Pachyderm

1993 Number 17

SPECIES SURVIVAL COMMISSION

Pachyderm

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Contents

Cover Photo: This black rhino was dehorned in May 1993, in the Midlands Sanctuary, Zimbabwe.
Photo Credit: Esmond Bradley Martin

All correspondence should be sent to:
Pachyderm
WWF Regional Office
PO Box 62440
Nairobi, Kenya
Tel: 254-2-331543/332963
Fax: 254-2-332878

Notice to Contributors

Pachyderm welcomes original manuscripts (not published elsewhere) dealing with the conservation and management of elephants and rhinos. All submissions are reviewed by at least two referees. Manuscripts should preferably not exceed 4,000 words; shorter ones have a greater chance of being published. Contributions may be written in English or French and should be typed on one side of A4 paper, double-spaced with ample margins. Al manuscripts must have an abstract or summary. Final versions of manuscripts should be submitted on IBM-compatible 3.5" diskettes in WordPerfect or Microsoft Word (preferred) format if possible. The full postal address of the first author should be included as well as the address of any other author.

Tables and figures should be submitted on separate sheets along with the captions to illustrations typed out on another sheet. Figures should be black-and-white high quality graphics, suitable for reduction. Photographs should be unmounted, glossy prints of good quality. Abbreviations and references should be made using the same format provided by the African Journal of Ecology.

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Chairman's Report
African Rhino Specialist Group

Martin Brooks

Natal Parks Board, P.O. Box 662, Pietermaritzburg 3200, South Africa

The African Rhino Specialist Group (ARSG) meeting, held in Zimbabwe late in 1992, identified the most important rhino populations remaining in Africa, and evaluated a number of projects considered critical to the survival of Africa's rhinos *(see Pachyderm* no.16). As such it provided direction and momentum for a number of initiatives planned for 1993.

This year, most disappointingly, has seen a continued sharp decline in the rhino populations in Zimbabwe and intensification of poaching activities in South Africa, which holds so many of Africa's key populations of both black and white rhinoceros. However, on the positive side, there have been a number of encouraging initiatives.

Attention was focused on UNEP's Rhino Range States and Donors meeting held in Nairobi from 28th June to 1st July 1993 As preparation, the ARSG Vice-chairman Dr. Rob Brett attended the preliminary meeting in December 1992, and the Rhino Range States drafted additional project proposals for consideration. The aim of the main meeting was to bring together representatives of the African and Asian Range States, major donors and countries where rhino horn trade continues, in an attempt to secure additional funds for rhino conservation and to reach agreement on which of the numerous projects presented were the most important. The procedure for identifying priority projects, which the ARSG developed at its last meeting, was adopted and appeared to assist the donor agencies and countries in their deliberations. While only limited new funds were announced and current funding levels fall well short of the US $ 30-40 million requested for Africa's rhinos, we can only urge the donor agencies and countries to redouble their efforts to secure additional funds, at least so as to meet the requirements of the most critically important projects.

A number of projects were earmarked for special ARSG attention during 1993 and good progress has been achieved. Action plans for the conservation of black rhinoceros populations in Cameroon and Tanzania were successfully developed at workshops organised by the respective States, and presented to the UNEP meeting for international support. Initiatives to secure funding for their implementation are ongoing. Core support for the employment of a Scientific Officer for the ARSG has been secured, and only limited additional funding is now required. The project to analyse supply/demand and black-market trading factors under different trading regimes appears well set, and a workshop on the drafting of a handbook on African rhino survey techniques is being planned.

The development of effective intelligence networks and law enforcement capabilities throughout the Range States remains the single most important consideration in the survival of Africa's rhinos in the short term; and these can only successfully be applied given close co-operation amongst the Range States. International funding is definitely required to secure the situation, but the full commitment of Africa's governments is also an essential ingredient for success. I would therefore appeal to all donors and potential donors to consider most seriously the option of underwriting the security of one or more of the key populations towards and beyond the year 2000, and to contribute to any relevant multi-national programmes aimed at eliminating illegal trading activities.

Rapport présidentiel
Groupe des Spécialistes des Rhinos africains

Martin Brooks

Natal Parks Board, P.O. Box 662, Pietermaritzburg 3200, South Africa

Le Groupe des Spécialistes des Rhinos Africains (GSRA), lors de sa réunion de la fin de 1992, au Zimbabwe, a identifié les plus importantes populations de rhinocéros qui restent en Afrique et a évalué un certain nombre de projets considérés comme étant de premiére importance pour la survie des rhinos africains *(voir Pachyderm,* n˚16). Ainsi, il a donné l'orientation et le dynamisme nécessaires à nombre d'initiatives prévues pour 1993.

Cette année, et c'est trés décevant, a vu la poursuite d'une diminution rapide des populations de rhinos du Zimbabwe et l'intensification des activités de braconnage en Afrique du Sud qui abrite tellement de populations-clefs de rhinos noirs et de rhinos blancs. Cependant, aspect positif, il y a eu un certain nombre d'initiatives encourageantes.

L'attention s'est concentrée sur la réunion de I'UNEP, des pays donateurs et de ceux où vivent des rhinos, qui s'est tenue à Nairobi du 28 juin au 3 juillet 1993. Pour la préparer, Rob Brett, viceprésident du GSRA, a assisté à la réunion préliminaire en décembre 1992, et les pays où vivent des rhinos ont ébauché des propositions de projets supplémentaires à prendre en compte. Le but de la réunion principale était de rassembler les représentants des pays africains et asiatiques qui hébergent des rhinos, des principaux pays donateurs et de ceux où le commerce de corne de rhino se poursuit, dans l'espoir d'assurer des financements supplémentaires pour la conservation des rhinos et de se mettre d'accord sur ceux des nombreux projets présentés qui seraient trouvés les plus importants. On adopta la façon d'identifier les projets prioritaires qui avait **été** mise au point par le GSRA lors de sa demnière réunion **;** elle semble avoir aidé les agences et les pays donateurs lors de leurs délibérations. Etant donné que l'on ne nous a annoncé que de faibles nouveaux financements et que le niveau actuel de financement reste très endeçà des 30 à 40 millions de US$ dont a besoin le rhino africain, nous pouvons seulement insister auprès des agences et des pays donateurs pour qu'ils redoublent d'efforts afin de trouver des fonds supplémentaires, de manière à financer au moins ceux des projets dont l'importance est la plus vitale.

Un certain nombre de projets ont gagné l'attention spéciale du GSRA, et des progrès appréciables ont pu être réalisés. On a développé avec succès des plans d'action pour la conservation des populations de rhinos noirs au Cameroun et en Tanzanie lors d'ateliers organisés par les états respectifs; ils ont été présentés à la réunion de l'UNEP pour obtenir un support international. Des initiatives sont en cours pour assurer le financement de leur réalisation. On s'est assuré l'appui pour l'emploi d'un responsable scientifique pour le GSRA et l'on n'a plus besoin que de quelques subsides supplémentaires. Le projet d'étude de l'offre et de la demande, et des facteurs commerciaux dans le marché noir, sous différents régimes de commerce, semble en bonne voie et l'on prévoit la tenue d'un atelier pour la rédaction d'un manuel sur les techniques de recherches sur le rhino africain.

A court terme, la seule considération très importante pour la survie des rhinos africains reste le développement de réseaux de renseignements efficaces et de moyens de faire respecter la loi dans tous les pays où vivent des rhinos. Ceci ne peut se réaliser de façon valable qu'avec une étroite collaboration des pays concernés. Le financement international est évidemment nécessaire pour y arriver mais l'implication totale des gouvemnements africains est aussi un des ingrédients essentiels pour en assurer la réussite. C'est pourquoi je voudrais faire appel à tous les donateurs actuels et potentiels pour qu'ils considèrent très sérieusement la possibilité d'assurer la sécurité d'une ou de plusieurs populations clefs jusque et même au-delà de l'an 2000, et de contribuer à tout programme multinational qui aurait pour but d'éliminer les activités de trafic illégal.

Chairman's Report African Elephant Specialist Group

Holly T. Dublin

On behalf of the AESG Co-chairs
WWF Regional Office, P.O. Box 62440, Nairobi. Kenya

Challenges continue in the conservation and management of the African elephant. Now, almost two years after the UNEP-sponsered African elephant donor and range states meeting in January 1992, most countries are reporting that their funding needs have not been met. The implementation of effective protection and conservation plans are, like most things in life, dependent on sufficient resources. These resources are still not forthcoming.

The international ban on ivory provided a breathing space, a time to regroup and to develop country and regional action plans - but the international ban has not provided a blanket solution to the longterm management and conservation of the species. We cannot sit back and rest. The shortfall in funding is now hitting hard. On the one hand, a number of range states are reporting an increase in elephants lost to poaching over the last two years mainly due to reduced funds available for protection. On the other hand, more and more countries are reporting an increase in conflict between man and elephants with no resources for-compensation nor the provision and maintenance of elephant-proof barriers.

These issues are not unique to the African elephant. At the International Seminar on the Conservation of the Asian Elephant in Mudumulai Wildlife Sanctuary, southern India, the shared problems facing the two species became evident as paper after paper underscored the similarities. Concern with the number of elephants killed by people has taken second seat to concerns over the number of people being killed by elephants. Both species are drawing considerable media attention throughout their mange where elephants interface with man. Elephant conservation is presenting an increasing management problem for wildlife authorities. How many elephants are enough? How many elephants are too many?

Such questions were discussed at length at the recent East African Regional Elephant Conservation Coordinating meeting in Arusha, Tanzania. Ethiopia, Kenya, Sudan, Tanzania and Uganda shared their problems and their mixed experiences with solutions. Whether it is construction of fences or the payment of compensation, virtually all solutions require additional funds and these are in woefully short supply. The AESG Secretariat frequently receives reports on the struggles of countries having to deal with elephant-human conflicts and requests for technical assistance. In response to the needs expressed, we have applied for funding to initiate field studies on these issues. It is our intention to host a formal working group on human-elephant conflict at the next meeting of the AESG, scheduled for mid-1994.

We also hope to use the next meeting as a vital opportunity to collect new information from members on elephant numbers and distribution. The AESG office has already distributed questionnaires en elephant status to members and specialists in nearly all the range states. Our overall aim is to publish an update of the continental database in time for the next Conference of the Parties of CITES in late 1994. The AESG data review taskforce, which met twice in 1993, has been working hard to improve the database and has set new goals for its future direction. Several issues have been debated at length, from basic concerns such as its role and its potential users, to the mere technical aspects of data quality, output, interpretation and analysis. The taskforce is also trying to secure a funding base for the longterm development of the database.

We must not become complacent. Current problems facing the conservation and management of the African elephant are net becoming fewer nor are they becoming any less challenging. The situation has not stabilised due to the international ban on trade in ivory and elephant products. The focus of our efforts on behalf of the species must continue to be responsive, dynamic and, to a large extent, adaptive to the needs as they occur.

Rapport présidentiel Groupe des Spécialistes de l'Eléphant africain

Holly T. Dublin

au nom des co-présidents du GSEA
WWF Regional Office, P.O. Box 62440, Nairobi, Kenya

Les défis continuent dans le domaine de la conservation et de la gestion de l'éléphant africain. Aujourd'hui, presque deux ans après la réunion de janvier 1992, sponsorisée par I'UNEP, des pays donateurs et de ceux où vivent des éIéphants, la plupart des pays signalent que leurs besoins financiers n'ont pas été satisfaits. L'établissement d'une protection efficace et de plans de conservation dépend, comme presque tout, de ressources suffisantes. Ces ressources ne sont pas encore en vue.

Le ban international sum le commerce de l'ivoire a donné le temps de souffler un peu, de regrouper et de développer les plans d'action nationaux et régionaux, mais le ban international n'a pas apporté de solution miracle pour la gestion à long terme et la conservation de I'espèce. Nous ne pouvons pas en rester là. Le manque de fonds est aujourd'hui très aigu. D'une part, un grand nombre de pays nous signalent une augmentation des pertes d'éléphants dues au braconnage au cours des deux dernières années, dues principalement à la diminution des fonds disponibles pour la protection. D'autre part, de plus en plus de pays rapportent une augmentation du nombre de conflits entre les hommes et les éléphants, sans avoir les moyens ni d'apporter des compensations ni de fournir et d'entretenir des clôtures qui résistent aux éléphants.

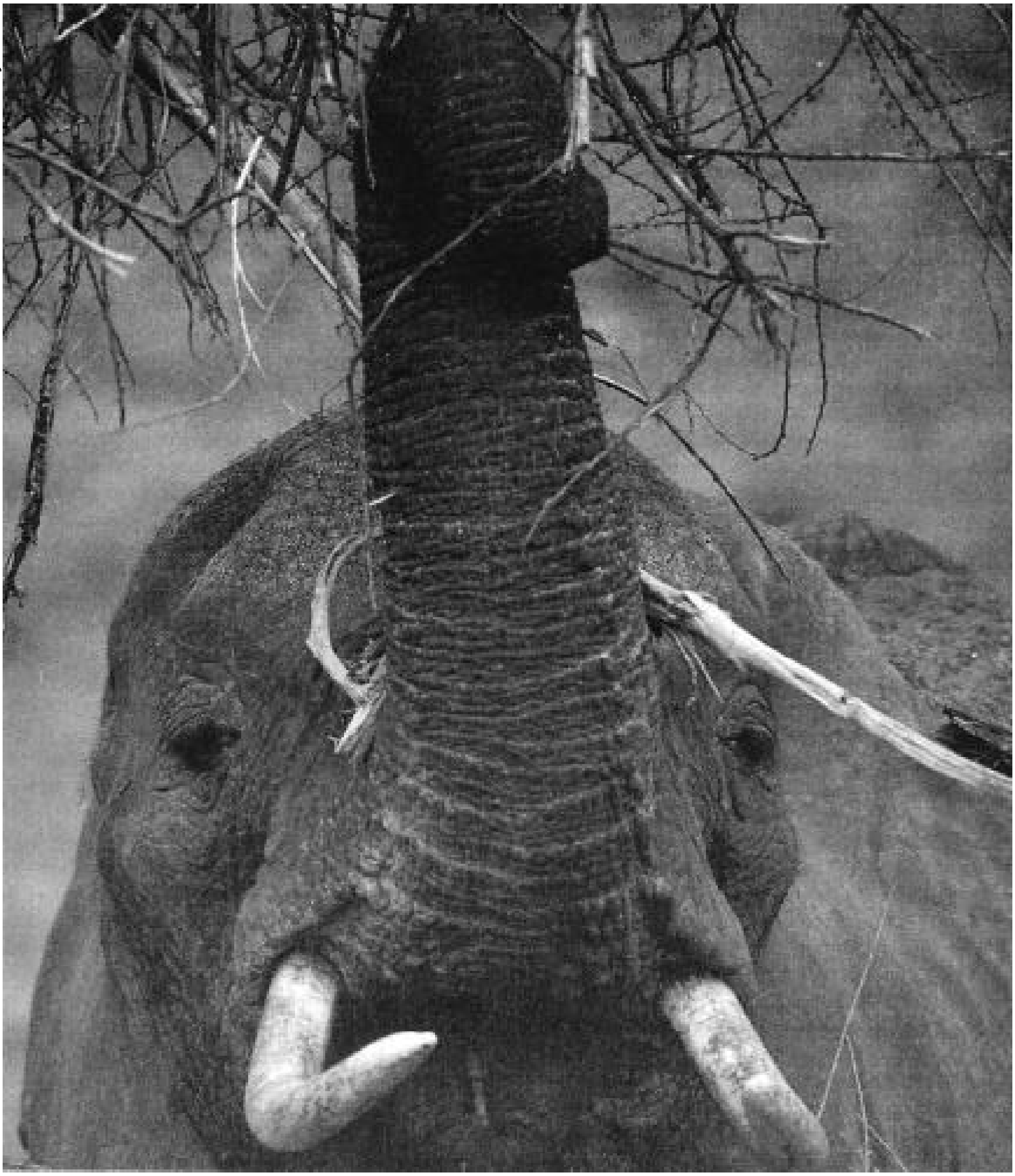
Ces problèmes ne sont pas réservés aux éléphants africains. Lors du Séminaire International sur la Conservation de I'EIéphant d'Asie, au Sanctuaire de Faune de Mudumulai, dans le sud de l'Inde, les problèmes communs que rencontrent les deux espèces sont devenus évidents, les articles soulignant les similitudes les uns après les autres. La préoccupation due au nombre d'éléphants tués par les hommes venait au second rang après celle due aux hommes tués par des éléphants. Les deux espèces attirent l'attention permanente des media partout où leur habitat recouvre celui des hommes. La conservation des éléphants représente un problème de gestion de plus en plus difficile pour les autorités responsables de la faune. Quel est le nombre idéal d'éléphants? A partir de combien sent-ils trop nombreux?

De telles questions ont été débattues longuement lors de la Réunion de Coordination Régionale sur la Conservation de I'Eléphant qui s'est tenue, pour l'Afrique de l'Est, à Arusha, en Tanzanie. L'Ethiopie, le Kenya, le Soudan, la Tanzanie et l'Ouganda ont partagé leurs problèmes ainsi que leurs expériences de différentes solutions. Qu'iI s'agisse de construction de clôtures ou du paiement de compensation, en fait, toutes les solutions nécessitent des fonds supplémentaires et ceux-ci sont hélas très réduits. Le secrétariat du GSEA reçoit fréquemment des rapports de luttes dans des pays qui sont confrontés à des conflits hommes-éléphants et qui demandent une assistance technique. En réponse aux besoins exprimés, nous avons demandé des subsides pour lancer des recherches sur le terrain dans ce domaine. Nous avons l'intention de créer un groupe de travail entièrement consacré aux conflits hommes-éléphants, lors de la prochaine réunion du GSEA, prévue pour mi-1994.

Nous espérons aussi que la prochaine réunion sera une excellente occasion de récolter de nouvelles informations de nos membres sum le nombre et la distribution des éléphants. Le bureau du GSEA a déjà distribué des questionnaires sur le statut des éléphants à ses membres et aux spécialistes dans presque tous les pays où vivent des éléphants. Notre but final est de publier une remise à jour de la banque de données à l'échelle du continent, à temps pour la prochaine Conférence des Parties de la CITES, fin 1994. L'équipe chargée de la révision des données, qui s'est réunie deux fois en 1993 a travaillé dur pour améliorer la banque de données et établir de nouveaux objectifs pour son orientation future. Plusieurs aspects ont été longuement débattus, des plus simples, comme son rôle et ses utilisateurs potentiels, aux plus techniques, comme la qualité des données, leur rendement, leur interprétation et leur analyse. L'équipe essaie aussi de s'assurer une base de financement pour le développement à long terme de la banque de données.

Nous ne devons pas nous endormir sum nos lauriers. Les problèmes actuels que rencontrent la conservation et la gestion de l'élèphant africain ne sont devenus ni moins nombreux ni plus faciles à rèsoudre. Le ban international sum le commerce de l'ivoire et des produits issus d'éléphants n'a pas stabilisé la situation. Nos efforts en faveur de 1'espèce doivent continuer à être spontanés, dynamiques et, dans une large mesure, adaptés aux nouveaux besoins qui se présentent.

Photo credit: Holly Dublin



Letters to the Editor

Dear Sir,

I refer to Lindsay's criticisms of my article in *Pachy*derm[1] in his contribution "Elephants and habitats:
the need for clear objectives."[2] While it is all very well to play the autocrat at the breakfast table, Lindsay should apply the same rigour to his criticism of others that he would have others apply to their utterances upon elephants and management. He states: "..his (Spinage's) only reference to habitat was the suggestion that by reaching K on the curve, the elephants would have reduced the Chobe woodlands to bare sand, leaving the definition of K (which should be "ecological carrying capacity") in a theoretical muddle." What I actually wrote was: "Even if left to increase to 135,000 (the value of K given in the model) or more there is little likelihood of a disaster..." And later, "But the unstable Kalahari sands which occur in the area, will not have the same resilience to vegetative loss as the fertile soils of, for example, Uganda's Queen Elizabeth National Park with its similar rainfall. The consequences to this habitat of uncontrolled, or even inadequately controlled, growth in elephant numbers could be catastrophic". Which is somewhat different to stating that the woodlands would be reduced to bare sand, and furthermore "could" is not the same as "would". Clearly it is Lindsay himself who sees that as a possible outcome otherwise he would have not said so.

K of course is never "reached" as Lindsay states, only approached, but I did not state that if numbers approach K in the model the results could be catastrophic. I wrote if numbers are "uncontrolled or even inadequately controlled", which could be interpreted to mean a cybernetic loop. To analyse articles with the rigour of scientific papers is didactic in the extreme, but it does fill up space at plenary sessions.

We can change the term "carrying capacity" to "temporary limit of sustainable growth" or some other term for the sake of epeolatry; but like "climax vegetation" I suspect that it will be with us for a long time yet. "Absolute peremptory facts are bullies, and those who keep company with them are apt to get a bullying habit in mind." As the autocrat asked, did a logical mind ever find out anything with its logic? While Lindsay labours to build his pons *asinorum* I suspect that shrewd people can bestride the chasm with ease.

Yours faithfully,

C.A. Spinage, D.Sc.
The Bungalow
Steventon Road
East Hanney, Wantage
OXON 0X12 OHS, U.K.

1. Spinage, C.A. 1990. Bostwana's problem elephants. *Pachyderm,* 13:14-19.

2. Lindsay, K. 1993. Elephants and habitats: the need for clear objectives. *Pachyderm,* 16:34- 40.

RESPONSE TO SPINAGE'S LETTER

I must admit surprise at Spinage's response, extensively embellished with metaphor and allusion, to a few lines in my paper on elephant-habitat interactions (Lindsay, **19931).** I can only conclude from the ferocity of his attack that I injured his feelings when I suggested that his use of the logistic equation and "carrying capacity" (Spinage. **19902)** was muddled. I did not and do not feel that it is didactic, autocratic, bullying or hurtful to do an author the service of trying to understand the logic behind his arguments in an article he has submitted for publication by a technical Specialist Group of IUCN. If l am mistaken in this belief or if my fault is a failure to understand, then I am genuinely sorry.

However, far from labouring on a Bridge of Asses at my breakfast table (?), I was attempting to clear away some of the clutter which has surrounded the issues of elephant - habitat interaction and has, I believe, prevented progress in approaching the subject. The use and abuse of the term "carrying capacity", with its many definitions and its invocation of an idealised stable equilibrium, symbolises the value-laden thinking about ecosystem dynamics perpetuated by many wildlife researchers and managers. In taking issue with its still common currency, I was merely standing on the shoulders of giants (e.g. Macnab, l9853).

I actually liked much of Spinage's article, but I had a problem in understanding his somewhat convoluted modelling of elephant population dynamics in northern Botswana. It was in my review of models used to explore habitat interaction that I commented on Spinage's efforts, among several others. At one stage in his article, he used the logistic population growth curve - there could be a book written on arguments over its application to large mammal populations - to extrapolate beyond recent aerial survey estimates fitted to the linear section of the curve and predict an equilibrium population density for elephants at K in the middle of the next century. The logistic curve, being a mathematical abstraction, requires a density dependent deceleration in population growth but says nothing about its mechanism. He went on to suggest that the woodlands along the Chobe and Linyanti river fronts - at a distance of up to 30km away? (it is not clear) - would be destroyed if elephant density was not reduced by management intervention to a much lower level, but that the elephants would probably be supported by floodplain grasses; competition over this limited resource would result in slower population growth, implying the negative feedback of the logistic model. "Disaster" on the scale of Tsavo was unlikely for the elephants, although the woodlands would take a beating.

Fine so far, I think. However, in his conclusion he stated that "limitations of habitat will eventually come to bear on this rate of increase", but that the unstable Kalahari sands are not as resilient to vegetative loss as are more fertile soils such as those in Uganda, and "the consequences to this habitat of uncontrolled, or even inadequately controlled, growth in elephant numbers could be catastrophic". These statements were unfortunately phrased in ambiguity, leaving open the question of whether the necessary control mechanism should be ballistic or a natural "cybernetic loop". If there is a natural limitation on population by habitat (is this still the floodplain or are we now talking about the Kalahari sand woodlands?), this implied his logistic model approaching K; how then could "uncontrolled" growth have catastrophic consequences for woodlands on Kalahari sands, away from the riverine? I must admit that by this stage I was seeing bare sand, where I now learn it was not intended.

To me this discussion seemed contradictory and well, muddled, and it appeared to typify the difficulties of trying to apply superficially simple concepts such as the logistic model and carrying capacity to describe the complex and still imperfectly understood effects of elephants on habitats and the parallel effects of habitat on elephants, against a background of other widely varying environmental factors such as rainfall, fire and frost. However, old shibboleths die hard and Spinage is probably right in predicting that "carrying capacity" and its related misleading, muddle-generating notions will linger on for some time to come.

W.K. Lindsay
Department of Zoology
University of Cambridge
UK

I. Lindsay, K. (1993) Elephants and habitats: the need for clear objectives. *Pachyderm,* 16:34-40.

2. Spinage, C.A. (1990) Botswana's problem elephants. *Pachyderm,* 13:14-19.

3. Macnab, J. (1985) Carrying capacity and related slippery shibboleths. *Wildlife Society Bulletin,* 13:403-410.

Errata

Please note the following corrections to the last issue (No.16) of *Pachyderm:*

1. Pages 1 and 14
   The date of the African Elephant Specialist Group meeting was November 1992, not 1993.

2. Page 36
   The paragraph under the heading "Carrying capacity" in the article by Keith Lindsay should read:

"Many managers of elephant populations continue to use the term "carrying capacity" as if it has an objective meaning grounded in ecological reality. The view that there is a self-defined carrying capacity for an area which is "ecologically correct", the one animal density which will avoid habitat "degradation", which allows for "healthy" wildlife populations and habitats and represents "sound management" has been expounded most recently in a book by Thomson (1992). If the reviews are to be believed, it is a popular account of wildlife management principles, yet it blandly assumes a single value system when in fact there is a great variety, each of which sets its own limits of acceptability for the density of plants and animals."

Working Group Discussion Three*
Elephant - Habitat Working Group

African Elephant Specialist Group Meeting, 17-22 November 1992. Victoria Fails, Zimbabwe

Dr. Russell Taylor chaired the elephant-habitat working group, consisting of about a dozen persons, through several hours of discussions and review over a two-day period, which he describes below.

TERMS OF REFERENCE

GOALS:

To address the current methods of monitoring the impact of elephants on habitat. Evaluate the theoretical models traditionally employed to elephant-habitat research and management in Africa (eg. climax, multiple stable and equilibrium). Question the impact of elephants on habitats, biodiversity and local economies and how these effects can be rigorously studied.

FOCAL TOPICS FOR DISCUSSION:

- Identify recent or on-going studies that have looked into these questions. Cite countries, habitat types and individual investigators.

  Assess whether the concept of "carrying capacity" is still useful. Is there another paradigm that better describes the relationship between elephant populations and their habitats?

- Discuss the impact of elephants on habitats and what bearing this has on biodiversity. both positive and negative.

- Critically assess methods used to measure habitat characteristics and biodiversity and subsequent changes in either or both.

- Review techniques that have been shown to be the most effective for the study of elephant-habitat interactions.

These may include:

  i. feeding behaviour studies (direct and indirect)
  ii. bioenergetics
  iii. movements in relation to habitat types
  iv. exclosure plots
  v. longterm vegetation monitoring
  vi. modelling
  vii. combinations of the above tools

- Define techniques for measuring the impacts of elephants on biodiversity. Critically assess the indicators that could be used. For example, changes in:

  i. species composition, abundance and distribution
  ii. biomass and productivity
  iii. physical structure of vegetation communities
  iv. plant community structure
  v. animal community structure
  vi. other quantifiable indicators

- Outline ways to measure seasonal variation in the impacts on both habitats/biodiversity.

- Develop meaningful ways of evaluating the economic cost of elephant-habitat interactions outside protected areas.

- Other topics that are considered relevant to the discussion.

DISCUSSION SUMMARY

The response of the working group is presented under the following headings:

* *Working Group Discussions One and Two are described in Pachyderm No. 16.*

1. Elephants and biodiversity
2. Conceptual models for elephant-habitat relationships
3. Management of elephants in protected areas
4. Special problems of elephant management outside protected areas
5. Monitoring elephant impact
6. Summary
7. References

1. ELEPHANTS AND BIODIVERSITY

One of the most widely quoted definitions of biodiversity is that of McNeely et *al.* (1990): “It is an umbrella term for the degree of nature’s variety, including both the number and frequency of ecosystems, species, or genes in a given assemblage”.

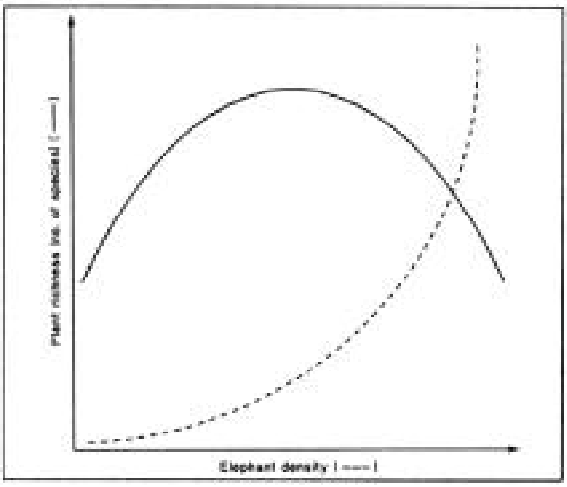
In examining biodiversity, the group noted that **in** general human influence poses the most fundamen-tal threat to change, manifested by ecosystem transformation or habitat modification, in which elephnts may play both an indirect and/or direct role. For sub-Saharan Africa, threats include population pressure, food production methods, foreign debt servicing, commercial land-use practices, over-harvesting, unviable populations of species, climatic change and alien species invasions (Stuart & Adams 1990). In the context of elephants and land use, elephants are probably a manifestation - rather than a fundamental cause - of change.

Whilst it was felt that protected areas could be managed for both elephants and biodiversity, and in fact that they need to be, the group noted that elephants can cause a diminishment in biodiversity as their numbers increase. In this regard, unique habitat types and/or areas of endemism may well have to be protected from elephants. Diversity may be increased, however, at lower elephant densities through the opening up of new habitats. Western’s (1989) data for Amboseli provide a useful empirical model from which to begin an examination of the impact of elephants on biodiversity (Figure 1). Waithaka (1993) provides similar evidence. The focus in these studies, however, has been primarily the impact of elephants on plant or habitat dynamics. The group suggested that other useful indicators which could be used to measure change in biodiversity include birds, as well as other vertebrate and invertebrate fauna, in terms of both species richness and abundance.

Of particular importance, noted the group, is the threshold at which irreversible change occurs. In most instances neither the threshold is known nor whether the change is irreversible or not. Many systems with elephants have changed, but in most in-stances little of the change has been quantified. Moreover, change in itself may well be necessary for the maintenance of resilience.

It was generally agreed that elephant-habitat interactions are complex and poorly understood, both in the long and short term, and that establishing cause and effect relationships is therefore inherently difficult.

Figure 1. The relationship between plant richness (numbers of plant species) and elephant density. Redrawn from Western (1989).



2. CONCEPTUAL MODELS FOR ELEPHANT HABITAT RELATIONSHIPS

The group agreed that models can improve understanding of both past and continuing relationships between plants and animals, and of natural processes of population regulation. Models can be used to describe, explore and refine interactive ecological processes, such as between elephants and their habitats, using actual measurements and real data when these become available. In addressing management questions, models can help to tell us what information to collect. Such information can then be used to improve or modify management inputs.

The group extensively reviewed the models that have been proposed to date and which attempt to explain some of these relationships (see also Lindsay, 1993). They were described as:

2.1The successional/climax or Clementsian model

Although this model is the traditional and most common range management paradigm, it is coming under increasing scrutiny as being inappropriate to explain what we see in practice and understand in theory (Westoby et *al.,* 1989). Implicit in this model is the carrying capacity concept and an underlying economic or production basis. It may have relevance in range-livestock systems but not in ecosystems managed for non-economic incentives. Rarely is this distinction explicitly recognised (Caughley 1979, Caughley & Walker 1983. Bell 1985, Behnke & Scoones 1991). This has led to confusion over the use of the carrying capacity concept, which has no objective biological criteria for its specification.

Carrying capacity may be any one of a number of points along a plant-animal isocline (Figure 2) and should be determined by the management objectives of the system under consideration. Some members of the working group felt that the term "carrying capacity" had become somewhat redundant and a more appropriate term might be "preferred management density" which is dependent on the choice of management options available to a manager. Thus management for high animal density implies a lower plant density and vice versa. It was recognised that the relationships depicted in Figure 2 are simplified and do not necessarily predict real plant-animal interactions. Nevertheless, Figure 2 does help to clarify carrying capacity and management by objective.

2.2 Equilibrial and non-equilibrial systems

The successional model assumes a stable or equilibrial system which Figure 2 also depicts. Here, herbivore numbers are controlled through forage availability and vice versa, so that through negative feedback of internal biotic controls a stable equilibrium between animal and plant populations is eventually achieved. A major assumption of equilibrial models is that abiotic or physical controls such as rainfall (which influences plant growth), are relatively constant and unimportant compared to the internal biotic feedbacks of the plant-animal interaction. However, where stochastic or variable abiotic conditions are dominant, the systems tend to be non-equilibrial because the stronger external controls override the internal feedback mechanisms of the plant-animal interaction (Behnke & Scoones 1991).

Figure 2. The plant-animal density isocline and its relationship to carrying capacity or preferred management density.

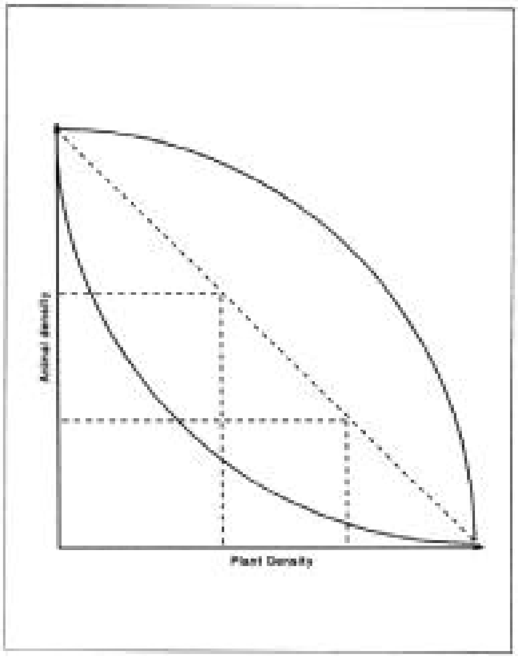
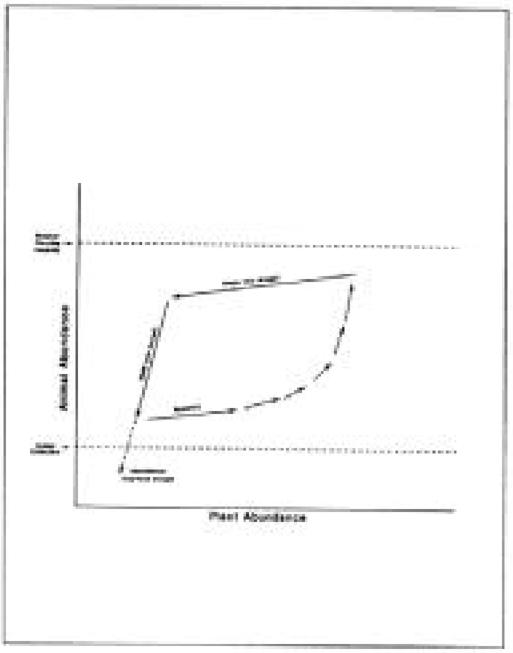


Figure 3. Plant-animal interactions under the influence of frequent drought in northern Kenya. Redrawn from Ellis and Swift (1988).



Such a non-equilibrial system is described by Ellis and Swift (1988) for plant-livestock interactions under conditions of frequent drought in Turkana, northern Kenya (Figure 3). In this system, plant and animal populations both increase under favourable rainfall conditions and contract in times of drought. Low rainfall, rather than too many animals *per* se, limits both food and animals.

2.3 Stable limit cycles

Caughley (1976) suggested that there was no attainable equilibrium between elephants and woodlands. Instead, he proposed - for the Luangwa Valley, Zambia - a stable limit cycle in which elephants increase while reducing woodland, and then decline to a density sufficiently low to allow woodland regeneration. This in turn triggers an increase of elephants and the cycle repeats itself. He argued that man can impose only an artificial equilibrium on the system such that trees and elephants are trapped at the low density phase of the cycle. Such a system, however, is essentially equilibrial but has such strong internal feedbacks that it departs from equilibrium and, when accompanied by time lags, results in a stable limit cycle (Ellis & Swift 1988).

Like Caughley's (1979) equilibrial carrying capacity model in Figure 2, the stable limit cycle model does not take into account the stochasticity of strong external abiotic controls. In addition, nonequilibrial systems tend to be spatially extensive and external factors (e.g. human influences) may be critical to their dynamics.

2.4 State and transition models

Westoby et *al.* (1989) argue that event-driven or episodic variables such as rainfall or fire, which are not constant in their effect, may change range-land systems in an irreversible way which is inconsistent with the succession model. This may be more so for arid and semi-arid regions. The state and transition model is proposed as an alternative to the range succession paradigm for nonequilibrial systems.

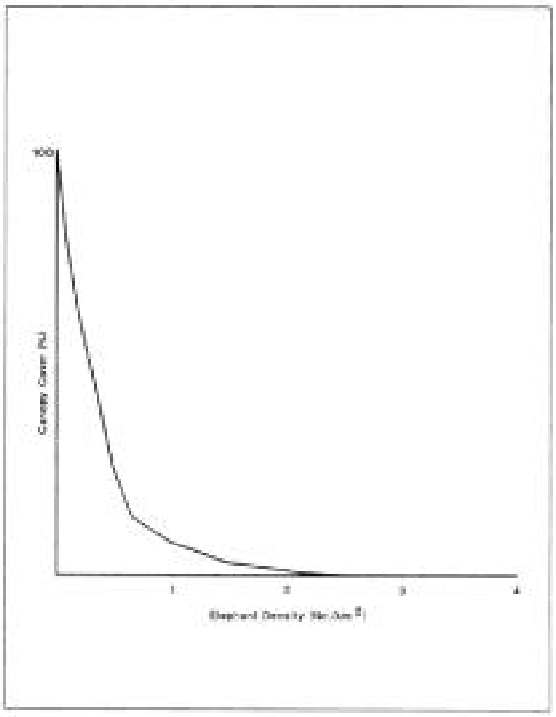
In this model, a system is described by a set of discrete vegetation states with a set of transitions between them. Transitions are triggered by natural events, management inputs or combinations of these. The probabilities of such occurrences are estimated through adaptive or experimental and opportunistic research. This model is proposed not so much as an advance on current theoretical models, but because it organises information needed for management. Hence management, rather than theoretical criteria, is used in recognising states under given situations.

2.5 Multiple stable states

Multiple stable states in ecosystems have been proposed theoretically. Boundaries will exist between states when the system, once moved into another state, does not return to its original state. The factor responsible for change returns to its original value and another factor holds the system in the new state.

These predictions have been examined for the Serengeti-Mara woodlands by Dublin et *al.* (1990). Elephant-woodland and fire-woodland interactions were modelled to test the hypothesis that elephants and fire, respectively, caused woodland decline and that the same two factors prevented its recovery. The conclusion was that fire alone, but not elephants alone, could change woodland to grassland but that once the grassland was formed, elephants alone would maintain the grassland state. When fire acted with elephants, this produced the highest rate of woodland loss, which most closely matched that which was measured off photographs. Elephants and fire together are probably preventing woodland recovery at present.

Figure 4. Tree-elephant equilibrium for Acacia woodlands in Zimbabwe. Redrawn from Craig (in press, a)



2.6Tree-elephant models

Specific tree-elephant models which hold one or the other factor constant and then measure the consequences have been developed by Barnes (1983) and more recently by Craig (in press, a). The influence of fire as an additional factor has been included in the models of Norton-Griffiths (1979) and Pellew (1983). Craig (in press, a) clearly demonstrates that for Zimbabwean woodlands, canopy cover can only exceed 50% at elephant densities below 0.2 el-ephants/km^2 (Figure 4). His model is essentially equilibrial, however, and makes use of a space transition matrix which assumes a stable age distribution for woodland.

2.7Dynamic system models

Most system models fail to account reliably for the dynamics of both trees and elephants and the interaction between them, and other stochastic variables, without the use of detailed measurements and/or unrealistic assumptions. The benefits from most conventional system models are usually lost in the uncertainty and complexity of the exercise.

Rule-based models (Starfield & Bleloch, 1986) are simple and make use of as much (or as little) information as is available. The artificial intelligence (AI) construct of a frame to describe ecosystem processes under different states or regions of operation allows for dynamic simulation capabilities while retaining the conceptual simplicity of a state and transition model (Starfield et *al.*, in press).

By partitioning the temporal dynamics of the system, only one simple model is operational at any time. Further refinements also provide for spatial heterogeneity to be taken into account, so that movement in and out of interacting regions can also be modelled. This approach is being explored presently in the management of elephants, fire and miombo woodlands in Zimbabwe (Starfield et *al.*, in press).

While perturbations and episodic events are accepted as key components of ecosystem processes, an often neglected factor is the scale, both spatial and temporal, at which these processes may have operated and the constraints at which they operate today. Models should also be applied to interactions with people and their economies. For example, hunting, poaching and human population expansion and contraction in relation to land use, in the past and now, have often been ignored as factors in elephant regulation (Hanks 1979, Owen-Smith 1983, Craig, in press, b).

3. MANAGEMENT OF ELEPHANTS IN PROTECTED AREAS

The working group recognised that managers are often required to manage protected areas which support elephants at a scale much smaller than before. Consequently, for many areas, implicit in their management is an underlying acceptance of the successional/climax mode! especially to minimise the risk of irreversible change. Such an approach to management often reflects caution without a real appreciation of the probability of risk involved.

Adaptive management means that simple system models of the underlying interactions can be built and tested in the day-to-day management of protected areas. Predicted outcomes can be measured through monitoring and evaluation, with feedback systems to allow for corrective action when and where necessary.

There was clear and strong consensus that management must be goal-orientated with goals and objectives flowing from an overall wildlife policy and its enabling legislation. It was recognised that for many wildlife agencies this had yet to be achieved.

It was pointed out that management by objective enhances flexibility and encourages adaptive approaches, especially when supported by rigorous monitoring and evaluation.

The group agreed that management goals will differ between management authorities, but the use of models could allow managers to begin to formulate their goals and objectives. For example, given the considerable confusion and lack of clarity that arise over the use of the term carrying capacity, managers could decide on a density of both plants and animals which reflects a preferred management option, derived from policy and objectives (Figure 2). Figure 4 (Craig, in press, a) provides a quantitative and objective basis for such decisions and gives managers a more realistic view of the problems they face. This approach allows levels of habitat use to be pre-determined which are permissible in terms of stated goals.

4. SPECIAL PROBLEMS OF ELEPHANT MANAGEMENT OUTSIDE PROTECTED AREAS

It was recognised by the group that many elephant populations, habitats, plant and animal communities which exist outside protected areas deserve attention. Specific problems include the impact of el-ephants upon habitats, the loss of habitat or its fragmentation due to human influences, and the growing conflict between elephants, people and other forms of land use such as agriculture and agro-forestry. For a number of countries elephant range extends beyond the boundaries of formally protected areas and significant numbers of elephants occur outside these areas (Thouless 1991, Taylor *et al.,* 1992). Consequently the movements of elephants have become restricted and/or their traditional range has undergone shifts, both in time and space.

Where this has lead to conflict between people and elephants there is now an urgent need either to reduce the level of conflict or to increase levels of human tolerance, or both. The group discussed the pros and cons of various measures to reduce conflict, which include control of elephants through shooting or harassment (both of which were felt to be of dubious benefit) and the use of electrified game fences. The latter is currently being attempted in various localities with different measures of success. Given the present state of technology, well-applied electric fences can act as a powerful deterrent to elephant entry and trespass (Hoare 1992). An often neglected aspect of electric fences is their cost-effectiveness, and to this end, economic cost-benefit analyses are essential prerequisites.

The group heard about other methods of deterrence presently being explored, which include the use of chemical aerosols (Osborn 1992). Osborn is also investigating the ecology of crop-raiding elephants, a hitherto neglected aspect of human-elephant conflict in Africa but one which has received considerable attention in Asia (Sukumar 1990).

Community-based wildlife conservation and management programmes are currently underway in a number of countries and include Admade in Zambia, Campfire in Zimbabwe, the auxiliary game guard system in Namibia, multiple-use areas in Bophutatswana as well as a number of initiatives in South Africa, notably Londolozi where private enterprise is directly and actively participating with local communities in shared financial and economic ventures.

Given the growing complexity of problems associated with elephants outside protected areas, as well as the potential for solutions which link economic incentives to elephant conservation, it was recommended that a working group be set up specifically to examine these multifaceted issues.

5. MONITORING ELEPHANT IMPACT

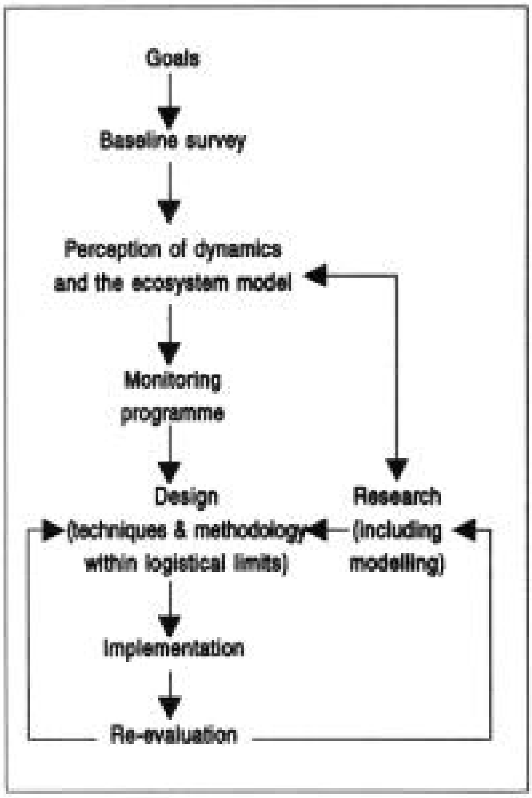
The group agreed that monitoring is of prime importance for providing information to evaluate management and to improve our understanding of ecosystems with elephants.

A monitoring system cannot be implemented in one step. A logical framework for developing such a system is shown in Figure 5 (Macdonald & Grimsdell, 1983) where it can be seen that the intended monitoring system must be linked, from the outset, to clear management goals.

Essentially, there are three approaches to management, namely:

- **i.** minimal management,
- **ii.** management for ecological objectives and
- iii. management for economic objectives.

Figure 5. A possible framework for the development of a monitoring system. Redrawn from MacDonald & Grimsdell (1983).



Monitoring will differ for each of these strategies. The role of a conceptual or ecosystem model helps in the design of the monitoring system and programme.

The group noted that a monitoring programme aims to measure the rate and direction of change in an ecosystem. An essential requirement of a monitoring technique is to provide the minimum data set needed to give the required information to detect such change. A further important component is time. Inevitably, much monitoring is longterm and repetitive - hence the importance of a model which identifies key variables and processes which may require monitoring and/or further research to ensure that costly omissions or mistakes are avoided.

The group discussed the components which must be considered during the initial design stages of the programme. Monitoring should be sufficiently straightforward and feasible to ensure continuity over time, and personnel must be adequately trained.

Several important variables were listed which need to be considered in relation to elephants, biodiversity and human activities. For each variable to be monitored in an ecosystem, it is necessary to consider the frequency, scale, replication, accuracy and precision of measurement needed to provide the desired level of resolution. Likewise, ecosystem components requiring monitoring will depend on the objectives of the monitoring system.

A discussion on the use of permanent plots, transects, fixed point photo-panoramas and aerial photography for measuring elephant impact followed the above points. Exclosures were considered useful for assessing site potential and likely recovery rates. Ways in which animals could be monitored were listed as simple wildlife reporting systems, ground counts, aerial counts and other indices of abundance. The group recognised that any technique would have to be area or component specific.

Macdonald and Grimsdell (1983) have compiled detailed tables and lists specifying those ecosystem components that require monitoring, and the levels at which they should be monitored, for arid, semi-arid and sub-humid bioclimatic zones. It was noted that these tables provide an extremely useful starting point for any intended monitoring system.

The working group also attempted to clarify the links between research and monitoring. Research is conducted, by way of testing hypotheses, to increase understanding of the ecological components and processes of ecosystems, whereas monitoring is the means to measure the direction and rate of these processes. Both research and monitoring are interdependent and should contribute to the same end. Although it may or may not be directly relevant to management objectives in the short term, research is essential in the long term for testing the assumptions on which most of our management is based. Monitoring, however, is directly related to management objectives.

In this regard, the organization and dissemination of information from a monitoring system, and its intended use, is of great importance. If the data collected are not effectively fed back to managers, then the investment in the monitoring programme is wasted. Thus information storage, analysis, interpretation and feedback, as well as regular reevaluation, are essential components of the system.

6. SUMMARY

Both within and outside protected areas, managers are required to take decisions in the light of presently inadequate knowledge or information. This continues to be so especially in the case of elephants, their habitats and the human populations around or amongst them - and the problems that manifest themselves as a result of these interactions. In the wide-ranging discussions outlined above, the group found the following schematic outline (Figure 6) was useful in bringing together these seemingly disparate components. This approach to the management of elephants and their habitats endeavours to provide linkages between policy, management, monitoring and research and brings some clarity to often misunderstood and confused ideas about the conservation of elephants.

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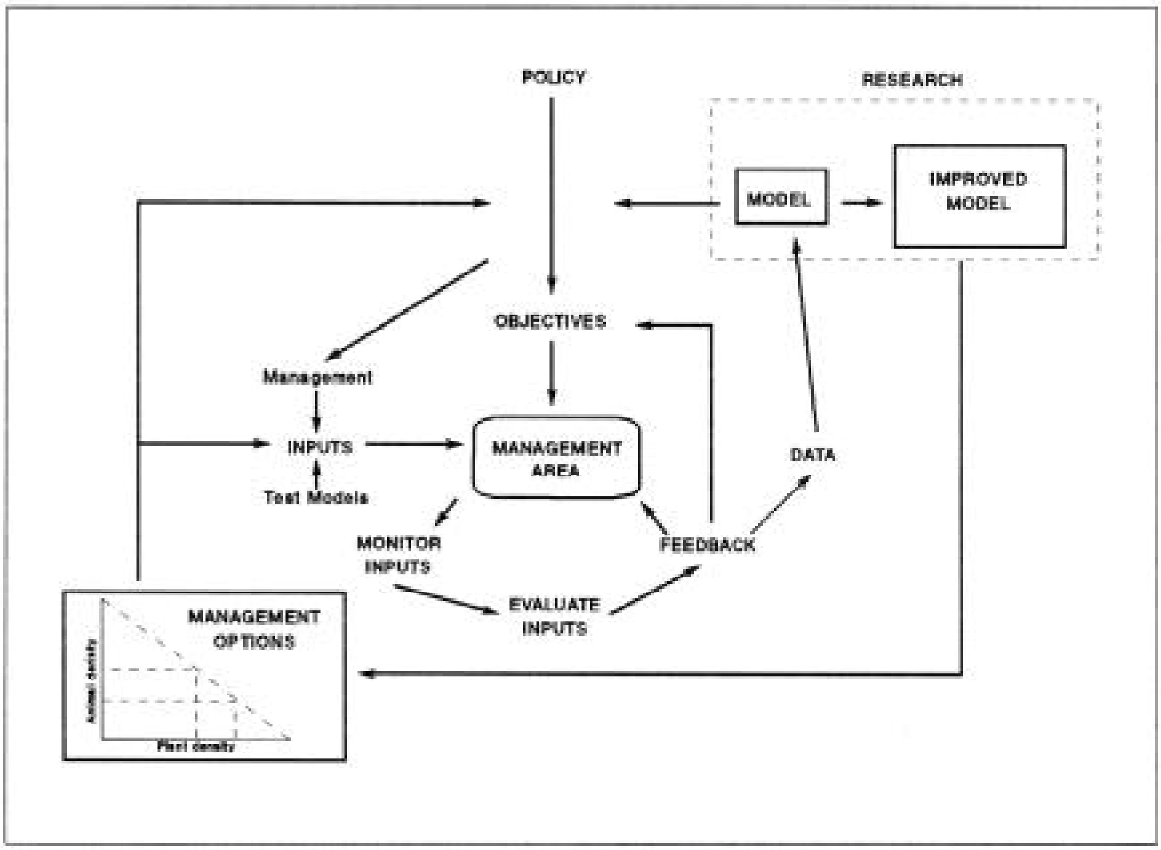
Figure 6. A suggested framework for the development of a management system in wildlife conservation areas. Such an approach may apply equally to protected or non-protected areas.



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Elephant Management in Nyaminyami District, Zimbabwe: Turning a Liability into an Asset

Russell D. Taylor

WWF Multispecies Project, P.O. Box 8437, Causeway, Harare, Zimbabwe

ABSTRACT

In Nyaminyami District, on the southern shores of Lake Kariba, 20,000 people share Omay Communal Land, an area of nearly 3,000 kin[2], with some 2,000 elephants and a range of other large wild mammals. Elephants are a major source of conflict between wildlife and people in Omay, largely on account of damage inflicted upon crops and property and injury or death to human life. Under the CAMPFIRE programme the management of elephants in Omay is presently being directed towards:

(i) reducing conflict through combining problem elephant control with sustainable trophy hunting of elephants; electrified fencing to protect arable fields and homes from the depredations of elephant; zonation of land use for tourism development and agricultural planning at ward and village level;

(ii) increasing tolerance towards elephants through revenues earned from safari hunting and other wildlife management activities, and wildlife-based tourism ventures with private sector operators.

The relative merits or otherwise of these various approaches are outlined and the implications for the long term conservation of elephants are discussed.

INTRODUCTION

A major source of conflict between wild animals and people is the damage inflicted by wildlife upon crops and property, and injury or death caused to livestock and on occasion to human life. This is especially true of elephant, but can also include other large dangerous game. Consequently, rural people are intolerant of wildlife. There is also often a tendency for farmers to inflate estimates of damage to crops and cultivated fields in anticipation of animals being shot and a supply of meat thus being made available (Taylor 1982).

The traditional and continuing response on the part of management authorities to problem animals, especially dangerous game, is attempted control through harassment and/or shooting of the culprits involved. The success of such action has yet to be critically evaluated despite the killing of many thousands of animals on control work, especially in colonial Africa (Bell 1985, Parker & Graham 1989). The nature of the problem needs careful assessment, especially where the economic value of problem animals potentially greatly exceeds their nuisance value, and where their sustainable use is threatened by excessive control measures.

Under the Zimbabwe Government's CAMPFIRE programme (Martin 1986; Anon. 1987) responsibility for wildlife was conferred on the Nyaminyami District Council of Kariba in northern Zimbabwe when it received "appropriate authority" status from the Department of National Parks and Wild Life Management (DNPWLM) in January 1989. The District Council is charged with the administration and management of the wildlife resources of the area for the benefit of the people of Nyaminyami. This paper outlines how the district is currently attempting to manage elephant in the area, both directly and indirectly, so as to minimise conflict and increase tolerance on the part of local people; improve the livelihoods of rural poor through sustainable wildlife use; promote sound and sustainable land use options and enhance biological conservation.

OMAY COMMUNAL LAND

Omay Communal Land in Nyaminyami District on the southern shores of Lake Kariba surrounds the inland boundaries of Matusadona National Park and has a total area of 2,870 km^2 (Figure *1)*. Omay has a population of some 20,000 people centred around four chieftainships, Mola, Negande, Nebiri, and Msampakaruma. Each chieftainship comprises two wards made up of a number of villages and households. Commercial growth based on tourism and fishing, is focused on Bumi Hills and Chalala, and Siakobvu is the administrative centre for the district.

Figure 1. Omay Communal Land in Nyaminyami District, Kariba, Zimbabwe. Hatching shows the major settlement areas within the chieftainships of Mola, Negande, Nebiri and Msamapakaruma. Siakobvu is the administrative centre of the district and Bumi Hills and Chalala are tourist and commercial growth points respectively. Completed (-) and proposed (—) electrified game fencing is also indicated.

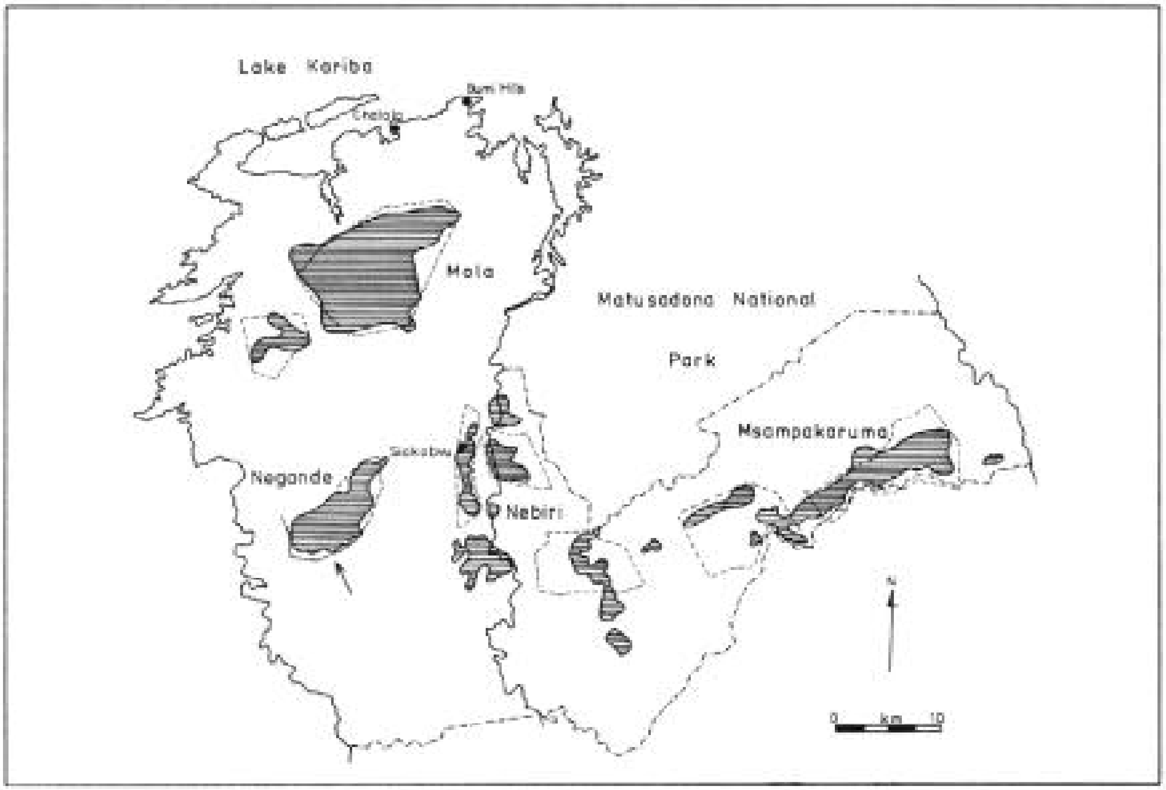


Figure 2. Trend in elephant numbers in Omay Communal Land, Nyaminyami District, from aerial census data over the period 1979 -1991. Data from Taylor (1988b, 199 1a).

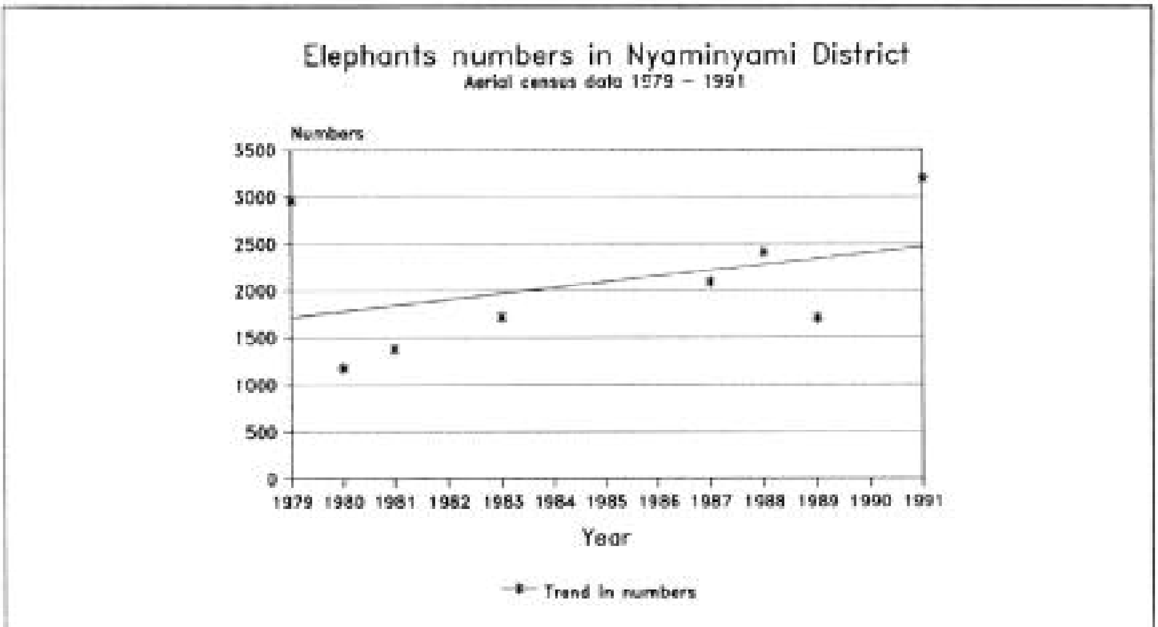
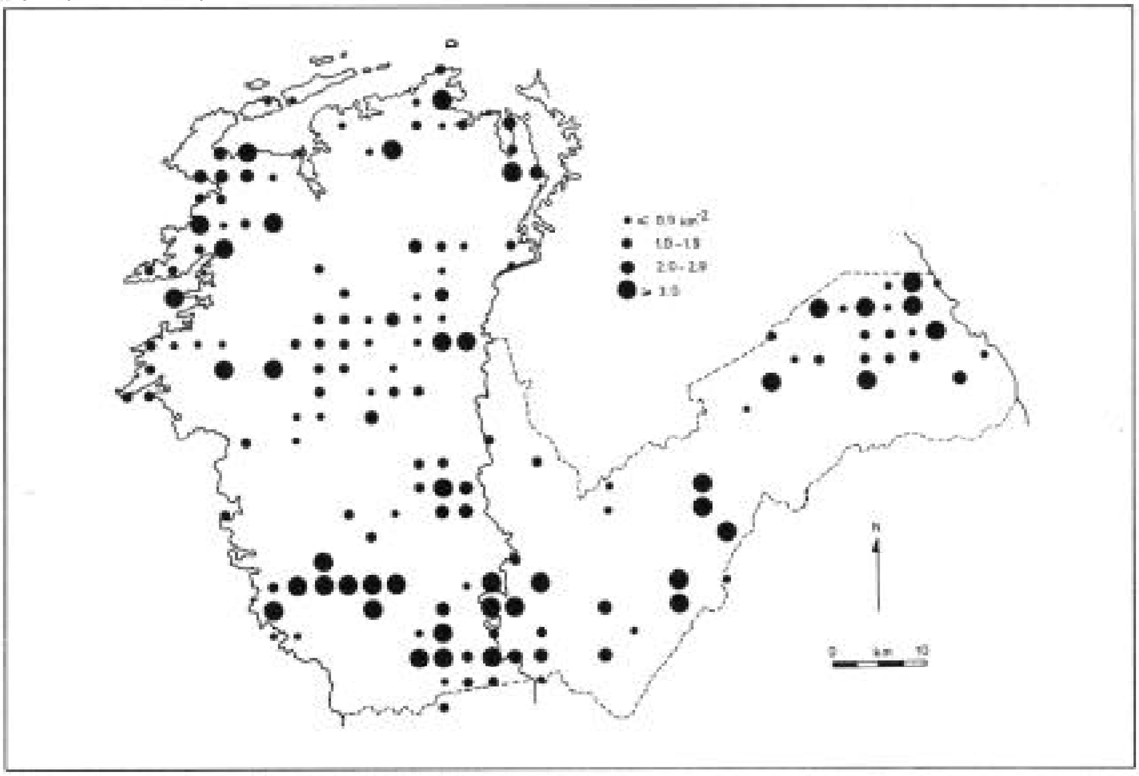


Figure 3. The dry season distribution and density of elephants in Omay Communal Land, Nyaminyami District. Data from Taylor (1988b, 1991a).



The environment is semi-arid with variable and seasonal rainfall amounting to 650 mm per annum, falling between November and March. The climate is hot with maximum temperatures in excess of 40 and minimum temperatures rarely falling below 17 Agriculture is limited to subsistence cultivation and livestock holdings are confined mostly to goats, cattle having been precluded until very recently due to the presence of tsetse fly *(Glossina spp.).* Large wild herbivore populations are typical of the Zambezi Valley (Taylor 1 988a). They include 2,000 elephant *(Loxodonta africana),* 6,000 buffalo *(Syncerus caffer),* 15,000 impala *(Aepyceros melampus)* and lesser numbers of a further 12 species (Taylor 1991a, Taylor, Cumming & Mackie, 1992).

ELEPHANT ABUNDANCE AND DISTRIBUTION

Census data for elephant in Omay have been obtained on an annual basis over the past 13 years, the mean number estimated being 2,098 ± 25% (95% C.L.; n = 10 counts). Notwithstanding the variability of individual estimates, these data indicate a longterm upward trend which predicts an annual growth rate of 3.4% (Taylor unpublished data, Figure 2). The mean crude density of elephants is 0.75/km^2 but distribution is clumped and closely associated with uninhabited terrain (Figure 3) so that localised densities may be as high as 3 elephant/km^2.

Although overall densities of elephant in the adjacent Matusadona National Park and Omay do not differ markedly between the two areas there are differences in distribution, ecological density, group size, home range size and movement (Taylor, 1 988b). This is largely a reflection of the management treatments to which elephants are subjected in the two areas. Whereas elephants enjoy protection in the absence of human disturbance in the National Park, they are subjected to hunting, harassment and human activities in the communal land.

MANAGEMENT OF ELEPHANTS SAFARI HUNTING

Big game trophies in Africa are highly sought after by foreign clients, mostly from the developed countries of the West in particular North America and Europe. Wildlife in Omay has been put to this form of use successfully over the past 20 years in both ecological and economic terms (Cumming 1989, Taylor 1990a). The safari hunting season usually commences at the end of April or beginning of May, following the cessation of the rains. This traditional date for commencement of hunting is largely for reasons of practical convenience and client comfort. Consequently, most elephants shot on the safari hunting quota are taken from May onwards, during the dry season. There is, however, no legal restriction to hunting earlier and indeed, in any given year, can commence on 1 January. Quotas for elephant, based on a population estimate of 2,000, have not exceeded 0.8% of total numbers in any given year over the past 10 years (Table 1).

ELEPHANT CONTROL

Elephants have been shot as part of control measures to protect crops and people in Omay since the late 195 Os, following the re-location of the Tonga people displaced by the filling of Lake Kariba. For the northern Sebungwe as a whole, some 348 elephants were shot between 1955 and 1979 on crop protection measures (Cumming 1981). In Omay, probably less than 10 elephants were shot annually during the 1970s (Taylor unpubl. data.). Numbers, both of elephants and people were still relatively low at the time, so that conflict was minimal. Furthermore DNPWLM personnel probably considered elephants more important than people and minimised efforts in dealing with the problems that arose.

From 1980 onwards the question of conflict between people and wildlife, especially elephants, took on a much greater importance in the eyes of a new government, and DNPWLM was required to deal with problem animals in communal lands far more diligently than had been the case previously. Nevertheless, the numbers of elephants shot on problem animal control (PAC) in Omay did not increase substantially although the number of requests to do so far exceeded the numbers actually killed. Although elephants hunted as trophies have been part of a strictly controlled quota, there has been no limit set for animals shot on PAC.

PROBLEM ANIMAL REPORTS

With the granting of Appropriate Authority in 1989, Nyaminyami District implemented a PAC monitoring programme in Omay (Taylor 1990a). A comprehensive, yet simple report and return form was designed for completion by authorised control officers and others involved in dealing with PAC. Between January 1989 and December 1991 some 1,000 PAC reports were filed

Table 1: Male PAC and trophy elephant offtakes in Omay Communal Land, 1983-1992. (Assumes an elephant population of 2,000).

YEAR	PAC OFFTAKE		TROPHY OFFTAKE		TOTALS	
	NUMBER	%	NUMBER	%	NUMBER	%
1983	5	0.25	12	0.60	17	0.85
1984	8	0.40	12	0.60	20	1.00
1985	6	0.30	12	0.60	18	0.90
1986	10	0.50	12	0.60	22	1.10
1987	6	0.30	12	0.60	18	0.90
1988	9	0.45	16	0.80	25	1.25
1989	9	0.45	14	0.70	23	1.15
1990	8	0.40	12	0.60	20	1.00
1991	12	0.60	10	0.50	22	1.10
1992	8	0.40	12	0.60	20	1.00
TOTAL	81		124		205	
MEANS	8.1	0.41	12.4	0.62	20.5	1.03

at Siakobvu, providing three years of information together with supplementary data extracted for the previous six years from DNPWLM records. Analysis of this data indicated that over 70% of reports were elephant-related and occurred during the rainy season, between January and the end of April (Figure 4). There was a peak of activity in February and March during which time growing maize, millet and sorghum are most attractive to crop-raiding elephants. Despite the high number of incidents, the number of elephant males shot on PAC between 1983 and 1992 averaged only eight each year (Table 1).

SUSTAINABLE TROPHY ELEPHANT HUNTING

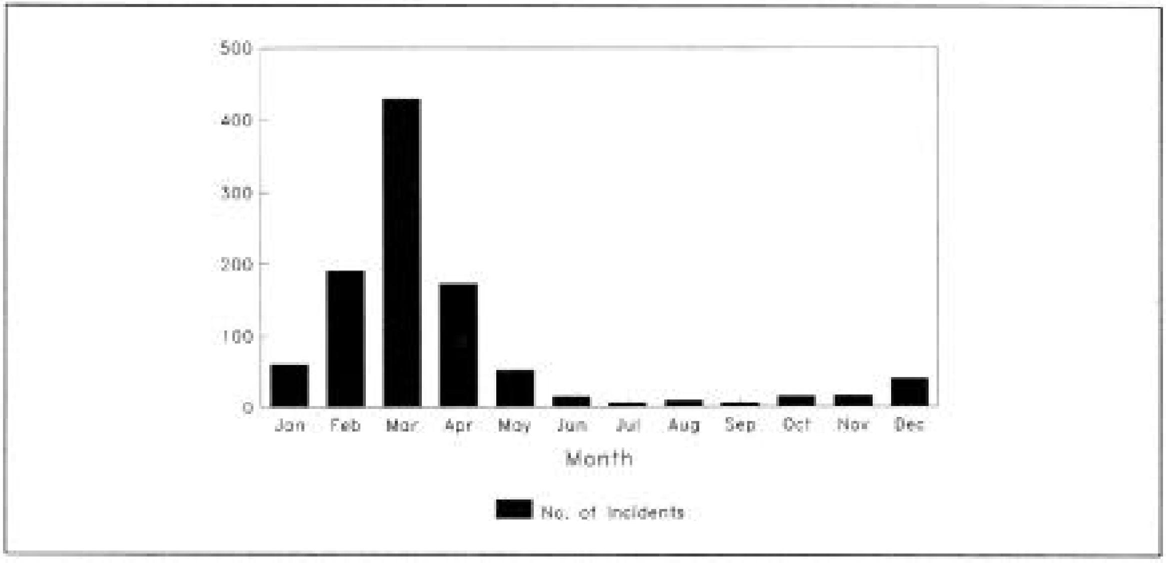
To sustain good quality trophy elephant hunting, quotas ideally should not exceed 0.7% (Martin 1990). Based on a population of 2,000 elephant in Omay, this has been maintained over the years at 0.62 ± 0.049% (Table 1). However, when the PAC offtake is added to the trophy quota, a sustainable trophy offtake is exceeded, as is also shown in Table 1. The longterm total offtake amounts to 1.03% and, clearly, either the numbers of animals shot on safari or the numbers shot on PAC have to be reduced if Nyaminyami District is to continue offering competitive big game hunting on the international market.

One possible solution to reducing both the conflict and the number of elephants destroyed on PAC is to open a wet season “window” of safari hunting. By bringing the safari hunting of elephant bulls for- ward into the wet season, it is possible for PAC animals to double up as safari trophies. In order to achieve this, the shift in hunting season will have to occur gradually over time and a number of conditions will need to be in place. Using the 10 year data set contained in Table 1, the following should apply:

i. A combined PAC and trophy hunting offtake of 20 elephant bulls is equivalent to 1% of the estimated population of 2,000 elephant. Such an offtake is not biologically damaging to the population as a whole, but it will not allow a sustainable offtake of trophy elephant bulls in the longterm. The desirable longterm trophy quota should be less than 0.7%, and initially 0.6% of the population, which is equivalent to 12 bulls per annum, if trophy quality is to be maintained.

ii. Setting an initial quota of 12 bulls only and hoping that this number will adequately cover PAC is not workable because it is not realistic. Setting a quota of 20 bulls to cover both PAC and safari hunting and then reducing this number to 12 over time is more workable, and especially so if the safari hunting can take place during the wet season.

Figure 4. The monthly incidence of problem animal reports in Omay Communal Land, Nyaminyami District, 1989-1991 (n1.013 reports).



- **iii.** Assuming a quota of 20 bulls in year l, this quota can then be allocated between PAC in the wet season and trophy hunting in the dry season, with the safari operator being allowed to market PAC elephant in addition to the trophy portion of the quota. However, the taking of PAC elephant by the safari operator should be subject to a number of conditions, and these are outlined below.

- iv. Over a five-year period, the 20 bulls allocated to the combined PAC-trophy hunting quota are progressively reduced to 12 elephant in year 5 and thereafter, when all or most are marketed as trophy elephants, but which are hunted in both the wet and dry season. The number actually allocated to wet season hunting would depend on the level of tolerance achieved and marketing success.

1n adopting this approach, PAC problems are being effectively dealt with and at the end of the five-year period, sufficient awareness should have been generated to encourage greater tolerance of problem animals. Such animals can now be shot as trophies, as and when they cause problems. Moreover, there is an increased financial return to the producer community, with a previous liability now converted into an asset.

Table 2 illustrates how such a scheme might operate. The allocation between wet season PAC and dry season trophy hunting can vary between years, but with the combined PAC-trophy quota constantly being reduced to the target figure of 12. Over five years a total of 80 elephant would be shot, representing no more than 0.8% of the total population. The decision as to how to allocate between PAC and trophy hunting can be taken by the District Council in consultation with the resident safari operators. Five different permutations are illustrated in Table 2, but these are by no means exhaustive. These permutations also indicate the allocation of even numbers of animals. This is because there are currently two safari operators in Nyaminyami District so that the quota must be divisible by two.

CONDITIONS AND MARKETING

‘Clearly, a number of detailed conditions must apply for such a scheme to work properly, but since these would be very area specific only a general outline is

Table 2: Suggested allocations and permutations for PAC and trophy hunting quotas for elephant in Nyaminyami District. (PAC=control quota; TH=trophy quota; GT=total quota).

SEASON	YEAR 1			YEAR 2			YEAR 3			YEAR 5			YEAR 4		
	PAC	TH	GT	PAC	TH	GT	PAC	TH	GT	PAC	TH	GT	PAC	TH	GT
WET	10			10			10			10			10		
DRY		10			8			6			4			2	
GT			20			18			16			14			12
WET	10			10			10			8			6		
DRY		10			8			6			6			6	
GT			20			18			16			14			12
WET	10			10			8			8			6		
DRY		10			8			8			6			6	
GT			20			18			16			14			12
WET	12			10			8			8			6		
DRY		8			8			8			6			6	
GT			20			18			16			14			12
WET	14			12			10			10			10		
DRY		6			6			6			4			2	
GT			20			18			16			14			12

given here. The total quota must not be exceeded, with all PAC being undertaken only in the wet season, either as such or on safari, and the quota must reduce to a sustainable trophy hunting quota over a specified time period. The elephant shot on PAC by a safari operator must be a genuine problem animal destroyed as and where the problem arises and prospective hunting clients would have no choice in the matter. Should the PAC quota have to be exceeded, as in the case .of loss of life, then only the appropriate authority will be permitted to shoot an elephant over and above the quota. Once the sustainable trophy quota has been achieved, animals still not shot on the PAC quota at the end of the wet season could then be carried over into the dry season as trophy animals.

The question of whether safari hunting can take place in the wet season or not is really a question of marketing. Certain safari operators are very keen to market wet season elephant hunting, particularly as very good trophy elephant (80-0001b tusk weight) have been shot in Zimbabwe during the wet season. Unfortunately, a number of these animals have been PAC animals. The same safari operators also recognize it is in their (and the country's) interests to reconcile the problem of PAC and trophy hunting.

Initially there may be market resistance so that the safari operator will be unlikely to market full hunts nor will there be enough hunting periods in the wet season "window" of 120 days (January-April) to cater for the number of PAC elephant likely to be on quota. Therefore the safari operator should be encouraged to market cheaper hunts (at least initially) for shorter periods of time. Because of the conditions imposed on the client, a sliding price scale can be attached to both the daily rate and weight of ivory from a PAC elephant, with the full trophy and daily rate fees being charged for an elephant shot with ivory greater than or equal to the average trophy weight for the district.

FENCING

An electrified fence of 18 km encircling the 50km^2 settlement area at Negande was erected in September 1990. The fence is open along 12 km to the north where an abrupt, steep-sided escarpment provides a physical barrier to elephant movement (Figure 1). Fence erection followed protracted community debate which commenced in late 1988 and involved the moving of three villages which, through their exclusion, the fence would not have protected otherwise. The ward has an area of 550 km^2 of which approximately 10% (5,000 ha) are protected by the fence. Following completion of the fence, crop raiding incidents fell by 65% (122 incidents in the 1990/91 season compared to only 42 in the following season, 1991/92) (Mackie 1992). Arguably, the effectiveness of the fence could be improved if the open end of the fence were to be closed but continued monitoring is necessary to ensure such closure is cost-effective.

Prior to the erection of the larger encircling fence, a smaller fence was installed around a 3 ha irrigation plot which produced green crops at the height of the dry season. This fence was severely challenged during the first dry season of its erection but no elephant entered the irrigation plot. Following reaping of the crop, villagers returned to their traditional wet season fields and abandoned maintenance of the fence. Not only did elephant and other animals penetrate the fence but much of it was either badly damaged or swept away by the seasonal rains. Technically, both these initial fencing projects have been successful and although there were some construction defects, these were easily rectified.

No economic cost-benefit analysis has been undertaken for the Negande fences. Whilst the most important perceived benefit is the reduction in crop losses there is no quantification of the economic saving thus made, especially when the costs offence construction and maintenance are taken into account (Jansen 1992). Moreover the real economic benefit may well be the elephants saved from being destroyed as PAC animals. Further fencing programmes are planned for the other major settlements in Omay (Figure 1), but cost-benefit analyses are essential prerequisites to their implementation.

ZONATION OF LAND USE

The longterm conservation of elephant will depend very much on an integrated approach to land use, which takes into account not only their presence, but also their management and productive role in the economy of the district. There are two levels of land use planning and zonation in the context of elephant and other wildlife management activities in Omay which need to be considered; firstly at the district level and secondly at the ward and village level. To date, planning has occurred at both levels but not necessarily in full consultation with the community in the case of the former and largely by agricultural extension officials in the case of the latter but without taking into account all the implications of wildlife management.

DISTRICT LEVEL LAND USE PLANNING

The district has embarked upon a plan for the development of tourism based on wildlife which includes proposals for zonation for different uses (Taylor 1 990b). The salient features of these proposals include:

- The formal establishment of a wildlife sanctuary within the existing Bumi Hills State Land where wildlife presently enjoys complete protection. (Bumi Hills is an important international tourist destination with spectacu1ar views of Lake Kariba amidst a full spectrum of wildlife. Here, elephants are especially important as a tourist attraction.)

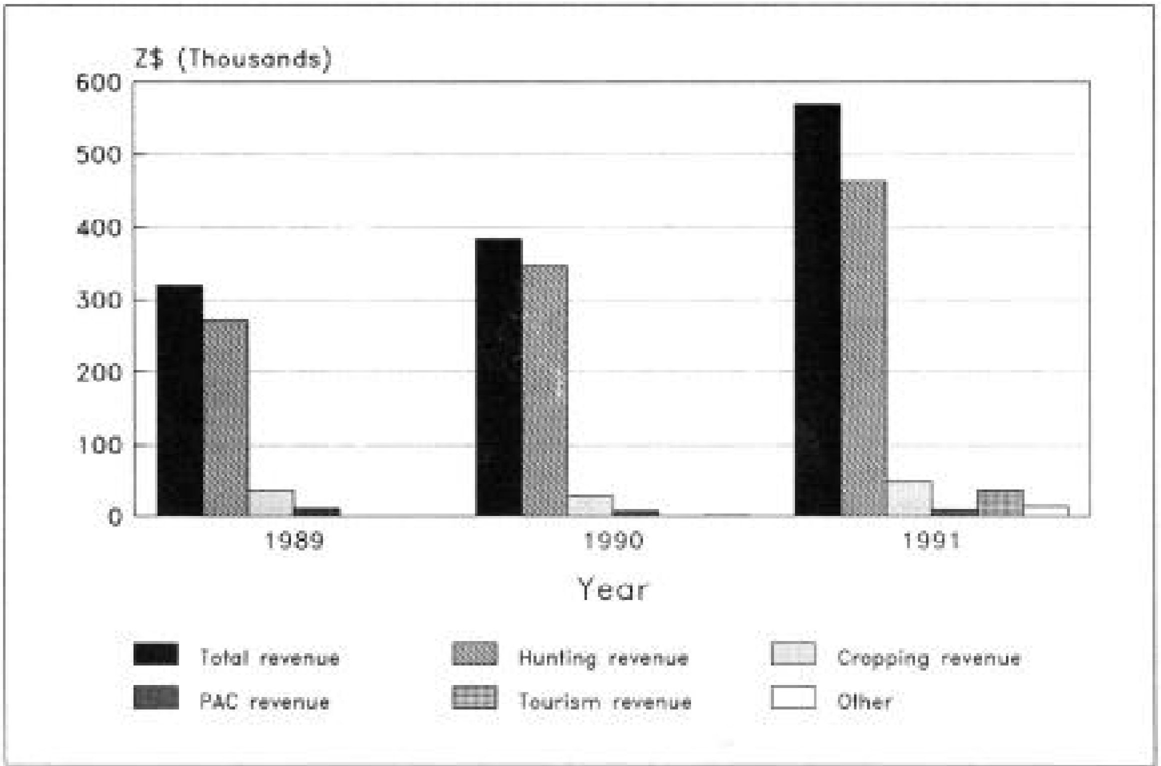
- The zonation of a range of hills, the Mapongolas, as a Conservation Area which would exclude human expansion and settlement and provide an effective link between Matusadona National Park on the Ume River in the east and Chizarira National Park on the Sengwa river in the west. This link would be particularly important for the longterm maintenance of genetic variability within the Sebungwe elephant population as a whole.

- The establishment of a number of lease sites with lakeshore frontage for the establishment of small (less than 20 beds) rustic camps for commercial safari operators who would make use of adjacent Parks and Wild Life areas, namely Lake Kariba Recreational Park and Matusadona National Park for walking, photographics and game viewing.

- The formal recognition of a number of key conservation areas including unique stands of vegetation such as thickets which constitute important habitats for elephant, crocodile breeding areas on the lakeshore, and smaller areas of wetlands and minor escarpments in the Omay hinterland.

Much of the remainder of the area would be devoted to safari hunting which, in terms of consumptive resource use, is an extremely conservative land use option and one in which elephants are a key component. Areas designated for cropping for meat production (Taylor 1991 b) would not conflict with other options such as tourism. Overall zonation would be linked to development objectives which are compatible and internally consistent.

Figure 5. Revenues from wildlife management activities in Nyaminyami District, 1989-1991. All values in Zimbabwe Dollars (Z$)



Elements of this planned zonation are in the process of being adopted. For example, five 10 ha lease sites have been identified for non-consumptive tourism, advertised in an open and competitive market and private sector operators objectively selected. The district is now entering into joint venture partnerships with these operators who will not only generate additional revenues for the district but also provide local employment (Jansen 1990; Taylor 1992).

AGRICULTURAL PLANNING AT WARD AND VILLAGE LEVEL

As much as 80% of Omay is unsuitable for arable agriculture due to poor soils and broken terrain. Settlement presently extends over some 10% of the district but this is expanding due to illegal in-migration (Taylor in prep.). Consequently there is a need for appropriate and participatory subdistrict level land use planning: and officers of the Department of Agricultural Technical and Extension Services (Agritex) are currently preparing residential, arable and grazing area plans for individual households at a ward and village level.

Whilst this involves greater community participation than does the district level planning, there has been a failure on the part of the agency involved to recognise the increasingly important economic role wildlife is beginning to play in the district. Consequently much of the planning at this level is being undertaken without due cognisance being given to wildlife. For example, grazing holdings are being allocated in anticipation of cattle introductions (cattle are excluded from most of Omay since tsetse fly has been eradicated only recently), rather than as holdings for wildlife. The major concerns surrounding the introduction of cattle relate to the appropriatc numbers that should or can be supported in relation to ecological sustainbility, competition for resources with wildlife and wildlife predation upon cattle, as well as upon other domestic livestock.

WILDLIFE REVENUES

Over the three ycars 1989-1991, Nyaminyami District has earned Z$1,273,503 (US$467,397) from its wildlife. Moreover, in each successive year these revenues have increased, albeit only slightly in real terms (Figure *5)*. Earnings have come from a number of management and utilization activities, including hunting, cropping for meat production, problem animal control and, more recently, from tourism. Elephants are very much at the centre of these earnings, in particular, sport hunting. Not only does hunting generate 85% of the total wildlife revenue (Figure 5), but elephants themselves contribute 38% of the total value of the hunting quota (Table 3). Even though PAC contributed only 2% to income, this again was generated mostly from elephants shot on control. More importantly, it serves to illustrate the imperative of avoiding shooting elephants on PAC wherever possible and rather to convert them to safari animals as described above. Income is increased nearly twenty-fold, and the prospects for sustaining and conserving this valuable resource are much improved.

Present guidelines issued by DNPWLM (Anon. 1991) in respect of wildlife revenues earned by districts with appropriate authority under the CAMPFIRE programme require that District Councils retain no more than 15% of gross revenue as a levy; that up to 35% may be allocated to district level capital and recurrent expenditure, provided such expenditure is linked to wildlifc management; and that at least 50% of revenue should be returned to wards, villages or households. Nyaminyami District has yet to meet these requirements. Only in 1989 was the ward dividend in excess of 50% of revenue and of the total Z$ 1 .27m earned to date only 39% has been returned to the wards.

DISCUSSION

Despite a growing human population in Omay, elephant numbers in the district have remained high,

Table 3: The proportion of revenue earned from the hunting quota of elephants in relation to the total value of the quota in Nyaminyami District.

YEAR	TOTAL VALUE OF QUOTA (Z$)	VALUE OF ELEPHANTS (Z$)	%
1989	189,400	83,000	43.8
1990	238,100	90,000	37.8
1991	223,100	75,000	33.6

at around 0.7/km^2 over the past 12 years and indeed have probably increased. Their continued existence, whilst ultimately linked to a limit in human population growth and immigration, is very much dependent upon human tolerance towards their presence. Such tolerance in Omay is being achieved through placing an economic importance on elephants which presently is being realised through high valued international safari hunting. To retain this value, limits have to be placed on the numbers of elephants destroyed in protecting crops.

During 1992 a quota was set for the number of elephants which could be shot on PAC and four such animals were successfully hunted by safari operators as trophy elephants following the approach described in this paper. Moreover, the District Council agreed to the revenues earned from these elephants being returned to the affected communities. Cheques varying in value from Z$13,000-Z$22,000 for each of the elephants shot were paid over to ward wildlife committee chairmen at the end of the rainy season by the safari operator concerned. 1n this way the offending crop raiding elephants were effectively dealt with; people benefited directly from the money earned through hunting; the safari operator was able to market more elephant and PAC was kept within sustainable limits.

The more benign forms of tourism based on game viewing, walking and photographic safaris are likely to become increasingly important in Nyaminyami as the joint venture partnerships come into operation over the next few years. Although this activity earned the district only 6% of its income in 1991, it is anticipated this will exceed the hunting revenue threefold over the next five years. Projected total earnings are likely to be around Z$6m per annum with non-consumptive tourism and hunting contributing Z$4.5m and Z$ I .5m respectively (V.R.Booth pers. comm.). Elephants, of course, are an essential and key component to such revenue generation, together with the full spectrum of spectacu1ar wildlife and scenery which characterise the district.

Earning money from wildlife can be achieved with a great measure of success as Nyaminyami District has demonstrated, and elephants are very much a part of that. But this is only one-half of the task at hand. It is even more important that the district ensures the wildlife revenues are returned, to the appropriate beneficiaries who are the rural poor and peasant farmers who have to live alongside the wildlife which has been so much of a problem to them in the past. Returning such benefits to people who bear the cost of living with wildlife is at the heart of the CAMPFIRE programme and this has yet to be meaningfully achieved. Not only must benefits be returned, however. There must also be greater participation on the part of local inhabitants and communities in the control and management of wildlife so that they become both responsible and accountable for their wildlife and wild-land resources.

CONCLUSION

Elephant conservation is as much an institutional problem as it is a technical one and its resolution lies in the hands of local people who will make the ultimate decision as to how they finally use their land. That decision will be strongly influenced by what benefits from wildlife, and elephants in particular, perceived and actual, accrue to individual householders and farmers. Only when perceived as an asset will the conservation of elephants truly become part of a locally developed and integrated approach to land use, and part of an economy that makes wise and sustainable use of natural resources.

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The Cost of Conserving Elephants

Nigel Leader-Williams

Department of Wildlife, P. O. Box 63150, Dar es Salaam, Tanzania

ABSTRACT

African elephants attract a variety of economic values, whether actual or potential. Furthermore elephants, to varying degrees in different range states, live both within and outside protected areas. 1n both situations, elephants are usually in conflict with man. Consequently range states have to expend funds if elephants are to be protected throughout their range. As a general rule, it was necessary to spend around US$200 per km^2 of protected area in 1981 to prevent the decline of elephants from severe commercial poaching for their ivory. Following the ban on international trade in ivory in 1989, it is imperative that costs of conserving elephants in and out of protected areas in different range states are quantified. Given that ensuring the success of law enforcement efforts is probably the most important management objective for the future conservation of elephants, and given the amount of less relevant research undertaken on elephants, greater emphasis needs to be placed upon collecting and analysing data on this topic.

INTRODUCTION

African elephants attract the interest of a wide variety of people, ranging from local farmers, meat hunters, commercial ivory poachers and safari hunters to tour operators and tourists, scientists and conservationists. Depending on one's perspective, elephants attract a variety of economic values, whether actual or potential, and can in part recover their costs through earnings from tourism, hunting, culling and so on (Barbier et *al.* 1990). Furthermore, elephants, to varying degrees in different range states, live both within and outside officially gazetted protected areas. 1n both situations and especially in the latter, elephants tend to be in conflict with their human neighbours. Since the passage of game laws, elephants have been seen by local people as a valuable source of income or meat from which they have been disenfranchised. With low incomes and the spiralling price of ivory of world markets prior to 1989, the incentive to hunt elephants was high throughout much of Africa (Milner-Gulland & Leader-Williams, 1992). Since the ivory ban in 1989, the available evidence generally suggests that commercial poaching for ivory has declined (Dublin & Jachmann, 1992), at least temporarily. It remains to be seen whether predictions that alternative markets will develop are to be fulfilled (Barbier et *al.* 1990). Outside protected areas, elephants are often in direct conflict with man for his land and crops, and considerable numbers of elephants are still shot annually throughout Africa as cheap sources of meat to compensate for real or fabricated crop damage.

Given the above, it has been appreciated that funds and resources need to be expended upon maintaining the integrity of protected areas in Africa, including the elephant component (Bell & Clarke, 1986; Leader-Williams & Albon, 1988; Parker & Graham, 1989). Outside protected areas, investments in elephants are also necessary to promote schemes that secure jobs locally and that give ownership and use rights to local people, such that some proceeds from safari hunting and tourism are returned to local people (Martin, 1986; Lewis et *al.* 1990). This short review examines the few available data that quantify costs of maintaining elephants and makes suggestions for placing research on this topic high on the agenda of the African Elephant Specialist Group (AESG).

COSTS OF PROTECTING ELEPHANTS FROM COMMERCIAL POACHERS

The former African Elephant and Rhino Specialist Group (AERSG) placed considerable emphasis during 1981 and 1987 upon collecting data from range states on the resources and budgets they devoted to their protected areas (Cumming et al. 1984, 1990). These data were obtained from questionnaire replies that attracted a disappointingly low response rate (see Table 1). It should be noted here that the data collected in these surveys represent the total manpower and budgets used by conservation agencies for a variety of activities (including road maintenance, routine monitoring, sanctioned culls, law enforcement patrols, burning and fire control, and so on). Therefore, these figures do not represent resources that can be attributed specifically to conserving elephants, but are those used by conservation agencies attempting to maintain the integrity of their protected areas, of which elephants are such an important component. Following the collection of the first survey data by AERSG in 1981, it was suggested that shortage of manpower and of financial resources on the part of national conservation agencies was a major constraint to the successful conservation of the African elephant (Cumming et al. 1984). Rules-of-thumb had suggested that around one man per 20 km^2 of protected area or the spending of around US$200 per km^2 was necessary to achieve successful conservation of valuable species like gorillas, rhinos and elephants (Bell & Clarke, 1986).

A detailed study of law enforcement undertaken in Luangwa Valley, Zambia, from 1979-1985 confirmed that levels of manpower and resources of this order were indeed necessary to protect elephants from heavy commercial poaching (Leader-Williams & Albon, 1988; Leader-Williams, 1990; Leader-Williams et *al*. 1990). Findings from Luangwa Valley were extrapolated to other African range states, using data on numbers of elephants during 1981-87, together with estimates of budgets and manpower in national conservation agencies in 1981 extracted from surveys undertaken by or on behalf of AERSG (Cumming et *al*. 1984, 1990; Bell & Clarke, 1986; Douglas-Hamilton, 1987). These continent-wide surveys of elephant numbers are prone to considerable methodological problems, but given the plight of the African elephant, I took the approach that it was preferable to learn from the best available estimates than to argue about data quality. There was a wide variation in the budgets allocated by central governments to national conservation agencies in 1980 and in their staffing levels, both absolutely and in relative terms when compared to the total areas under protection. Using data from 14 countries from which there were both a measure of change in elephant numbers and of budgets, it was apparent there was a direct relationship between estimated declines of total numbers of elephants and spending, corrected for total area (Figure 1). To have achieved a zero decline of elephants, the relationship predicted that 1981 spending levels should have been US$215 per km^2 (Leader-Williams & Albon, 1988; Leader-Williams, 1990).

Table 1. The rite of response to AERSG questionnaires on the resources available to national conservation agencies In 1981 and 1987 (from Cumming et al. 1984, 1990).

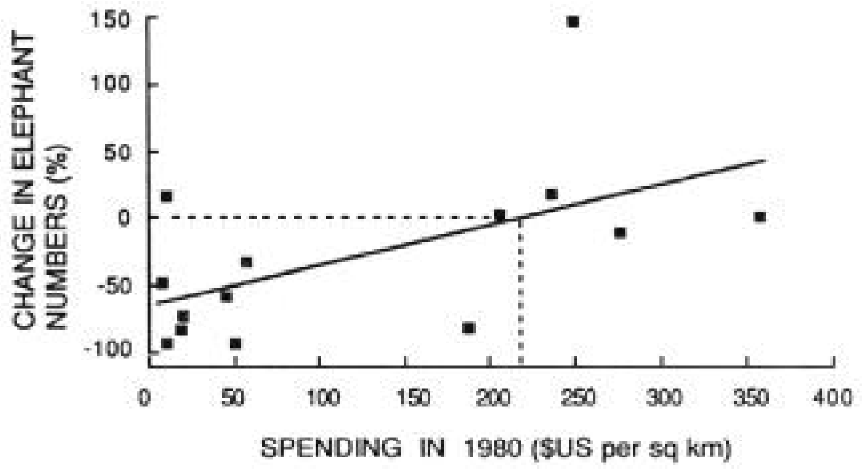
	1981	1987
No. Questionnaires	29	47
No. Replied	15	14
No. Fully covered by both questionnaires	3*	
No. Half covered	2	

**Additional data was provided for Malawi 1n 1981 by Bell and Clarke (1386), which is included 1n Table 2.*

The relationship between spending and success in protecting elephants was significant but only explained 32% of the variance. Clearly many other factors could have been involved here, and throwing conservation funds at a problem was no guarantee of success. Staff of the wildlife authorities need motivation such that they themselves do not become involved in killing elephants and that they spend an effective amount of time on patrol. Patrols must be balanced between field patrols that ensure elephants receive sufficient protection and the more cost-effective investigative patrols which ensure that offenders are caught. The degree of challenge faced by elephants in different situations also varies due to such factors as the size and density of elephant populations (and their attractiveness to commercial poaching operations), the degree of political stability and availability of weapons in particular range states, the severity of penalties in range states and the likelihood of apprehending those entrepreneurs or senior politicians involved in organising the poaching, and so on (Bell & Clarke, 1986; Douglas-Hamilton, 1987; Parker & Graham 1989; Leader-Williams et *al*. 1990; Dublin & Jachmann, 1992).

One of the many major flaws with the data in Figure 1 was that it was not possible to separate out the costs and successes of protecting elephants in and out of protected areas. There are many reasons for this, not least the institutional differences between range stages in jurisdiction of the wildlife authorities and what actually comprises a protected area in different countries, and the difficulty of stopping elephant censures at protected area boarders.

Figure 1. Estimated declines of total numbers of elephants in relation to spending in 1980.



Making the distinction between costs of protecting elephants in different categories of land is clearly one of great importance, as evidenced, for example, by Botswana which was one of the outliers in Figure 1. Botswana's wildlife authority spent very little per km^2 of protected area yet the country's elephants, living largely outside protected areas, appeared to have increased significantly (assuming the censuses were correct). One study, also from Luangwa Valley, documents the costs of protecting elephants living amongst humans outside protected areas (Lewis et *al.* 1990). The employment of village scouts and the initiation of a range of activities during 1985-87 that provided revenue to villagers from wildlife cost US$22 per kin^2, and resulted in reduction of poaching of elephants, as evidenced by carcass finds. This study demonstrates the potential of reducing the costs of conservation if conflicts can be resolved outside protected areas, but future studies of this kind should be accompanied by more appropriate indices of the success of conserving elephants than carcass finds that are not corrected for population size.

CHANGING CIRCUMSTANCES

The figure of US$215 gives some idea of the sum it was necessary to spend to prevent the decline of elephants in protected areas during a period of intense commercial ivory poaching during the early and mid 1980s. Several events have occurred since that time. On the one hand, with inflation the 1981 sum of US$215 is now equivalent to US$340. On the other hand, the African elephant was moved to Appendix I of CITES in 1989, and the demand for ivory appears to have plummeted in Europe, America and to have fallen by 50% in Japan. This might have been expected to reduce the incentive of commercial poachers to kill elephants for their ivory within protected areas throughout their range. However, evidence from certain southern states suggests that there is still sufficient incentive to poach elephants (Dublin & Jachmann, 1992).

When it was time to ask the question "has the ban worked?" to provide delegates to the 1992 CITES Conference with scientific evidence to enable them to make an informed decision on whether to vote for continuation of the ban, it was like drawing teeth to provide that evidence. Visits to six range states revealed a paucity of relevant data and, despite all the research that has been conducted on elephants to date, the information needed to develop proper management and conservation strategies is simply not collected in the vast majority of key conservation areas (Dublin & Jachmann, 1992). This remains a sad indictment upon the scientific community and national wildlife authorities, for exhortations to carry out research that is relevant to management have been made for many years (MacNab, 1983; Bell, 1986). Indeed when such research is carried out, it has proved to be of considerable interest to academics (Leader-Williams & Albon, 1988; Leader-Williams *et al.* 1990) as well as hopefully being of some practical importance.

From my perspective, I would hope for improvements in the way such questions are approached at two levels, namely the micro-level, comprising individual populations within range states, and the macro-level, comprising data across range states. At the micro-level, Luangwa Valley in Zambia remains the only conservation area in Africa where a concerted effort has been made over the course of more than a decade to collect in-depth data on law enforcement input and poaching levels (Leader-Williams *et al.* 1990; Bell et *al.* in preparation). I believe it is vital that such data are collected in other areas that encompass elephant populations both within and without protected areas and at different levels of challenge and conflict, and as far as possible in a standardised manner that facilitates comparisons between areas both at national and international levels.

At the macro-level it is important that efforts of the AESG focus on ensuring further co-operation between range stages in pooling and sharing their data. The African Elephant Database contains a considerable quantity of information on censuses and population sizes. Yet, when attempting to compile an updated figure similar to Figure 1 for inclusion in this paper, I found there were insufficient data on budgets available to different range states in 1987 that could be matched against reliable changes in population size between 1987 and 1991 even to construct a graph. I hope, therefore, that my earlier comments on the disappointing response of range states to requests for such information (Table 1) will be viewed more positively. An updated graph would have provided an opportunity to examine whether, over the period embracing the ivory ban, it appeared that the challenge to Africa's elephants had lessened in terms of resources necessary for successful conservation. Such data are vital to the future of the African elephants and necessary for AESG to have at hand in order to shore up the scientific basis of important policy decisions.

1n making this point, it must be remembered that conservation efforts in Africa are taking place against a background of declining government budgets to wildlife authorities (Table 2). Whether considered as actual budgets or when corrected for inflation, or as manpower, the budgets and resources of five countries which answered both 1981 and 1987 questionnaires

Table 2. The declining budgets available to national conservation agencies (from Cumming et al. 1984, 1990; Bell & Clarke, 1986). The budgetary data for 1981 is shown both in actual terms (shown as 1981) and in real terms, corrected for inflation with a base of 1987 (shown as 1981').

Country	Year	Area protected (sq km)	Total budget (US$x1000)	Budget / area ($/sq km)	Field force (N men)	Area / man
Central African Republic	1981	57,000	460	8.0	167	341
	1981*		576*	10.1*		
	1987	270,000	1,267	4.7	400	675
Mozambique	1981	32,500	600	18.6	305	105
	1981*		751*	23.1*		
	1987	65,700	448	6.8	58	1133
Zimbabwe	1981	47,000	13,000	276.6	1894	24
	1981*		16,270*	346.2*		
	1987	47,000	9,117	194.0	1380	34
Malawi	1981	11,000	500	45.0	240	46
	1981*		626*	56.9*		
	1987	10,800	526	48.7	191	56

have declined in real terms. This shortfall may in part be provided by increased external donor assistance to range states. For example, elephant action plans for 33 range states requested assistance of the order of US$360 million through the African Elephant Co-ordinating Group in 1991, and perhaps one-tenth of this sum may have been forthcoming after one year. Given such funding shortfalls, it can only be stressed again that it is incumbent upon AESG and its members to ensure that appropriate data to answer such fundamental questions as "how much funding is required to conserve elephants?" and "has the ivory ban worked?" are collected and co-ordinated. By and large I believe we have failed to date and so let us work quickly to ensure that this state of affairs does not continue for much longer.

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The Introduction of Elephant into Medium-sized Conservation Areas

Jeremy L. Anderson

KaNgwane Parks Board, P.O. Box 1990, Nelspruit, 1200, South Africa

INTRODUCTION

There is no clear definition as to what constitutes a medium-sized reserve, so for the purposes of this paper it will be regarded as a reserve greater than 5,000 hectares but smaller than 100,000 hectares. There are currently a number of reserves in South Africa, the TBVC and National States, which fall into this category. As most of these reserves comprise habitats suitable for elephant, it can be appreciated that there is considerable potential for the re-distribution of the species in the region.

JUSTIFICATION FOR THE INTRODUCTION OF ELEPHANT

The re-introduction of elephant should only be considered if one of the objectives of the reserve is to re-establish the wildlife community which formerly occurred in the area, and that sufficient grounds exist to accept that the species did formerly occur. Once this has been established, there are secondary reasons which should be considered, namely the ecological role which elephants will play in the system and the value of the species for visitors.

Recent evidence has indicated (Whateley & Wills, in prep.) that the prolonged absence of elephant from the Hluhluwe/Umfolozi Complex has been a major reason for vegetation succession towards thicket and close woodland. Further investigation may show that this phenomenon is widespread.

It is considered very acceptable to re-establish elephants primarily for their visitor appeal. Revenues generated from tourism are becoming increasingly important in assuring the availability of conservation areas. If the re-introduction of elephant is likely to be a positive factor in “balancing the budget”, it should be automatic.

The experiences of the large scale re-introductions into Pilanesberg National Park and the Hluhluwe/Umfolozi Complex, described below, perhaps encapsulate all the problems that are likely to arise in a project of this nature.

PILANESBERG NATIONAL PARK

The first introduction of elephant into Pilanesberg was not preceded by a specific plan of operation. As summarised in Table 1, four animals of between three and five years of age were introduced from Addo National Park in 1980. As the perimeter fence of the game reserve had not been completed they were released into a holding camp of approximately 700 hectares. Shortly after their release, an incident occurred during which the animals were harassed and one young male broke through the perimeter fence. Three days later, he had traveled over 50 kilometres and was involved in the tragic death of a farmer.

The remaining animals were recaptured and held in a small boma to await the completion of the perimeter fence. During this period they were fed contaminated food and one animal died. The two survivors were immediately released into the original holding camp. This happened in September 1980 when food quality and availability were at their lowest, compounded by the fact that the holding, camp was heavily stocked with other ungulates. Within days, one of the two had died of starvation and the lone survivor was recaptured and again transferred back to the boma. Following a change in senior management of the Park, the animal was released in December when food quality and availability were optimal. Thereafter, no further problems were experienced with the animal.

After the perimeter fence had been completed, a further introduction was planned with animals to come from the Kruger National Park. A large and substantial boma was constructed in the centre of the Park, and the animals which were received in June 1981 were held until November before their release. Several of these animals had been selected for overseas export when captured and were considered to be too small for release into the wild. However, with the

Table 1. The Introduction and known mortality of elephant to Pilanesberg National Park.

Year	Number	Age	Source	Recorded Deaths
1980	4	Juvenile	Addo National Park	3
1981	18	Juvenile	Kruger National Park	5
1982	2	Adult	Kruger National Park	0
1983	14	Juvenile	Kruger National Park	1
1983	2	Juvenile	Namibia	0

cancellation of their purchase order, they were included for introduction. It was not surprising that 5 of these smaller animals did not survive the following winter.

The following year, 1982, 2 circus trained animals, both 18-year-old females originally from the Kruger National park, were- successfully re-introduced (Moore & Munnion, 1989). Their re-acclimatisation to the world was a gradual process accomplished most successfully by their trainer and owner Randall Moore. On their release, these animals took over the leadership of the younger animals, released the previous year, and behaved like wild elephants.

1n 1983 the introduction of a further 14 animals from Kruger National Park took place. These were larger than those of the first introduction and only one animal was lost, suspected to have been killed by a rhino. On their release, the remaining animals joined the group led by the 2 adult females described above.

During the same year a further 2 tame Namibian bull elephants of approximately 5 years of age were donated by the S.A. Police. These both settled down without any problem.

The first calf was born in 1989 to one of the animals introduced directly from Kruger. A second was born during 1990, and a third early in 1991.

The Pilanesberg elephants have remained fairly shy and keep to the wilderness zone of the Park. Recently, a group of 16 young bulls has formed which ranges more widely than the females and young (Keffen, pers. comm).

Despite the debacle of the first release, the re-introductions are considered to be highly successful overall. The mortalities in the Kruger National Park introductions were probably because many animals were too young to survive without supplementary feeding.

HLUHUWE/UMFOLOZI COMPLEX

The re-introduction of elephant into the Hluhluwe/ Umfolozi Complex commenced in 1974 with strong motivation from the Field and Research *staff.* After satisfactorily resolving the concerns of the Parks Board’s senior management, and drawing up a detailed plan for the introduction and subsequent monitoring, the first animals were re-introduced in July 1981.

They were released into a holding boma of 20 m^2 and after *5* days they were released into a 200 m^2 paddock for 2 months.

By November 1985, 30 animals had been introduced to Umfolozi with 27 surviving, and 26 to Hluhluwe with 18 surviving.

Much of the concern about animals breaking out of the complex was allayed by the experience gained through the existing introduction. Greater emphasis was instead attached to the role which elephants would play in the vegetation management of the area. This motivated the decision to increase the numbers of introduced animals to 150. The programme was implemented in subsequent years and the introductions are summarised in Table 2.

FACTORS TO BE CONSIDERED 1N ANY RE-INTRODUCTION

Habitat evaluation and stocking levels

Woodland is considered to be an essential element, because it has been favoured by all the introduced populations.

Knowing that the introduced populations eventually had to be managed, a set number of animals was introduced to Pilanesberg, based on the desired carrying capacity.

1n the Hluhluwe/Umfolozi re-introduction, the possible beneficial impact of elephant in the control of thicket encroachment was highlighted as one of the major reasons to support the introduction.

Attitude of neighbours

The attitude of a reserve's neighbours towards any proposed re-introduction of elephant must be considered. Attitudes will be affected by the type of land-use being practised and the socio-economic situation of the community. For example, sugar farmers will view the introduction of elephant differently to cattle ranchers.

To avoid any adverse attitudes, introduction of elephant should be preceded by an information programme in the community informing the people about the operation, the reasons behind it and the measures which will be taken to safeguard the interests of the community.

Fencing

Consideration must be given to the standard of the perimeter fence. As a general rule, the smaller the reserve the more substantial the fence required. This is because in small reserves there is likely to be greater degree of contact with the fence.

1n some reserves, such as Pilanesberg, the fences which have been erected are strong enough to be physical deterrents. However, it has been shown that electrification of fences to form impenetrable barriers is not essential, provided that animals are "trained" to respect a fence.

Bomas

1n all the re-introductions into medium-sized reserves, the animals have been held for varying lengths of time prior to release.

It is advisable to construct the training boma to appear as similar as possible to the boundary fence, although it may be substantially stronger.

1n Pilanesberg and in the Hluhluwe/Umfolozi the bomas were not electrified but were stronger than the boundary fence, to which they bore little resemblance. In Mthethomusha, in KaNgwane, the boma looked more like the perimeter fence but was electrified. Also, the boma fence in Mthethomusha was visually strengthened with game capture plastic which was only removed four days after the released animals settled down and had already been in contact with the electric wires.

The animals should stay for at least a month in the bomas before their release. The release itself should be accomplished by simply opening the bomas and allowing the animals to find their own way out. Disturbance during the release should be kept to a minimum.

Timing the release

The phenology of the vegetation must be accounted for when the animals are released. Whenever possible, the release should take place when there is widespread water and when food quality is high, i.e. shortly after the commencement of the rainy season.

Table 2. The introduction and known mortality of elephant into the Hluhluwe/Umfolozi Complex.

Year	Hluhluwe	Umfolozi	Recorded Deaths
1981	8	-	4
1983	8	-	4
1984	10	-	1
1985	-	30	7
1986	6	-	1
1987	18	-	0
1988	-	34	5
1989	35	-	0
1990	-	23	0

Genetic Considerations

1n planning their objectives, most managers of conservation areas take cognisance of the World Conservation Strategy and its goal to "preserve genetic diversity". Much attention is also given to preserving the genetic integrity of species.

1n Pilanesberg, the first animals to be introduced were from Addo. When the surviving Addo bull was due to be joined by a larger introduction from the Kruger National Park, the idea of removing him to avoid mixing Addo and Kruger genes was seriously considered. However, it was concluded that, historically, there must have been contact between these populations. Therefore by allowing them to mix again, the gene flow - which existed before the populations were fragmented - would be restored. The later introduction of two males from Namibia was viewed in the same way.

All other introductions into medium-sized reserves have been confined to animals from the Kruger National Park. These populations will not improve the genetic diversity of the Kruger population.

Animal size

The larger the animals are, the greater their chances of survival. Currently, animals of up to 2.3 metres high at the shoulder are being successfully caught and translocated from both the Kruger National Park and the Gonarezhou in Zimbabwe.

Two re-introduction programmes undertaken since 1991 have illustrated the lower mortality when larger animals are moved. 1n Songimvelo Game Reserve there were no losses in the re-introduction of 20 animals, and in Madikwe National Park 185 animals were re-introduced with only 6 lost (4 which were due to accidents). The 2 trained adult animals introduced into Pilanesberg have added a new dimension to re-establishing elephant populations.

Group size and leadership

Because of the close-knit matriarchal social structure of elephants, there is considerable stress on young animals which are relocated. Large animals in a group are followed by the younger ones, as a substitute for parental leadership. The leadership by the two adult cows in Pilanesberg over a large group of young animals illustrates this need well.

The view expressed by Wills (pers. Comm..) that larger groups experience lower mortality rates than smaller groups should be noted, especially where animals are to be introduced into areas which harbour lion and spotted hyena.

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PERSONAL COMMUNICATIONS

Dr R. Keffen, Pilanesberg National Park, P.O. Box 1201, Mogwase, 0302, Bophuthatswana.

A. Wills Esq. Bophuthatswana Parks Board, Private Bag X2078, Mafikeng, 8670, Bophuthatswana.

Rhino Poaching in Namibia from 1980 to 1990 and the Illegal Trade in the Horn

Esmond Bradley Martin

WWF Regional Office, P.O. Box 62440, Nairobi, Kenya

INTRODUCTION

The black rhino population in Namibia has been increasing since the early 1 980s from around 400 to about 560, one of only two countries in Africa where there has been a notable success in black rhino conservation during this period (see Table 1). 1n the late I 970s, however, there was serious black rhino poaching, especially in northwest Namibia (also called the Kaokoveld), to meet the demand for the horn in Asia.

This paper will chronicle the anti-poaching efforts in the main regions for rhinos: Etosha National Park, Waterberg Plateau Park and the Kaokoveld; give numbers of rhinos poached in Namibia from 1980 to 1990; state how they were killed; give information on the trade routes for the horn through and out of Namibia; and record prices the poachers and middlemen received for the horn. Most importantly, the paper will examine how the non-government organizations and government authorities in Namibia severely reduced poaching by implementing new policies in the late 1980s.

These successful conservation strategies should be examined in detail by other wildlife departments in Africa to see whether they are appropriate in reducing rhino poaching elsewhere. Also, suggestions are made on how Namibia can raise more money to protect its rhinos which are likely to become further threatened by poachers in the near future.

THE BLACK RHINOS OF ETOSHA NATIONAL PARK

The largest number of black rhinos in Namibia are in Etosha National Park. (There are no white rhinos in this Park). From 1980 to June 1991 its rhino population grew from an estimated 275-350 to between 400 and 450 animals (see Table I). These are net figures, however, as some rhinos were translocated out to other parts of Namibia or exported, and poaching reduced the population by a minimum of 48 animals in that period.

The first recent serious poaching of Etosha's black rhinos occurred in 1984. Herero people armed with .303 rifles shot at least 15 animals during the day time and removed only the horns. This poaching occurred in the west of the Park, where most of the rhinos are to be found and because many Hereros live just outside. Also, a road gives access to the region. Unfortunately, little patrolling was done away from the main roads, there was insufficient staff in the area to act as a poaching deterrent, and no arrests were made (Allan Cilliers, Chief Conservation Official - Management - Etosha, pers. comm.).

No poaching was recorded in 1985 or 1986, but in 1987, poaching flared up once again. A Herero businessman from the Kaokoveld supplied .303 and G3 rifles to a gang of Hereros. The men stayed in the Park for about a day and killed seven rhinos, again on the western side. The middleman offered the poachers 200 rands ($98) for a pair of horns which weighed 3.5 to 4 kilos. This contact man in turn may have sold the pair of horns for up to 2,000 rands ($980) to middlemen in Kamanjab and Otjiwarongo towns just south of Etosha. From there, the horn may have gone to Windhoek and Lisbon. Two middlemen and several poachers were arrested (A. Cilliers, pers. comm.).

1n 1989, 23 rhinos were known to have been killed in the northwest of the Park by Ovambo and Herero poachers. Their contact men, Hereros and Ovambos, lived at Opuwa in the Kaokoveld and Oshakati in Ovamboland; they supplied food, guns, ammunition and transport. They offered 200 rands ($76) for a pair of horns. About five small gangs, usually consisting of only two people, spent between one and three days in the Park. They shot the animals during the day; and as well as the horns, for the first time in recent years, they also took some skin (A. Cilliers, pers. comm.) The contact men hoped to sell a pair of horns to Portuguese and Angolans in Windhoek for 2,000 to 4,000 rands ($760 to S 1,520). Most of the poachers and contacts were caught, however. Their sentences varied from six months to eight years in prison.

Table 1: Estimated Number of Black Rhinos in Namibia from 1980 to 1991.

Year	North-west	Etosha	Waterburg	Other	Total
1980	100 [1]	275 [2]	0		c.375
1980	100 [1]	350 [1]	0		450[1]
1982	66 [3]		0		
1983	65 [1]		0		
1984	66-76 [4]	>300[5]	0		400 [6]
1985		440 [1]	0		
1986	90-108 [7]	350 [7]	0		440-458 [7]
1986	90-95 [1]	340 [5]	0		430-435
1991	109 [4]	400-450 [5]	23 [8]	5 [9]	537587

Sources:

I Garth Owen-Smith, pers. comm.
2 Allan Cilliers, pers. comm. and IUCN, WWF, NYZS "African Rhino Group Action Plan for the Conservation of African Rhinos" (December 1981), unpublished, no page number.
3 Rudi Loutit, pers. comm.
4 Blythe Loutit, pers. comm.
5 Allan Cilliers, pers. comm..
6 David Western and Lucy Vigne, "The Deteriorating Status of Africa's Rhinos", Oryx, *Vol. XIX (October 1985), p.216.*
7 D.H.M. Cumming, R. F. Du Toit and S.N. Stuart, African Elephants and Rhinos: Status Survey and Conservation Action Plan, *IUCN (1990), p.9.*
8 Peter Erb, pers. comm.
9 Martin Britz, Chief Ranger, Hardap Game Reserve, pers. comm.

Note:

Most wildlife officials who have worked with rhinos in Namibia, many of whom read this paper in draft form, believe that there were approximately 275 black rhinos in Etosha Nationai Park 1n 1980. However, one person, Garth Owen-Smith, who carried out extensive field work on rhinos in the 1980s and is definitely a leading authority on the subject, believes that there were at least an additional 75 black rhinos 1n Etosha at that time. This figure is based on a census carried out by Ian Hoffmeyr and Garth Owen-Smith between May and November 1980. The result of this census was a minimum of 350 black rhinos with about half occurring to the west of the power-lines crossing the Park (between Okaukuejo and Otjovassandu). However, senior officials of the Directorate of Nature Conservation later cast doubts on this figure (G. Owen-Smith, pers, comm.).

Whatever number is correct, the black rhino population in Namibia has been expanding at least from the middle 1980s until today.

Photo credit: David Coulson

Desert rhinos of Damaraland near Uniab riverbed.

The following year, only two animals were poached, one in the west and one in the east. In the west, a .303 rifle was used by Herero or Ovambo hunters. In the east, a businessman in Oshakati supported the hunters. In both cases, the horn was most likely sent to Portuguese traders in Windhoek (A. Cilliers, pers. comm.).

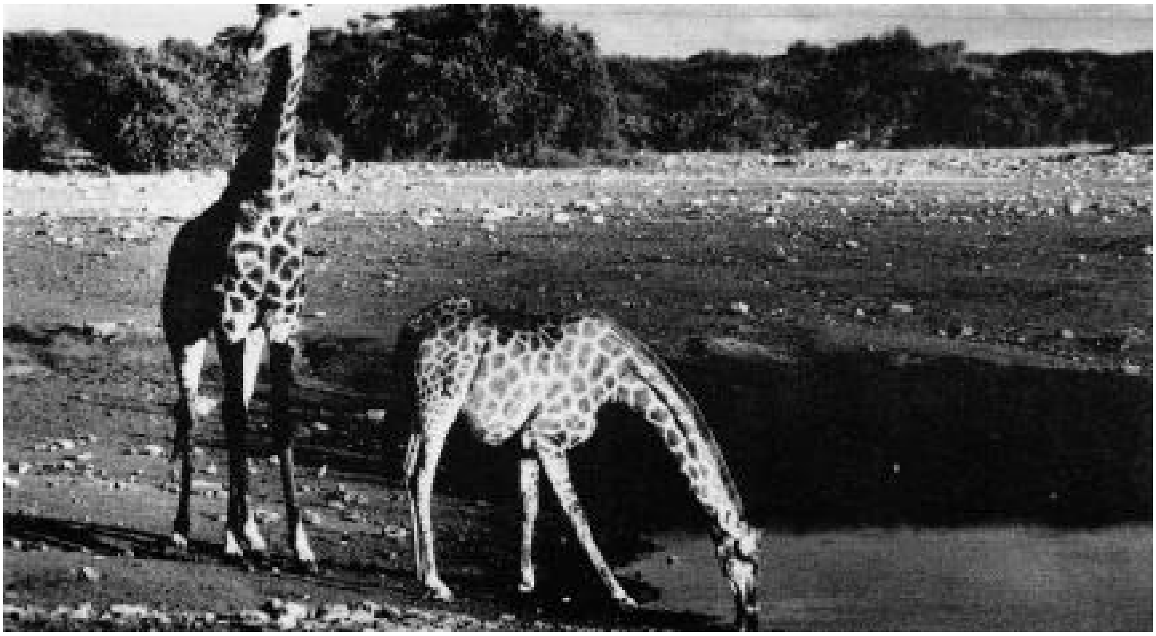
This sharp decline in rhino poaching in 1990 was due to new policies implemented by Etosha Park's senior staff. Up until 1989, the worst year for rhino poaching in Namibia as a whole, Etosha had had no special anti-poaching unit nor a formal intelligence gathering network. In 1989, anti-poaching staff was recruited which by 1991 consisted of 23 well-trained men. Half of these men are armed and they travel on foot, on horses or in vehicles. This unit spends *50%* of its time patrolling outside the Park, mostly in the north and west, obtaining information from informants in the villages. So far, the unit has been a success. This can be attributed to their honesty, motivation, discipline and good training. The officer in charge carefully chose these 23 men from 120 individuals to make up this elite anti-poaching corps. They are given certain bonuses including an extra allowance, and men working away from home are offered more benefits. Such a person thus earned in 1991 1,080 rands a month ($382), considerably more than the average scout.

Along with the new anti-poaching unit, a more formal intelligence gathering system was set up in Etosha. Relatively large sums of money were made available to pay for information. Data leading. to a conviction can earn an informer up to 6,000 rands ($2,143).

In order to increase the efficiency of the Park staff who handle the illegal activities within the Park, some have been sent for further training to the Po-lice Academy, to learn how to identify empty cartridge cases, fill out dockets, etc. Thus both in-house and external training of Etosha's staff has been greatly increased in order to combat poaching of rhinos, and also other animals such as giraffe, springbok, zebra and ostrich.

The Etosha authorities, especially Allan Cilliers, greatly increased their efforts in identifying individual rhinos in the Park. Although Allan Cilliers started to monitor rhinos in 1986, he expanded this work in 1989 after the severe poaching, by attempting to photograph each rhino in the Park. He used a flash camera with black and white film to photograph each rhino as it came to the waterholes at night to drink. This is only effective a few days before and after the full moon. Although, the photographers are on foot, incredibly, the black rhinos do not attack at night. It would be impossible to get so close to them during the day. Allan Cilliers has trained six people to carry out this photographic identification system. By July 1992, he had recognized 372 individual

Photo credit: David Coulson



A waterhole in Etosha National Park near Namutoni.

rhinos. He estimates that the Park holds 400 to 450 black rhinos and that they have been increasing at 5.6% per annum since 1986.

THE BLACK AND WHITE RHINOS OF WATERBERG PLATEAU PARK

Unlike Etosha which was proclaimed a game reserve in 1907, Waterberg Plateau Park is relatively new, having been created in 1972. It is only 40,500 hectares in size and consists mainly of a plateau. Most of the Park is covered with a nutrient-deficient Kalahari sand which supports a deciduous broad-leafed woodland.

The average rainfall is 450 mm a year, significantly higher than western Etosha. There were no black rhinos in the Park, however, until 1989, when 17 were brought in from Etosha and 10 from Damaraland. Unfortunately five died in the same year. One cow fell off a cliff, another female died in a boma following recapture after escaping from the Park, two young males perished from fight injuries, and one male died from stress after only a month in the Park. Further difficulties arose in February 1991 when the first black rhino was poached. A Herero, who earlier had broken into the tourist camp restaurant and had stolen various items, reentered Waterberg and shot an adult female with one bullet from a 9 mm pistol. Ten days later, he returned to the Park and took the horns, before the Park authorities had found the carcass The police were called in and about two weeks later the criminal was arrested (Peter Erb, Researcher, Waterberg Plateau Park, pers. comm.).

In order to prevent more rhino poaching, the Park authorities have increased foot patrols within Waterberg. Several ex-soldiers were transferred to the Park to improve the rhino monitoring. They usually go out for five-day foot patrols. The Park also now employs six trackers who work on foot or on horseback to monitor the movements of the rhinos. They carry radios, but not firearms. Often a ranger will accompany them. Informant money is available for intelligence gathering outside the Park as well, and contacts with the surrounding farmers are being improved.

During 1975 and 1976, 15 white rhinos were moved in from Umfolozi in Natal and in 1990, six more came from Kruger. Although, so far none of these has been poached, some died after translocation. The Kruger rhinos were not put into bomas after being caught, but were sent directly on a 37-hour journey to Waterberg. Four died soon afterwards, probably from stress (P. Erb, pers. comm.). The initial animals from Natal have done well. By July 1991, there were 40 in total.

THE BLACK RHINOS OF THE KAOKOVELD (NORTH WEST REGION)

The dry regions of Damaraland and Kaokoland together referred to as the Kaokoveld in northwest Namibia are home to the desert black rhinos. Because of the aridity of the area and therefore the general lack of browse, they move long distances for food and water, probably more than any other rhino population in Africa.

In 1970 there were at least 250 and possibly 350 black rhinos in the Kaokoveld, but by the end of the decade, most of them had been killed by poachers (Garth Owen-Smith, presently Director of Integrated Rural Development and Nature Conservation, pers. comm.). From 1975 to 1981, Hereros and Himbas used mainly .303 rifles to kill these animals. The buyers, who paid from 50 to 200 rands ($63 to $250) for a pair of horns, were farmers in the Kamanjab district, garage owners in the town of Outjo, as well as civil servants and businessmen in Okahandja, Swakopmund and Windhoek (Rudi Loutit, Senior Conservation Officer for Nature Conservation, North West region, pers. comm.). From Namibia, the horns were sent mostly to South Africa, especially to Krugersdorp and Pretoria. From there, the horns were exported to eastern Asia, especially to Hong Kong, China and Taiwan.

This intensive poaching of the desert rhinos, and to a lesser extent drought, greatly reduced their numbers so that by 1982, only 66 remained. The population, in recent times, had never before been so low. In that year, Garth Owen-Smith, who had previously been working in Etosha, was appointed by the Namibia Wildlife Trust to be the Senior Field Officer for Kaokoland and Damaraland. His main duties were to encourage the Damaras and Hereros to participate in wildlife conservation and to assist the greatly understaffed Nature Conservation Department with their anti-poaching activities. At the time of his appointment, there was only one government Nature Conservator (Chris Eyre) who was based at Khorixas and his Herero assistant (with no one stationed in Kaokoland) to patrol the whole Kaokoveld, an area of nine million hectares, four times larger than Kruger National Park. It was a scandalous state of negligence by the government authorities. No wonder that so many rhinos had been killed illegally. Soon after Garth Owen-Smith joined, the Namibia Wildlife Trust employed a full-time staff of four. The Trust spent most of its effort on setting up a community game guard system which actively involved the local community in nature conservation, and on patrolling in the western Kaokoland and Damaraland, the main locations for the rhino. From 1982 to early 1984 with assistance from the Trust, the Nature Conservation Department convicted 35 people in 16 cases of poaching or illegal possession of rhino horn and ivory (G. OwenSmith, "Namibia's Most Valuable Resource", *Quagga,* no. 7, Spring 1984, pp. 10-11).

In 1982 one dealer, the owner of a garage, was arrested by the police with 68 rhino horns. He was, however, only fined effectively 2,000 rands, a fraction of the value of the horns. This middleman was found in possession also of uncut diamonds and for this he was sentenced to two years imprisonment. It was -unfortunate that the judges did not also take poaching of the highly endangered desert rhino seriously (G. Owen-Smith, p. 11).

At this time, Garth Owen-Smith also developed a scheme of obtaining co-operation from the local people of the area, which has proved to be very effective and is being studied by conservationists in many parts of Africa. Specifically, his activities focused on involving the local population and thereby stopping them from poaching, as well as using their expertise such as tracking skills and local knowledge, to discourage or catch poachers coming in from the outside (G. Owen-Smith, pers. comm.). In 1983, headmen of regions with rhino poaching were asked to appoint their own game guards who were to patrol regularly the waterholes and check for any unusual activities. This worked very well. By early 1984 six auxiliary game guards were operating in northern Damaraland and western Kaokoland (G. Owen-Smith, p. 11).

After the introduction of these anti-poaching efforts, poaching of desert rhinos decreased sharply. In 1982 only two fresh carcasses were found (a cow and a calf which had been illegally killed) (G. Owen-Smith, pers. comm.). The following year several Hereros from Sesfontein shot three rhinos with .303 rifles. They sold the horns to middlemen for about 150 to 200 rands ($140 to $188) a pair. The middlemen probably sent some of the horns to Swakopmund and then to adjoining Walvis Bay for sale to eastern Asia. In 1984 only one rhino was poached and this was by a Damara who was a farmer and a local government employee (R. Loutit, pers. comm.).

In the early 1 980s, two men, a farmer and a garage owner, were the main buyers of these horns. The garage owner, as mentioned above, was caught dealing in diamonds and rhino horn, and was jailed. He reportedly ground up some of the horn inside his garage and exported the powder to Hong Kong (Tommy Hall, Principal Nature Conservation Officer, Damaraland, pers. comm.). The farmer was never caught, however, and could still be trading horn.

Between 1985 and 1988 only two black rhinos were poached in the Kaokoveld. This success was due to several factors. The number of auxiliary game guards was increased (the Endangered Wildlife Trust was supporting ten of these men in 1988). These guards regularly liaised with Garth Owen-Smith, Blythe Loutit (Director of Save the Rhino Trust), and officials of the Directorate of Nature Conservation in anti-poaching work and in obtaining information about poachers and traders. Senior officers of the Nature Conservation Department, especially Rudi Loutit and Tommy Hall also worked closely with everybody involved in protecting the desert black rhinos.

In 1989, poaching increased once again in the northwest of Namibia when seven animals were slaughtered. One of the reasons for this was the massive unemployment in the area, exacerbated by the return to the country of thousands of political refugees, plus the partial redundancy of many men formerly employed by the South West African Territory Force. Also, many more firearms became available. In the early 1980s between 1,500 and 3,000 .303 rifles were distributed to local headmen by the South African Defence Force and many were used for illegal hunting (G. Owen-Smith, pers. comm.). In addition, in 1987 and 1988 around 1,000 G3 rifles were handed out to people in Kaokoland by the government as part of their counter-insurgency strategy. But probably most importantly, in 1989 middlemen realized the high value of rhino horn in South Africa and eastern Asia and thus offered poachers over three times more for rhino horn than in 1982 (500 to 800 rands for a pair of black rhino horns or $460 to $740) (R. Loutit, pers. comm.).

One man in particular responded to this increased financial incentive and killed five of the seven poached animals in the Kaokoveld in 1989. He was a 25-year-old farmer originally from Rehoboth, over 800 kms away, but his father often took him to Damaraland so he was familiar with the area. This farmer employed several Damaras who spent a fortnight looking for rhinos. When they were found, the farmer himself shot five of them with a G3 rifle, as well as nine to 14 elephants, in the Klip River and Otjihavera areas. Some of the horn may have been sold to traders in Okhandja. Soon afterwards, this poacher was arrested, convicted and sentenced to nine years or a 15,000 rand fine plus five years community service (R. Loutit and T. Hall, pers. comm.).

The other two black rhinos killed in northwest Namibia were shot in separate areas, one near Etosha by Hereros and the other by two young Hereros from Sesfontein who sold the horns to an official in Sesfontein. This man in turn sold the horns to a person in Opuwa, the capital of Kaokoland. Both poachers from this latter incident were caught and convicted.

On account of this alarming upsurge in poaching in the Kaokoveld in 1989, Blythe Loutit and her husband Rudi Loutit decided a new strategy was needed. They proposed that some of the rhinos in Damaraland should have their horns removed so that the poachers would have no reason to kill them. They convinced the Nature Conservation officials of this controversial plan and then in mid-1989 chose a group of rhinos which were close to the main road (and thus more vulnerable to poachers), and which were actually known by a gang (R. Loutit, pers. comm.). Twelve of these rhinos were dehorned in an efficient operation in which not a single animal died. The exact number of rhinos dehorned was at first kept secret from the press in order to give the impression to potential poachers that most rhinos in the area had been dehorned; this was a wise decision.

Immediately after the dehorning, the Namibian authorities were severely criticized, especially by South Africans. They complained that the rhinos need their horns for a variety of purposes including self-defence and feeding, and by removing them, social behaviour such as mating might be adversely affected. Since most rhinos did have horns, how would one without them defend itself'? Others argued that as the horn grows back, the process would have to be repeated continuously throughout the life of the animals. It is expensive to dehorn, and some said the money could have been better spent by employing more guards to protect the rhinos and by improving the intelligence system.

Those who supported the exercise noted that unlike most other parts of Africa, there were extremely few natural predators in the region which could threaten calves, such as hyenas or lions, so that mothers did not really need their horns to protect their young. Furthermore in the vast open spaces of Damaraland which is unlike the

Photo credit: Esmond Bradely Martin

A desert rhino finds shade under a bush near Wereldsend in Damaraland.

thick brush usually inhabited by black rhinos elsewhere in Africa, poachers could easily see whether a rhino had its horns. They dismissed the possibility that poachers would kill them from spite, although this did later happen in Hwange National Park in Zimbabwe in early 1992, as the vindictive poachers were so furious, having tracked two white rhinos, to find them with their horns removed.

So far, the 1989 dehorning exercise in Damaraland has been successful. Indeed, according to information from Tommy Hall, two attempts were made in 1989 and 1990 to kill two rhinos, but once they saw the rhinos had no horns, the poachers left them alone. In 1991, the dehorning was repeated: at least eight rhinos had their horns sawn off by government officials in southern Damaraland, near a mine which had just closed down, putting several thousand people out of work. In fact, the officials had learned just before the dehorning that some men were looking for rhinos in the area to shoot. The second dehorning project also passed without a single fatality. The 1989 dehorning project was the first ever to be carried out in the world for a wild population of black rhinos. In the same year, the Namibian authorities undertook another unique, highly controversial new policy for rhino conservation. They sold some of their rhino horns as part of a regional investigation into the illegal trade in rhino products. Approximately 60 choice horns weighing 135 kilos belonging to what was then the South West African government were sold for 150,000 rands ($57,000) and sent to South Africa. Since South West Africa was politically controlled by South Africa and was therefore not a member of CITES, the movement of horns was probably legal. These horns were used to catch traders from all over southern Africa, including Namibia. Several arrests resulted from this undercover operation (confidential sources in Namibia and South Africa).

Partly because of these new official policies carried out in 1989, the number of black rhinos poached the following year declined to only two. The first poachers were two young Damaras from Khorixas (one of whom was a senior employee of Save the Rhino Trust) who went by vehicle searching for rhinos. When they found a male, they shot him and attempted to blow off his horns with pellets from a 12 gauge shotgun. They took the horns to Swakopmund to sell (Sharon Montgomery of Save the Rhino Trust and R. Loutit, pers. comm.).

The second in 1990 was the most pathetic poaching incident for many years. Two Damara farmers went up to a mother and calf near Twyfelfontein. They picked up some stones and threw them at the six-month-old calf, eventually killing it, while the mother stood by watching this appalling sight. The men then cut off some pieces of flesh from the neck and shoulder to eat. In Namibia, eating rhino meat is virtually unheard of. The baby rhino of course had no horns. The poachers were quickly caught and sentenced to 30 months each with half of the term suspended which meant an effective imprisonment of only 15 months. Garth Owen-Smith believes that the punishment was appropriate as no commercial motive was established (G. Owen-Smith, pers. comm.). The editors of *The Windhoek Advertiser*, a local newspaper, were so incensed by this insignificant punishment, however, that they published a leader in the 13 April 1991 issue stating: "...when one looks at the sentences meted out this week in respect of two grown men who stoned to death a black rhino calf, one's senses are outraged. At the risk of committing contempt of court, we state today that a magistrate handing down a sentence like that should be removed from the bench!"

WILDLIFE LAW ENFORCEMENT IN NAMIBIA

Namibia is unique in that of all the countries in the world with serious rhino poaching, Namibia is the only one where most of the illegal hunters and traders are caught and sentenced to prison or fined. This has not happened in Asian countries where there are rhino populations, for example, India, Nepal, Malaysia and Indonesia, nor elsewhere in Africa such as Tanzania, Central African Republic, Sudan, Zambia, Zimbabwe

Table 2. Court Cases in Namibia on Controlled Game Products trom 1983 to 1990.

Year	Total cases	Total people accused for rhino and ivory tusk violations	Number of rhino hams involved	Weight of horns in kg	Total number of elephant tusks involved	Total weight of elephant tusks in kg
1983	9	7	0	0	142	
1984	12	8	4		77	193.2
1985	11	0	10	4.4	40	113
1986	18	17	6	7.2	170	1062.9
1987	23	35	11	27.85	198	841.1
1988	12	16	6	19.55	216	1154.9
1989	34	33	25	46.4	1139	7901.8
1990	47	78	53	78.6	200	1375.
Total	166	194	115	184	2182	12642.2

Source: Government of Namibia (unpublished)

and Mozambique, where there has been heavy poaching over the past ten years. What are the reasons for Namibia's unique success in law enforcement?

Firstly, in the main areas where there are black rhinos - Etosha, Kaokoveld and Waterberg Plateau -there is sufficient money officially available to pay for information on potential poachers and middlemen. For example, in 1990 and 1991 the police paid a minimum of 500,000 rands ($175,000) a year to informers on rhino horn and ivory cases. In some instances, informers were paid more by the police than they could earn by selling rhino horn. In addition, some of the non-government organizations such as Save the Rhino Trust also pay out rewards for information. One senior police officer told me that informers have been responsible for the arrest of 60% of the poachers and middlemen in Namibia from 1987 to 1991. Garth Owen-Smith believes that the reward system is accountable for over 80% of the arrests, as the local people in Damaraland and Kaokoland are now involved with the wildlife management of the area and thus give information to the authorities quite freely (G. Owen-Smith, pers. comm.).

A second reason is that most of the investigations, especially of middlemen, are carried out by the Diamond and Gold Branch of the Police, an extremely well trained unit. These officers have their own special method of investigation, including entrapment, and special ways of handling information.

Another explanation is that there is a lot of close co-operation between the Nature Conservation Department and the Police. All important cases of poaching and trading in rhino horn involve not only Nature Conservation officials but also the Diamond and Gold Branch of the Namibian Police. In 1991, the Commanding Officer had 40 policemen, including administrative personnel, working for him.

Fourthly, Namibia has been successful because the police also have close co-operation with the customs personnel at the country's main airports and international border posts. With the co-operation of the various government departments, the police know many of the main dealers in Windhoek and elsewhere. In the late 1980s and early 1990s, the middlemen buying rhino horn in Windhoek were Namibians, and also Portuguese who had left Angola and were dealers in elephant tusks and diamonds as well.

Not all the rhino horns traded in Namibia come from locally killed animals. Some originate from Angola, Zambia and Zimbabwe. Traders in Namibia buy these horns to move to South Africa for sale. Few horns have come in from Angola recently, but horns have come through the Caprivi from Zambia and Zimbabwe. At the time of my visit to Namibia in July and August 1991, I was told by a senior Nature

Conservation officer that one trader in Swakopmund had 13 horns for sale and one man in Arandis, just east of Swakopmund, possessed three black rhino horns. From 1983 to 29 July 1991 the Namibian government authorities confiscated 150 rhino horns weighing 262 kilos (see Table 2 for the years 1983-90), including some originating outside the country. As in many other countries, theft has occurred from government stores. In 1990 the Windhoek storehouse was broken into by a former employee of the Nature Conservation Department, who stole five rhino horns to sell; he was arrested and pleaded guilty to the theft. The official stores in Khorixas were also invaded and rhino horns were illegally taken.

THE NAMIBIA - SOUTH AFRICA - TAIWAN CONNECTION

After the horns leave Namibia, almost all of them are sent to traders in South Africa, although small quantities are transported directly to Taiwan (Republic of China) and perhaps Hong Kong. South Africa is not only an entrepot for horns from Namibia, but also from Zambia, Zimbabwe, Angola, Mozambique and Swaziland. The two main reasons for this are that the rand is a stronger and a more convertible currency than others in southern Africa, and there are many Taiwanese living in the country who are willing to buy the horn to export to Taiwan. Another advantage is that South .Africa is part of a Customs Union and therefore, if the horn is smuggled into one of the other countries in the Union (Namibia, Botswana, Swaziland and Lesotho), it can be moved to Johannesburg without the parcel being inspected by customs or other government authorities. In fact, most officials in the police and the parks and reserves dealing in anti-poaching claim that the sealed containers which are continually moving in and out of South Africa are the greatest boon to the wildlife traders; less than 1% are ever inspected.

In 1990 and 1991 Taiwanese and other buyers in South Africa were purchasing horns for 1,200 to 2,500 rands ($435 to $900) a kilo. Most of them were then sold for export to Taiwanese, mostly businessmen, government officials and sailors, in order to supplement their incomes. It appears that many Taiwanese seamen are aware of the value of rhino horn. An interesting incident confirms this. In. 1991, a Taiwanese ship docked in Port Elizabeth and four of the crew hired a taxi to drive to Addo National Park 70 kilometres north. As far as was known by the Park officials, these were the first Taiwanese to visit for several years. All they were interested in were two rhino horns on public display in the Park's tourist shop. They attempted to buy the horns, but were refused repeatedly by the shop's manager.

In addition to the use of sealed containers in South Africa, rhino horns are sometimes put into small parcels and posted to Taiwan or carried by Taiwanese on aeroplanes and ships to Taipei and Kaohsiung. There is no evidence that South Africans are taking the horns to Taiwan. On reaching Taipei and Kaohsiung. many of the sailors involved go around to the main wholesalers and managers of the pharmacies and sell to whomever offers the highest prices. In 1990, someone who smuggled the horn into Taiwan could expect to receive about $2,000 a kilo, a considerable sum compared to what the person would have paid for it in South Africa. Although the trade was illegal in the late 1980s, Taiwan was then the largest importer of African horn in the world. This was partly because dealers there paid some of the highest prices. For instance, they offered twice as much as traders in Yemen. In Taiwan, the African horns were either consumed locally for medicine, especially to lower high fevers, or they were re-exported, mainly for the Chinese market.

PROSPECTS FOR NAMIBIA'S RHINOS

From 1980 to 1990 a minimum of 64 black rhinos (see Table 3) and a few white rhinos were illegally killed in Namibia. Compared with most other countries in Africa with large rhino populations, Namibia's losses were very small indeed. For example, Zimbabwe lost from poaching over 800 black rhinos during the same period, and the large rhino populations in Mozambique, Zambia, Angola, Tanzania, Kenya and the Central African Republic were reduced to very low numbers during the last decade. To some extent, Namibia's low human population has been advantageous to rhino conservation. In addition, the presence of the South African Defence Force made it more difficult for foreign poachers and middlemen to operate in the country. A further deterrent_was that in 1990 the national government passed very tough legislation against rhino poaching: the maximum penalty was a 200,000 rands ($73,500) fine and or 20 years imprisonment. This is one of the severest penalties in the world for rhino poaching.

In the early 1980s, most rhino poaching occurred in central and eastern Africa, especially the Central

African Republic, Sudan, Kenya and Tanzania. With most of the animals hunted out by 1985, poaching gradually moved south, especially into Zimbabwe. By the early 1990s, poaching was becoming significant in South Africa where previously there had been hardly any rhino poaching at all: in 1991, ten rhinos (all whites) were killed and in 1992 at least 13, again all white rhinos. (Also, from 1990 to 1992 Swaziland lost 60% of its white rhinos, about 50 animals, to poachers.) By 1992, the countries still with the largest black rhino populations were South Africa (819), Namibia (560) and Zimbabwe (425) - all in southern Africa. The most northerly of these populations, that of Zimbabwe, is being heavily poached, especially by Zambians, with at least 200 animals killed in 1991. With the price of African rhino horn remaining high in Asia, it can be expected that poaching efforts in the near future may intensify in Namibia. The authorities must now prepare themselves for this likelihood.

In the financial year 1990/91, the Namibian government could not significantly increase the amount of money for wildlife protection. In fact, some budget cuts had to be introduced. This unfortunate cost-cutting continued in the 1991/92 appropriations. One of the first items affected was informant money. This should have the highest priority as it is by far the most cost-effective method of catching poachers and traders. It is absolutely essential that the intelligence gathering network be expanded, not decreased. The Nature Conservation Department should also expand the training of officers involved with law enforcement. This is especially so since the Diamond and Gold Branch of the Police, who have over the past few years successfully investigated most of the major cases of poaching and trade in wildlife products, may not be able in the future to allocate so much time to this, as drugs and diamonds are of a higher priority to the government. Some anti-poaching units have also been recently cut which has had the added effect of lowering the morale of senior officers. Some men have left government service altogether, due to the relatively poor terms given, especially salaries.

It is unlikely that the budget of the Nature Conservation Department will increase significantly in the near future. Thus, Nature Conservation must look at ways of increasing its own revenue. The government does encourage wildlife utilization by allowing sales of wild animals and large mammal trophy hunting mostly by foreign tourists. Also, there is general sport hunting, cropping operations mainly for gemsbok and springbok for meat sales in South Africa, export of skins, and ostrich and crocodile farms. But more needs to be done on government land.

Table 3. Minimum Number of Black Rhinos Poached in Namibia from 1975 to 1990.

Year	Northwest	Etosha	Waterberg	Total
1975—1981	39		-	
1980			-	
1981		1	-	
1982			-	
1982	4			
1983	1	0	-	1
1984	0	15	-	15
1985	2	0	-	2
1986	0	0	-	0
1987	0	7	-	7
1988	0	0	-	0
1989	7	23	0	30
1990	2	2	0	4

Sources: Garth Owen-Smith, Rudi Loutit, Peter Erb, Allan Cilliers and Tommy Hall, pers. comm.

Table 4: Estimated Number of White Rhinos in Namibia from 1981 to 1992.

Year	Number
1981	70
1984	70
1986	63
1991	80
1992	91

Sources: IUCN, WWF, NYZS, "African Rhino Group Action Plan for the Conservation of African Rhinos" (December 1981), unpublished, no page number; David Western and Lucy Vigne, "The Deteriorating Status of African Rhinos", Oryx, *Vol. XIX (October 1985), p. 216;*
D.H.M. Cumming, R.F. Du Toit and S.N. Stuart, African Elephants and Rhinos: Status Survey and Conservation Action Plan, *IUCN (1990), p. 9; Eugene Joubert as mentioned in the unpublished IUCN paper compiled by Martin Brooks, "Population Estimates for Black Rhinoceros* Diceros bicornis *and White Rhinoceros* Ceratotherium simum *in Africa in 1991, and trends since 1987" (8 August 1991); and Martin Brooks, "Chairman's Report African Rhino Specialist Group",* Pachyderm, *No. 16 (1993), p.3.*

Table 5: Number of White Rhinos Legally Hunted in Namibia from 1986 to 1990.

Year	Number
1988 1	
1987 2	
1988 0	
1989 2	
1990 1	

N.B. All white rhinos were hunted on private land Source: Ministry of Wildlife, Conservation and Tourism (unpublished).

White rhinos, which numbered 91 in Namibia in 1992 (see Table 4), are allowed to be shot on private land, and on average, one a year is hunted by wealthy foreign clients (see Table 5). The government might think of raising revenue by permitting darting safaris for white rhinos on public land, and possibly black rhinos as well. In 1991 on the Botsalano Game Reserve in Bophutatswana, an American paid $8,000 to tranquilize a white rhino. The fee for such a darting safari for a black rhino would be many times greater; it has not been yet tried anywhere in Africa.

In order to reduce the amount of money required to look after over 550 black rhinos on government land, Nature Conservation is seriously thinking of allowing some black rhinos to be translocated onto privately-owned ranches which are willing to spend the appropriate funds required to look after the animals. In both Kenya and Zimbabwe, this policy has proved to be very successful and has permitted the wildlife departments to concentrate their anti-poaching efforts and limited funds on fewer rhinos on public land. In addition, on some of the ranches which have black rhinos, foreign tourism has increased, earning more money for the country.

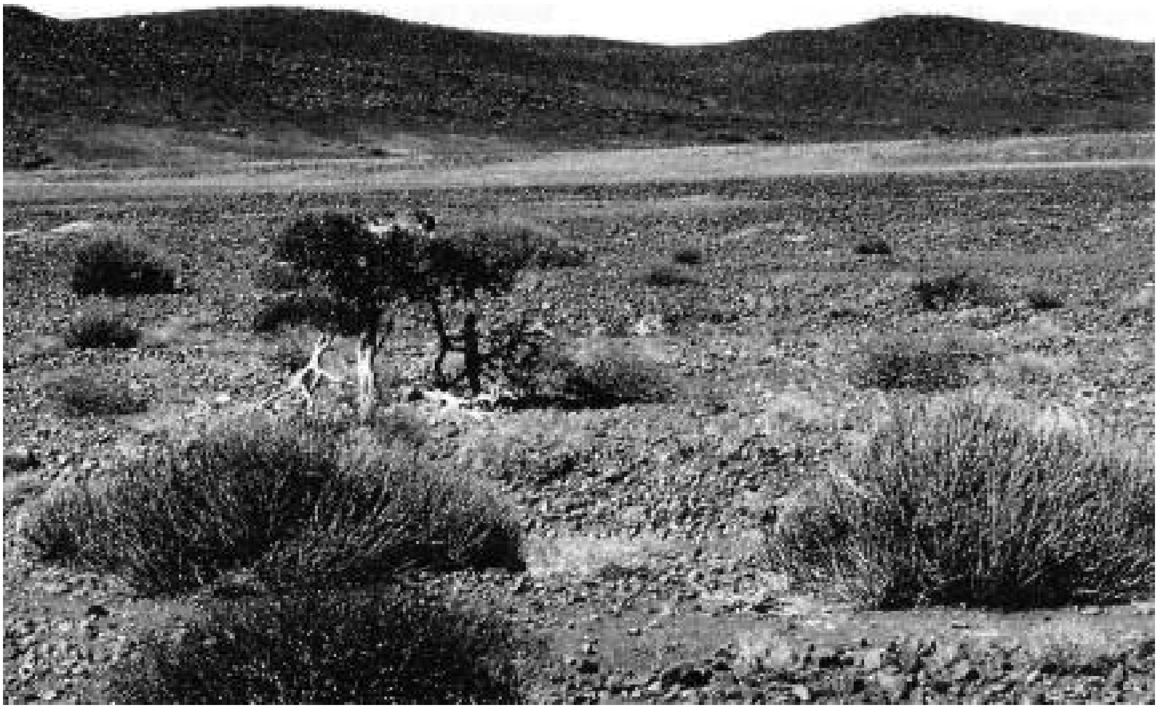


Photo credit: Esmond Bradley Martin

This is typical rhino habitat in Damaraland.

At the moment, the funds raised by Nature Conservation go directly into the coffers of Namibia's central government, so there is no great incentive to increase revenue. In order to change this situation, Nature Conservation should consider becoming a parastatal which would be permitted to raise and keep funds, such as those from government donors, non-government organizations and park entrance fees. Recently, this change in status has occurred successfully in Kenya. The government has allowed the newly-formed Kenya Wildlife Service to raise large sums of money directly from foreign donors including the World Bank; $112,000,000 has been allocated for the 1992-1996 period. In Tanzania, the parks can keep a considerable portion of the entrance fees, which are paid in hard convertible currency, for their own use. The South African Parks Board can retain all the money the Board raises through entrance fees, hotel accommodation and other revenue earners. Thus a major incentive is given to the staff to earn as much money as is possible to re-invest into the parks.

The easiest method for Namibia's Nature Conservation Department to raise revenue is to increase park entrance fees for both citizens and foreign visitors. The fees are now very low. Almost all the tourists who visit the parks arrive in vehicles or aeroplanes and they certainly can afford to pay more than the 1991 fee of four rands ($1.40) for a local person and five rands ($1.75) for a non-resident. In comparison, the entrance fees for Kruger National Park in the same year were 14 rands per person per trip and 12 rands for a car - and these charges also are too low. In Botswana, a non-resident pays 50 pulas (about $22) to enter the main parks. In Tanzania in 1991 foreign visitors paid $15 per day in the parks in hard currency plus significant vehicle charges. In Kenya, non-residents must pay 450 shillings a day (about $15) plus vehicle fees. It is unfortunate from an economic point of view for the government of Namibia to undercharge for the use of a government resource to such an extent as Etosha National Park, one of the finest protected areas on the African continent. At the moment, the Namibian government is losing large sums of money because it is not charging the true market value for non-residents to enter the parks.

In conclusion, during the 1980s, the Namibians did a very good job in conserving their black and white rhinos, especially compared with other parts of Africa where most of them were massacred. Now, in the early 1990s with severe poaching in Zimbabwe and Swaziland, there will probably be greater pressure put on the rhino populations of Namibia, which include the unique desert rhinos. This means that Namibia will have to find new

Photo credit: Esmond Bradley Martin

Desert Elephants in Damaraland.

sources of money to combat this threat. The most likely source is from the tourist industry. Namibia can offer some of the most spectacular scenery and wildlife in Africa. With proper management, high-priced safaris could be greatly expanded. This is especially so as Namibia already has an excellent infrastructure of airports, roads and accommodation. Most foreign tourists would not object to paying increased park charges if they knew that the money was going towards the protection of the wildlife, especially to anti-poaching efforts to conserve the rare black rhinoceros.

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Is Dehorning African Rhinos Worthwhile?

E.J. Milner-Gulland[1], N. Leader-Williams[2] and J.R. Beddington[3]

[1] Ecosystems Analysis and Management Group, Department of Biological Sciences, University of Warwick, Coventry, CV4 7AL, UK
[2] Department of Wildlife, P.O. Box 63150, Dar es Salaam, Tanzania
[3] Renewable Resources Assessment Group, Imperial College, 8 Princes Gardens, London SW7 1NA, UK

INTRODUCTION

We have recently developed a simple model for the growth of rhino horn, which was used to analyze the efficacy of rhino dehorning in preventing poaching, and its potential profitability if there were to be a legal horn trade (Milner-Gulland, Beddington & Leader-Williams 1992). The model requires data on the growth rate of rhino horns before and after dehorning, and on the cost-price ratios (ratio between the cost of killing a rhino and the price obtainable for its horn) of harvesters, whether they be poachers or managers. The results of the model must be interpreted taking into account any mortality occurring during dehorning operations. Using the best available data at the time, we concluded that dehorning had to be carried out annually to deter poaching, and that although this dehorning rate could produce near-maximal profits, it would not be sustainable, due to the mortality incurred during the dehorning process. Given that rhino horn cannot at present be sold legally, the point was made that dehorning must be considered as a crisis anti-poaching measure like any other, and its benefits assessed in terms of the reductions in rhino deaths per dollar spent.

Dehorning exercises have now been carried out in Namibia, Zimbabwe and Swaziland, and in June 1992, dehorning became a national conservation policy objective in Zimbabwe. It is planned that all Zimbabwe's rhinos will be dehorned in due course (Milliken, Nowell & Thomsen, 1993). Therefore, since the publication of the model, further data have been collected on all the parameters mentioned above (Table 1), and here we recalculate the results of the model in the light of these data. We conclude that neither the profitability nor effectiveness of dehorning as an anti-poaching measure can be assessed accurately, since the data are too disparate and patchy for generalizations to be made. However, the model, as presented in this paper, can be used for predicting the outcome of future dehorning operations when further data become available, and in assisting decision-making in relation to operations presently underway. The recent loss in early to mid 1993 of the white rhinos experimentally dehorned in Hwange National Park in Zimbabwe in November 1991 makes a re-examination of the issue of dehorning particularly timely and urgent.

THE NEW DATA

i) Mortality

The mortality rate associated with dehorning does not affect the results of our model (Milner-Gulland *et* al). 1992), but is only used in the interpretation of the results. Unfortunately, this point has been

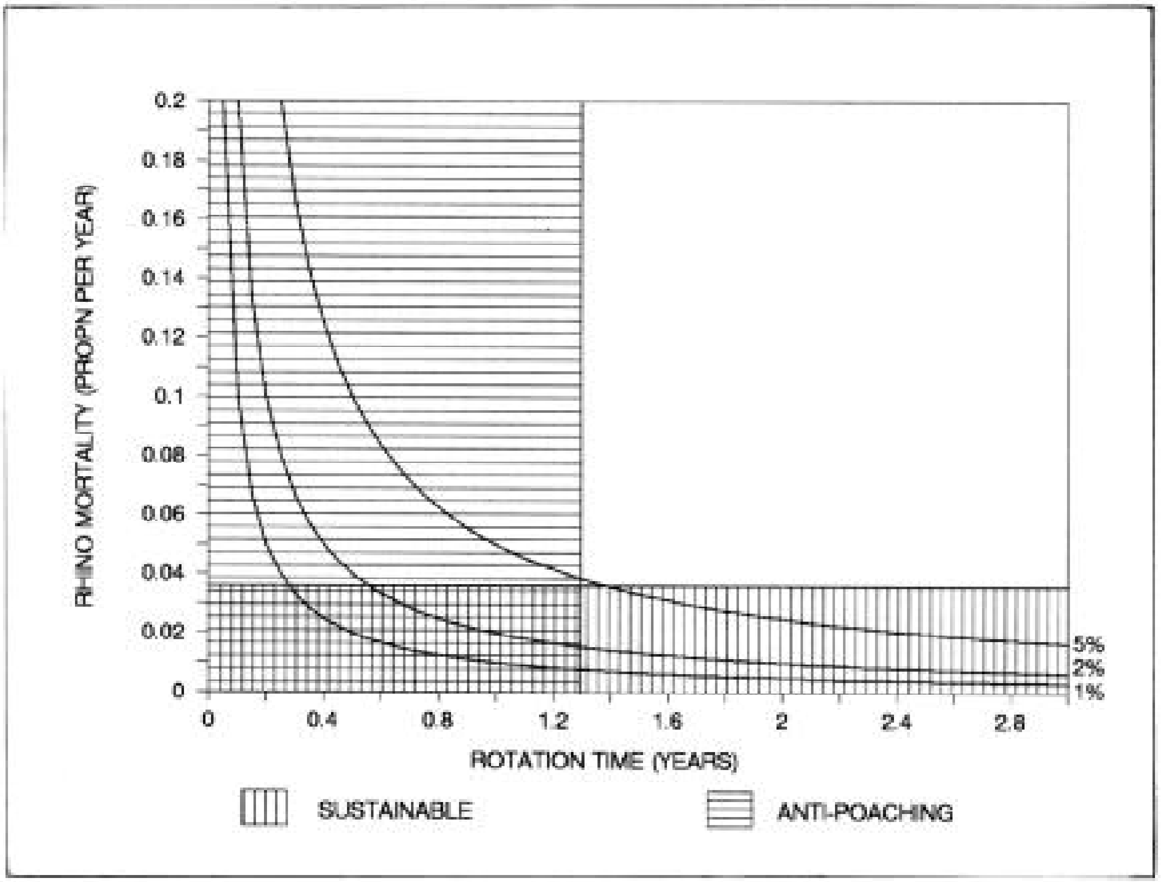
Table 1. Data on rhino dehorning.

Source	Manager			Poacher	
	Dehorning costs (per rhino)	Horn price (per kg)	Associated mortality (%)	Horn price (per horn)	Poaching costs (per rhino)
Milner-Gulland et al. (1992)	$960	$750	9%	Cost-price ratio = 1.2	
Milliken etal. (1993)	$350-$1 ,800		<2%	$100-$360	
R.B. Martin, pers. comm. Kock & Atkinson (1993)	$500	$2,000	1%		
J. Berger (1993)	$1,400			$1 ,775-$7,750 (after 1yr growth)	
Morkel & Geldenhuys 1993	$1,500		0%		

misunderstood by some who have suggested that the predictions of the model are actually affected by the mortality rates associated with dehorning (Milliken et al). 1993). Rhino mortality from dehorning and poaching combined must not exceed 3.7% per annum if dehorning is to be sustainable as a longterm strategy (Milner-Gulland 1991). However, in discussing the results of our original model we assumed that as many as 9% of rhinos could die as a consequence of the dehorning process, based on mortality rates associated with trans-location in the 1960s (Roth & Child 1968). Accordingly, we concluded that dehorning as a longterm strategy would not be sustainable.

Because more recently published data are now available based on the actual dehorning operations (Morkel & Geldenhuys 1993; Kock & Atkinson 1993; Milliken *et al.* 1993), it is clear that a dehorning-associated mortality of 9% is much too high, since both technology and experience have improved. Mortality rates associated with dehorning are now less than 2%, and even as low as 0% (Table 1). Assuming that there is no other human-induced mortality operating, for example that poaching has been completely halted, then with these recent low dehorning mortalities, dehorning might be sustainable as an anti-poaching measure (Figure 1). If the mortality associated with dehorning were only 1%, then 3 dehornings a year could be carried out sustainably, whereas at 9% mortality, dehorning could only be carried out every 2.5 years to be sustainable. As dehorning changes from a once-off crisis response to poaching onslaughts, as it was when first practised in Namibia, to an institutionalised activity that authorities aim to carry out regularly, as is now the policy in

Figure 1. The relationship between rhino mortality and dehorning rotation time. Sustainable human-induced mortality rates and rotation times that will deter poaching are shown as shaded areas - where they overlap, dehorning is both sustainable and a deterrent. Contours are drawn on for dehorning mortality rates of 1%-5%. The rotation times for which dehorning is both sustainable and deterrent can be read off for a given dehorning mortality rate as the times for which the contour is in the double-shaded box. Thus dehorning at a mortality rate of 5% is never both sustainable and a deterrent, whereas at a mortality rate of 1%, dehorning is both sustainable and a deterrent at rotations of 0.3-1.3 years.



Zimbabwe, it is important that this point is recognised in relation to our earlier conclusions (Milner-Gulland et *al*. 1992).

ii) Horn growth rate

When the model was produced, very few data were available on horn growth rates, either after dehorning or on a young animal. For that reason, a function for horn growth was assumed, which gave smooth growth to a maximum horn weight of 3kg, slowing as horn weight neared the maximum. Horn growth rate was assumed to be identical for a dehorned rhino as for a young rhino, and not to vary with age or sex of the rhino. The horns of dehorned rhinos have been observed to grow back rapidly and without deformity, reaching slightly less than full size after three years (Berger 1993). In general, the results of our model are not sensitive to the rate of horn regrowth assumed, particularly if regrowth is faster than is assumed in the model (Milner-Gulland et *al.* 1992). Data are not yet adequate to determine the functional form of horn regrowth, so the form of horn regrowth assumed in the model was not changed.

iii) Cost price ratios

The ratio between the cost of killing a rhino and the price obtained for its horn is clearly key to the profitability of hunting for the poacher, and of dehorning for the manager. The cost-price ratio is extremely hard to estimate for poachers, and will vary depending on whether the poacher is in an organised gang or is more opportunistic, as well as with the economic situation of the country from which the horn is exported (Milner-Gulland & Leader-Williams 1992). Thus large disparities appear between the poacher prices of rhino horn reported by Berger (1993) and Milliken et *al.* (1993) (Table 1). There are no new data on the costs of poaching. Therefore, the poacher cost-price ratio assumed in Milner-Gulland et a). (1992) is retained here, since the costs and prices assumed in this ratio are internally consistent. The ratio was calculated for the Luangwa Valley, Zambia, in 1985, and so is rather out of date and is for a country that has not carried out dehorning. Data on poacher costs and prices are crucial to an accurate assessment of the time after dehorning at which a rhino will be susceptible to poaching, and so need urgent attention. These data should include, for a particular area: the price obtained by the poacher and middleman for the horn; the costs of mounting a poaching expedition, including paying the gang members; the probability that a gang member will be captured, and the penalty he is likely to face if caught; and the number of trophies that are captured on each hunting expedition (depending on the length of the expedition, the density of the prey population, weapon efficiency, and visibility of the prey).

Since several dehorning exercises have now taken place, the costs of dehorning to a manager are now better known (Table 1). However, the reported costs vary between US$350 and US$1800 per rhino, depending on the rhino species, density and the terrain. The price per kg of horn obtained by a manager was assumed in the previous paper to be US$750, but R.B. Martin (pers. comm.) states that the prices being negotiated at present for horn from dehorning exercises are in the region of US $2000/ kg. These data produce cost-price ratios for profitmaximising managers that range between 0.18 (350/ 2000) and 2.4 (1800/750), which is a very large range of possible ratios. Perhaps the most likely ratio to be correct, that expected by the Zimbabwe government, is around 0.25 (R.B. Martin, pers. comm.). The optimal rotation times for managers to maximise their profit, and the rotations on which a rhino must be dehorned to prevent poaching, were calculated for a range of cost-price ratios (Figure 2). The poachers' cost-price ratio leads to the rhino being poached 1 .3 years after dehorning, substantially earlier than the lowest optimal rotation time for a profit maximising manager of 1.7. The new data on the costs of dehorning therefore do not substantially alter the conclusion of our earlier paper, that a rhino will be killed by a poacher before the profit-maximising manager dehorns it, and that annual dehorning is necessary to prevent poaching. If further data on cost-price ratios are received, the resulting optimal rotation or killing time can simply be read off the graph in Figure 2.

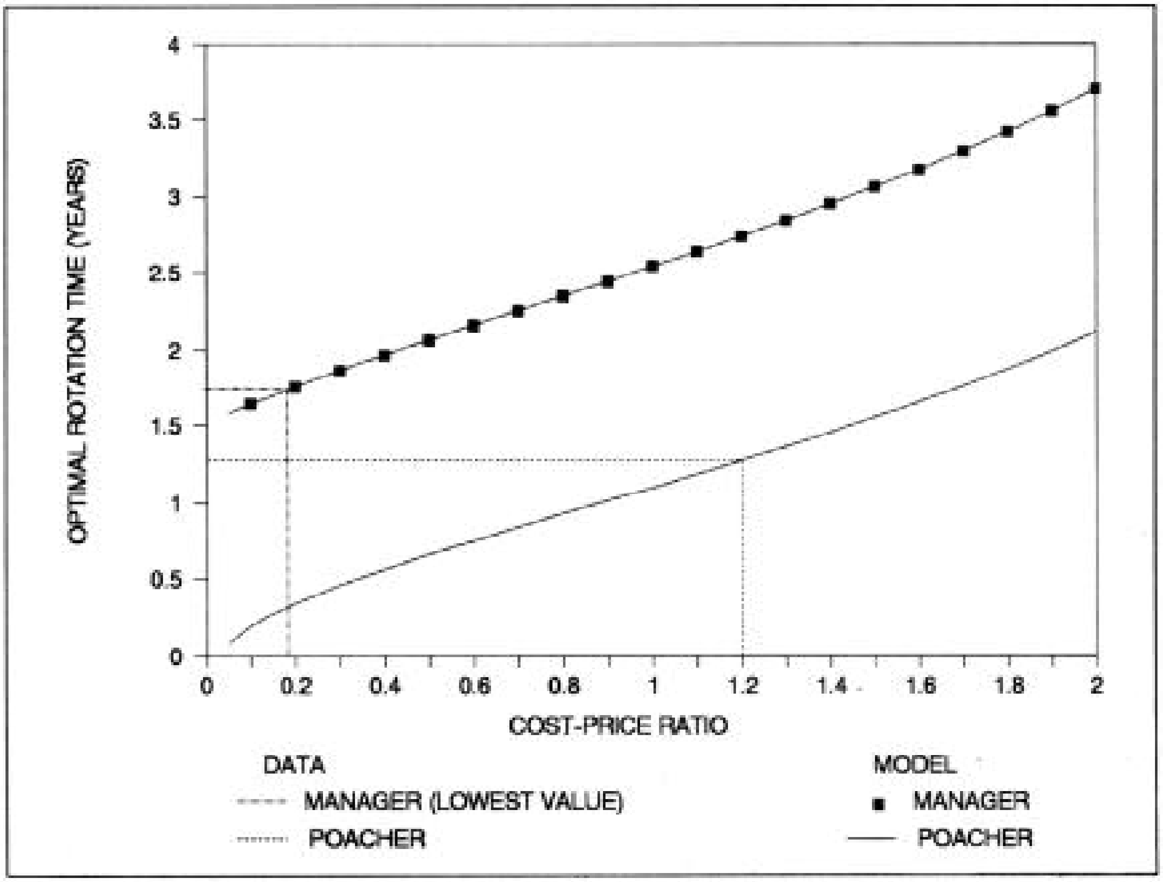
These results can also be interpreted in terms of the present value of the lifetime supply of horn from a rhino at birth, which is the sum of profits from dehorning throughout the rhino's life, but with the profits in the distant future reduced using the discount rate, which represents the fact that income in the distant future is worth less than income today. The rhino is assumed to live for 40 years, and to be dehorned at the same interval throughout its life. The present value of a rhino will depend on the manager's cost-price ratio and discount rate, and on the mortality rate associated with dehorning. It is worthwhile to consider profits to be made from dehorning despite the fact that horn cannot be traded legally, because the debate on whether to reopen trade in rhino horn continues, and has been fuelled by the growth in stocks of horn from dehorned rhinos.

Our model can help to give an idea of the potential profitability of dehorning if the trade reopened, and thus inform the debate.

Figure 3 shows the present value of a rhino at various dehorning rotation times, for a range of cost-price ratios from the data in Table 1. The present values are shown as percentages of the maximum present value at the optimal rotation rate for a particular cost-price ratio. Thus at a cost-price ratio of 0.2, the optimal rotation time is about 1.8 years (Figure 2), which is when the present value is 100% of maximum. At rotation times lower than optimal, the present value drops rapidly, and soon becomes negative, since the costs of dehorning outweigh the revenues from the small amount of horn obtained at each dehorning. At rotation times longer than optimal, the present value decreases gradually because longer rotation periods reduce the total number of rotations possible, even though the amount of horn obtained per dehorning may be larger than at the optimum. As the cost-price ratio increases, the optimum rotation time and the break-even rotation time become longer, as dehorning becomes more expensive. The curves are all scaled to 100% at the maximum present value, for the sake of clarity. Although it is not shown in Figure 3 because of the rescaling, the maximum present value also gets smaller as the cost-price ratio increases and dehorning gets more expensive.

A line on Figure 3 shows the rotation time of 1.3 years needed to deter poachers. The profits gained by a manager who dehorns at this time depend on his cost-price ratio. If it is 0.2, then profits are 98% of the maximum, while at a cost-price ratio of 1.4, a

Figure 2. Changes in optimal rotation time and optimal poaching time as coat-price ratios vary, for a poacher (solid line) and a profit-maximising manager (squares). Details of the calculations are in Milner-Gulland et al. (1992). The lowest optimal rotation time for a profit-maximising manager is shown (dot-dashed line), together with the optimal time for a poacher to kill a rhino (dashed line), both from Table 1. The lowest optimal rotation time for a profit-maximising manager is significantly higher than the poacher's optimal poaching time, despite the manager's cost-price ratio being much lower than the poacher's, so the rhino will be killed by a poacher before a profit-maximising manager would dehorn it.

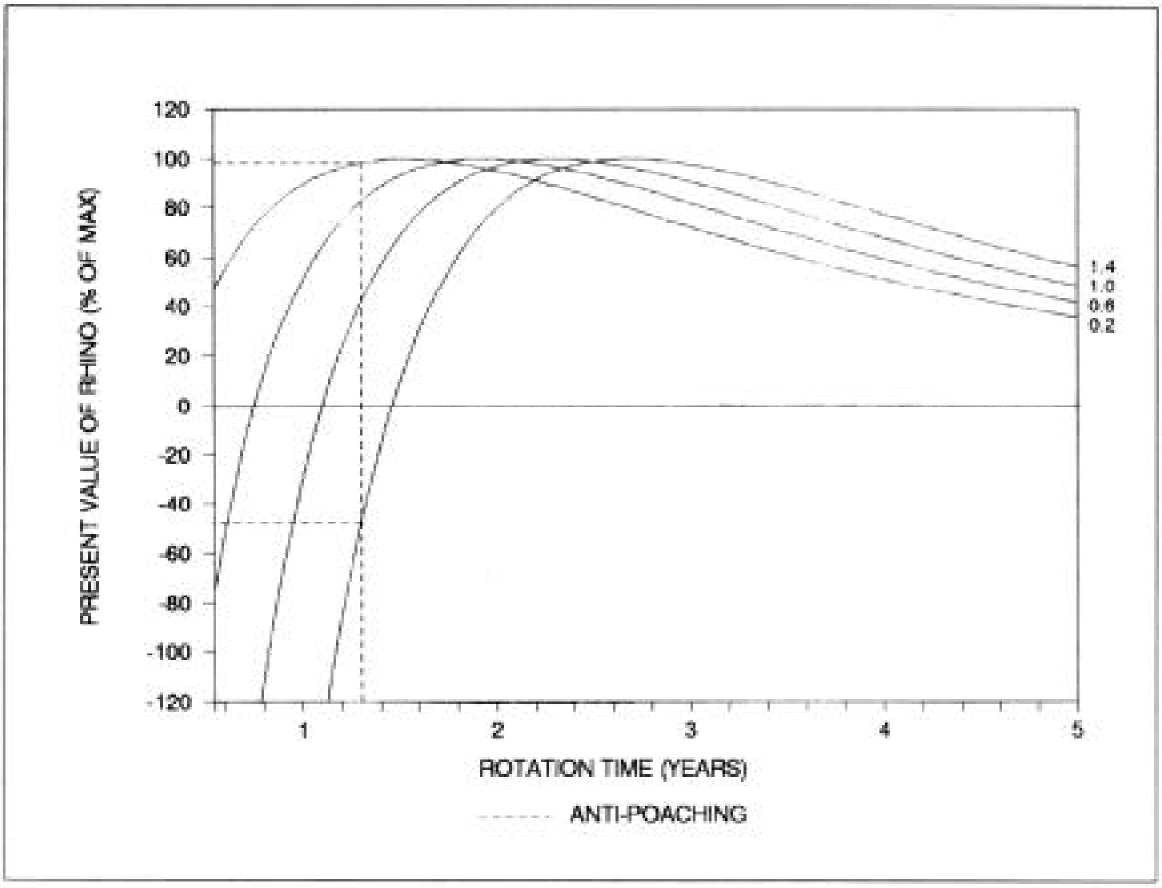


loss would be made. The data in Table 1 give cost-price ratios of 0.18-2.4, so the potential profitability of dehorning as an anti-poaching measure will vary with the circumstances. However, it should be noted that the losses associated with high cost-price ratios are less than the gains associated with low cost-price ratios, since the maximum profits to which losses are scaled are lower at high cost-price ratios. So if the cost of dehorning a rhino is assumed to be US$500, then dehorning to prevent poaching leads to a present value of a lifetime s supply of horn of US$5,350/rhino at a cost-price ratio of 0.2, or -US$130/rhino at a cost-price ratio of 1.4. By comparison, a common rule of thumb is that $200/km^2/year was needed effectively to control poaching in protected areas in 1980, which translates to $500/rhino/year at a rhino density of 0.4/km^2 (Leader-Williams, 1990).

DISCUSSION

The conclusions to our original paper (MilnerGulland et *al.* 1992) were that there were three possible intervals at which a manager might dehorn rhinos, depending on his objectives. At present, rhino dehorning is used only as a crisis anti-poaching measure, and as such, dehorning needs to be done as soon as the horn has regrown sufficiently for it to be profitable for a poacher to hunt the rhino. The data suggest that annual dehorning would be necessary to fulfill this objective. If a manager wished to exploit rhinos commercially by removing and then selling horn, either on a ranch or to fund rhino conservation, and assuming the horn could be sold legally, the rhino would be dehorned at the profit-maximising rotation period, calculated as once every two years.

Figure 3. The present value of a rhino at birth depending on the dehorning rotation rate, assuming that the manager has a discount rate of 0.3, and the rhino will be dehorned at the same interval throughout its 40-year lifespan. The manager is assumed to be dehorning at a sustainable rate, with a dehorning-induced mortality rate of 2%. Results are shown for cost-price ratios of 0.2-1.4, scaled to the maximum present value at the optimal rotation time. The present value of a rhino dehorned at the rotation time necessary to prevent poaching is shown (dashed line).



Finally, assuming a mortality rate of 9% associated with dehorning, the population would decline under any rotation less than 2.5 years due to the extra mortality caused by dehorning. It was concluded that a conservation measure that caused a population to decline was not practical in the long run (although in the short run it might still reduce the rate of population decline more than any other available measure). Therefore, a pessimistic note was struck about the likely success of dehorning as a conservation measure, although it was noted that if poaching could be stopped by other means, conservation could perhaps be funded by sustainable dehorning.

Since the paper was published, the results of the first dehorning exercises have appeared, and so the model has been recalculated using data from these exercises. Several new conclusions can be reached:

1. The mortality associated with the dehorning operation is now substantially lower than was assumed in discussing the results of the model. This means that the sustainable rotation period is shorter than that needed to deter poachers, and so loses its importance as a determinant of the usefulness of dehorning as a conservation measure.

2. The data on horn regrowth rates are scanty, and neither justify nor contradict the assumptions made in the model. More data are needed on this parameter, especially on the functional form of horn regrowth, which is particularly important for the validity of the model. Sensitivity analyses have shown that the effects of changes in the rate of horn regrowth are less likely to have a major effect on the results than changes in the functional form for regrowth.

3. There are few up-to-date data on horn prices received by poachers, and none on the costs of poaching, for the countries where dehorning has taken place, or may soon take place. The poacher's cost-price ratio is the crucial determinant of the interval between dehornings, since mortality during dehorning is less important. The data used here for the poacher's cost-price ratio are still the best available, despite being for the Luangwa Valley, Zambia, in 1985. This lack of data on the costs of poaching must be rectified if a rational programme of dehorning for control of poaching is to become a major part of the rhino conservation effort.

4. The costs of dehorning to managers are the best documented data, but the costs vary in magnitude by a factor of five. The price of horn to managers has been estimated twice, but must remain unclear until there is a realistic possibility of a legal horn market. The manager's cost-price ratio could therefore take a large range of values, and so could the potential profitability of dehorning and selling the horn. It is impossible to tell at this stage whether dehorning could cover the conservation budget of a country or be a drain on resources. Partly this depends on whether dehorning is used as a method of deterring poaching as well as generating money, or whether it is carried out on a secure population of rhinos.

5. The data still suggest that dehorning as an anti-poaching measure must always be carried out sooner than would be optimal for a profit-maximising manager. The low mortality associated with dehorning, and the apparent, although thinly documented, success of dehorning in preventing poaching over the last three years (Milliken et *al.* 1993) might have led us to be more hopeful about the future of dehorning as a sustainable conservation strategy. Indeed, results from black rhinos in Zimbabwe remain encouraging in that only 14 or 15 rhinos have been poached out of a total of around 210 dehorned (Milliken pers. comm.). However, the loss of most of Hwange's dehorned white rhinos in early to mid 1993 may raise further concerns over the decision to dehorn. At least two factors may have come into play here: the rotation period between dehornings and the lack of protection for dehorned rhinos.

In relation to the first factor, our own model suggests that rhinos need to be dehorned every 1.3 years to deter poachers (Figure 2), and most of the Hwange white rhinos had been dehorned slightly longer ago than this when they were killed. Therefore, one possible implication from our model is that the horns had already grown enough to be attractive to poachers, and indeed many of their horn bases and regrown stumps had been removed by the poachers. Other explanations that have been advanced include that having tracked a rhino, only to find it dehorned, poachers kill it so as not to waste time in future following its tracks (Milliken pers. comm.); and that there may be interest among speculators in exterminating all rhinos, dehorned or not, in order to increase the value of illegally held stockpiles (Kock & Atkinson 1993).

The second main factor is that Zimbabwe has been through a funding crisis in which the Department of National Parks and Wild Life Management budget has been cut, and anti-poaching patrols ceased during early to mid 1993 in Hwange, thereby providing dehorned rhinos with no protection and so reducing the costs of poaching. Without further information, it will probably not be possible to determine the extent to which these various factors were responsible, alone or in combination, for the extensive loss of these dehorned white rhinos in Hwange.

In conclusion, it appears clear that while dehorning mortality is less of a concern than we had originally assumed, other factors, such as the optimal rotation times between dehornings and continuing to provide adequate protection, will remain important considerations in determining whether dehorning is likely to succeed as a measure that will contribute to the successful conservation of African rhinos presently facing an onslaught of poaching in southern Africa.

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Des Eléphants et des Hommes. Etude de Gas: Les Populations d'Eléphants d'Alfakoara (Nord-est du Bénin)

Gerard Sournia

UICN-France et pays francophones UICN, 2 rue de Bel Air, 37400 Amboise, France

Petit pays côtier, situé le long de la côte Atlantique du golfe de Guinée en Afrique de l'Ouest, le Bénin est, malgré sa position géographique, plus un pays de savanes soudaniennes qu'un pays forestier. Comptant près de 5 millions d'habitats reepartis sur 112 6OO km^2, le Bénin est un pays essentiellement agricole, sans ressource minière et sans tissu industriel significatifs. La quasi-totalité de sa frange nord, limitrophe des pays voisins, est constituée par un réseau d'aires protégées (pares nationaux, zones cynégétiques, forêts classées). C'est dans ce contexte que se localisent le site d'Alfakoara et l'étude de cas présentée ci-après.

Alfakoara, village développé le long de l'axe Parakou-frontière du Niger à une quarantaine de kms au nord de la ville de Kandi (et à 65O km de Cotonou la capitale, est situé au contact direct de la Zone cynégétique de la Djona (ZCD) et de la Forêt classée de Goungoun (Figure 1).

Depuis quelques années, et sans que l'on en connaisse avec précision les raisons, un troupeau d'éléphants comptant plusieurs dizaines de têtes et de toutes classes d'âge, fréquente les abords immédiats du village et plus précisément une zone dépressionnaire large de quelques dizaines de mètres et longue de quelques centaines située à l'ouest du contact des cultures, du village et de la ZCD.

Cette fréquentation quotidienne ou bi-quotidienne, semble incontestablement motivée par la recherche de l'eau dont, on le sait, les éléphants ont un grand besoin et toujours en grande quantité. La dépression s'assèche assez rapidement en surface dès les mois de janvier-février, mais le niveau de la nappe n'étant jamais trés profond, les pasteurs puis les éléphants aidés en cela par les habitants, ont creusé un certain nombre de trous de 2 à 3 m de profondeur et de diamètre réduit (équivalent de l'ouverture d'un grand seau), grâce auxquels les éléphants parviennent à s'abreuver avec difficulté et à procéder à une aspersion avec encore plus de difficultés. L'accès aux trous d'eau est si limité en nombre et si malaisé que lorsque le groupe d'éléphants est relativement important (32 têtes comine nous avons pu le constater le sainedi 11/ O4/93, lors d'une visité effectuée sur le site à la tombée du jour), chacun doit attendre son tour pour y accéder et les accidents n'y sont pas rares; deux éléphanteaux sont morts embourbés, un autre a pu être sauvé par les villageois qui se sont mobilisés à cet effet.

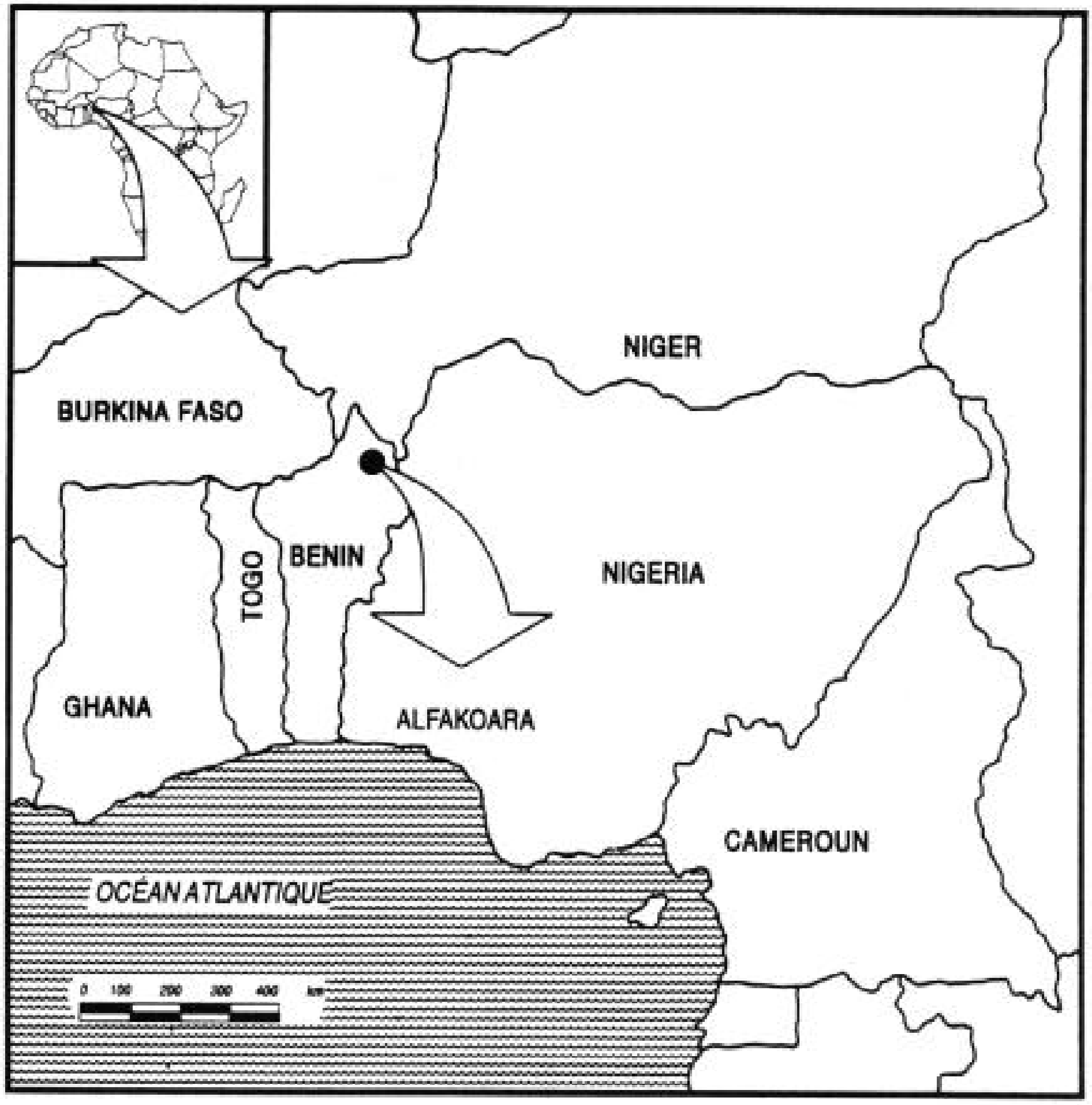
LES ELEPHANTS D'ALFAKOARA

Le groupe qui fréquente le secteur est estimé à plus de 15O têtes, éclaté en plusieurs groupes familiaux parfois eux-mêmes regroupés en clans. Leur zone de fréquentation pourrait être grossièrement circonscrite à un rayon de 15 à 2O kms à partir des points d'eau. Ils traversent l'axe goudronné (cf. schéma de localisation) plusieurs fois par jour et en particulier le matin en direction de l'Est.

Ces éléphants se caractérisent par une taille modeste et par l'absence ou la dimension réduite des pointes. Le troupeau, tout au moins celui que nous avons pu observer (mais nos remarques rejoignent celles d'autres observateurs), apparaît bien structuré avec la présence de représentants de classes d' âge différentes dont de nombreux petits; sur le groupe de 32 observés le samedi 11/O4, 2 ou 3 avaient moins de 6 mois et 2 ou 3 autres entre 1 et 2 ans.

Cette constatation réconfortante confirme les observations faites ailleurs en Afrique de l'Ouest au cours de ces dernières années; à savoir, que suite à l'interdiction du commerce de l'ivoire an plan, international et à la chute des prix et de l'intérêt des consommateurs pour cette matière, les pressions sur les populations d'éléphants ont très sensiblement diininué et cette espèce retrouve un certain nombre de réflexes et de comportements qui étaient les siens avant Ia flainbée des prix de l'ivoire et les hécatombes qui l'ont suivie dès le début des années 7O.

Figure 1. Carte montrent la situation d'Alfakoara (Bénin)



Le cas des éléphants d'Alfakoara est intéressant à divers titres, mais il n'est pas exceptionnel en Afrique de 1'Ouest; la cohabitation entre les hommes et les pachydermes existe en maints endroits: au Niger, dans la forêt de Baba N'Rafi à proximité de Maradi et de la frontière du Nigéria -dans ce cas, c'est aussi le problème de l'accès à l'eau qui constitue le point essentiel; au Mali, dans la région du Gourma où quelques centaines d'éléphants cohabitent, au cours de leur migration annuelle avec les pasteurs et leur bétail aux abords des mares; au Togo dans la forêt classée de la Fosse aux Lions, au nord du pays (mais suite aux récents évènements que connaît ce pays, le troupeau d'éléphants a été décimé ou dispersé); au Burkina Faso dans la forêt classée des Deux Balé et aux abords immédiats de la route Ouagadougou-Bobo Dioulasso et à proximité de la ville de Boromo.

Dans le cas d'Alfakoara, des analyses d'eau et de terre devront être effectuées pour mieux en connaître la composition et les éventuelles particularités; il est tout à fait pensable en effet que ces points d'abreuvement jouent en même temps un rôle de salines (“pharmacies naturelles”), trés recherchées par la plupart des espèces qui en ont besoin pour leur développement physiologique. Des traces d’hippotragues et de phacochères ont également été relevées sur le site.

Quelques travaux universitaires ont été consacrés à Alfakoara; ils fournissent un certain nombre d’informations et tentent d’apporter quelques éléments explicatifs quant à la présence de cette population d’éléphants en ce lieu précis, sans pouvoir trancher ni sur son origine, ni sur ses raisons.

Cette présence stigmatisée depuis 2 ou 3 ans serait, si 1’on en croit le témoignage d’un agent forestier (décédé depuis peu), signalée depuis beaucoup plus longtemps; ce serait donc 1’intérêt particulier qui lui est porté depuis peu qui serait relativement nouveau.

PROBLEMATIQUE

Le particularisme d’une telle situation réside dans le fait que ce groupe d’éléphants cohabite, jusqu’à maintenant, en bonne harmonie avec les populations locales qui manifestent à leur égard intérêt et considération; plusieurs témoignages concordent dans ce sens: action spontanée de surcreusement de trous pour favoriser l’abreuvement, assistance à des éléphanteaux en difficulté, manifestations de joie à l’arrivée quotidienne des troupeaux **...**

Si cette coexistence peut être maintenue, elle devrait être renforcée et rationalisée afin de favoriser au maximum la maîtrise de l’espace, le partage équilibré des ressources (eau et pâturage en particulier) et d’accroître la responsabilité des populations locales.

Les éléphants d’Alfakoara commencent à être connus; le site reçoit des visiteurs en provenance de Cotonou ainsi que les voyageurs de passage sur l’axe bitumé situé à 5OO m du site. Le développement d’un projet d’écotourisme de dimension modeste, à mener en liaison et avec la participation et l’intéressement effectif des populations locales est tout à fait envisageable.

Pour le PGRN, et plus particulièrement pour son volet Faune et Eco-Développement rural, l.’analyse, le traitement et la gestion d’une telle action seront un test révélateur de la volonté des autorités administratives et techniques de s’impliquer dans cette nouvelle approche plus participative.

Les propositions formulées ci-après s’inscrivent dans cette optique; elles s’efforceront de tenir compte:

- de l’aménagement du point d’eau, de son alimentation permanente,
- de 1’intérêt des autres occupants de l’espace (terroir villageois et surtout pasteurs et leurs troupeaux),
- de la nécessité d’impliquer, de responsabiliser au maximum les populations tout en veillant à ce que leur engagement se traduise par des retombées sociales significatives pour l’ensemble de la communauté villageoise,
- du développement d’une campagne d’information favorisant l’émergence d’un écotourisme; cette campagne pouvant être relayée par le programme d’éducation environnementale **.**

PROPOSITIONS D’ACTIONS ET SOLUTIONS POSSIBLES

1. Aménagement et gestion des points d’eau

Le principe essentiel à respecter est de pouvoir garantir l’accès à la ressource eau et donc sa pérennité tout au long de l’année et en particulier lors des moments les plus difficiles de la saison sèche (janvier à avril-mai).

Toutefois, les propositions développées ci-après ont été discutées et testées auprès de plusieurs personnes et en particulier auprès des responsables du Service des Volontaires Allemands basés à Parakou et Kandi qui ont déjà procédé à de nombreux creusements de puits dans ce secteur géographique; leur avis technique s’est révélé relativement positif (sous réserve d’un contrôle technique du terrain).

Deux hypothèses sont envisagées. Les deux ont pour objet de creuser la dépression: soit dans sa totalité (hypothèse I), en reliant l’ensemble des trous existants; soit en procédant au creusement de plusieurs mares (3 ou 4), chacune correspondant à la liaison de plusieurs trous, pour constituer autant de mares individuelles de 5OO à 1OOO m^2 chacune (hypothèse II). Dans les deux cas, le plancher de creusement se situerait au niveau où l’eau qui filtre actuellement (c’est-à-dire en fin de saison sèche) et ce afin d’être assuré d’obtenir sur l’ensemble de la surface (ou des surfaces ainsi dégagées) une hauteur d'eau régu1ière.

La seconde hypothèse permettrait une meilleure répartition des groupes d'éléphants et une meilleure utilisation de la ressource eau dans la mesure où les é1éphants, lorsqu'ils n'ont pas affaire à de l'eau courante apprécient de pouvoir distinguer entre le point d'abreuvement proprement dit et le point d'aspersion et de "toilette".

Quelle que soit l'hypothèse retenue, le creusement de deux puits aux extrémités longitudinales de la dépression sera indispensable afin, en particulier, de maintenir le niveau de l'eau dans la, ou les, mare(s) constant et suffisant pour l'ensemble des besoins du troupeau au coeur de la saison sèche. Pour chacun de ces puits, un creusement d'une dizaine de mètres serait certainement suffisant si 1'on se réfère au niveau constaté de l'eau dans les trous actuels et celui du poste de garde situé légèrement en surplomb et où l'eau était accessible entre 7 et 8 m (mi-avril).

Les puits seraient alimentés par une pompe solaire installée sur la bordure nord de la dépression, naturellement élevée et qui pourrait être surélevée par l'entassement des déblais de terre consécutifs au creusement de la dépression; l'installation solaire serait protégée par un fossé interdisant son accès aux éléphants; l'énergie solaire s'avérant préférable à l'énergie éolienne et ce pour diverses raisons.

L'accès au plan d'eau par sa partie sud serait aménagé en pente douce et pavé de pierres de latérite afin d'éviter glissades et embourbements.

Les travaux de creusement de la dépression et si possible des puits seraient confiés (sous contrôle technique) à la communauté villageoise dont les membres seraient payés pour effectuer les travaux. Cette période de travaux se situerait pendant la saison sèche, période laissant le plus de disponibilités au plan agricole et période où la nappe phréatique est la plus basse. Les travaux effectués dès le matin jusqu'à midi seraient peut-être compatibles avec la poursuite de fréquentation du site par les é1éphants, en particulier en fin de journée et pendant la nuit. Toutefois un aménagement alternatif sera proposé pour le cas où cette cohabitation pendant les travaux serait jugée incompatible. Cette contribution rémunérée des villageois, constituerait une forme d'intéressement et de participation active à la gestion des resources naturelles (eau, faune *sauvage…)*

2. Mesures alternatives et d'accompagnement

Si à l'analyse de ces propositions, il s'avère que les travaux à effectuer sont incompatibles avec la fréquentation quotidienne par les é1éphants, une solution alternative sera proposée afin de maintenir le troupeau sur le site, ou dans son voisinage immédiat. Dans cette optique, il pourrait être envisagé d'identifier un bas-fond alimenté pendant la saison des pluies, situé à 1 ou 2 km d'Alfakoara et sur lequel pourrait être aménagée une retenue d'eau (type Nazinga) qui serait destinée à fixer les animaux. Cette retenue serait également construite en faisant appel à la main d'oeuvre locale; elle devrait être réalisée trés rapidement afin de pouvoir être fonctionnelle et opérationnelle lors de la prochaine saison sèche.

Par ailleurs, un aménagement hydraulique devra être consenti aux éleveurs et aux villageois en permettant le creusement d'un puits à l'est de l'axe goudronné, et ce, afin de ne pas créer de perpétuelles tensions entre les divers utilisateurs de l'espace et de la ressource eau.

3. L'écotourisme

La présence permanente des éléphants et leur observation aisée vont incontestablement créer un point de fixation et d'intérêt adapté à un certain type de tourisme.

C'est dans cette optique que le site doit être organisé (si toutefois les aménagements proposés s'avèrent pertinents et rationnels) afin de faciliter l'accès au site, l'observation des pachydermes et le séjour des visiteurs.

A cet effet, il est proposé de construire deux miradors d'observations aux abords de la mare, dissimulés dans le rideau d'arbres, d'une capacité de 7 à 8 personnes chacun. Ces rniradors seront reliés par un sentier pédestre depuis le poste de garde, dont le tracé épousera l'abri de la ligne d'arbres. Ce sentier pourra éventuellement être prolongé vers la retenue aménagée au niveau du basfond, si celle-ci était faite. La construction d'un mirador serait alors également indispensable. Si les conditions de relief le permettent, il peut également être envisagé de creuser des caches; ces abris enterrés offrent un champ de vision qui se situe légèrement au-dessus du niveau du sol et permet de ce fait d'avoir une excellente perspective du site et d'effectuer d'excellentes prises de vues.

Au niveau du poste de garde, deux appatams (toiture de paille sur de ciment), pourraient être construits pour accueillir des visiteurs dotés d'un matériel de camping autonome et qui voudraient profiter de l'observation la plus favorable, celle de la tombée de la nuit; un aménagement de type 'barbecue" pourra également être proposée Ce minicampement sera réalisé et géré par les villageois; les prix seront à déterminer localement.

L'édition d'une plaquette et d'un autocollant sur les éléphants et pouvant être vendus aux touristes peut également être envisagée. Les prix de visite et la répartition de la recette seront également des points à discuter entre la communauté villageoise et le PGRN; la création d'une Association de protection des EIéphants d'Alfakoara pourrait être le début d'une organisation locale.

Le budget global estimé pour l'ensemble de ces aménagements et sur la base des informations recueillies sur place devrait être de l'ordre de 8 à 1O millions de FCFA.

4. Participation et intéressement des populations

Les populations d'Alfakoara seront totalement impliquées dans les aménagements décrits.

Elles devront être associées à la réalisation du projet dès sa conception.

Leur intéressement prendra la forme d'une participation rémunèrée à l'ensemble des travaux envisagés, tant au niveau de l'aménagement du site, qu au niveau des aménagements liés à l'écotourisme. Une campagne d'information devra être misc en place dès le début des discussions avec les populations.

Au niveau scolaire, une forte sensibilisation sera effectuée en direction des éIèves et de leurs enseignants par le biais de l'antenne d'éducation environnementale qu'il est proposé d'installer à Kandi.

Si cette action spécifique est couronnée de succès, elle devra être l'objet d'un suivi scientifique qui concernera la diversité biologique mais également, au plan social, les relations populations locales-gestion des ressources naturelles. Et sur ce point une collaboration avec l'Université nationale du Bénin doit être encouragée et privilégiée.

Le cas d'Alfakoara est exemplaire d'une situation qui, certes, existe déjà ailleurs mais risque de se multiplier compte tenu d'une sensible remontée constatée des effectifs des populations d'é1éphants, tout au moins dans certaines parties du continent. La solution qui y sera apportée dans le souci de prendre en compte tant les intérêts des populations humaines locales que de la ressource faune dans un contexte de développement, sera un bon test de la capacité d'un gouvernement et de ses partenaires internationaux de relever et de gérer ce genre de défi; ce sera aussi un test quant à l'avenir et à la sauvegarde des éléphants.

An Aerial Survey of Rhinoceros and Elephant in a Portion of the Chobe National Park and Surrounding Areas, Northern Botswana, September 1992

M.H. Knight', P. Hitchins [2] and K.P. Erb [3]

[1] Scientific Services, National Parks Board, P O Box 110040, Hadison Park 8306 Kimberley, South Africa
[2] Rhino & Elephant Foundation, P O Box 381, Bedfordview 2008, South Africa
[3] Research Section Ministry of Wildlife Conservation & Tourism, P/Bag 2506, Otjiwarongo, Namibia

ABSTRACT

A low intensity total count aerial survey, using two aircraft simultaneously, was undertaken specifically for black and white rhinos, and elephants, over 15057 km^2 of northern Botswana during the 1992 dry season. No black rhinos were recorded, while a total of 7 white rhinos were counted in the survey. Inclusion of a visibility correction factor of 1.017 for elephant raised the total number of elephant counted to 14758 individuals, an estimated density of 1.15 elephant/km^2. The search rate for elephant was estimated at 305 km^2/hr. The relatively low corrected rate for elephant carcass ratio of 3% was indicative of a population with a reduced mortality and/or increased immigration.

INTRODUCTION

Northern Botswana is one of the last refuges of free-ranging large mammal populations in southern Africa. It is home to a large and increasing elephant population estimated at 55,000 animals (A. Verlinden *pers. comm.).* However, the black Diceros *bicornis* and white *Ceratotherium* simum *simum* rhinoceros populations are in a more critical state.

Black rhinos, once relatively common in northern Botswana, were drastically reduced in number by past hunting and more recently by poaching activities. Less than 20 individuals were suspected to occur within the region in 1968 (Smithers, 1971), and even fewer towards the end of the 1980s (Potgeiter & Walker, 1989). Although the Botswana population was considered a separate subspecies D.*b. chobiensis,* based chiefly upon skull morphology (Rookmaaker & Groves, 1978), preliminary mitochondrial DNA analyses have revealed a closer affinity with the south-central ecotype D. *b. minor* than with the more arid-adapted southwestern ecotype D.b.bicornis (Harley, 1990), recognised by the African Rhino Workshop (Cincinnati, October 1986). Nonetheless, given the slight morphological differences found in the Botswana population, the conservation of this genetic stock would be advantageous for the sake of preserving genetic heterozygosity until further definitive taxonomic work can be undertaken.

White rhinos became extinct within Botswana by the end of the 19th century through hunting activities (Bryden, 1893). Through a reintroduction programme between 1967 and 1981, a total of 71 white rhinos were successfully re-established in Chobe National Park and Moremi Game Reserve in Botswana from Natal, South Africa (Hitchins, 1988). However, owing to recent poaching activities the population has again been greatly reduced (Gavor, 1988).

The tenuous state of the rhino populations, in particular that of the black rhino, prompted the need for an intensive aerial survey of those areas where they were last recorded to ascertain if they still existed and what their actual status and distribution was. The ultimate goal of the operation was to relocate the few remaining black rhinos to a sanctuary situated elsewhere in Botswana to form a safe breeding nucleus.

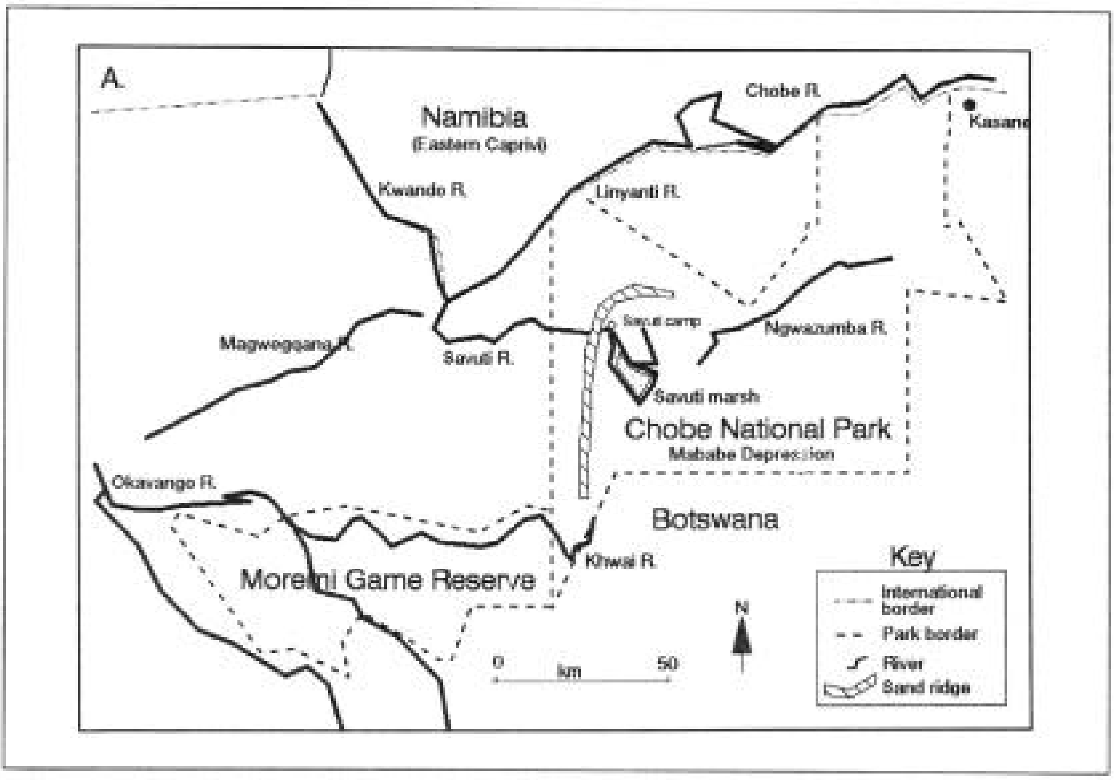
To make the survey that much more beneficial, it was decided to incorporate counts of white rhino and elephant *Loxodonta africana* within the study.

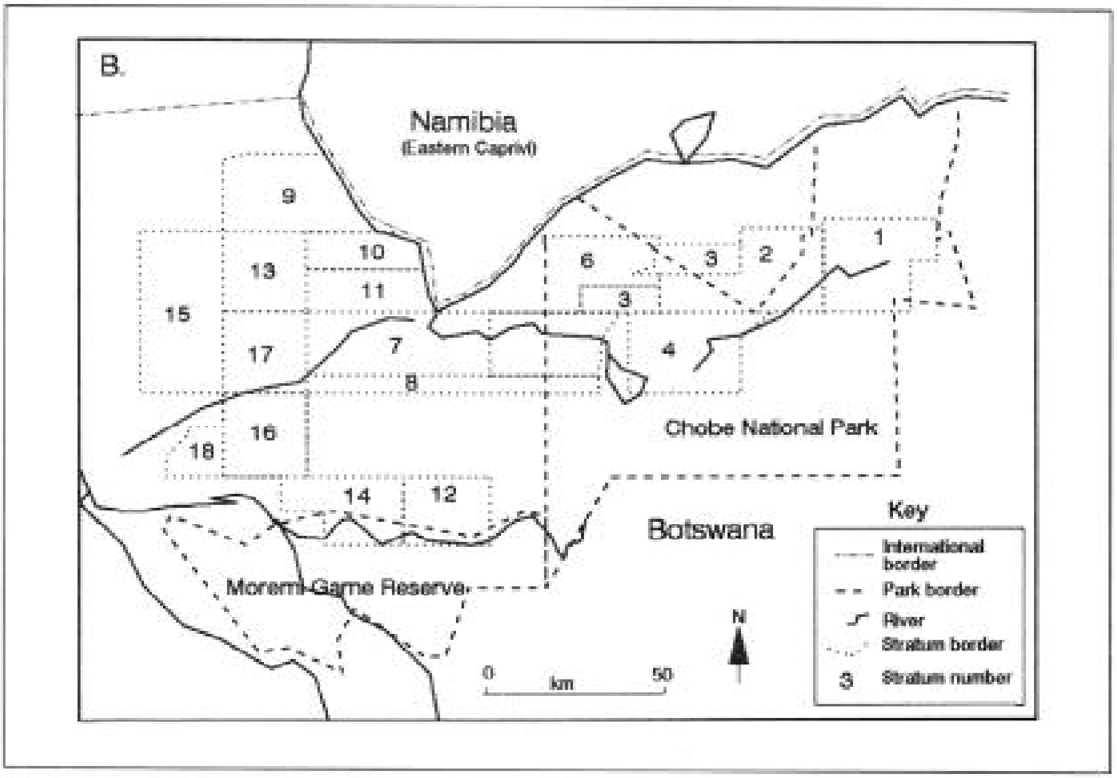
STUDY AREA

The survey area incorporated the Chobe National Park (CNP) (except the area north of the 18 and the area between the northern border of the Moremi Game Reserve, and the Caprivi Strip, Namibia (Figure lA).

With the exception of a few hills in the Savuti area, the flood plains of the Kwando and Linyanti rivers in the north and the Okavango delta ito the south, the vast majority of the survey area was flat and featureless (Figure 1). The perennial Kwando and Linyanti rivers formed the north western border of

Figure IA & B. The study area (A) with survey strata (B) in and around the Chobe National Park, Botswana.





the survey area while the Khwai river (part of the Okavango Delta) formed the southern border. The predominantly dry Savuti channel and Magwegqana (or Selinda spillway) run from the Linyanti swamps and Okavango delta, respectively. The former river periodically drained into the Savuti 'marsh', part of the larger Mababe Depression. Similarly, the ephemeral Ngwezumba river also drains into the Depression in exceptionally high rainfall years. Bisecting the study area is a sand ridge that runs from the northern side of the Mababe Depression, southwards to the eastern side of the Okavango delta.

The region receives between 400-800 mm of rain between October and March, with the greatest proportion falling in the latter half of the summer season. The remainder of the year is dry.

The vegetation consists predominantly of deciduous dry woodland and scattered grasslands on either Kalahari sands or shallower clay soils. The vegetation consists of open grasslands in association with large pans in the east. From this, a northern band of open stands of *Baikiaea plurijuga*, *Burkea africana* and *Pterocarpus angolensis* on deep Kalahari sands stretches to the western extreme of the study area. Large areas of the southern sections of the survey area, north of the Khwai river, consist of *Colophospermum mopane* on shallower soils with a higher clay component.

Along the Savuti channel large trees of *Acacia erioloba*, *A.nilotica*, *A. nigrescens* and *Combretum imberbe* were found. The riparian vegetation along the Kwai, Linyanti and Kwando rivers appeared similar with stands of *Kigelia africana*, *Ficus natalensis*, *A. nilotica*, *Hyphaene benguellensis* and *Phoenix reclinata* in association with short green grazing lawns.

METHODS

FLYING AND COUNTING PROCEDURE

The principle aim of the survey was to locate black rhinos. The survey was undertaken in the late dry season (September) when the visibility is least impaired by the vegetation. The selection of areas most likely to have black rhinos was based upon past sighting records of animals or their tracks (M. Slowgrove, L. Wilmot, G. Calef, M. van der Waller and D. Joubert pers. comm.), the availability of dry season drinking water supplies, and the absence of human settlements. Aerial coverage did not extend beyond 30 km from waterholes the maximum foraging distance black rhinos were noted to forage water in the dry season (Joubert & Eloff, 1971).

In order to maximize the chances of detecting black rhinos, it was decided to use two aircraft simultaneously to scan along each transect. Two Cessna 210 aircraft were used in the survey, with the flying formation consisting of the leading aircraft flying at low level (70 m above ground level [AGL]). The second aircraft flew at 140 m AGL and maintained a track approximately 300 m to the right of the leading aircraft and trailed by 600-700 m (or a 10 sec separation). Both aircraft maintained a ground speed of approximately 90 knots. It was intended that the lower flying lead aircraft would flush any black rhino for the trailing aircraft to detect.

The leading aircraft was manned by a pilot, navigator, and three or four observers, two of whom were always seated on the right-hand side of the aircraft looking into the track of the trailing aircraft. The leading aircraft's objectives were to navigate the predetermined transects for both aircraft, flush any rhinos potentially obscured by vegetation or directly under the aircraft for the second aircraft to detect, as well as observe animals (both alive and dead). All navigation was done with the aid of a Global Positioning System (Garmin 100 ADV). The objective of the second aircraft with pilot, observer! recorder (seated directly behind the pilot), the three or four observers (one of whom was always seated on the left-hand side behind the recorder) was to record all sightings of rhinos, noting their positions on a separate GPS system. The positioning of the second aircraft was designed to cover the obscured zone beneath the leading aircraft. The flying formation thus allowed four observers to scan the 300 m between the two aircraft.

As the estimation of animal densities was not a specific task of the survey, all black and white rhinos and elephants seen from the second aircraft within the unbounded transects were recorded. Thus the survey could be described as a low intensity total count. The maximum detection range for large conspicuous species such as elephants in the open, leafless savanna was estimated to be about 900 m on either side of the second aircraft. This was estimated on the ground by measuring the distance to recognizable features during trial runs. As transects were 2 km apart, the chances of double counting were therefore considered remote.

The survey area of 15057 km^2 was subdivided into 18 strata, ranging in size from 547 to 142 km^2 (Figure 1 B). Transects were orientated in an east to west direction and the strata were flown in sequential order from east to west.

On spotting a rhino, the second aircraft would maintain its altitude and circle the position while guiding the lower aircraft in to determine the sex and age of the animal and take photographs.

VISIBILITY BIASES

Although the counts were not within defined strips, an indication of potential visibility biases between observers, particularly with respect to counting elephants, was determined using the Petersen markrecapture method (Seber, 1982), as modified by Marsh & Sinclair (1989). This entailed the observer/ recorder of the second aircraft noting what elephant groups he detected (SF), what groups the second observer directly behind the recorder saw (Sr) and what they both observed (B). A perception correction factor (C) for groups of elephants per stratum was calculated by:

C=((Sf+B) (Sr+B))/(B(Sf+Sr+B)

with the coefficient of variation (Cp) calculated by:

Cp=((Sf+Sr)/(Sf+Sr+B))* √((Sf*Sr) (B((Sf+B) (Sr+B)))).

An elephant herd was defined as any aggregation showing some form of cohesion that was separated from other groups or individuals by a clear break that was greater than the diameter of the herd in question.

CARCASSES

The coordinates were recorded for every rhino and elephant carcass seen by either of the two aircraft. Communications between the two aircraft reduced the chances of double counting carcasses. The carcasses were categorised as:

1 . 'Old': white scattered and bleached bones.

2. 'Fresh': skin covering the skeleton. With a closer inspection from the air, the age was more precisely estimated in either weeks or months depending upon: the presence of scavengers (vultures, jackals and spotted hyenas); signs of blood or body fluids around the carcass; the degree of bloat and the open patch around the carcass through trampling and the concentration of body fluids. Where possible, the presence or absence of ivory, or horns in the case of rhinos, was also noted.

A carcass ration, calculated as a percentage of the combined total number of carcasses and the alive animals counted per strata was calculated. As no correction factor for the under-counting of elephant carcasses was estimated, the three times correction suggested by Dublin & Douglas-Hamilton (1987) was used.

DISTRIBUTION OF PANS

All pans with a diameter greater than 50 m across their flat unvegetated surface were noted for the presence of drinking water. The coordinates of those holding water were recorded on the GH S system.

TREE DAMAGE

An estimate of 'tree damage' (defined as felled trees only), assumed to have been caused by elephant, was determined during the latter half of the survey. A roughly five, minute scan interval was used in which the proportion of felled trees were categorised into one of four subjective categories: nil (0-10 **%),** light (11-25 **%),** moderate (26-50 **%),** and heavy (>50 **%),** depending upon the percentage of felled trees to those standing. A tree was defined as being greater than 5 m in height.

RESULTS

BLACK RHINO

No black rhinos were seen during the survey.

WHITE RHINO

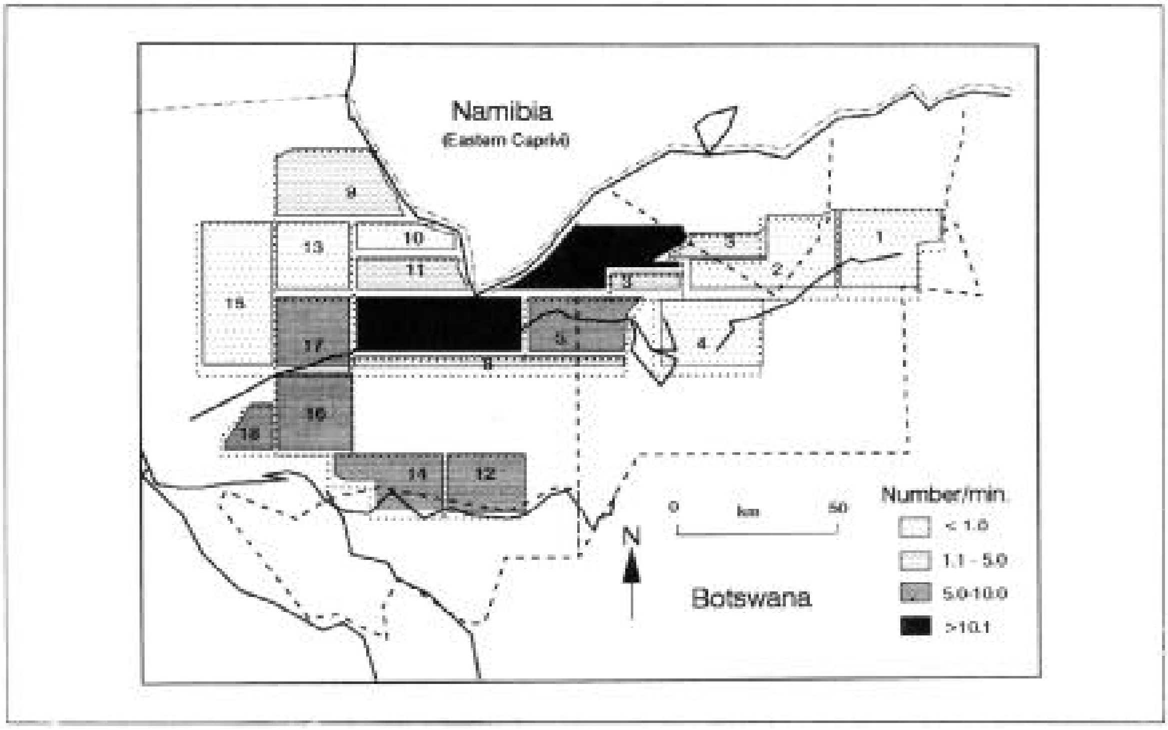
A total of seven white rhinos, in four groups, were counted during the survey. Two individuals (an adult male and female) were found in northern Moremi Game Reserve, while the remaining five animals (two adult females, one unsexed subadult and two unsexed immature individuals) were located in eastern Chobe National Park.

A single fresh white rhino carcass was also located in eastern Chobe, from which the horns were noted to have been removed.

Table I. Stratum areas, flying times and the number of elephants counted in each stratum.

Date	Stratum No.	Area (krn2)	Flying time (h)	Elephants counted	Elephants counted / min. flying
19.9.92	1	1,065	3.5	195	0.9
20.9.92	2	1,318	3.5	53	0.3
20.9.92	3	785	1.2	108	1.5
21.9.92	4	1,080	3.0	125	0.7
21.9.92	5	660	1.8	783	7.4
22.9.92	6	1,114	3.1	4,717	25.4
23.9.92	7	1,158	3.5	2,751	13.1
23.9.92	8	533	1.4	168	2.0
24.9.92	9	1,084	2.8	311	1.9
24.9.92	10	399	1.5	56	0.6
25.9.92	11	480	1.9	212	1.9
26.9.92	12	596	1.9	657	5.8
27.9.92	13	726	2.1	117	0.9
28.9.92	14	757	2.9	861	4.9
29.9.92	15	1,452	2.4	45	0.3
30.9.92	16	726	2.5	869	5.8
1.10.92	17	726	2.1	977	7.8
2.10.92	18	547	0.8	435	8.9
Mean (±SD)					5.0± 6.3
Total		15,057	41.9	13,440	

Figure 2. The distribution and number of elephants counted per minute flying time in and around Chobe National Park.



ELEPHANT

The rate (number counted/min flying time) at which elephants were counted varied greatly between strata (Table 1 and Figure 2). Strata 6 and 7 had the largest number of elephants counted (4717 and *2751),* plus the highest count rates of 25.4 and 13.1 elephant/min flying time, respectively, well above the average of *5.0±6.3* elephants/min. The largest concentrations of elephants (> 5 elephants counted/min flying) were found in association with riverine or swamp vegetation types with predictable supplies of permanent drinking water, as opposed to those areas with rather unpredictable supplies of water in the many scattered pans.

ELEPHANT HERD COMPOSITION

Breeding herds, which were on average larger than bull herds, were found to represent about 90.8 % of the

Figure 3A & B. The frequency distribution of breeding (A) and bull (B) herd sizes in vicinity of Chobe National Park, Botswana.

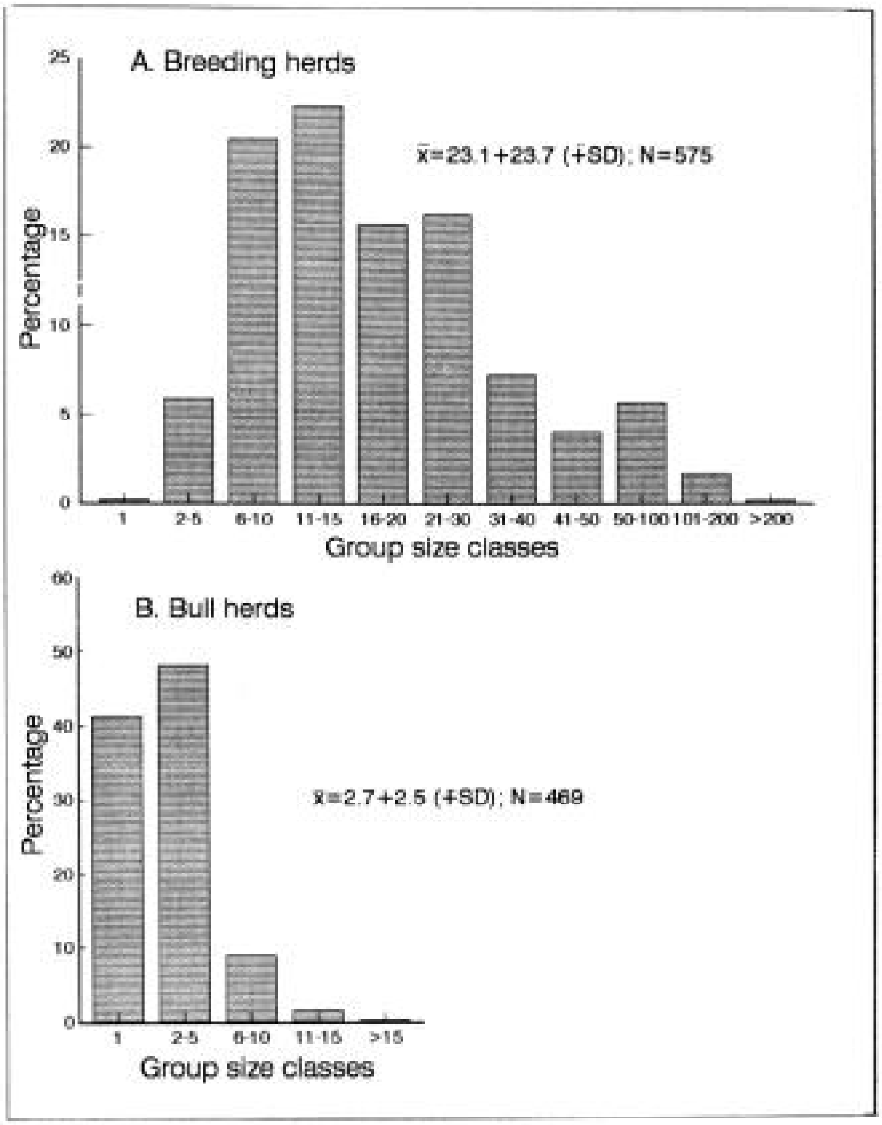
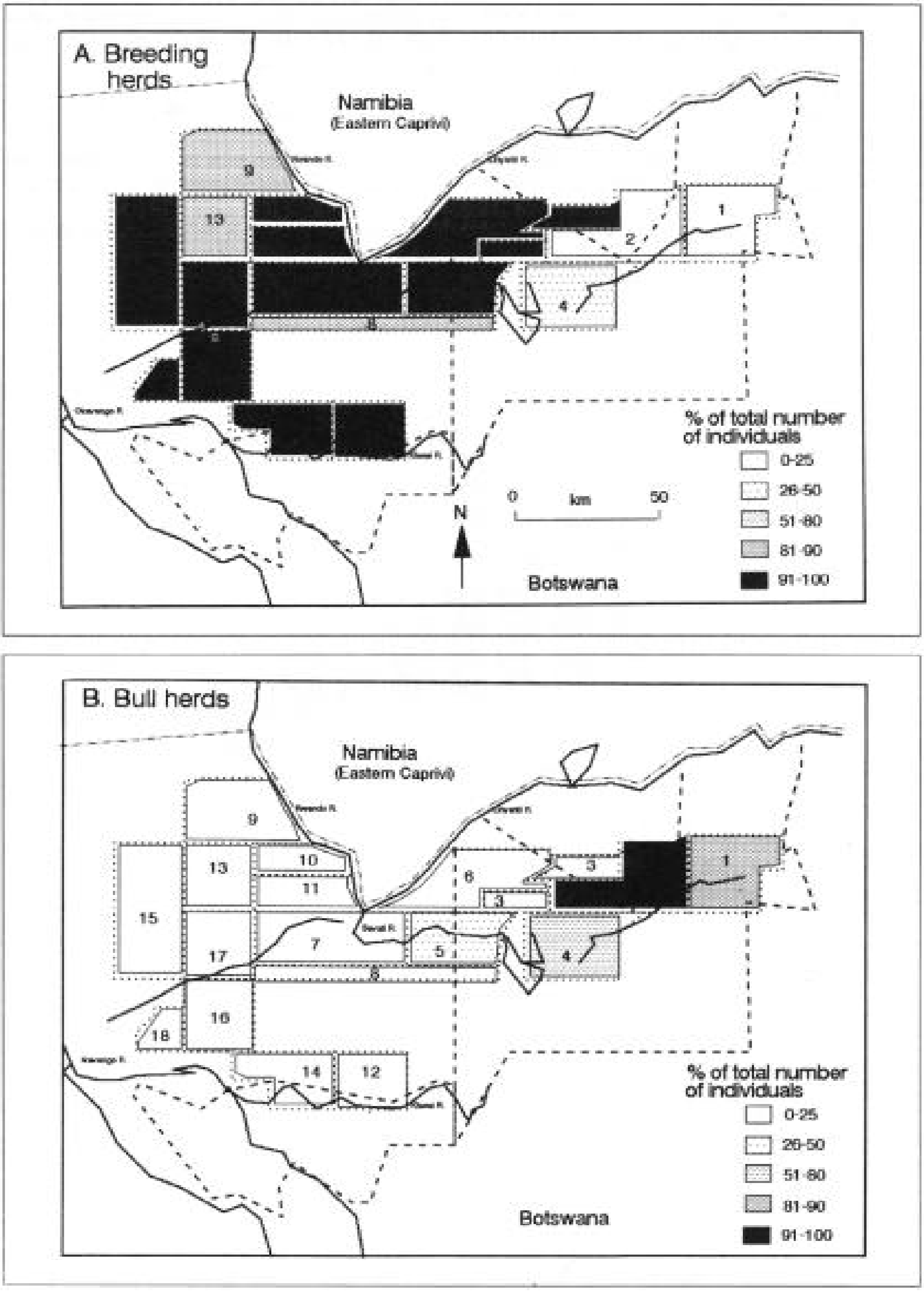


Figure 4A & B. The distribution of elephant breeding (A) and bull (B) herds in and around the Chobe National Park.



surveyed population (Figure 3). Although the mean breeding herd size was 23±24, the median herd size appeared to be between 11-15 individuals. It was noted that as the proportional representation of bulls within a stratum increased, so did the herd sizes ($r=0.488$; $N=16$; $P<0.05$). No similar relationship was detected for the breeding herds ($r=0.306$; $N=16$; $P>0.05$).

During this late dry season survey; breeding herds were noted to be predominantly concentrated within strata that had permanent riverine water supplies (Figure 4A), while a large proportion of the bulls was found well away from the riverine water supplies in strata 1, 2, 4 and 5 (Figure 4B).

ELEPHANT CARCASSES

An average uncorrected carcass ratio of 1 % was estimated for the entire survey area (Table 2). Certain areas, particularly strata 2, 15, 10, 11 and 1, had the highest ratios. A ratio of 41:59 fresh:old carcasses was recorded for the survey area. There appeared to be no link between the distribution of old and fresh carcasses, as old carcasses tended to be concentrated in strata 1 and 2, while the fresh ones were predominantly found in strata 10 and 11. The majority of the fresh carcasses were estimated to be less than three weeks of age. The carcasses tended to occur individually except for one cluster of four that appeared to have had their tusks removed. Only one other fresh carcass was noted to have had the tusks removed, more than likely indicative of poaching activities.

No relationship was detectable between the number of fresh and old carcasses and the total number of pans and the proportion of pans with drinking water.

Table 2. The number of fresh and old elephant carcasses, and carcass ratio in Chobe National Park and the surrounding area. Nmbers in parentheses had tusks removed.

Stratum	Elephant Carcasses			
	Old	Fresh	Number/h flying	Carcass ratio
1	13	0	3.7	6.3
2	19	0	5.4	26.4
3	5	0	4.2	4.4
4	9	0	3.0	6.7
5	4	0	2.2	0.5
6	0	1(1)	0.3	0.0
7+8**	0	11	2.3	0.4
9	0	4	1.4	1.3
10+11**	2	28 (4)	8.8	10.1
12**	4	0	2.1	0.6
13**	0	3	1.4	0.3
14	0	1	0.4	0.1
15**	2	0	0.8	11.8
16	3	0	1.2	0.3
17	0	0	0.0	0.0
18	8	0	10.0	1.8
Total	69	48		
Mean (±SD)	4.3±5.5	3.0±7.4	3.0±2.9	0.8

**Strata with river frontage

PERCEPTION CORRECTION FACTOR

With a total of 63, 68 and *435* elephant groups seen by the front, rear and both observers, respectively, the perception correction factor for elephant groups within the unbounded transects was 1.017, with a low coefficient of variation (CV) of 0.2 % over the entire survey. This is indicative of little variability between the two observers in detecting elephant groups. Assuming that the maximum detectable range of elephants was 900 m, a relatively high overall coverage of 85.5 % (range 40.2 - 99.2 %) of the area was obtained while counting elephant. Using the perception correction factor and the average elephant group size of 13.9±20.4 (±SD) (N=1044), the corrected number of elephant directly counted would be 14758, 9.8 % greater than the actual number counted.

ESTIMATED TREE DAMAGE BY ELEPHANT

Within the. 10 strata surveyed for tree damage by elephants, heavy damage was recorded in only 5.3 % of scans (N=l 86). This was restricted predominantly to strata 7, 8 and 18 that were associated with the Savuti and Magwegqana rivers. Nil to limited damage was recorded in the strata north and west of Kwando and Magwegqana rivers, respectively. A significant positive relationship (r=0.80; n=1 0; P<0.0 1) was found between the number of elephant (represented as the number seen/ min. flying) and the combined percentages of scans with heavy and moderate tree damage.

DISCUSSION

I. RHINOS

Although no black rhinos were actually detected during the relatively intense survey, some individuals may still exist within northern Botswana. The vastness of the area and the poor detectibility of this species in most aerial surveys (Goddard, 1967; Kiwia, 1989) may have allowed a small population to go virtually undetected. Nevertheless, the longterm survival of this population is clearly in great jeopardy, unless action is undertaken to find and relocate the few remaining animals (Hitchins, 1992). Instead of undertaking further aerial surveys, it is recommended that those pans holding rain-water during the late dry season, particularly within the more likely north western areas of the survey range, should be checked on the ground for rhino tracks.

The few sightings of white rhinos confirm that the population in northern Botswana is at an extremely low level. From the present survey and other sporadic reports during the survey, Hitchins (1992) estimated the white rhino population in Moremi and northern Botswana to be about 27 individuals. This estimate is about 13 % of the expected population size of about 216 animals since reintroduction, that is with normal recruitment and the total absence of poaching. The presence of a freshly poached white rhino found during the survey reiterates the danger that this small population is on the brink of extinction, albeit for the second time in Botswana. The urgency of the situation resulted in a capture and relocation programme of four white rhinos from eastern Chobe to a safe, fenced sanctuary elsewhere in Botswana. However, the fact that one of the animals subsequently died from bullet wounds inflicted by poachers prior to the capture operation further emphasises the seriousness of the poaching threat facing this and other rhino populations in the rest of southern Africa.

2. ELEPHANTS

While the survey was primarily designed to optimise the detection of rhinos, a reasonably accurate low intensity total count of elephant was obtained. The open, dry and leafless tree savanna, characteristic of the late dry season, against which elephants were easily detected, more than likely accounted for the relatively wide strips of about 1.8 km. This provided an estimated maximum 85 % coverage of the survey area for elephant. This suggests that the searching rate was in the order of 305 km^2/hr and can thus be classified as a T3 total survey (Anon 1993).

Although total counts offer reasonable precision, albeit on the conservative side, they fail to offer any indication of accuracy as no confidence intervals result from the analysis, that is unless replicates are undertaken. Additional problems relate to the efficiency of counting animals in unbounded transects, particularly as smaller groups are generally more difficult to detect farther from the aircraft, thus biasing one's count towards the closer and larger groups (Burnham, Anderson & Laake, 1980). Having wide transects leads to an under-representation of smaller groups farther from the aircraft. The use of additional narrower, demarcated strips - as is done in most aerial surveys - would improve the accuracy of the population estimate (Caughley & Goddard, 1975; Western & Lindsay, 1984). However, the relatively small visibility correction factor calculated in the present survey indicated that few elephant groups were in fact missed by the observers. Using the correction factor and an assumed 85 % coverage, the average elephant density for the survey area was 1.15 elephant/km^2. This falls well within the range of dry season elephant densities estimated for the study area as recorded. from low intensity aerial surveys undertaken by the Department of Wildlife & National Parks, Botswana (Craig, 1990). Furthermore, the concentration of elephant in the vicinity of the Linyanti and Savuti rivers in the present survey reflects the normal dry season pattern (Craig, 1990).

The majority of elephants, and predominantly breeding herds, were found to be associated with permanent drinking water along the Linyanti, Khwai, Savuti and Magwegqana rivers. Along the Kwando river, relatively few elephants were recorded, possibly a result of disturbance from hunting operators and close proximity of human settlements in Namibia. The fact that a disproportionately large segment of the bull population (41%) was found well away from the riverine water supplies in strata 1, 2, 4 and 5 that amounted to about 27% of the survey area suggests a degree of concentration by the bulls in these areas. As natural supplies of drinking water were rare within these strata, the animals probably relied heavily upon the few borehole-fed waterholes.

The tendency of breeding herds to concentrate along the river-lines more than likely relates to their larger group sizes, relatively higher mass-specific energy demands (owing to a smaller body size) and the need for better quality food required for themselves (to sustain lactation and pregnancy) and dependent calves (Barnes, 1983). By contrast, the bulls could remain within the interior, where limited food and water was available, by virtue of their smaller herd sizes and the need for only enough food to meet maintenance requirements.

Increases in elephant populations can result in greater incidences of elephant ‘damage’ or restructuring of the vegetation (Croze, 1974; Thompson, 1975). However, other studies have noted that elephant damage in Sengwa, Zimbabwe (Anderson & Walker, 1974) and northern Botswana (Ben Shahar, 1993) was specific to habitats and plant species, and independent of local elephant densities. In the present study, a positive relationship existed between elephant density and the incidence of ‘heavily’ and ‘moderate’ tree damage sites. These areas, and particularly the heavily damaged sites, occurred along watercourses where elephants traditionally concentrate during the dry seasons. The process of restructuring the vegetation should possibly be seen as a natural negative feed-back mechanism through the vegetation in response to localised concentrations of elephants. Inclusion of the under-counting factor of 3 for elephant carcasses counted from the air (Dublin & Douglas-Hamilton, 1987) raised the carcass ratio to 3 % for the present survey area. This was comparable with areas experiencing a ‘normal’ to slightly lower mortality and increased immigration (Dublin & Douglas-Hamilton, 1987), phenomena suggested to be occurring in the Botswana population (G. Calef, per. comm.). The fact that carcasses still with their tusks tended to be found singly but restricted to specific areas (strata 2, 10, 11 and 15) suggests that either disease or poisoning (from plants) may have been the cause of death. The former factor may have accounted for the relatively high fresh to old carcass ratio of 1:1.4, the majority of which were restricted to a limited area in strata 10, 11, 7 and 8 (P. Morkel, pers. comm.). Poaching of elephant appeared to have accounted for 10% of the fresh carcasses and they were predominantly restricted to strata 6, 10 and 11, all situated along the northern border with Namibia, relatively close to human settlements.

The vastness and largely featureless expanse of northern Botswana, one of southern Africa’s true last wilderness areas, appears to offer no escape to threatened rhino populations. Without intense protection within smaller sanctuaries, the species may continue to fall easy victim to poachers. On the other hand, the elephant population appears to be on the increase, possibly through a combination of a low natural mortality and increased immigration from Namibia, Angola and Zimbabwe.

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PERSONAL COMMUNICATIONS

Dr. A. Verlinden, Wildlife Biologist, Department of Wildlife & National Parks, Gabarone, Botswana.

Mr. M. Slowgrove, Kasane, Botswana (former warden of Chobe National Park).

Mr. L. Wilmot, Savuti, Botswana.

Dr. G. Calef, Department of Wildlife & National Parks, Savuti, Botswana.

Mr. M. van der WaIler, Savuti, Botswana.

Mr. D. Joubert, Savuti, Botswana.

The Relative Effects of Hunting and Habitat Destruction on Elephant Population Dynamics over Time

E.J. Milner-Gulland[1] and J.R. Beddington [2]

[1] Ecosystems Analysis and Management Group,
Department of Biological Sciences, University of Warwick, Coventry CV4 7AL, UK
[2] Renewable Resources Assessment Group, 8 Princes Gardens, Imperial College, London SW7 1 NA, UK

INTRODUCTION

Over the last two hundred years, the ecology of Africa has changed substantially. One of the best documented changes has been the decline of the continental population of the African elephant, *Loxodonta africana,* (Burrill & Douglas-Hamilton 1987; Douglas-Hamilton 1988). Two major factors are likely to have contributed to this decline - reductions in the carrying capacity of Africa for elephants, due to habitat change; and hunting for ivory. The relative importance of hunting and habitat loss in driving population decline has been at issue for several years (Parker 1979; Douglas-Hamilton 1979; Parker & Graham 1989a&b), although there is evidence that the population decline since 1979 can be explained solely by hunting for the ivory trade (Milner-Gulland & Mace 1991). In this study, we attempt to tease out the effects of the two factors on the elephant population over the last two centuries, and discuss the likely effects of each in the future.

Although ivory exports from Africa are well documented from 1979 onwards, only one study has attempted to put the ivory trade into an historical context (Parker 1979). That study brought together many of the available data on the volume of ivory leaving Africa, from the 16th century onwards. However, the data were not used to relate the documented ivory trade to changes in the elephant population size. In this paper, the data compiled by Parker (1979) and others are used to give an estimate of the volume of trade leaving Africa from 1814 to 1987. This estimate is used in a model of elephant population dynamics, from which the relative effects of carrying capacity changes and the ivory trade on population decline can be deduced.

A MODEL OF ELEPHANT NUMBERS

A non-linear Leslie matrix is needed fully to describe elephant population dynamics under harvesting, because it is a long-lived species and hunter selectivity for large tusks has a profound effect on population structure (Milner-Gulland & Mace 1991; Wu & Botkin 1980). However, the formulation used in this paper is extremely flexible, allowing many combinations of maximum and minimum parameter values. This approach is thus a robust simplification of more complex non-linear Leslie matrix formulations. The population size each year is calculated as:

1.
$N(t+1) = (N(t)1e\text{-}m(t) + R(t)\,] - [1 + i]H(t+1)$

Where

$N(t)$	=	*Population size, after harvest, at time t*
$m(t)$	=	*Adult natural mortality rate at time t*
$R(t)$	=	*Recruitment rate at time t*
i	=	*Incidental hunting mortality*
$H(t)$	=	*Number of elephants killed at time t*

The recruitment rate represents the ratio of young:adult individuals in the population, and is therefore easily measured in the field. The adult natural mortality rate has also been extensively measured, although less easily. The incidental mortality represents the calves that die when their mothers are killed, which are not recorded in the trade statistics because their tusks are too small or they die undetected later. About one calf dies for each adult female killed (Poole 1989), so the incidental mortality rate is approximately equal to the proportion of adult females in the population.

ASSUMPTIONS AND PARAMETER VALUES

a. Density dependence

Two parameters are varied with population size to simulate density dependence; adult natural mortality (equation 2a) and recruitment (equation 2b). The density dependent response is (Lankester & Beddington 1986):

2a

$P=P_{ma} (P_{max} – P_{min} (1 – (N_{t-L}/K)^{ß}]$

2b

$P=p_{min}+ (P_{max} - P_{min})[1 - (N_{t-L}/K)^{ß}]$

where

$(P_{max}$	=	*maximum value for recruitment or mortality*
P_{min}	=	*minimum value for recruitment or mortality*
N_t	=	*population size at time t*
L	=	*time lag in response*
K	=	*carrying capacity*
$ß$	=	*exponential response parameter*

The form of the density-dependent response in elephants is not established. Poole (1989) presents evidence for a negative effect at low population sizes which is too anecdotal for inclusion in the model. The recruitment rate is an amalgamation of several fecundity-based factors, including age at sexual maturity, interbirth interval and juvenile survival (Fowler 1981). The elephant's long interbirth interval could lead to a time lag, but juvenile mortality is likely to be one of the first parameters to increase with increased density. Recruitment rate as a whole is known to respond rapidly to changes in vegetation availability, so was assumed not to be lagged (Laws 1969). Adult mortality is likely to have a lagged response **to** increased density, which is included in the model (Laws 1969; Corfield 1973; Owen-Smith 1988).

The exponential response parameter 13 determines the degree of nonlinearity in the density dependence. If ß=1, the density dependent response is linearly related to population size, while if ß=0 there is no density dependence. If ß<1, density dependence is strongest at low population sizes, if ß>1 it is strongest near carrying capacity. ß was varied between O and 2 in the model. However, long-lived species tend to exhibit density dependence most strongly near carrying capacity, so a near zero is less likely than a ß above 1 (Fowler 1984).

b. Carrying capacity

The area and vegetation of elephant range changed significantly over the period studied, so separate values for carrying capacity in 1814 and 1987 were calculated (Parker 1979, 1989a; Douglas-Hamilton 1979; Burrill & Douglas-Hamilton 1987). Ecological carrying capacity is the number of elephants that a particular habitat can support indefinitely without degradation. This is an adequate definition on the local scale but not the continental scale, particularly for a species that has disappeared from vegetationally suitable areas due to human interference. Climate change can be ignored for the 174 years modelled, but logging, for example, has created large areas of secondary forest, increasing the carrying capacity of the area for elephants (Barnes 1989).

The carrying capacity in 1814 was estimated using White's (1983) classification of African vegetation types. These were divided into range and non-range, according to contemporary reports of elephants living in the vegetation type (Bryden 1903) and estimates of current elephant densities in the vegetation type (Burrill & Douglas-Hamilton 1987), from which densities at carrying capacity were inferred. The estimate of pristine carrying capacity in 1814 is 27 million elephants (Table 1). The 1979 and 1987 carrying capacities were found using the range areas in Burrill & Douglas-Hamilton (1987) and Douglas-Hamilton (1988). Areas not containing elephants in 1979 and 1987 were thus assumed to be non-range regardless of vegetation type. The estimate of carrying capacity in 1979 is 11 million, and in 1987, 9 million elephants (Table 2). These estimates are crude and subject to unquantifiable error, particularly that for 1814.

An expression for the rate of carrying capacity change over time is needed. Two major factors could have caused a reduction in range - increases in human population size and expansion of agriculture. Contemporary observers state that elephants were driven back by European civilisation (Bourgoin 1956, Bryden 1903). The colonial period involved massive agricultural expansion and intensification throughout Africa, so that by 1900 much of the suitable land was cultivated, implying a rapid early carrying capacity decline (Oliver & Atmore 1967). The human population was relatively stable throughout the colonial period due to the slave trade, and only increased rapidly in the 1960s, although much of this increase was in the urban population (Oliver & Crowder 1981).

Carrying capacity can either decline because total range area declines or because of changes in the proportions of different vegetation types. Savanna range, the most suitable for agriculture, declined particularly sharply, so that the proportion of forest increased from 10% to *25%* of the total range. Forest supports a density of 0.5 elephants/km^2 as opposed to 2/km^2 in savanna.

c. Volume of the ivory trade 1814 to 1914

All the data used for the period up to 1914 are in Parker (1979). The records are fragmentary and give a limited picture of the magnitude of the early ivory trade. Parker and contemporary writers have made informed guesses as to the true volume of trade, but this paper keeps as far as possible to documented trade. There are some data on the ivory trade before 1814, going back as far as 1500. However, they are very fragmentary. Other factors, like the vegetation pattern and mean tusk weight, are unlikely to have remained constant from 1500 to the present day. The data improve from 1814, and the colonial period of major elephant exploitation starts soon afterwards, so 1814 is taken as the starting point for the population model.

Imports are divided into ivory exported directly from Africa (ex-Africa ivory) and that exported from non-producer countries. For several importers, there are long time series of total ivory imports but only a few years of ex-Africa imports. In these cases, the proportion of total imports represented by ex-Africa imports was calculated for the years with data, and applied to the other years. The proportion of imports to Britain that were ex-Africa varied markedly over time, and so in the absence of data, a linear function was assumed for the period of extrapolation, 1850-1906. In general, if there were no supporting data, point values were not extrapolated to the whole time series. This is likely to have led to an underestimation of the trade between 1850 and 1880. However, sensitivity analyses show that the possible underestimate was insignificant to the results. The final estimate of the volume of ivory traded before 1914 is a mixture of ex-Africa imports when available and exports for the years with no import data.

1915 to 1950

Data for this period are sketchy due to the two World Wars. Parker (1979) gives import and export data for East African countries for the period 1925-1977, while

Table l. Maximum elephant carrying capacity (K) in 18 14, using vegetation categories and areas from White (1983) and rough estimates of densities. The forest density is based on Barnes (1989), the Highveld and Sahel densities on contemporary accounts of elephant abundance and data in Burrill & Douglas-Hamilton (1987), and the others on data in Burrill & Douglas-Hamilton (1987). The Karoo-Namib desert zone and the Sahara and Mediterranean zones are non-range.

Zone (type)	Area (km²)	Density (km-2)	K
Guineo-Congolian (forest)	2,800,000	0.5	1,400,000
Guineo-Congolian/Zambezian	705,000	2	1.410,000
Zambezian (woodland)	3,770,000	2	7,540,000
Guineo-Congolian/Sudanian	1,165,000	2	2,330,000
Sudanian (wood/grass)	3,731,000	2	7,462,000
Somalia-Masal (bush/grass)	1,873,000	2	3,746,200
Cape (bush)	71,000	2	142,000
Afromontane (mountain)	715,000	2	1,430,000
Lake Victorian (forest)	224,000	2	448,000
Zanzibar-lnhambane (coastal)	336,000	2	672,000
Tongaland-Pondoland (bush)	148,000	2	296,000
Kalahari-Highveld (grass)	1,223,000	0.01	12,230
Sahel (grass)	2,482,000	0.01	24,820
Total range	19,243,000 km²		
Total carrying capacity			26,913,000

Douglas-Hamilton (1979) gives data for West Africa, Central Africa, and Somalia for 1915-1977. The data from Douglas-Hamilton (1979) are fragmentary, but again there was no extrapolation between data points. To get total East African exports, trade between the countries themselves was re-moved. A total for the period was then obtained by adding together the data from Parker (1979) and the modified Douglas-Hamilton (1979) data.

1950 to 1987

The data derived from Parker (1979) and Douglas-Hamilton (1979) for 1925-77 are very incomplete, but particularly so after 1950, when other countries rose to prominence as ivory exporters. When estimates using these data after 1950 are compared **to** those of Pearce (1989) and Parker's (1979) estimate of "minimum world imports", there is no significant correlation. Pearce and Parker worked on the same customs data, but with different aims. Parker wanted a measure of trading activity, arguing that the data were too unreliable, the records too incomplete, and the methods too crude to allow an accurate estimate of African exports. Pearce attempted an accurate estimate of the African exports by eliminating double-counting. The two estimates are similar, but Pearce's estimate for 1950-79 was used.

Table 2. Elephant ring. In 1987, using Douglas-Hamilton's (1988) vegetation categories and areas, which are based on White's. The estimated average density In each category le given; the variation l. due to variations in sampling method as well as genuine change (Douglas-Hamilton 1988). Note the change in range area for different vegetation types compared to 1814.

Zone	**Area(km2)**	**Density(km-2)**			**K**
		1979	**1987**	**Max**	
Forest	1,166,000	0.3	0.33	0.5	583,000
Swamp forest	334,000	0.5	0.35	0.5	167,000
Secondary woodland	71,000	0.01	0.03	1	71,000
Forest/grassland	681,000	0.21	0.08	2	1,362,000
Miombo woodland	1,450,000	0.28	0.17	2	2,900,000
Sudanian woodland	479,000	0.12	0.08	2	958,000
Woodland mosaic	529,000	0.32	0.15	2	1,058,000
Coastal mosaic	154,000	0.11	0.11	2	308,000
Montane	95,000	0.17	0.09	2	190,000
Bushland thicketed	537,000	0.09	0.09	2	1,074,000
Grassland	125,000	0.04	0.05	1	125,000
Azonal	125,000	0.14	0.13	1.5	187,500
Semi-desert	142,000	0	0.02	0.01	1,420
Desert	16,000	0.01	0.01	0.01	160
Total range	5,904,000k^2				
Total carrying capacity					8,985,000

Figure 1A. All available data on total ex-Africa ivory trade, 18 14-1987. Data, as discussed in the text, are from Parker (1979) [1814-1914, labeled 'customs to 1914'; 1915-1977, labeled 'customs 1915-1977'; 1950-1979, labeled 'Parker MWI']; Douglas-Hamilton (1979) (1915-1977, labeled 'customs 1915-1977']; Pearce (1989) [1950-1979, labeled 'Pearce']; and Luxmoore, Caldwell and Hithersay (1989) (1979-1987, labeled 'WTMU']. Parker's guess at the pre-1914 volume of trade is also shown.

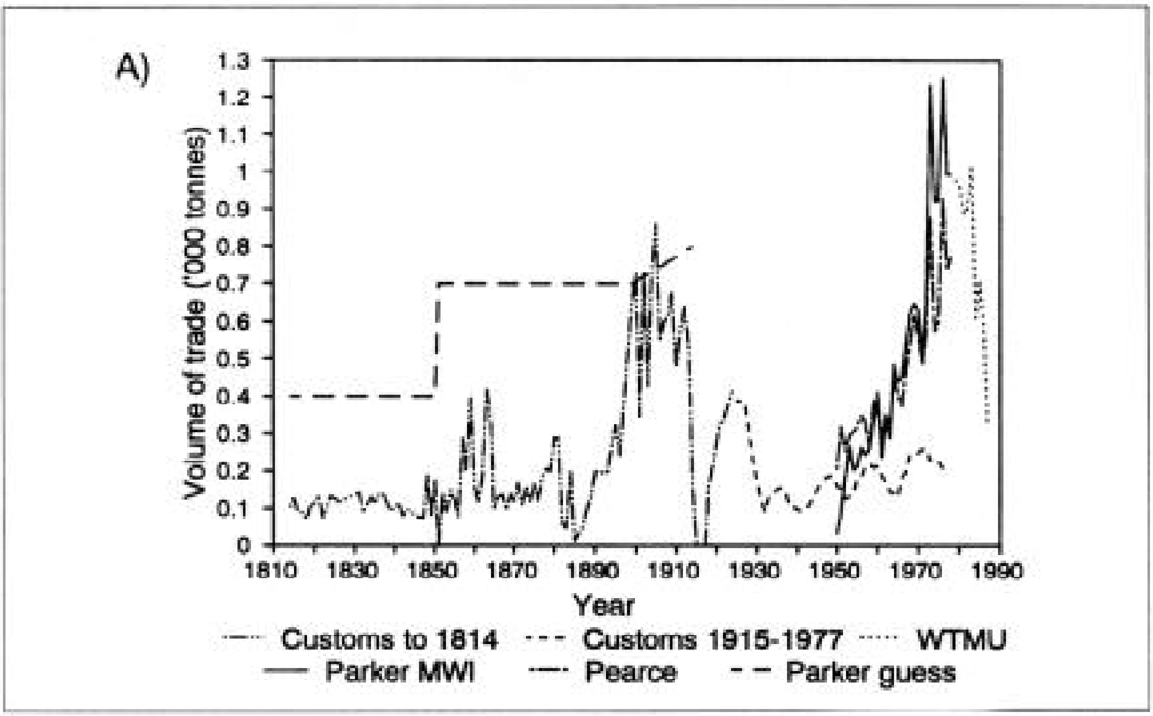


Figure IB. Estimate of the volume of ivory leaving Africa 1814-1987, using the above data and smoothed using 5 year running means.

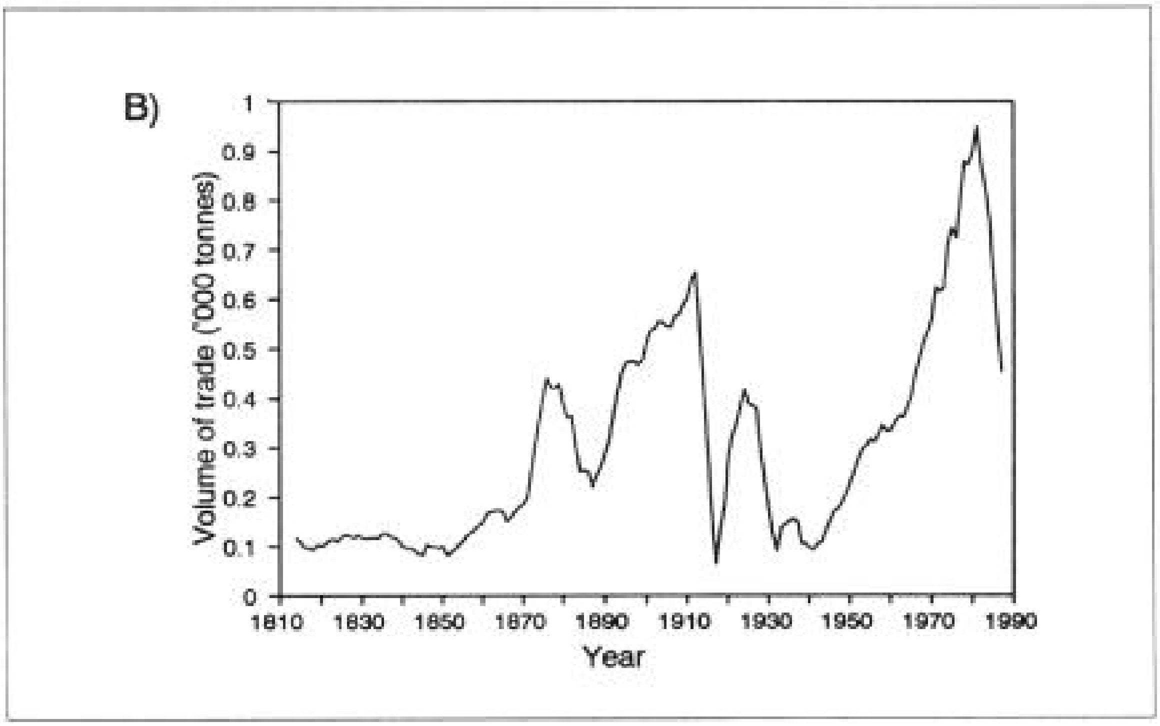


Table 3. A. Values for recruitment rate and adult natural mortality used in the population model, where P_{max} and P_{min} are as defined In equation 2.

Parameter	Recruitment		Mortality	
	Max	Min	Max	Min
Pmax	0.11	0.01	0.10	0.04
Pmin	0.06	0.02	0.04	0.01

B.The sources of the parameter values.

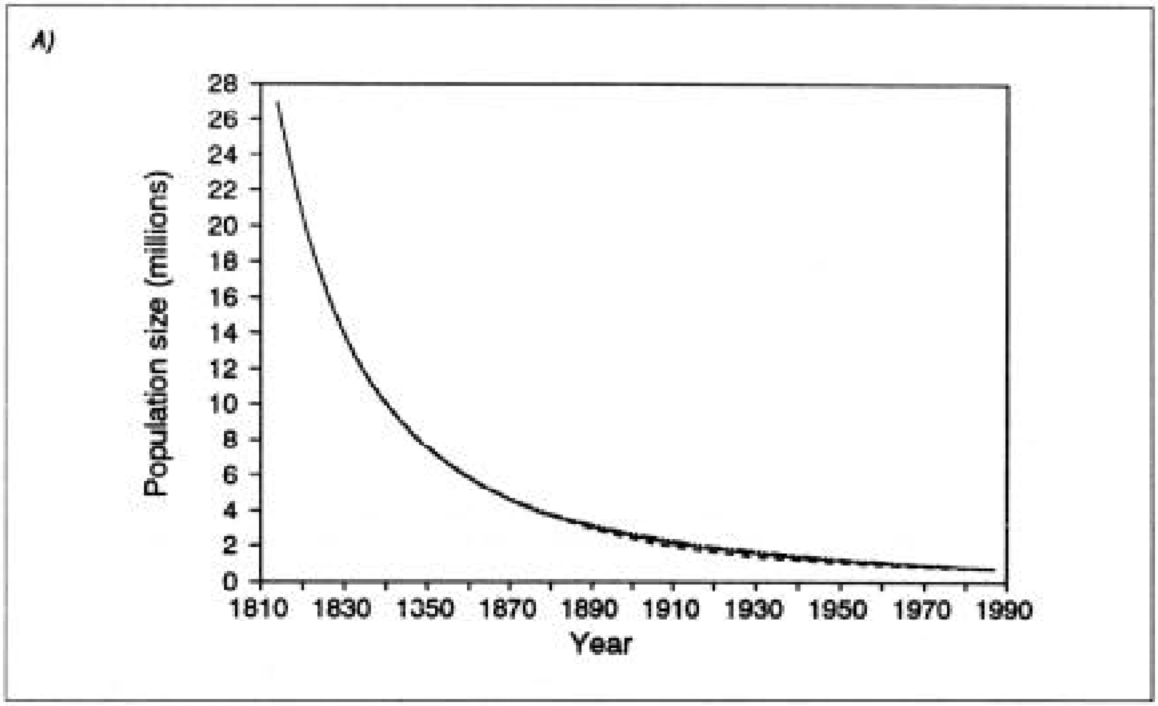
Source	Recruitment	Mortality
Douglas-Hamilton (1972)		0.02-0.04
Hanks (1972)	0.06	
Jachmann (1986)	0.09	0.08
Laws (1969)		0.02-0.1
Laws, Parker, Johnstone (1975)		0.02-0.08
Leuthold (1976)	0.05-0.11	
Ottichiko (1986)	0.06	
Owen-Smith (1988)	0.02-0.1	
Sherry (1975)	0.07	
Smuts (1976)	0.07	
Williamson (1976)	0,09	

After 1979, the estimates of the Wildlife Trade Monitoring Unit (WTMU) of IUCN were used (Luxmoore, Caldwell & Hithersay 1989). These were compiled from customs data and Convention on International Trade in Endangered Species (CITES) data. CITES has controlled and monitored trade in ivory among member countries since 1981, introducing a system of quotas in 1985 and a moratorium on international trade in 1989, which was reaffirmed in 1992. Using these data, WTMU traced individual ivory shipments from country to country, practically eliminating double-counting. The smuggling and under-reporting of ivory shipments undoubtedly increases at times of high ivory value and trade restrictions, in order to evade taxes or quotas. Since CITES quotas were introduced, and especially since the 1989 international trade ban, there has therefore been little way of estimating the true volume of ivory leaving Africa. This may also have happened in Zanzibar in the early 19th century, when taxes were imposed on goods entering the island (Oliver & Atmore 1967). Given this problem of under-reporting and the incompleteness of the data, the final estimate of the volume of the ivory trade since 1814 must be seen as a minimum (Figure 1).

THE SEPARATE EFFECTS OF HUNTING AND CARRYING CAPACITY

The model was first run using two extreme assumptions - either there was .no hunting and changes in carrying capacity alone affected population dynamics, or carrying capacity was constant over the period, and only hunting affected the population. This allows the separate effects of each factor on elephant population dynamics to be assessed. A range of values was used for maximum and minimum recruitment rate and natural mortality, set to reflect the likely range of these parameters found in different habitats and under different population structures (Table 3). Values for maximum and minimum recruitment and mortality rates and ß were varied systematically between runs, so that the full range of parameter values was covered.

Figure 2. The mean population size and mean rate of population change over the study period, 1814-1987, when carrying capacity change8 alone are assumed responsible for population decline. The population is assumed to be at pristine carrying capacity in 1814. The results for three possible carrying capacity trajectories are shown:fast-slow, slow-fast and linear.
A) Population size



B) Rate of population change

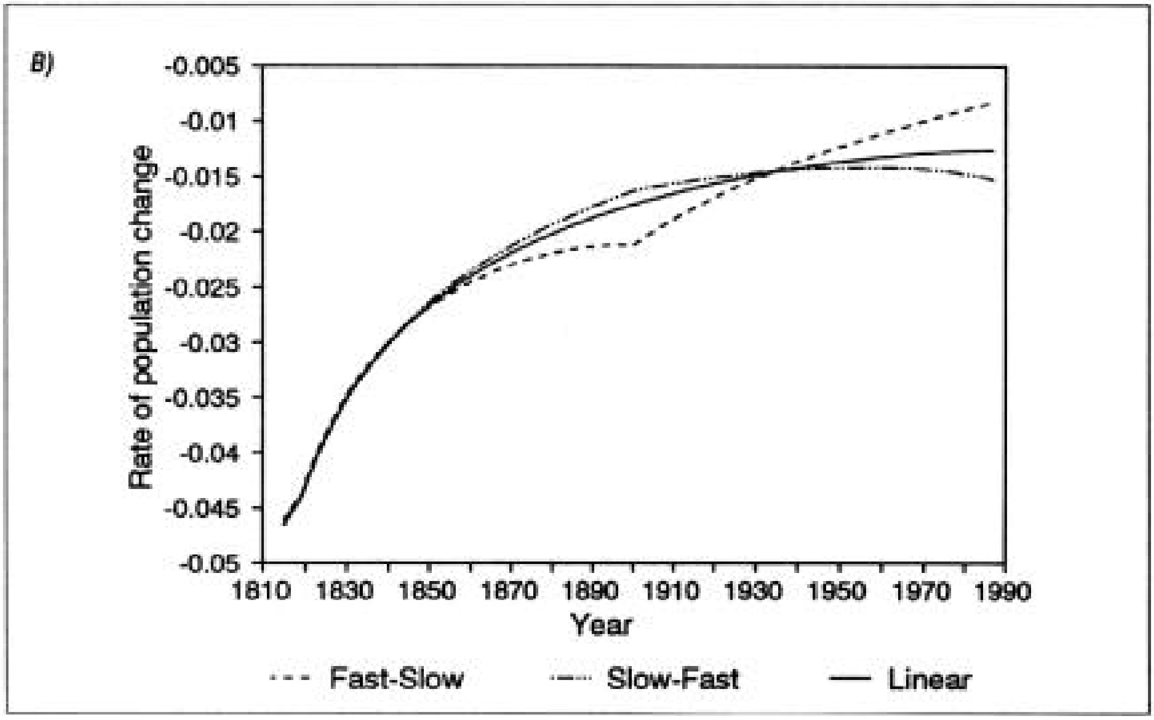


Figure 3. The mean rate of population change over time when hunting alone is assumed responsible for population decline, compared to the results when carrying capacity alone is assumed responsible. The fast-slow carrying capacity trajectory is used, and both populations start from carrying capacity. If hunting alone is assumed responsible for population decline, decline is slower than that with carrying capacity changes alone until the 1970s, when decline becomes very rapid.

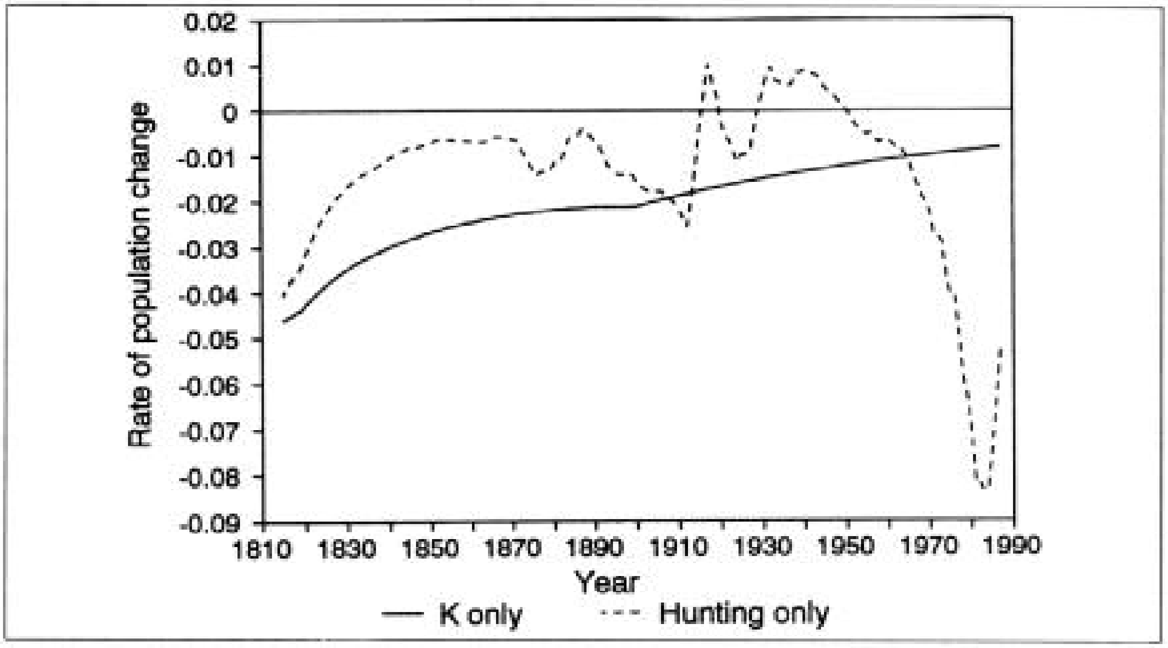
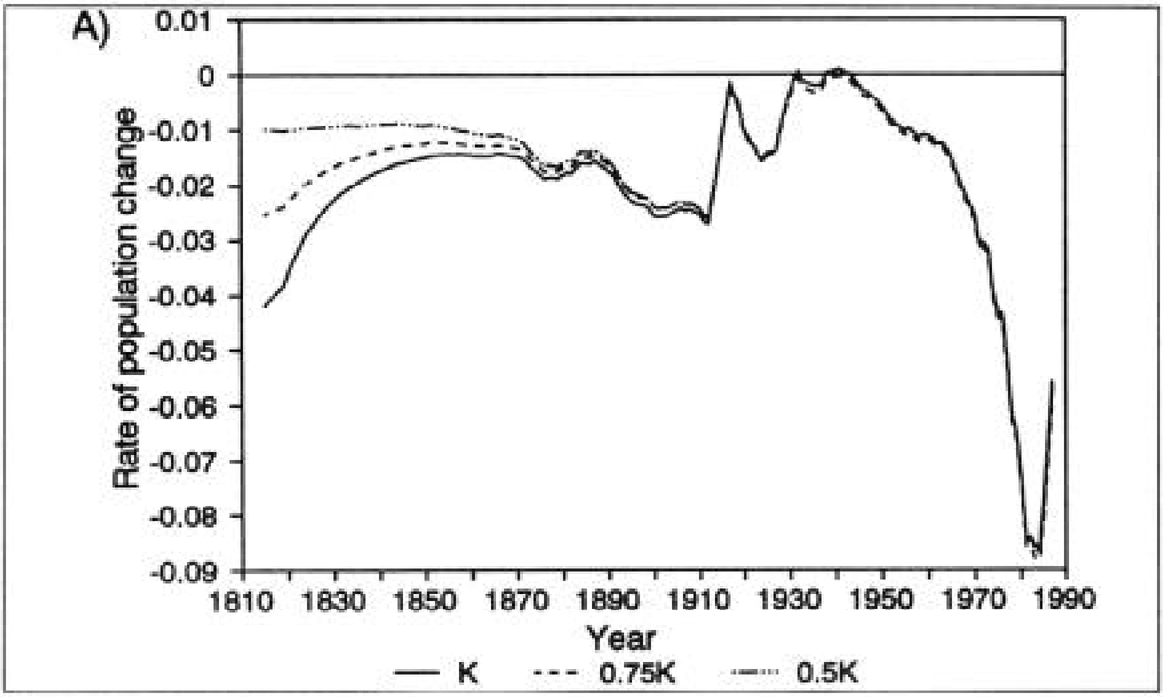


Table 4. Results of the simulation runs, showing the number of trajectories fulfilling the constraints for various population sizes in 1814 and carrying capacity trajectories. The average and maximum values of B and the range of the 1979 population size (in millions) in the trajectories fulfilling the constraints are also shown. The total number of trajectories investigated was 17,640.

1. Fast-slow trajectory					
1814 population	Mean ß	Max ß	Trajectories	1979 population	
				Max	Mn
K	0.64	1.7	333	1.66	1.12
0.75K	0.59	1.7	369	1.83	1.12
0.5K	0.61	1.7	375	1.76	1.12
2. Linear trajectory					
1814 population	Mean ß	Max ß	Trajectories	1979 population	
				Max	Min
K	0.48	1.2	229	1.75	1.19
0.75K	0.45	1.2	257	1.74	1.21
0.5K	0.50	1.2	236	1.76	1.19
3. Slow.fast trajectory					
1814 population	Mean ß	Max ß	Trajectories	1979 population	
				Max	Min
K	0.37	1.O	183	1.81	1.22
0.75K	0.33	1.O	211	1.78	1.21
0.5K	0.4	1.O	I50	1.76	1.22

Figure 4A. The effect of the starting population size assumed, as a proportion of pristine carrying capacity, on the mean rate of population decline. A fast-slow scenario is assumed. The starting population size makes little difference after the first 60 years.



B. The mean rate of population decline under three carrying capacity scenarios, starting from 75% of carrying capacity. Differences between the results for the three scenarios are slight.

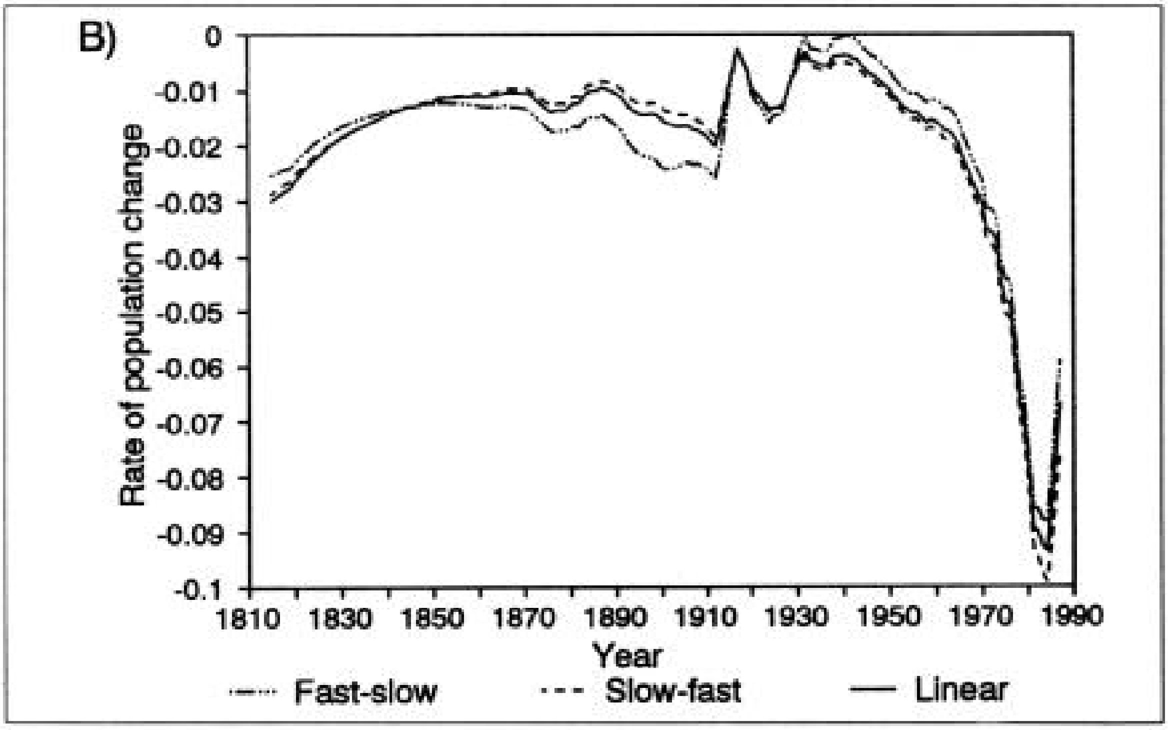


Figure 5A. The population trajectory for the fast-slow scenario starting from 75% of carrying capacity. The mean of the trajectories passing through the 1987 window is shown, together with the maximum and minimum values of population size for those trajectories passing through the window (dashed lines).

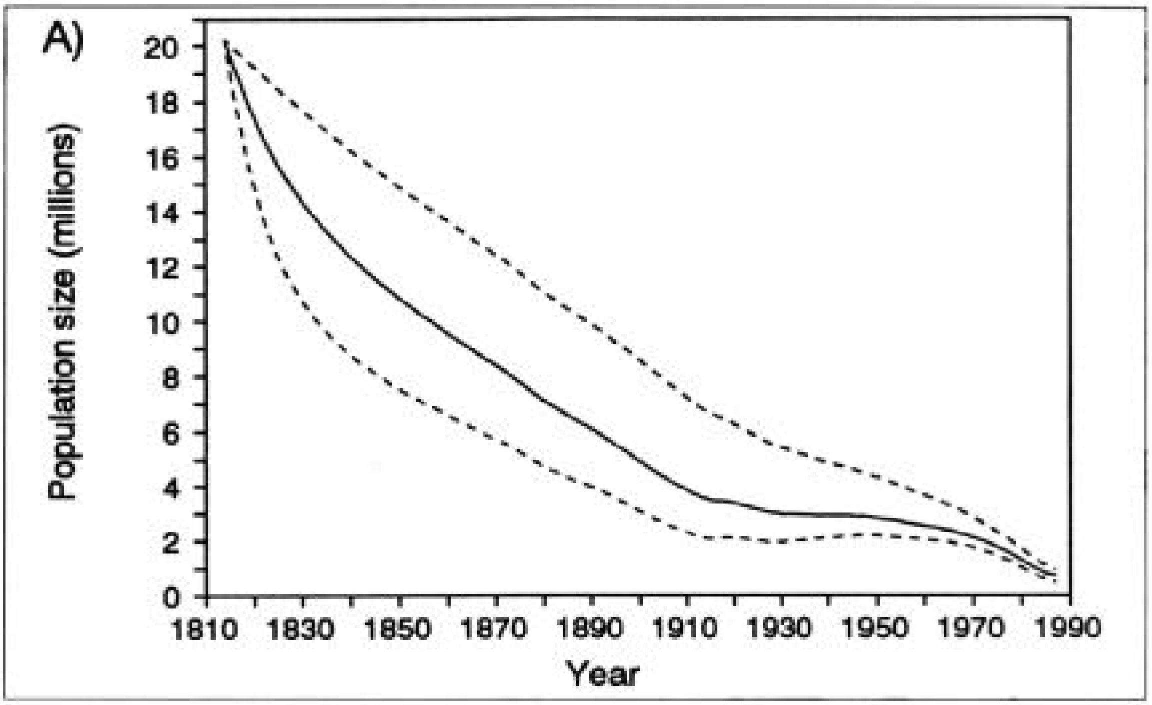


Figure 5B. The rate of population change represented by A), with the maximum and minimum trajectories again shown as dashed lines.

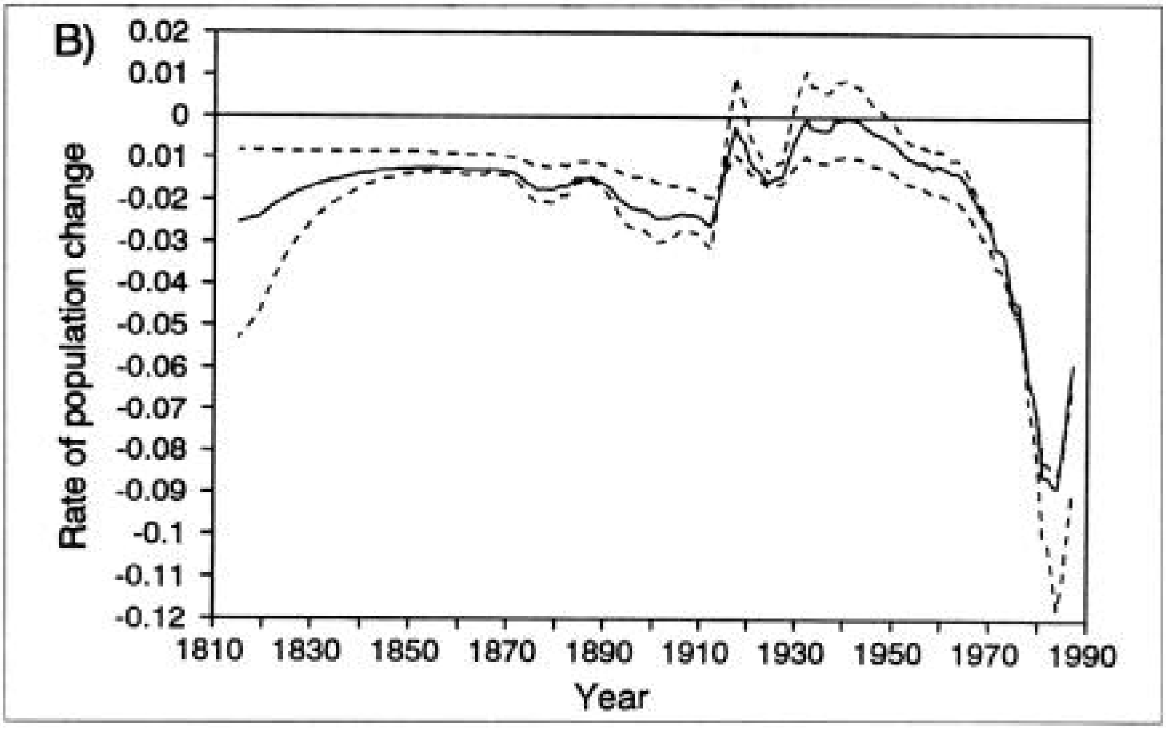
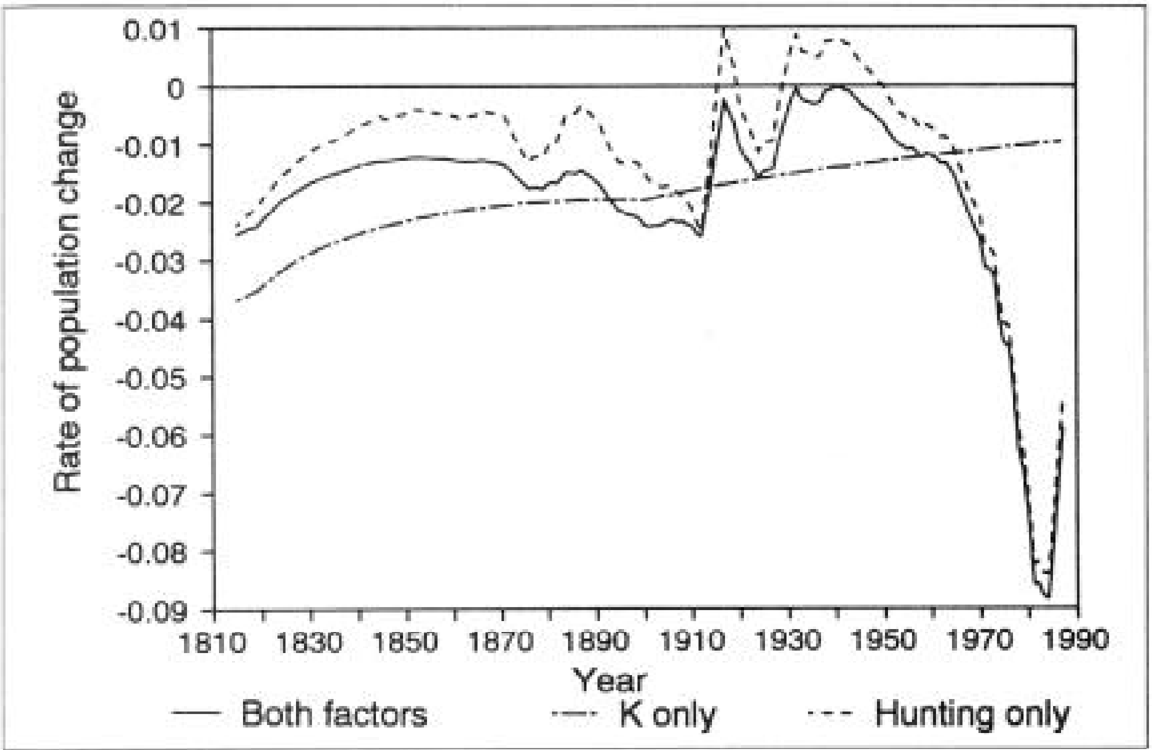


Figure 6. A comparison of the mean rate of population change when hunting alone, carrying capacity alone, and both factors are assumed responsible for population decline. All trajectories start from 75% of carrying capacity, and the scenario assumed is fast-slow. Until around 1970, the trajectory where both factors are involved is between the trajectories of the two extreme assumptions, indicating that both factors play a part, but after that, hunting becomes the major factor involved in population decline.



This gave density dependent values for mortality rate and recruitment (equation 2), allowing the calculation of a population trajectory (equation 1). Only trajectories leading to 1987 population sizes within ±33% of the estimated value of 720,000 (Douglas-Hamilton 1989) were accepted.

When investigating the effects of carrying capacity alone, three different carrying capacity trajectories were used: a linear decline from 1814 to 1987 ("linear"); carrying capacity constant for the first half of the period, then declining linearly to the 1987 level ("slow-fast"); and a linear decline to the 1987 level in the first half of the period, then constant in the second half ("fast-slow"). These three scenarios represent the most likely range of carrying capacity trajectories. The rate of population change varies only slightly with the carrying capacity scenario assumed (Figure 2). When investigating the effects of hunting alone, the carrying capacity was assumed to remain constant at the 1987 level throughout the period, since the evidence is stronger for the 1987 carrying capacity estimate than for the pristine estimate. Hunting alone produces a very different rate of population change to carrying capacity change alone. The rate of population decline is lower for the first 150 years of the simulation, then increases rapidly in the final few years (Figure 3).

THE MEAN TUSK WEIGHT IN THE TRADE

In order to include the effects of hunting in the model, the number of elephants killed for trade each year is needed. This is obtained from an estimate of the volume of trade, together with the mean tusk weight in the trade at a particular time, assuming that each elephant killed contributes 1.88 tusks (Parker 1979). The mean tusk weight determines the number of elephants killed to produce a given volume of ivory. It is influenced by the structure of the hunted population and hunter selectivity for certain tusk sizes. When a non-linear Leslie matrix is used to represent elephant population dynamics, the mean tusk weight declines rapidly when hunting begins, reaching a stable value which depends on the hunting mortality and hunter selectivity (Milner-Gulland & Mace 1991). A simple representation of this effect, in which the mean tusk weight declines exponentially with time, is (Basson, Beddington & May 1991):

3.
$w = A + a(Nt)z$

where

A	=	*mean tusk weight at end of period*
a	=	*scaling constant for mean tusk weight at begining of period*
z	=	*exponential rate of decline of mean tusk weight*

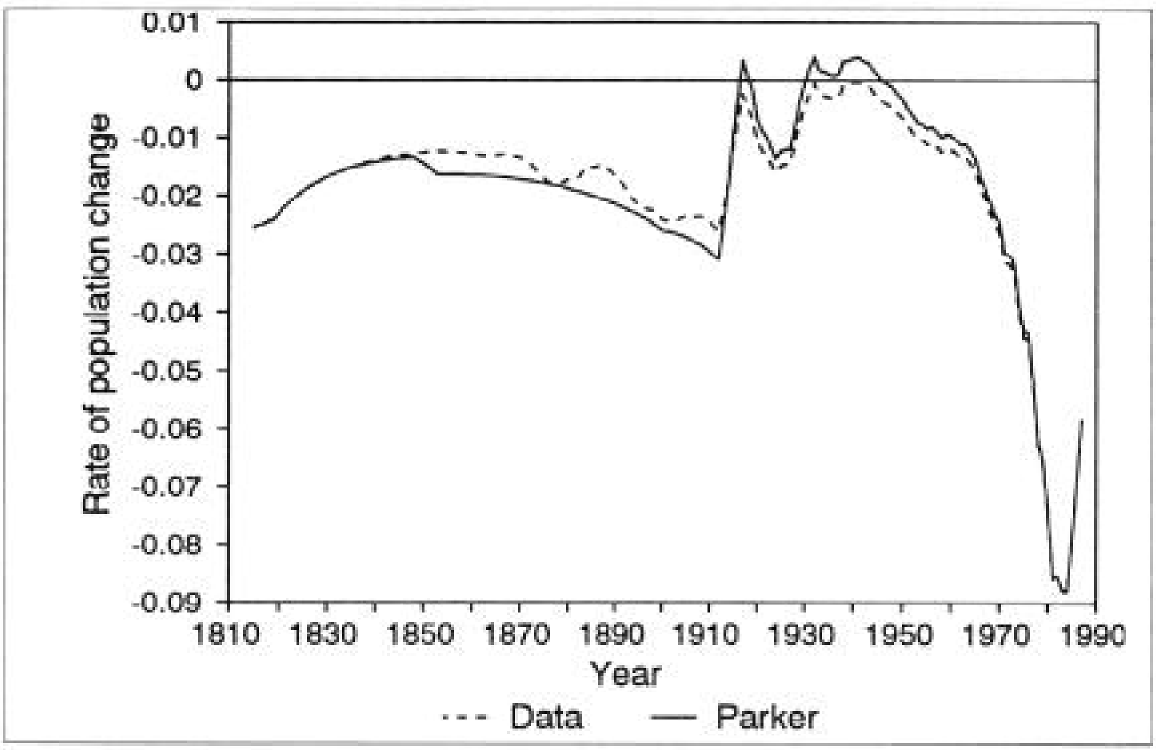
In this case, A and a are scaled so that the mean tusk weight in the trade at the beginning of the period is 15kg, and that at the end is 5kg. The former is reasonable given the data presented in Parker (1979), while the latter is the mean tusk weight observed over the last decade (Milner-Gulland & Mace 1991, data from WTMU). If z=0, the mean tusk weight remains constant at the 1987 level throughout the period, while at z= I there is a linear decline in mean tusk weight over time. As z increases above I, the exponential rate of decline in mean tusk weight with time increases. Basson, Beddington and May (1991) put z at 1.7, and in this study it is set at 2. Trade records of mean tusk weights are very variable, although the assumption of an overall decline in mean tusk weight over the whole period seems to be supported (Parker 1979).

THE EFFECTS OF BOTH HUNTING AND CARRYING CAPACITY

The constraints built into the model determine the basic shape of population trajectories; carrying capacity drops dramatically over the period, and the two population sizes fixed at either end are also very different. The population in 1814 is assumed to vary between 50% and 100% of pristine carrying capacity, but the 1987 population is only 8% of the 1987 carrying capacity. However, the assumptions made about hunting mortality and trade levels are likely to interact to determine the shape of the population trajectory. In particular, a number of those individuals killed for trade would have died anyway, so hunting affects the strength with which density dependence acts.

The results of the model are shown in Table 4 for starting population sizes varying between *50%* and 100% of

Figure 7. The effect of using Parker's guess at pre-1914 trade on the mean rate of population change under a fast-slow scenario starting from 75% of carrying capacity. There is little difference between the results using the best estimate of pre-1914 trade and those using Parker's much higher trade estimates.



carrying capacity, and for the three carrying capacity scenarios. The most likely scenario will have the largest number of trajectories through the 1987 population window; the highest mean and maximum value for *ß*, since Fowler (1984) shows that a 13>1 is likely for the elephant; and the lowest minimum 1979 population size. The published estimate for the 1979 population size is 1,340,000 (Burrill & Douglas-Hamilton 1987), but the authors say that their figure is likely to be an overestimate. The total number of trajectories passing through the window is shown rather than a mean with confidence limits because the distribution of 1987 populations is non-normal.

The fast-slow scenario is the most likely under the above criteria (Table 4). The population size in 1814 makes little difference ***to*** the output, only affecting the population trajectory for about 60 years (Figure 4a). A 0.75K population size in 1814 seems the most realistic of the three modelled, given that light exploitation had occurred before 1814. The rate of population change is similar for the three carrying capacity scenarios (Figure 4b). Taking the fast-slow carrying capacity trajectory and a population size of 0.75K in 1814 as fitting the data best, 75% of the population is lost in the first 100 years, then the rate of decline slows around 1914, increasing again from around 1950 (Figure 5a). This represents a steady decline of 2-3% a year until 1914, with some recovery in the war years, and a very rapid increase in the rate of population decline from around 1970 (Figure Sb). The similarity of the maximum and minimum population trajectories shows that results are very similar over the wide range of recruitment rates, mortality rates and density dependent responses tested in the model. Carrying capacity changes and hunting mortality both affect the rate of population decline in the first 150 years, but hunting clearly causes the sudden rapid decline in population size from around 1970 (Figure 6).

SENSITIVITY ANALYSES

The population parameters used are z, which descrihes the rate of mean tusk weight decline over time (equation 3); the incidental calf mortality; and the lag in the density dependent response of adult mortality. The effects of changes in these parameters, within reasonable bounds, are not significant (Milner-Gulland & Beddington 1993).

Although it is likely that the carrying capacity in 1814 was much higher than in 1987, the 1814 carrying capacity calculated in Table 2 could well be an overestimate. The model is not sensitive to relatively small changes in the pristine carrying capacity, and running the model with carrying capacity held constant at the 1987 level sets a lower limit on possible population trajectories. The rate of population change over time is similar whether this extreme assumption or a. fast-slow scenario is used, suggesting that it is determined by the ivory trade rather than the carrying capacity trajectory. Fewer trajectories fulfilled the assumptions under the 1987 carrying capacity assumption than when pristine carrying capacity in 1814 is assumed, but the fact that ß is higher suggests that a lower carrying capacity than that calculated for 1814 might be closer to reality.

Parker (1979) made an informed guess at the maximum likely trade levels before 1914, which are much higher than the documented evidence suggests, using subjective contemporary accounts of the volume of ivory leaving ports. By running the model using Parker's guess, the likely range of trade levels before 1914 is covered. Changing the incidental mortality rate and the mean tusk weight assumption also indirectly changes the number of elephants assumed to have been killed for the trade. Changes in these parameters have little effect on the results. However, this systematic increase in numbers killed throughout the simulation is different to Parker's informed guess at the likely maximum trade level in each period. The results using Parker's guess are little different to the previous results, just rather smoother (Figure 7). This is due mainly to the pre-1914 trade not removing a large proportion of the elephant population, even at the high levels guessed at by Parker, and to the action of density dependence. Thus the model is insensitive to the possible under estimation of pre-1914 trade levels.

DISCUSSION

The model used for this study of the ivory trade since 1814 is simple, yet extremely robust. The results strongly suggest that carrying capacity declined rapidly at first, and then more slowly. This is consistent with historical patterns of agricultural expansion. The trade data have given an estimate of the volume of ivory leaving Africa over the period studied, and sensitivity analyses have shown that the results are robust over the likely range of trade volumes. Given a volume of trade and a carrying capacity trajectory, the model results are similar over a wide range of possible recruitment rates, mortality rates and density dependent responses. The population trajectory produced is insensitive to changes in assumptions about the biological parameters.

The results suggest that African elephant numbers were dramatically reduced during the 19th century, but only at a rate of about 2% per annum. There was a lull in the first half of the 20th century, with rates of population change around zero. From 1950 onwards, the population has been declining with increasing rapidity, the rate of decline only dropping in 1987. For the first 150 years, the rate of decline is determined by the interaction between changes in carrying capacity and hunting. However, from around 1970, the hunting mortality rate has increased dramatically, and become the dominant influence on elephant population dynamics.

The elephant population of the whole of Africa is modelled as a single entity in this paper, although local changes in elephant abundance and carrying capacity clearly will not necessarily follow this trend. However, modelling the whole population gives an overall picture of the important factors involved in the determination of elephant numbers. It is unlikely that a dataset exists with which population dynamics and trade data can be coupled at a local level over a long period of time.

The colonial period was thus one of steady decline in elephant numbers, far slower than the dramatic decline in numbers since the second wave of hunting fuelled by the Far Eastern ivory market. Although 19th-century volumes of trade were similar to those of the 1 970s-80s, they were taken from a larger population and so caused far less population reduction. However, contemporary writers such as Bryden (1899,1903) saw disastrous reductions in elephant numbers. This suggests either that hunting was localised, not affecting the major elephant populations, or that the massacres which they reported were less severe than they appeared. The former seems more likely, particularly since hunting probably occurred in the same areas as the carrying capacity reductions.

Decreasing carrying capacity is still a threat to the elephant. The population size in 1987 was only 8% of carrying capacity, but 83% of the elephant range is completely unprotected (Douglas-Hamilton 1988). If elephant habitat continues to be destroyed, and particularly if ivory continues to be a valuable commodity, elephants will increasingly be confined to protected areas. The carrying capacity of moderately and effectively protected areas is 528,000 animals, 73% of the 1987 population size. Most protected areas are already becoming crowded as elephant populations in unprotected areas dwindle. Halting the ivory trade will not solve the basic problem of habitat loss. Both the ivory trade and reduced carrying capacity are causing the decline in the continental elephant population, and both must be tackled.

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