of the mortalities of the black rhinos in the crater in 2000-2001 is attributable to infection by haemoparasites and the drought and stress-related lack of resistance of the rhinos to this disease. Future mortalities must be averted by proactive measures to improve the rhino habitat in the crater, increase the areas available for refuge and feeding and overall ecological and social carrying capacity for black rhinos, and thus reduce the susceptibility of individual animals to drought-related effects.

Ecological and human-related changes in the crater that have reduced overall carrying capacity for rhinos since the late 1960s, and that have increased stress on individual animals, need further monitoring, particularly following management actions recommended for implementation in the short term, and as part of the long-term future management of the crater.

Improving rhino habitat and increasing the areas used by rhinos in the crater should lay a foundation for improved population growth, and rapid expansion beyond the minimum founder number (ca. 20 rhinos) 'bottleneck' below which the rhino population has languished for the past 15 years. Maintenance of adequate standards of monitoring, surveillance and protection to deter and react to any poaching threats remains first priority.

RECOMMENDATIONS

- ☞ Introduce controlled burning programme in Ngorongoro Crater (as recommended by Trollope & Trollope 2001) with immediate effect, with first burns of selected areas carried out in October/November 2001.

- ☞ Extend areas for controlled burning to include (a) marsh habitats with large amounts of moribund sedges, (b) areas with major infestation by *Erlangea cordifolia*, where moribund material can be cleared to remove interference to browsing by black rhinos on preferred leguminose species (e.g. *Trifolium masaiense*).

- ☞ Monitor the effects of controlled burns, in particular (a) the use of burnt areas by rhinos as part of ongoing monitoring, and (b) incidence and distribution of preferred plant species (Table 1) and their use by rhinos as part of a new black rhino feeding and habitat utilisation study.

- ☞ Close canals draining water from Loitokitok swamp in order to minimise any shrinkage of this area covered by this swamp and any consequent negative effect on the size of the Lerai forest.

- ☞ Ensure effective monitoring of any diseases detected in live animals or mortalities, particularly black rhinos. Inoculate and treat as recommended by team veterinarians (Mlengeya, Fyumagwa, Kock, Morkel 2001). Although genetically (and possibly demographically) desirable, any future introductions of *D.b.michaeli* from other areas to reinforce the NCA black rhino population must include adequate screening of diseases including the *Theileria/Babesia* detected in the 2000-2001 mortalities.

- ☞ Screen black rhino populations of *D.b.michaeli* in East and South Africa (including Addo NP) for ticks and blood parasites to confirm presence and/or remove implication of translocation as source of infection by the specific *Theileria/Babesia* species detected at NCA. Close cooperation between veterinarians from TAWIRI, TANAPA, OAU/PACE, KWS and SANP is required.

- ☞ Introduce booking system for controlling numbers of vehicles using the crater floor on a daily basis, preventing the number of vehicles from exceeding an agreed ceiling (e.g. 50 vehicles). Explore options for increasing visitor/vehicle ratios through use of high volume vehicles operated by lodges on the crater rim (e.g. forward control Land Rovers) licensed for exclusive use of the crater floor.

- ☞ Develop and introduce a code of practice for black rhino viewing by tourist vehicles, to be provided to all vehicles entering the crater. Monitor (NCAA/FZS Rhino Protection Unit) behaviour of tourist vehicles, with provision for temporary or permanent ban on vehicles and/or operators that knowingly or deliberately infringe the agreed code.

- ☞ Operate Rhino Monitoring Database and Rhino Condition Scoring Protocols, as provided to FZS Rhino Project operatives during the study visit.

ACKNOWLEDGEMENTS

I am grateful to Mr and Mrs J Robinson for their hospitality during Prof Horak's and my visit to NCAA, and their help with large volumes of background material, reports and data. Also to Prof Horak, Pete Morkel, Richard Kock, Rian Labuschagne, Joe ole Kwai and Markus Borner for verbal and email advice.

REFERENCES

Adcock, K *et al* (2001) Black Rhino Condition Assessment Protocol. AfRSG/RMG

Fosbrooke, H (1972) Ngorongoro: the Eighth Wonder. Andre Deutsch, London.

FZA/NCAA (1998) NCA Rhino Project Reports (wet, dry season)

FZS/NCAA (1999) NCA Rhino Project Reports (wet, dry season)

Fyumagwa, R (2001) Investigation into the cause of disease outbreaks and wildlife mortalities in the Ngorongoro Conservation Area. Unpubl Report for NCAA Multidisciplinary Team.

Goddard, J (1967) Home range, behaviour and recruitment rates of two black rhinoceros (*Diceros bicornis*) populations. East African Wildlife Journal 6: 1-18

Goddard, J (1968) Food preferences of two black rhinoceros populations. E African Wildlife Journal 6: 1-18

Horak, I G (2001) Free-living ticks collected from the vegetation in the Ngorongoro Crater, Tanzania. Unpubl Report for NCAA Multidisciplinary Team. July 2001.

Kiwia, H Y D (1986) Diurnal activity pattern of the black rhinoceros (*Diceros bicornis*) in Ngorongoro, Tanzania. African Journal of Ecology 24: 89-96

Kiwia, H Y D (1989a) Black rhinoceros (*Diceros bicornis*) population size and structure in Ngorongoro, Tanzania. Population Structure. African Journal of Ecology 27: 1-6

Kiwia, H Y D (1989b) Ranging patterns of the black rhinoceros (*Diceros bicornis*) in Ngorongoro, Tanzania. African Journal of Ecology 27: 305-312

Klingel, H & Klingel, U (1966) The rhinoceros of Ngorongoro Crater, Tanzania. Oryx 8:302-306.

Kock, R A (2001) PACE Epidemiology Unit Mission Report: Ngorongoro Crater, Tanzania. Unpublished Report for NCAA Multidisciplinary Team. April 2001.

Makacha, S, Mollel, C L & Rwezaura, J (1979) The conservation status of the black rhinoceros (*Diceros bicornis*) in the Ngorongoro Crater, Tanzania. African Journal of Ecology 17:97-103.

Mlengeya, T (2001) Abnomal animal mortalities in the Ngorongoro Conservation Area. Unpublished Report for NCAA Multidisciplinary Team. March 2001.

Morkel, P vdB (2001) Report on the mortality of black rhino at Ngorongoro Crater from suspected Babesios. Unpublished Report for NCAA Multidisciplinary Team. February 2001.

Trollope, W S W & Trollope, L A (2001) Relationship between range condition and the incidence of ticks in the Ngorongoro Crater in Tanzania. Unpublished Report for NCAA Multidisciplinary Team. April 2001.