REPORT ON DEHORNING OF BLACK (Diceros bicornis) AND WHITE (Ceratotherium simum) RHINOCEROSES IN ZIMBABWE

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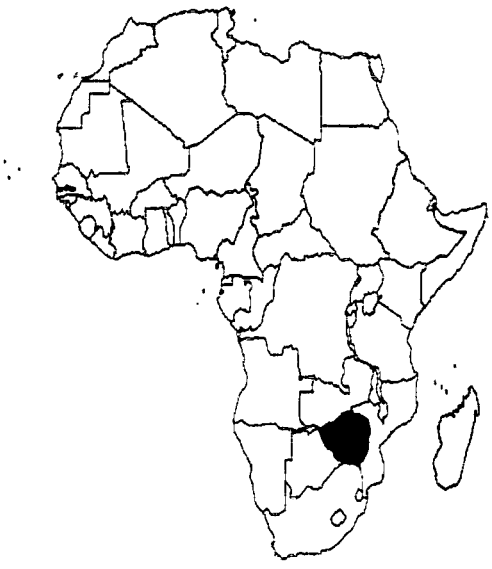

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Summary: Following the experimental dehorning exercise carried out on white rhinos (*Ceratotherium simum*) in 1991 in Hwange National Park, only 6 white rhinos have been killed by poachers. The number of rhino killed per poaching incursion in the Main Camp region of Hwange National Park has dropped from 2.0 in 1990 to 0.5 in 1992, while the number of known incursions has tripled. Behavioural effects of the dehorning have been minimal, with several dehorned males maintaining territory after being dehorned. In 21 months, a total of 17 dehorned rhinos of both species have been killed by poachers in Zimbabwe. Contrast this with the fifty-two horned black rhinos that were known to have been killed, between September 1991 and January 1992, in Parks and Wildlife Estate.

Despite the situation in Hwange National Park with white rhinos, black rhinoceros (*Diceros bicornis*) have suffered catastrophic declines due to poaching. These losses were considered unsustainable, especially with no increased commitment by Government to better protection of Wildlife Estate land holding black rhinos. In January, a request was submitted to the Ministry of Environment and Tourism to dehorn as many black rhinos as possible throughout Zimbabwe. During the 3 month delay before permission was granted, over 30 black rhinos are known to have been killed in Matusadona National Park. With such an unsustainable loss rate, dehorning appeared to be the only innovative option open to the Department of National Parks and Wildlife Management.

The first dehorning of black rhinos was carried out in Matusadona National Park, where 17 animals were dehorned (two calves were not dehorned). The population estimate for Matusadona was approximately 150 animals, therefore, the discovery of only 19 animals after 2 weeks of intensive searching sounded alarm bells. The dehorning exercise was continued throughout the Wildlife Estate, including Chizarira National Park, Chirisa Safari Area, Sengwa Research Area, the Lower Zambezi Valley, Hwange National Park, Matobo National Park and in several Conservancies in the Lowveld. It soon became apparent that the original estimate of > 2000 black rhinoceros in Zimbabwe was incorrect and that the known numbers were probably 300, with a possible total of 440 animals. This catastrophic decline had occurred despite "Operation Stronghold", which supported an aggressive anti-poaching policy, resulting in the shooting of over 150 poachers and the arrest of many more.

By March 1993 over 158 black rhinos had been dehorned, with a mortality rate associated with the immobilisation of 0.6%. Over 112 white rhinos have been dehorned (1991/1992 and 1993) with a mortality rate of < 2%. As of March 1993 only 11 dehorned black rhinos had been killed by poachers, with three animals dying of natural or undetermined causes. The loss rate of both black and white rhinos following dehorning appears to be sustainable, taking into consideration that over 100 animals were being lost per year prior to the implementation of this programme. Indications now are that very little quality horn is crossing back into Zambia. Cost of dehorning varies from US$350 to US$1800 per animal.

The research programme on white rhinos continues in Hwange National Park, as well as monitoring of dehorned populations elsewhere in the country. Immobilisation of 19 animals in 1992, who were dehorned in 1991, revealed a regrowth rate of 6.7cm/year for the front horn and 2.9cm/year for the rear horn. Horn cutting techniques were improved after several white rhinos were noted to have abnormal horn regrowth, although none had their health impaired. The shape of horns was roughly cylindrical after 1 year of horn removal. Dehorning continues in 1993.

Harare, April 1993

* RHINO * OBHEJANE * BATSHIMPEMBELE * ZVIPEMBERE *

Because our rhino are being poached and killed for their horns, the Zimbabwe Government decided to remove the horns from all the living rhinos.

All the live rhinos have now been dehorned. The horns have all been cut off the live rhino and taken away to a place of safe keeping by the Zimbabwe government.

It is useless to kill rhino because they have no horns now. Poachers who hunt rhino are risking their lives for nothing.

Ngenxa yokuthi obhejane bethu sebezingelwa bekhitshwa impondo, uHulumende we Zimbabwe usethe kungcono akhiphe impondo zonke kubobhejane abaphilayo.

Bonke obhejane abaphilayo sebekhitswe impondo zathathwa nguHulumende weZimbabwe wazibeka endaweni lapho ezilondolozeke khona.

AKUSELA SIZATHO SOKUBULALA OBHEJANE NGOBA PHELA KABASELA MPONDO. ABAZINGELI ABANGELA MVUMO BAFAKA IMPILO ZABO ENGOZINI NGEZE (MAHALA).

Mbukuli kuthi batshipembele besu bonseni balikubvimigwa nkabagwisigwa meja iHulumende yaZimbabwe yakathi chibotu kuthi igwisye meja kulibonse batshipembele bachipona.

Bonseni batshipembele batshipona bakagwisigwa meja bakatholegwa aHulumende waZimbabwe kuchithilakuthi abalele obothu.

TACHIIKWE CHAKUJEELA BACHIPEMBELE PE. NKAAMBO TABACHIJISI MEJA. BASIKUJAYA BANYAMA ABO BAVWIMA BACHIPEMBELE TABAKWE NCHIBATAFWIDE PE.

Nokuda kokuti zvipembere zvedu zviri kuvhimwa nokuurawa pamusana penyanga dzazvo, Hurumende yeZimbabwe yakafunga kubvisa nyanga dzese dzezvipembere zvichirikurarama.

Zvipembere zvese zvipenyu zvakabviswa nyanga. Hurumende yeZimbabwe yakaendesa nyanga dzese kunzvimbo yakanaka yokudzichengetedza.

NEKUDARO HAPACHISINA CHIKONZERO CHEKUURAYA ZVIPEMBERE NEKUTI HAZVICHISINA NYANGA. VAVHIMI VEZVIPEMBERE VARIKUZVIPINZA MUNJODZI PASINA MUBAIRO.

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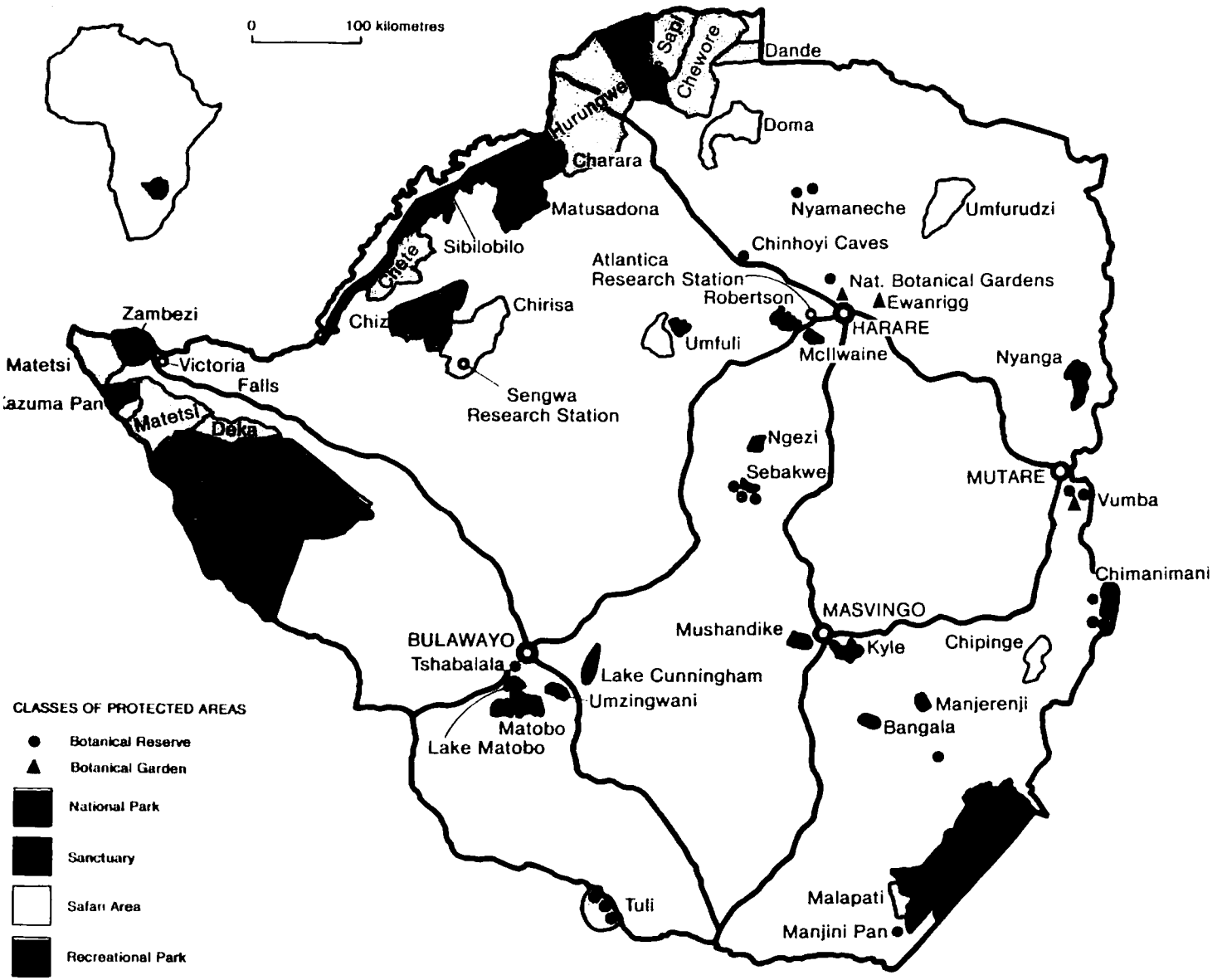
Leaflet for distribution in Zimbabwe and neighboring countries, explaining dehorning in several languages.

THE PARKS AND WILD LIFE ESTATE, ZIMBABWE.

Source: Department of National Parks and Wild Life Management



Funding of Operations and Acknowledgements

The funding of the white rhino dehorning operation in 1991 was almost entirely provided by external donors. The situation with the 1992 operation was no different. Funding acknowledgements are usually confined to the Appendices of a report, but due to the fact that over 95% of the 1992 dehorning programme and the ongoing efforts in 1993 were funded by the International and local private community, it is warranted that this section be a prominent part of this report. This is in recognition of those who supported the Department. Details of financial and equipment support are to be found in Appendix 1.

It would not be appropriate to single out one individual or organisation that supported dehorning, both logistically, financially or with equipment. It was a team effort both locally and internationally. We thank and acknowledge all the individuals and organisations, without your support none of this would have been possible. Within the DNPWLM several field stations provided support with trackers and scouts. Many of the Wardens were particularly helpful. To those of you who supported the dehorning teams, thanks! We thank the Director, DNPWLM for permission to publish this report.

This report has been compiled by the two Departmental Veterinarians (DNPWLM), and they accept full responsibility for the contents of the report, any errors or omissions. ULG Consultants (Harare Office and Warwick, UK), especially Russell Dorrell and David Jones, helped with production, IWVS Inc., (California) provided financial support. Thanks to Rowan Martin, Janet Rachlow, Raoul du Toit, and Nancy Kock for editing and reviewing drafts of this report. The support of the International Rhino Foundation (IRF) in the publication of this report is also acknowledged.

Dr Michael Kock is currently employed as the Wildlife Veterinarian in the DNPWLM through a Technical Assistance Contract entirely financed by the European Commission.

Abbreviations and Definitions

Agonist - drug that produces similar effects to the drug it may antagonise. High doses of an antagonist may produce agonist effects
Antagonism - term used to describe reversal of drug (narcotic) effects
Antagonist - drug used to reverse effects of narcotic or opioid
Boma - holding pen or corral for wild or domestic animals
Cavitation - hole that may form in the centre of new horn growth
ChNP - Chizaria National Park
CITES - Convention on International Trade in Endangered Species of Wild Flora and Fauna
Conservancies - private ranches (up to 3,000 sq/km) holding black rhinos in Zimbabwe. Similar to Kenyan Sanctuaries
Contingency - used to add undetermined (extra) costs, usually 10%, to cost analyses, funding requests etc.
CpSA - Chipinge Safari Area
DeSA - Deka Safari Area
Detomidine - sedative similar to xylazine, used with etorphine
Diprenorphine (M50-50) - standard narcotic antagonist for etorphine. May have agonist properties at higher doses
DNPWLM - Department of National Parks and Wild Life Management
Dophram - respiratory stimulant, acting centrally in the brain
Etorphine (M99) - narcotic or opioid used to immobilise rhino
Fixed-wing - aircraft, as opposed to a rotor-wing or helicopter, used to spot rhinos on the ground
Free-ranging - wild populations of animals
HNP - Hwange National Park
Hypercapnia - rapid and shallow movement of chest (and lungs)
Hypertension - high blood pressure
Hypoxemia - lack of oxygen in blood stream
Hypoventilation - poor ventilation of lungs, with inadequate air movement
Incursion - term for an illegal crossing of poachers across an International border
Induction - time from dart impact until the rhino becomes immobile
IPZs - Intensive Protection Zones - areas where black rhino would receive better protection than elsewhere in the Wildlife Estate
IM - intra-muscular injection
IV - intra-venous injection
MatNP - Matobo National Park
MaNP - Matusadona National Park
Nalorphine - narcotic antagonist
Naloxone - pure narcotic antagonist
Naltrexone - pure narcotic antagonist (long-acting)
Narcotic - term used to describe class of drugs derived from morphine, used to immobilise wild animals, other term is opioid
NGO - Non-Government Organisation
Nulbuphine - narcotic agonist and antagonist
Non-invasive - refers to a procedure that can be carried out without surgery
Operation Stronghold - aggressive anti-poaching and rhino translocation programme, initiated to combat the rise in poaching of black rhino, in the Zambezi Valley in 1984
Oxygenation - term for venous blood becoming oxygen filled, after passage through lungs
Pulse Oximeter - machine used to measure arterial oxygen
Recumbency - animal lies or falls down in either lateral (side) or sternal (chest) position
Re-narcotization - return of the effects of the narcotic following reversal with an antagonist. Animal will show partial narcosis, with wandering and sleepiness
S_aO_2 - estimated arterial oxygen saturation, measured by pulse oximeter

Sedation - sedation or tranquillisation (calming), state achieved after administration of sedative
Spoor - print impressions left on the ground by an animal as it walks or runs
Tracker - skilled individual who follows print impressions of animals along the ground
Traffic - Trade Records Analysis of Flora and Fauna in Commerce
Vlei - flat grassy area usually with water or wet ground, often old river bed or fossil river drainage
Xylazine - sedative used with etorphine
ZBRCS - Zimbabwe Black Rhino Conservation Strategy

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1. Introduction

The experimental dehorning operation on white rhinoceros (*Ceratotherium simum*) was completed in October 1991. The operation involved the immobilisation of 71 white rhinos, and the dehorning of 59. A research programme was implemented during this operation to evaluate the effects of dehorning on behavioural, reproductive and health parameters. It was intended to follow these animals for 3 years, evaluate the effectiveness of dehorning as an anti-poaching strategy, and determine any adverse behavioural effects. The results of the research program, 1 year after implementation are reported later (see **5.3 Research and Monitoring Program**).

1.2 Conservation Strategy

Zimbabwe's Black Rhino Conservation Strategy (ZBRCS) was finally approved and published by Government in January 1992, after a delay of 2 years. The publication coincided with the CITES meeting in Kyoto, Japan. The objectives of this Strategy include:

* *to conserve viable populations of black rhino in the Parks and Wildlife Estate.*

* *to develop breeding nuclei elsewhere in Zimbabwe and to maintain their genetic variability.*

* *to develop one or more captive breeding centers in Zimbabwe.*

* *to support an international ex-situ captive breeding programme.*

Since the publication of this Strategy, Zimbabwe's attempts to reopen a limited official trade in rhino horn were rejected at CITES (1992). This is despite the fact that the world trade ban on rhino horn has been in place under CITES for 17 years, but has had no apparent effect on the decline of the species. Black rhino appear to be valuable only to the illegal hunter (ZBRCS, 1992). Parts of this Strategy have quickly become out of date due to rapid developments in Zimbabwe associated with illegal killing of black rhinos. In 1992, a SHORT AND MEDIUM TERM ACTION PLAN (SMTA PLAN) was published by the DNPWLM and a fifth objective has been formulated and is defined as: *To support innovative conservation measures, including attaching a commercial value to rhino and their horns.* A result of this fifth objective within the SMTA PLAN, is the current dehorning programme, which was implemented primarily to try to reduce the risk of a rhino being poached, with secondary considerations such as the possible introduction of a legal trade in rhino horn.

1.3 Background to Zimbabwe Operation, 1992

Following the completion of the experimental operation in Hwange National Park, it soon became apparent that, despite the efforts of "Operation Stronghold" since 1984, the pressures from illegal hunters on black rhinos in the north of Zimbabwe continued unabated. Indeed, the pressures appeared to be increasing. Between September 1991 and January 1992, there were 62 known illegal incursions by Zambian poachers into Zimbabwe. This resulted in the killing of 52 horned black rhino and several elephants. Anti-poaching patrols managed only

10 contacts resulting in one poacher being apprehended. Zimbabwe's black rhino population could not afford to wait for the findings from the experimental operation in Hwange National Park.

Chete Safari Area (CSA) was used as a capture and translocation area during 1991 and 1992. The animals captured in CSA were destined to be shipped to the USA and Australia as part of an agreement between the Zimbabwe Government and the International Black Rhino Foundation (IBRF). Several animals were also translocated to Conservancies in the Lowveld. Following the capture of 20 animals in June 1991, over 30 black rhinos were killed by poachers by the end of 1991 in the CSA. In 1992, the last 13 animals were captured and translocated. From an estimated population of 150 animals in 1989, CSA now no longer has any black rhino.

Due to the unsustainable loss rate of black rhinos to illegal hunting, a proposal was put forward to the Ministry of Environment and Tourism to dehorn as many black rhinos as possible, throughout the Parks and Wildlife Estate and Conservancies. This proposal was submitted in January 1992, but it took 3 months for approval to be given. During this delay, over 30 black rhino were killed in Matusadona National Park and many more elsewhere in the Wildlife Estate. Approval was finally given in May 1992.

1.4 Rationale for further dehorning

During the period of Operation Stronghold from 1984 until 1992, over 150 poachers were killed by DNPWLM anti-poaching units and many poachers apprehended. Despite this over 1000 black rhinos have been killed and it is likely that the losses are considerably higher than this. Confronted with an unsustainable onslaught on the black rhino, the options open to the DNPWLM were few. Government continues to provide a totally inadequate budget to the Department for financing the Parks and Wildlife Estate, especially provisions for increased protection of rhinos. This is despite that fact that the tourist industry in Zimbabwe is one of the fastest growing sectors (20%/annum) with over Z$500 million generated yearly, and despite the fact that the black rhino generates considerable interest amongst visitors.

Evidence from Hwange National Park suggested that poaching risk may be lower for dehorned rhino than those with intact horns. Therefore, the only viable option that could be implemented without delay was a massive dehorning campaign for black and white rhinos throughout Zimbabwe. This was implemented in May 1992 and continues into 1993.

1.5 Evaluation of the programmes, 1991 and 1992

Preliminary results from dehorning of white rhinos, and several black rhinos destined for private rhino Conservancies during 1991 and early 1992, provided the catalyst for the implementation of further dehorning. The Hwange research programme, with Janet Rachlow, whose programme is funded by Frankfurt Zoological Society, will continue through 1994. This work will focus on white rhinos but may be expanded to black rhinos within the Park. Collaboration continues with Dr Joel Berger in Namibia. Evaluation of the 1992 programme continues, but research has been limited by the vastness of the areas covered by the dehorning teams. Several promising research programmes are being developed and implemented in Matusadona National Park, and the Sinamatella region of Hwange National Park. These are all designed to improve the chances of survival of the remaining black and white rhinos in Zimbabwe.

Print 1: Helicopter and Super-Cub operating from Linkwasha Vlei, Hwange National Park, 1992.

2. Materials and methods

2.1 Lessons learned from 1991 and Main program for 1992

The implementation of a major dehorning exercise requires coordination and planning, with the use of the most skilled and professional individuals. Failure to do this will result in inefficiencies, lack of cost-effectiveness and the potential for adverse results. Lessons learned from the white rhino operation in 1991 included:

-the need to improve methods of locating rhinos, especially more cost effective methods,
- need to improve drug immobilisation techniques, especially for white rhinos,
-improved cutting techniques whilst dehorning,
-improved monitoring, including identification of individual rhinos and radio-collaring techniques.

The dehorning operation began in May 1992, with the priority area chosen as Matusadona National Park (Detail on regional areas is presented, see **4. Regional Results**). Following this operation the dehorning/capture team moved to Chete Safari Area to complete the capture and translocation of the remaining black rhinos. Several of these were dehorned prior to translocation. The team then split with Dr Atkinson and Raoul du Toit moving to the Sebungwe region, including Chizarira National Park, Chirisa Safari Area, Sengwa Research Area and Matusadona National Park (second operation). Dr Kock moved to Hwange National Park to complete dehorning of white rhinos, reimmobilise animals from the 1991 operation, measure horn regrowth and attach radio-collars. After this the team concentrated on black rhinos throughout Hwange National Park. Upon completion of the Hwange operation, the team moved to Matobo National Park to dehorn both black and white rhinos.

Dr Atkinson, following the completion of the Sebungwe region moved into the lower Zambezi Valley with Raoul du Toit, where Drs Foggin and Anderson were operating as another dehorning team. The lower Zambezi valley operation proved to be extremely difficult with a combination of dehorning and translocation. The lack of viable numbers of animals and poor co-operation by National Parks management staff on the ground provided significant constraints. The final operation in the Valley involved locating and dehorning rhinos in the Chewore Safari Area. Following this operation, Dr Atkinson, with Raoul du Toit dehorned animals in the privately owned Save Valley Conservancy. Further operations were carried out in March and April 1993 at Chipinge Safari Area, Kyle Game Park, Matobo National Park and the Save Valley Conservancy.

Prior to the start of the 1992 dehorning operation individuals were cautiously optimistic concerning numbers of rhinos in the Parks and Wildlife Estate. This optimism proved to be mistaken. It soon became apparent that there had been a catastrophic decline in numbers from the estimated population of 2095 (ZBRCS, 1992). For details of numbers immobilised and dehorned see **3. Results** and **4. Regional Results.** Revised estimates for black rhinos in Zimbabwe (including the Conservancies) as of March 1993 are: definite numbers=299, combining probable (n=66) and possible (n=65), total numbers=430. For white rhinos, the numbers reflect previous estimates with definite

numbers=198, probable (n=24) and possible (n=16), total numbers=238.

2.2 Solving the problems

Due to the high cost of both helicopter and fixed-wing hours, methods had to be devised to reduce the cost of locating and dehorning individual rhino, especially with the low density of rhinos in many areas. Several methods were used to locate rhinos including: location of spoor and tracking, chance encounters, fixed-wing spotting, helicopter spotting and various combinations of these. In Hwange National Park, we were able to locate several horned white rhinos after radio-collaring several individuals, especially large bulls. These animals were often accompanied by other rhinos, horned and hornless. Location of white rhinos for regrowth studies were essentially random.

It soon became apparent during the dehorning operations that a low density of rhinos resulted in a cost of >US$1000 to dehorn one individual. High density areas resulted in the cost dropping to < US$300/rhino. The greatest expense was incurred in locating animals, especially with the fixed-wing or helicopter. In Hwange National Park, the most cost effective way of locating black rhinos was by tracking. Scouts were driven or flown by helicopter to water points to check for spoor. Location of fresh spoor (within last 12 hours) resulted in a team of two scouts tracking that animal. This system initially produced good results with several tracking teams operating with radio communication to the dehorning team. After a number of rhinos were dehorned, the chances of tracking a dehorned animal increased. Therefore, a system of notching the front and rear feet was devised (see Diagram 1, Print 2). This method proved to be effective in 90% of cases.

Print 2: Spoor of a dehorned black rhino, identified by notching pattern on front nail (see Diagram 1).

Failures occurred when the ground was difficult (hard and stony) or the animal had spent sometime in mud. In the latter case, the notching was not picked up until the animal had travelled for a few kilometres. The trackers were skilled and following their advice we developed a notching system that worked consistently (see Diagram 1, Print 2).

The fixed-wing was used for spotting in the early morning and late afternoon, which proved cost effective. Use of the helicopter for initial searching was restricted, but good results were obtained during late afternoon flights in areas of known concentrations of rhinos. The major constraint to ground tracking was the terrain and wind. If rhinos determined that they were being followed either from noise or the unavoidable scent on the wind, they often moved ahead of the trackers several kilometers and stayed down wind. These instances proved difficult, but the protocol was: if the trackers had been following the animal for >4-6 hours, the fixed-wing then flew ahead of the trackers in an attempt to locate the animal. This often proved successful, but if not the helicopter was employed for short periods. These episodes demonstrated, on several occasions, the difficulties in spotting black rhinos from the air. Occasionally, both aircraft failed to locate the rhino despite using several experienced observers, whilst the trackers relocated the spoor and continued to follow the rhino. It was only with the efforts of the trackers that the chase was eventually successful. Financial incentives paid to the trackers proved invaluable.

Timely implementation of the ZBRCS in 1990, with consideration for a selective dehorning program, would have resulted in a far different scenario in 1993. Many more rhino would have been found, improving the cost-effectiveness of the various conservation measures, and many more rhinos would be alive today.

Print 3: Immobilised black rhino, prior to monitoring and dehorning. Animal will be placed in sternal recumbency, Hwange NP, 1992.

2.3 Immobilisation and reversal drugs

2.3.1 *White rhinoceros*

Although problems were encountered, initially with the immobilisation of white rhino during the 1991 dehorning exercise in Hwange National Park with some mortalities (Report on an Experimental Dehorning Operation on White Rhinoceros (*Ceratotherium simum*) in Hwange national Park, 1991. Internal Report, Department of National Parks and Wildlife Management, Zimbabwe and see **3. Results, 3.3 Mortalities**), modifications and improvements in the immobilising protocol resulted in no further mortalities. The 1992/1993 dehorning programme allowed for the opportunity to further improve and refine drug combinations used on white rhinos.

Of the 141 white rhinos of various ages that were immobilized in 1991 (n=71) and 1992 (n=70), 23 were darted on foot and 118 were darted from a helicopter. Fifty-five animals were immobilized using a combination of etorphine (4.2mg) and xylazine (123mg). Thirteen animals were immobilized using a combination of etorphine (2mg) and fentanyl (30mg), sixty animals were immobilized with etorphine (3.9mg) and detomidine (13mg), and 12 animals were immobilized with etorphine alone (1.16mg). (see **5. Discussion, 5.1 Chemical immobilisation**, Figure 1).

Modifications of drug dosages and combination resulted in a major improvement in the quality of anaesthesia, with a more stable animal. Use of new monitoring equipment assisted in evaluating these modifications (see **5. Discussion, 5.1.1 Innovative Research-pulse oximetry**). Further improvements were developed with the use of emergency drugs, resulting in safer anaesthesia. The new drug protocol developed using M99/detomidine was considered to be superior to the recommendations of Flammand et al., 1984.

Further research was carried out with reversal drugs used to arouse the animals from the narcotic. In 1991, incomplete arousal with narcotic recycling and depression were noted. This was a potential problem especially for female white rhinos with calves. A new drug protocol developed for reversal of the narcotic, using naltrexone (50mg/ml, Wildlife Laboratories) at 50-100mg IV, proved to be very effective in eliminating many of the problems encountered in 1991 (see **5. Discussion, 5.1.1 Drug Reversal**, Figure 3).

2.3.2 *Black rhinoceros*

Immobilisation techniques for the black rhinoceros have been refined and improved considerably from previous operations in Zimbabwe (Booth and Coetsee, 1989). Modifications in drug dosages (Kock et al, 1989) and combinations (Morkel, 1989, Kock, 1992) have resulted in faster and smoother induction times with a reduction in stress and capture related complications. All back rhinos were immobilised with combinations of etorphine (M99, 9.8mg/ml, C-Vet Ltd., Minster House, Bury St. Edmunds, Suffolk, UK) and xylazine (Rompun, 100mg/ml, Bayer, Leverkusen, Germany (n=135) or detomidine (Domesedan, 10mg/ml, Norden Laboratories, Stevenage, Herts., UK) (n=10), combined with hyaluronidase (Hyalase, D. Morton, Faculty of Veterinary Science, University of Zimbabwe, Harare, Zimbabwe). A standard dose of between 3.5-4mg M99 with 100mg xylazine combined with 1500IU hyalase was used for black rhino. Doses for calves of M99 alone ranged from 0.01-0.5mg.

These combinations were applied during the 1992/1993 dehorning programme and proved to be very effective (see **4. Regional Results** and **5. Discussion, 5.1 Chemical Immobilisation**). Average induction times approached 3.0 minutes, resulting in less stress and improved cost effectiveness, especially reducing helicopter hours (Figure 4)

Significant improvements in reversal of the narcotic used to immobilise black rhinos were achieved with new reversal drugs (see **5. Discussion, 5.1 Chemical Immobilisation**, Figure 6). The use of these drugs resulted in consistent and smooth arousal of rhinos. This was especially valuable when females with very young calves were immobilised. The smooth reversal ensured that the two remained together. Separation of the calf would have resulted in a significant risk of hyaena or lion predation. Various combinations of reversal drugs were used including diprenorphine (6-12mg/ml, C-Vet Ltd.), naloxone (Naloxone, 50mg/ml, Wildlife Laboratories, Fort Collins, Colorado 80525, USA) and naltrexone (50mg/ml, Wildlife Laboratories).

2.4 Darting equipment

Projectile syringes were 3-4ml in volume with 47-68mm collared needles. A combination of bevelled and non-bevelled needles were used (D.L. Tranquillizer Systems, Fenny Bentley, Derbyshire, UK and CapChur, Palmer Chemical and Capture Co., Georgia, USA). Non-bevelled needles were preferred when darting from a helicopter as there was less chance of deflection with angled shots. A bevelled (cutting edged) needle was preferred for ground darting. Due to the thick skin of the rhino, sufficient power was necessary to cut through the skin into muscle. On several occasions partial cutting occurred with subcutaneous injection of the immobilising drug. This was due to a an insufficient charge in the projectile gun or poor distance estimation. A compressed air rifle (D.L. Tranquilliser Systems) or powder charge rifle (Pneu-Dart, Model 151C, PO Box 1415, Williamsport, PA 17703, USA) both with a red dot point scope were used to propel the projectile syringes. Most rhinos immobilised from the helicopter were darted in the dorsal thigh/rump area; those on the ground were most often darted in the neck/shoulder area. Ground darting of subadults or calves was carried out using either 2ml Pneudarts with 38mm collared needles or 2-3ml Palmer CapChur darts with 3mm x 45mm barbed needles. The former presented difficulties with skin plugging and the latter were preferred as they were more reliable.

2.5 Capture technique

In most instances, after successful darting, the spotter aircraft and/or helicopter followed the animal until it became recumbent. The dehorning crew was then ferried to the location by helicopter and a vehicle was driven as close to the recumbent animal as possible. The trackers were instructed to follow the rhinos' spoor until they reached the recumbent animal, to assist in the dehorning. Several rhinoceroses, (especially large male white rhino), had to be roped and/or given more narcotic by hand in order to achieve safe restraint and recumbency. Following immobilisation, the following procedures were carried out:

* evaluation of anaesthesia, with close monitoring of physiological parameters including temperature, respiration and pulse rates was begun. Pulse oximetry was used routinely (see **5.1.1. Innovative Research-pulse oximetry**). Dopram (Doxapram HCL, 20mg/ml, Continental

Ethicals (Pty) Ltd, Port Elizabeth, RSA), and/or nalorphine (Nalorphine, 10mg/ml, Centaur Labs., (Pty) Ltd., Johannesburg, RSA) or Nubain (Nulbuphine hydrochloride, 10mg/ml, Boots Co. (SA) (Pty) Ltd., Electron Avenue, Isando, RSA) were given, if necessary, to stimulate respiration (see **Discussion, 5.1 Chemical Immobilisation**).

* measurements of horn lengths, and anterior (front) and posterior (rear) basal circumferences were taken.

* removal and shaping of both horns using a 13" chainsaw, followed by the application of Stockholm Tar to the cut surfaces.

* blood samples were collected for evaluation of baseline biological data and stress parameters. Notation of the colour of the blood also provided an indication of oxygen status and was an early warning sign of impending problems. This was correlated with pulse oximetry.

* animals were given a body condition score, 1=emaciated, 2=poor, 3=fair, 4=good, 5=excellent, to aid in assessing health.

* measurements of body size including chest girth, neck girth, body length and head length were taken.

* ear-notching, application of an ear-tag (white rhino only), placing of a subcutaneous passive transponder (Trovan, Electronic Identification Systems, AEG Telefunken, Germany), and painting of a number on the back to aid in identification (both ground and aerial) were done.

* with black rhinos, a front and rear foot was notched to aid trackers in identifying whether a rhino had been previously dehorned (see **2.2 Solving the problems**, Diagram 1).

All data were collected on individual data sheets (Appendix 2), and rhinoceroses were classified into "outcome" categories at capture (stressed or non-stressed) to aid in evaluating the stress response.

2.6 Data reporting and analyses

Immobilisation and other data collected for black and white rhinos, were analyzed using a statistical graphics program (StatGraphics, Statistical Graphics Corporation, Rockville, Maryland 20850, USA). Specific statistical tests were applied following exploratory data analysis, including one-way analysis of variance (ANOVA). All data are presented as mean ± standard error (SE) of the mean.

3. Results

Target Animals: Animals were dehorned in areas where viable populations were thought to occur (> 20 individuals). Animals captured and translocated were those considered to be resident in locations where viable populations no longer existed and hence, reproduction was unlikely.

3.1 Numbers: Immobilisations and dehornings

More than 310 immobilisations of both black and white rhinos were carried out in 1991/1992 and 1993 in Zimbabwe (Table 1 and 2). Of these, approximately 270 animals were dehorned. Not all animals that were immobilised were dehorned, as several were young sub-adults or calves and the horns were too short to cut without causing damage to the germinal areas and nasal bones.

3.1.1 *White rhinoceros*

In 1991, 71 white rhinos were immobilised in Hwange National Park (1 was immobilised in a Forestry Commission area, n=72)). In 1992/1993, a further number (n=84) were immobilised in Hwange National Park, Matobo National Park, the Save Valley Conservancy and Kyle Game Park, with a total of 151 immobilisations (1991/1992/April 1993). Of these, 123 were dehorned.

3.1.2 *Black rhinoceros*

Prior to 1992, a few black rhino had been dehorned during translocation exercises but the major dehorning of black rhinos commenced in 1992 and continued into 1993. The main areas covered included, Matusadona National Park, Hwange National Park, Chizarira National Park, Chirisa Safari Area, Sengwa Wildlife Research Area, Lower Zambezi Valley, Matobo National Park and several private Rhino Conservancies. As of April 1993, a total of 165 animals were immobilised, with 148 of these being dehorned.

3.2 Immobilisation data: Induction, recumbency and reversal

3.2.1 *White rhinoceros*

The mean induction time for all drug combinations used on white rhinos was 6.4 minutes (median 5 minutes). There were no statistically significant differences in induction times between M99/xylazine, M99/fentanyl, M99/detomidine and M99 alone. Although M99/detomidine consistently produced a more rapid and smoother induction (Mean ± SE, 5.6 ± 0.51 minutes, Table 4, Figure 1)(see **4. Regional Results**, and **5. Discussion, 5.1 Chemical immobilisation**).

Induction in white rhinos was characterised by increasing incoordination with an occasional high stepping gait. The development of signs was not as abrupt as seen with black rhinos. Many animals became immobile simply because of inability to negotiate an obstacle (tree, incline). Large bulls often managed to remain on their feet and could be roped and held in standing sedation prior to processing.

Table 1: White rhino *(Ceratotherium simum)* status after dehorning (1991, 1992 and up to March 1993): numbers immobilised, dehorned, dehorned rhinos killed by poachers and death from unknown causes.

	Immobilised	Dehorned	Dehorned/ died (Dhp)[a]	Dehorned/ died (Dhk)[b]
Hwange NP/ Deka SA	89[c]	81	6	2
Matobo NP	32	31	0	0
Mat. North/ Forest Areas	1	1	0	0
Save Valley Conservancy	2	2	0	0
Kyle Game Park	8	8	0	0
Totals	132	123	6	2

[a] Poacher mortality (Dhp). Data as of 31st March 1993.

[b] Death from unknown causes (Dhk) could be due to natural mortality, trauma or undetermined.

[c] 23 white rhinos were re-immobilised in 1992, for horn regrowth measurements. These are not included here.

Table 2: Black rhino (*Diceros bicornis*) status after dehorning (1992 and upto March 1993): numbers immobilised, dehorned, dehorned rhinos killed by poachers and death from unknown causes.

Area	Immobilised	Dehorned	Dehorned/ died (Dhp)[a]	Dehorned/ died (Dhk)[b]
Hwange NP/ Deka SA	60	51	2	1
Matusadona NP	20	18	4	2
Save Valley Conservancy	22	22	0	0
Chizarira NP	19	17	5	0
Zambezi Valley	6	6	0	0
Mat. North/ Forest Areas	9	7	0	0
Chirisa SA	4	4	0	0
Chiredzi River Conservancy	7	7	0	0
Chipinge Safari Area	7	6	0	0
Matobos NP[c]	10	9	0	1
Ruwanzi Ranch	1	1	0	0
Totals	165	148	11	4

[a]Poacher mortality (Dhp). Data as of March 31st, 1993.
[b]Death from unknown causes (Dhk) could be due to natural mortality, trauma, or undetermined.
[c]Operation completed April, 1993.

In 1991, white rhinos were recumbent for an average of 41 ± 3.2 minutes (range 16-150 min.). In 1992, combining data from Hwange and Matobo National Parks, rhino were recumbent for an average of 38.7 ± 2.5 minutes, a slight improvement on 1991. Comparisons between Hwange (39.9 ± 2.1 minutes, 1991/1992) and Matobo (29.8 ± 1.6 minutes, 1992) demonstrated increased efficiency with the Matobo operation. Combined data for 1991/1992 from both Parks revealed a down time of 37.7 ± 1.7 minutes (range 4-150 min.) (Figure 2).

Reversal time following administration of the narcotic antagonist, in 1991, was an average of 92.7 ± 7 seconds and reflected the specific antagonist properties of naloxone administered IV (combined with M50-50 IM). Despite this rapid arousal, reversal was often incomplete or animals showed evidence of re-narcotization several hours after administration of the antagonist. The use of naltrexone (75-125mg) resulted in an average reversal time of 92 ± 5 seconds and most

notable was the quality of reversal (Figure 3). Animals reversed smoothly, consistently and were alert. There was little evidence of re-narcotization (see **5. Discussion, 5.1 Chemical Immobilisation, 5.1.1 White rhinoceros**).

3.2.2 *Black rhinoceros*

The mean induction times for black rhinos ranged from 1-14 minutes, with an average for Hwange National Park of 3.9 ± 0.23 minutes. The median, which more accurately reflects the true down time, was 3.2 minutes. Induction times for black rhinoceros using M99 and xylazine, with good dart placement, were rapid and consistent (Table 5, Figure 4)

Induction in the black rhinos differs from white rhinos in that the former are more agile and move at considerable speed after darting. There is little initial sign of drug effect in the first 2-3 minutes after dart placement. After this period signs develop rapidly with ears being laid back, animals run through, rather than around bushes, there is a high stepping gait and rapid slowing. Immobilisation and recumbency soon follow. The presence of obstacles or inclines assists in stopping the rhino.

Despite rapid induction times for black rhinos, total immobilisation times were similar to those for white rhinos, ranging, on average, from 38.1-53.2 minutes (Figure 5). These reflected the amount of time necessary for dehorning and the collection of research data. The range for total down times for black rhinos in Hwange National Park, for example, was 19-75 minutes compared to 4-150 minutes for white rhinos. This reflected easier anaesthesia with black rhinos, smaller base circumference of horns reducing cutting time and a more efficient operation as a result of experience.

Reversal times in black rhinos was achieved using M50-50 (IV), M50-50 (IM) and naloxone (IV) or naltrexone (IV). The last two reversal drugs produced rapid reversal times, with animals becoming consistently aroused at approximately 90 seconds (Figure 6). This was particularly important with reversal of young calves (see **5. Discussion, 5.1 Chemical Immobilisation, 5.1.2 Black rhinoceros**). Arousal with M50-50 was always more prolonged but complete. There was no evidence of recycling with any of the drugs used for reversal.

3.3 Mortalities

Of the 71 white rhinos immobilised in 1991, five died (direct mortality rate=7%), all of which occurred early in the dehorning operation (5 mortalities in the first 34 animals immobilised). Improvements in technique and modifications in drug combinations effected safe immobilisation of the remaining 37 animals (see 6. Conclusions 6.1 **Mortalities**). No mortalities were experienced in 1992 (n=74). The overall direct mortality rate for white rhinos was 3.26% (5/153, including Kyle Game Park, n=8).

As of April, 1993 only 1 black rhino has died specifically related to dehorning (mortality rate=0.6%), although there were some mortalities related to capture for translocation but the circumstances were exceptional (n=2, mortality rate=1.2%). The overall direct mortality rate for all immobilisations of both species of rhinos was < 2%, with a direct mortality rate of 1.6%. for dehorning.

4. Regional Results

4.1 Hwange National Park

Hwange National Park (HNP) is located in north-west Matabeleland and is 1,465,100ha in extent. The vegetation represents a transition between dry western deserts and moist savanna woodlands with vast teak (*Baikea* spp.) forests and typical sandveld woodland areas.

Print 4: Elephant near Linkwasha Windmill Pan, Hwange National Park. The surrounding area is prime habitat for white rhinos, and is a major focus for the research and monitoring program.

Fossil rivers and other areas are characterised by open grassland often bordered with *Acacia erioloba* trees. Kalahari sand covers some 947,000ha, which is gently undulating country. To the north, more broken country with mopane, *Combretum* spp., and *Commiphora* woodland, includes basalts, grits, sandstones, gneisses and paragneisses where streams and rivers rise and drain north towards the Zambezi river (IUCN Directory of Afrotropical Protected Areas, 1987). This area is contiguous with the Deka Safari Area (DeSA). The varied habitat, natural pans and artificial water supplies support a large diversity of wildlife. Hwange has the largest populations of both white and black rhinos left in Zimbabwe. Original estimates for white rhinos, which occur mainly in kalahari sandveld country, was 140 animals (Aerial Census of Elephants and other Large Mammals in North-West Matabeleland, Sept-Oct, 1991) and for black rhinos, which occur mainly in the north of the Park estimated numbers were 250 (ZBRCS, 1992).

Table 3: HWANGE NATIONAL PARK: Black (*Diceros bicornis*) and white (*Ceratotherium simum*) rhino immobilisation and dehorning data. Numbers, sex and age, 1991/1992.

	Black rhino		White rhino	
	Immobilisation	Dehorning	Immobilisation	Dehorning
Number	69[a]	58	110[b]	81
Male	31	26	58	42
Female	38	32	52	39
Adult	49	49	78	78
Subadult	10	8	17	3
Calf	10	1	15	0

[a]Includes 9 animals from adjacent Forestry land
[b]Includes reimmobilisations, n=23

4.1.1 *White rhinoceros*

The dehorning programme in Hwange National Park began in 1991 with an experimental programme (Report on an Experimental dehorning operation on White Rhinoceros (*Ceratotherium simum*) in Hwange National Park, DNPWLM, Internal Report, 1991).

In 1992, in conjunction with dehorning of black rhinos in HNP, the white rhino programme had two components:

a. Reimmobilisation of animals dehorned the previous year to document rate and form of regrowth. This was important for several reasons:

* to determine rate of regrowth, and therefore, the likely time scale when horns would need to be removed again and the monetary value of horn after 1 year (in the event of farming rhino horn and the opening of a legal trade) (see **5.3 Research and Monitoring Program, 5.3.2 Horn regrowth: rates and form**).

* to determine whether regrowth was normal using the dehorning techniques developed. This was crucial for future operations, as any medical or long term complications to the health of dehorned rhinos would be detrimental in sustaining current population levels, i.e. if there were any mortalities related directly to complications associated with horn removal (see **5.2 Dehorning Tools and Procedure**) this would be a constraint to dehorning.

b. The location of white rhinos still with horns and placement of radio-collars for tracking rhinos for the research programme.

The monitoring of rhinos with or without horns is difficult due to the behaviour of the animals and the habitat that they live in. The Research component of the dehorning programme involves monitoring of rhinos at waterholes at night, and to a limited extent, during the day. The development of long term monitoring techniques was considered essential to enhancing the data

collected during the research programme (see **5.3 Research and Monitoring, 5.3.4 Radio-Collaring**).

Four different drug combinations were used in 1991/1992 to immobilise animals. Mortalities that occurred with all of the combinations early in 1991 appeared to be related to prolonged recumbency, with the resultant hypoxemia (oxygen debt), and finally cardio-vascular system collapse (see **5. Discussion, 5.1. Chemical Immobilisation, 5.1.1 White rhinoceros**).

The protocol in 1992 involved further evaluation of drug combinations used in 1991, but with a more thorough research protocol established prior to implementing the dehorning. Seventy-four white rhinos were immobilised (32 in Matobo NP) without any mortalities. The Wildlife Veterinarians felt that the combination of M99 and detomidine represented a new and superior drug combination for chemical immobilisation of the white rhino (see **5. Discussion**). A total of 110 immobilisations in HNP (1991/1992) were carried out, of which 81 involved actual dehornings (Table 3). Forty-two male and 39 females were dehorned, with 78 adults, and 3 subadults.

Twenty-three white rhinos were reimmobilised in 1992, of these 19 were dehorned in 1991, and 4 were dehorned in 1992. The latter represented animals that were too young to dehorn in 1991 (subadults and calves), but sufficient horn growth had occurred to justify dehorning in 1992. Eighteen new animals were located of which 11 were dehorned. A total of 12 animals had radio-collars fitted.

Table 4: HWANGE AND MATOBO NATIONAL PARK: White rhino (Ceratotherium simum) immobilisation data, including drug combination, induction times, and total down times.

	DRUG COMBINATION			
Parameter	M99	M99/FENT	M99/XYL	M99/DET
Number	12	13	55	59
Induction (min)	8.08 ± 1.6	7.4 ± 1.3	6.8 ± .6	5.6 ± .51
Number	-	12	41	45
Distance Moved (km)	-	1.2 ± .17	0.61 ± .05	0.51 ± .06
Number	11	12	51	54
Down time (min)	28.5 ± 3.4	32.8 ± 3.6	41.7 ± 3.7	37.2 ± 1.9
Number	10	12	52	50
Temp (deg C)	38.5 ± .25	38.3 ± .31	38.1 ± .15	37.9 ± .15
Number	9	12	45	48
Pulse (bpm)	152 ± 11.6	115 ± 5.6	110 ± 2.9	84 ± 4
Number	10	12	52	48
Resp (bpm)	11.4 ± 1	9.6 ± .8	10.6 ± .47	10.5 ± .41

1991/1992 data for Hwange, 1992 for Matobo.
FENT=fentanyl, XYL=xylazine, DET=detomidine.
M99/DET (n=28) and M99/XYL (n=3) used at Matobo.

Data concerning white rhino horn measurements is presented (Table 5) with age and sex differences (Table 6). Regrowth data is presented (Table 20) and discussed under **5.3 Research and Monitoring Program, 5.3.2 Horn regrowth**).

Table 5: HWANGE NATIONAL PARK: White rhino (*Ceratotherium simum*) horn measurement data, before and after dehorning, 1991.

Measurement	Number	Mean	SE	Min	Max
Front horn length (cm)	68	47	2.8	3	97
Cut front[a] horn (cm)	41	4.5	0.29	1	9
Rear horn length (cm)	66	15	1	1	36
Cut rear[a] horn (cm)	40	3.6	0.22	1	6

[a] Measurement from skin to cut surface (side).

Table 6: HWANGE NATIONAL PARK: White rhino (*Ceratotherium simum*) horn measurement data: age and sex differences from 1991 dehorning exercise.

Age/sex	Number	Front horn (cm)	Rear horn (cm)
Calf	10	9.2 ± 2.2	2.0 ± 0.7
SubAdult	10	27.7 ± 2.2	7.4 ± 0.7
Adult	48	59.3 ± 2.2	18.6 ± 0.9
Male (adult)	22	61.0 ± 2.8	19.6 ± 1.4
Female (adult)	26	57.2 ± 3.3	17.6 ± 1.2

4.1.2 *Black rhinoceros*

Sixty-nine black rhinos were immobilised in HNP, Deka Safari area (DeSA) and Forestry Commission land adjacent to HNP during 1992. Of these 31 were male, 38 female, and 49 adults, 10 subadults and 10 calves. Fifty-eight animals were dehorned, of which 26 were male, 32 female, and 49 adults, 8 subadults and 1 calf (Table 3). The greatest concentration of black rhinos existed in the north of HNP and in the DeSA. Evidence suggests that there are animals distributed, at varying densities, throughout HNP, as single animals were located that were widely dispersed and were far from other black rhino concentrations. The number of black rhinos in HNP cannot be accurately estimated at this time, but probably exceeds 100. It is unlikely to approach the official estimate of 250 (ZBRCS, 1992). The numbers of black rhino in HNP has the potential to expand significantly, but there are worrying historical facts that need to be addressed (see **Historical information** pg. 32).

The majority of black rhino immobilised in HNP were darted with a mixture of etorphine and xylazine (n=58) or detomidine (n=3) (Table 7) mixed with 1500IU Hyalase. The average induction time was 3.9 ± 0.23 minutes (median 3.2 min.)(Figure 4). This induction time was consistent with accurate dart placement and was instrumental in reducing stress and eliminating direct capture related mortalities. Total immobilisation time was, on average, 41.4 ± 1.6 minutes (range=19-75 min.) and reversal was smooth and consistent, using a variety of reversal agents, averaging 86 ± 3.9 seconds (Table 7, Figure 6). Naltrexone and M50-50/naloxone was superior to M50-50 alone (see **5. Discussion, 5.1 Chemical Immobilisation, 5.1.2 Black rhinoceros**).

Table 7: HWANGE NATIONAL PARK: Black rhino (*Diceros bicornis*) dehorning exercise. Immobilisation data, including induction times and total down times.

Measurement	Number	Mean[a]	SE	Min	Max
Etorphine (mg)	69	3.9	0.16	0.01	4
Xylazine (mg)	58	91.2	2.8	20.0	100
Detomidine (mg)	3	9.3	0.66	8.0	10
Induction (min.)	63	3.9	0.23	1.0	10
Reversal time (sec.)	37	86.0	3.9	60.0	140
Down time (min.)[b]	63	41.4	1.6	19.0	75

[a] Median=3.2 minutes, SE=standard error of the mean
[b] Total immobilisation time (min.)

Black rhino horn measurement data is presented (Table 8) with age and sex differences (Table 9). There were no significant sex differences in horn length or circumference, although male horns appeared to have a greater base circumference. Total average weights of cut horn, age and sex differences collected in HNP are presented (Table 10, n=44).

Table 8: HWANGE NATIONAL PARK: Black rhino (*Diceros bicornis*) horn measurement data, before and after dehorning, 1992.

Measurement	Number	Mean	SE	Min	Max
Front horn length (cm)	58	37	1.9	2	61
Circumference (cm)	48	50.0	1.5	20.0	66
Cut front[a] horn (cm)	51	5.04	0.19	3	8
Rear horn length (cm)	57	18	1.06	1	39
Circumference horn (cm)	46	46	1.6	10	58
Cut rear[a] horn (cm)	51	3.4	0.13	1.5	5

[a] Measurement from skin to cut surface (side).

Table 9: HWANGE NATIONAL PARK: Black rhino (*Diceros bicornis*) horn measurement data. Age and sex differences, 1992.

Age/ sex	n	Front horn (cm)	Rear horn (cm)	n	Front Circum. (cm)[a]	Rear Circum. (cm)
Calf	4	6.1 ± 1.4	1.5 ± .28	3	21.6 ± 1.6	-
Sub Adult	9	21.8 ± 2.6	10.2 ± .98	6	40.1 ± 2.9	33 ± 3.7
Adult	45	42.7 ± 1.5	20.1 ± .98	39	53.4 ± 1	48.6 ± 1.2
Male	26	36.4 ± 2.7	14.8 ± 1.2	23	51.2 ± 2.3	44.4 ± 2.9
Female	31	37.8 ± 2.9	20.1 ± 1.6	23	48.8 ± 2	47.6 ± 1.1

[a] Base (circum.) circumference.

Table 10: HWANGE NATIONAL PARK: Black rhino (*Diceros bicornis*) horn weight data, 1992.

Measurement	n	Front	n	Rear
Total mean weight (kg)	44	1.21 ± 0.08	43	0.6 ± 0.05
Male	20	1.24 ± 0.15	19	0.55 ± 0.09
Female	23	1.21 ± 0.1	23	0.66 ± 0.06
Adult	38	1.34 ± 0.08	38	0.66 ± 0.05
SubAdult	5	0.36 ± 0.05	5	0.2 ± 0.03
Calf	1	0.75	-	-

Total weight of chips=20.8kg.
Total weight of shavings=3.4kg.
Total weight of horn=79.45kg.

Historical information and evaluation of population estimates: The majority of black rhinos have been introduced to HNP, although Selous (1908) made the first reference to black rhino (hooked lipped) in the area that is now HNP. In 1942, the first black rhino, a pair, were seen near the Deka river. The first black rhino relocation to HNP occurred in November 1961, from Lake Kariba (Herbert and Austen, Report DNPWLM, The Past and Present Distribution of the Hooked Lipped and Square Lipped Rhino in the Wankie National Park, Dec, 1971). In October 1962, 6 male and 2 female rhinos were released at Mandavu Dam, a further 1 male and 3 females were released in March 1963. Four of the 1963 animals died from a variety of causes. In 1965, 31 black rhino were released into HNP (location unspecified, although it is mentioned that spoor was seen in the southern areas of HNP, i.e., Ngamo, Makololo, Zibanini etc.), with 16 males and 15 females. In May 1971, 7 black rhino were released at Deteema dam. The population estimate at that time was >23 animals in HNP and the DeSA. According to a DNPWLM report (T.C. Ballance, Warden Sinamatella, October, 1982) a rhino survey was carried out in 1982 of the Sinamatella sub-region. The method involved monitoring water points, incoming and outgoing spoor. The results suggested a population estimate of 47 black rhino. A similar survey carried out in October 1982, in the DeSA revealed a estimated population of 37 black rhinos (Total for HNP and DeSA=84+). In 1984/1985, a total of 46 animals were released at Shapi Pan (Booth and Coetsee, 1988).

Evaluation of reports from 1962-1988 are significant in several respects:

* there was a high mortality rate related to management (capture and/or translocation). Induction times were often prolonged, suggesting stressful capture episodes.

* an excessive number of animals appeared to have experienced trauma and, most significantly, many lost horns (a significant risk factor for indirect mortality, related to long term survival (see 6.3 **Numbers and Distributions**)(Kock et al., 1990)

* there is very little detailed follow-up data on the long term survival of translocated black rhino, prior to 1988. The survival status of the 46 animals released at Shapi is unknown, although Booth and Coetsee (1988) describe some rhino movements post-release, but comment that few sightings were made of animals released in 1985. It was concluded that the majority of animals scattered widely.

The significance of this historical information (or lack of) is that: during the 1992 dehorning exercise, extensive aerial (helicopter and fixed-wing) and ground work based out of Shapi Pan, resulted in very few black rhinos being located. One bull was immobilised and dehorned near Guvalala Pan, but no further animals were located within a radius of 10km from Shapi Pan. The nearest group of animals was located near Tshompani and Inyantue dam, some distance away from Shapi (15km and 30km, respectively). Apparently, all rhino released at Shapi in 1984/1985 had identification in the form of ear notches and/or ear tags (or holes left, as the tags were unlikely to be present 8 years later). Only 1 or 2 animals in the north of HNP, during the entire dehorning exercise, were considered to be possible 1980's releases. The question that must be addressed is "*Where are all the translocated animals from 1984/1985, taking into account natural mortalities and unforseen circumstances?*". There is no doubt that there is a huge discrepancy in potential numbers between releases over the last 20 years, and the numbers actually located and dehorned.

From experience gained by the authors of this report, with evaluation of long-term survival (Kock et al., 1990; R. du Toit, pers. comm.), the possible explanations for this discrepancy are, that mortalities from capture and translocation related to the 1962-1982 exercises were undereported or not reported and losses were probably significantly high (see **6. Conclusions, 6.3 Numbers and Distributions**), OR that there has been significant poaching of rhinos during the period 1975-1992 in HNP that has gone undetected, OR the dehorning team did not locate all the rhinos, especially if they dispersed widely.

It is worth noting the information provided by DNPWLM staff prior to the start of the dehorning programme for the Sinamatella/Deka SA subregion for rhino numbers. The estimates were based on: scout patrol reports for a six month period, interviewing scouts and patrol debriefings. The estimate for black rhino numbers was 42 animals, the estimate for white rhinos was 26 animals. Based on the findings from the dehorning exercise, the black rhino numbers were an underestimate (by 28%), whilst the white rhino numbers were significantly overestimated (by 89%). This questions the validity of estimating rhino numbers purely from patrol reports and spoor counts. These results emphasise the difficulties in presenting accurate population estimates for rhinos on the ground.

4.2 The Sebungwe Region: Chizarira National Park, Chirisa Safari Area and Sengwa Wildlife Research Area

Chizarira National Park (ChNP) is 191,000ha and is virtually contiguous with the Chirisa Safari Area (CsSA) (171,300ha). Vegetation is dominated by *Brachystegia/Julbernardia* Miomba woodland, with areas of *B. boehmii* and mopane, *Colophospermum mopane*.

Print 5: Elephant in the Sengwa River, Sengwa Wildlife Research area

Most of ChNP is on undulating, dissected plateau descending in the north in wooded ridges, mountains and rocky valleys to the 500m escarpment overlooking Lake Kariba (IUCN, 1987). Sengwa WRA is 40,000ha in extent and is solely devoted to wildlife research by the DNPWLM staff and visiting scientists. Population estimates for these areas included 300 black rhinos for ChNP, 200 for CsSA (including Sengwa) (ZBRCS, 1992).

The operation carried out in the Sebungwe Region was coordinated by Dr Mark Atkinson with significant help from Raoul du Toit. Details of drugs used, capture techniques are summarised and included in this section (see **2. Materials and Methods**, 2.3 **Immobilisation and Reversal Drugs**). Although not major, differences in drugs used and technique

were important and the information useful. Several animals captured in the Sebungwe Region and lower Zambezi Valley were dehorned and translocated. Details of these are included in this report.

Immobilising Drugs: All rhinoceroses were immobilized with either etorphine and xylazine (n=23) or etorphine and detomidine (n=10)(Table 11 and 12). Adults received a standard dose of 3.5-4.0mg M99 with 80-100 mg xylazine and subadults, 3-3.5mg with 80-100mg xylazine. When detomidine was used, animals received a standard dose 3.5mg M99 and 9-10mg detomidine. Hyaluronidase was added to each dart mixture at a rate of one vial (2000 IU/vial) per dart.

Reversal drugs: Etorphine was reversed using naloxone, naltrexone or diprenorphine(M50-50,12mg/ml,C-Vet Ltd)(Table 12). On occasion animals were reversed using a combination of naloxone intravenously (i.v.) and diprenorphine intra-muscularly (IM) (n=10). Partial reversal to assist in loading captured animals was achieved using nalorphine.

Tranquillising drugs: Captured animals were given a long- acting neuroleptic before loading to facilitate easier handling and to reduce stress associated with transport and boma confinement (n=5). The drug chosen for this was zuclopenthixol-acetate (Clopixol-Acuphase, 50mg/ml, H.Lundbeck A/S, DK-2500, Copenhagen, Denmark).

4.2.1 *Black rhinoceros*

Twenty-six black rhinos were located (Table 11), 23 of these were adults and were dehorned. Three were calves and not dehorned. One of the adult animals was located in the Siabuwa area, and was captured and translocated to the Bubiana Conservancy in West Nicholson.

Table 11: CHIZARIRA NATIONAL PARK: Black rhino (*Diceros bicornis*) immobilisation and dehorning data, 1992. Numbers, age and sex.

Sex/age	Immobilisation	Dehorning
Number	20	17
Male	7	7
Female	13	10
Adult	17	17
SubAdult	-	-
Calf	3	-

For animals immobilized with combinations of etorphine and xylazine, the range of induction times was 2.83-9.50 minutes (n=13). Due to equipment constraints, 5 animals were injected with projectile syringes which did not discharge due to incompatible plungers, and in all of these cases, the time to induction was greatly increased. Average induction time for all animals (n=13) was 5.5 ± 0.69 minutes. Removal of animals with prolonged induction times due to dart failure resulted in an average induction time of 3.79 ± 0.23 minutes (n=8).

For animals immobilized with combinations of etorphine and detomidine, the range of induction times was 3.0 - 14.0 minutes (n=10). Two of these animals had long induction times due to incomplete discharge of the projectile syringe. Average induction time for all animals (n=10) was 6.8 ± 1.17 minutes, with an average induction time following removal of animals with prolonged induction of 5.28 ± 0.67 minutes.

The period between recumbency and full reversal was measured for each animal dehorned (n=24). On average animals were immobilised for 53.2 ± 4.35 minutes. Time for full reversal of the narcotic by injection of an antagonist was measured for each animal. For animals antagonised by diprenorphine only (n=11), the average reversal time was 87.5 ± 5.13 seconds. For animals antagonised by naloxone (IV) and diprenorphine (IM) , the average reversal time was 55.3 ± 2.66 seconds. For the one animal antagonised by naloxone only, the reversal time was 56 seconds and two animals antagonised by naltrexone only (2 juveniles) reversal time was 36 ± 0.99 seconds. No mortalities were recorded in this phase of the operation.

Table 12: CHIZARIRA NATIONAL PARK, CHIRISA SA: Black rhino (*Diceros bicornis*) immobilisation data, including induction times, total down times, and reversal times, 1992.

Measurement	Number	Mean	SE	Min	Max
Induction time[a] (min.)	13 (8)	5.5 (3.8)	0.69(0.23)	2.8	9.5
Induction time[b] (min.)	10 (8)	6.8 (5.3)	1.17(0.67)	3.0	14.0
Reversal time[c] (sec.)	11	87	5.13	-	-
Reversal time[d] (sec.)	10	55	2.66	-	-
Reversal time[e] (sec.)	2	36	0.99	-	-
Down time (min.)	24	53.2	4.35	-	-

[a]M99/xylazine, figures in brackets represent normal functioning darts, [b]M99/detomidine, [c]M50-50 only (IV)
[d]Naloxone (IV) and M50-50 (IM), [e]Naltrexone (IV)

4.3 Matusadona National Park

Matusadona National Park (MaNP) is 137,000ha in extent and comprises mixed miombo woodland (*Brachystegia spp.*) and savanna grasslands. It is situated on the shores of Lake Kariba. There is an abrupt and rugged escarpment separated from the lake-shore by an apron of flatland or Valley floor. Population estimates for black rhinos in this Park were 150 (ZBRCS, 1992).

4.3.1 *Black rhinoceros*

The first phase of dehorning black rhinos, in Zimbabwe commenced in MaNP and provided an opportunity to assess the effectiveness of aerial surveying for rhinos and ground based location methods (see 6.4 **Cost of dehorning**). The total number of black rhino located in MaNP (including Partridge Island, 1 adult female) was 20, with 18 animals

Print 6: Zambezi Valley escarpment, Matusadona National Park. View looking towards Tashinga and Lake Kariba.

Table 13: MATUSADONA NATIONAL PARK: Black rhino (*Diceros bicornis*) immobilisation and dehorning data, 1992. Numbers, age and sex.

Age/sex	Immobilisation	Dehorning
Number	18	18
Male	6	6
Female	8	8
Adult	15	15
SubAdult	-	-
Calf	-	-

immobilised and dehorned (Table 13). Seven were male and 8 female, 15 adults and 3 subadults. Immobilisation and dehorning techniques were standard, but little data were collected during this exercise.

4.4 Lower Zambezi Valley, Zambezi Valley Wildlife Estate (including Mana Pools National Park, Sapi and Chewore Safari Areas).

These areas have extensive frontages along the lower Zambezi River from Kariba Dam to the Mozambique border, with approximately 1,000,000ha of area, within which is important black rhino habitat.

Print 7: Dehorned black rhino, soon after reversal, Zambezi Valley, 1992.

In fact, the lower Zambezi Valley, including Mana Pools National Park, was declared a World Heritage Site, because of the black rhino. The rugged Zambezi escarpment, which rises 1000m from the valley floor forms the southern border of this vast wild area. The escarpment is dominated by well-grassed *Brachystegia* woodland and the valley floor by mopane and jesse thickets (IUCN, 1987). Black rhino population estimates for the lower Zambezi Valley approached 870 animals (ZBRCS, 1992). The present numbers are estimated to be 12 animals.

4.4.1 *Black rhinoceros*

Twelve black rhino were located. Nine of these were adults, 2 were subadults and 1 was a juvenile (Table 14). Of these 12 animals, five were captured and placed in bomas for translocation. The captured

animals originated from the Sapi Safari Area. No animals were located in the Mana Pools National Park. The remainder were found in the Chewore Safari Area.

All adult and subadult animals in this operation were immobilised using combinations of etorphine and xylazine (n=11). One juvenile was immobilised using etorphine only. Two adults were darted using projectile syringes which did
not discharge due to incompatible plungers. Average induction time for all animals, excluding a calf, was 4.59 ± 0.87 minutes (n=10). Animals darted with normal functioning darts had an average induction time of 3.99 ± 0.28 minutes. Induction time of the juvenile was 3.33 minutes.

Table 14: ZAMBEZI VALLEY, WILDLIFE ESTATE LAND: Black rhino (*Diceros bicornis*) immobilisation data, including induction times, total down times, and reversal times, 1992.

Measurement	Number	Mean	SE
Induction time[a] (min.)/	10	4.6	0.87
Induction time[b] (min.)	8	3.9	0.28
Reversal time[c] (sec.)	6	54	4.0
Down time (min.)	6	38.1	6.16

Data includes both dehorning and capture/translocation.
[a]All data, malfunctioning darts included.
[b]Normal functioning darts.
[c]Naloxone (IV)

The period of immobilisation between recumbency and complete reversal (n=6) was 38.1 ± 6.16 minutes (range=18-56 min.) (Table 14). In those instances where rhinos were destined for translocation, the period of immobilisation of animals captured was measured from the time the animal was recumbent until it was reversed and placed inside a crate (n=5). Total immobilisation time was 446 minutes (range=180-780 min.). These prolonged immobilisation times reflected the extreme difficulty the capture team experienced in recovering rhinos from inaccessible areas, with limited back-up and support.

Time for full reversal of the narcotic by injection of an antagonist was measured for each animal. All animals dehorned were reversed with naloxone, with an average reversal time of 54 ± 4.0 seconds (n=6) (Table 14).

4.5 Matobo National Park

Matobo National Park (MatNP) is located in Matabeleland South Province and the entire Park is 46,100ha in extent (IUCN, 1987). The "game" area is 16,500ha in extent. The National Park occupies the core of the Matobos hills, consisting of granite Kopjes with numerous caves. The vegetation reflects the variety of habitats and is characterised by a diversity of species and communities. The hills are interspersed by valleys with deeper soils, vleis and streams.

Print 8: Immobilised white rhinoceros in Matobo NP game area, 1992.

The majority of rhinos are found in the "game area", but there are several in the surrounding National Park. Population estimates for white and black rhinos are 36 and 14, respectively (ZBRCS, 1992). This National Park has the potential for acting as a pool for rhino of both species, as animals appear to be thriving, especially white rhinos.

Table 15: MATOBO NATIONAL PARK: White (*Ceratotherium simum*) and black (*Diceros bicornis*) rhino immobilisation and dehorning data. Numbers, sex and age, 1992 and 1993

	White rhino		Black rhino	
	Immobilisation	Dehorning	Immobilisation[a]	Dehorning
N	31	30	10	9
Male	13	12	4	4
Female	18	18	6	5
Adult	28	28	9	9
Subadult	2	2	-	-
Calf	1	-	1	-

[a](Cow and calf immobilised together).

4.5.1 *White rhinoceros*

31 white rhino were immobilised over a 5-day period in MatNP, with 30 of these animals being dehorned. One animal was a young calf, too young for dehorning. 13 males and 18 females were immobilised, and 28 adults, two subadults and one calf (Table 15).

The operation was characterised by its efficiency and demonstrated the value of experience. Factors such as high density and that all individual rhino are known by scouts in a relatively small area, probably contributed to increased efficiency. Ten white rhino were immobilised in the first day. The majority of animals were immobilised with a mixture of etorphine (n=31) and detomidine (n=28) or xylazine (n=3) with an average induction time of 4.35 ± 0.25 minutes (range 3-10 min.). Rhinos were immobile for an average of 29.8 ± 1.6 minutes, with a smooth reversal achieved with naltrexone (104 ± 7 seconds) (Table 4 and 16). The opportunity to critically evaluate the M99/detomidine mixture was taken and the quality of anaesthesia achieved was considered excellent (see **5. Discussion, 5.1 Chemical Immobilisation**).

Horn measurement data is presented (Table 17). On average front and rear horns were longer than those recorded at HNP (Table 5 and 6), although the horns in HNP were more massive and the longest (100cm) was removed in Hwange. The longer average length may reflect an older age structure in the MatNP population.

Table 16: MATOBO NATIONAL PARK: White rhino (*Ceratotherium simum*) immobilisation data, including induction times, total down times, reversal times and physiological data, 1992.

Measurement	Number	Mean	SE	Min	Max
Etorphine (mg)	31	4.10	0.13	0.4	4.5
Xylazine (mg)	3	106.0	29.6	50.0	150.0
Detomidine (mg)	28	14.10	0.44	5.0	18.0
Induction (min.)	31	4.35[a]	0.25	3.0	10.0
Reversal time (sec.)	30	104.0	7.0	55.0	215.0
Down time (min.)[b]	28	29.8	1.6	20.0	54.0
Temperature (deg C)	26	37.8	0.19	36.2	39.3
Pulse (bpm)	27	87.1	5.5	46.0	150.0
Respiration (bpm)	27	11.5	0.55	5.0	20.0

[a] Median= 4min.
[b] Total immobilisation time (min.)
SE=standard error of the mean.

Table 17: MATOBO NATIONAL PARK: White rhino (Ceratotherium simum) horn measurement data, before and after dehorning, 1992.

Measurement	Number	Mean	SE	Min	Max
Front horn length (cm)	30	51.7	3.0	4	83.0
Circumference (cm)	29	59.6	2.10	20.0	77.0
Cut front[a] horn (cm)	27	6.2	0.2	4	8.5
Rear horn length (cm)	29	12.6	0.86	6	24.0
Circumference horn (cm)	27	46.8	1.9	15	64.0
Cut rear[a] horn (cm)	26	4.19	0.22	3	7

[a] Measurement from skin to cut surface (side).

4.5.2 *Black rhinoceros*

In 1992 only one black rhino female (with a young calf) was immobilised in MatNP and she was dehorned. Difficulties were experienced in locating black rhinos due to the terrain, although two bulls were seen fighting. The use of ground tracking in 1993 resulted in the further immobilisation of eight animals (Table 15). Of these, one bull died after running into a river pool during drug induction. He recovered from anaesthesia but auscultation of his chest prior to reversal indicated that water had entered his lungs, he died the following day. All other immobilisations went smoothly.

4.6 Save Valley Conservancy

A six day operation was performed between the 15th and 20th December 1992 in order to start the dehorning on private land before the end of the year. 19 rhinos were dehorned, 17 of which were black rhinos and two were white rhinos. A further three animals were dehorned in February, 1993, including one adult male, one subadult male and one juvenile male.

Table 18: SAVE VALLEY RHINO CONSERVANCY: Black rhino (*Diceros bicornis*) immobilisation data, including induction times, total down times, and reversal times, 1992.

Measurement	Number	Mean	SE
Induction time (min.)	17	4.2	0.29
Down time (min.)	17	49.4	2.42
Reversal time (sec.)	16	91.7	6.25

4.6.1 *White rhinoceros*

Etorphine and domosedan was the combination used for the two white rhino (4.0mg etorphine, 13mg domosedan per animal)

4.6.2 *Black rhinoceros*

Immobilizations were carried out using etorphine and xylazine at the previously documented doses. Of the black rhino, 15 were adults, two were subadults and three were juveniles (juveniles not dehorned). Seven were female and 10 were male.

Average induction time for 17 black rhino was 4.2 ± 0.29 minutes, with an average total immobilisation time of 49.4 ± 2.42 minutes. Reversal time using naloxone was 92 ± 6.25 seconds. There were no mortalities.

4.7 Chipinge Safari Area (CpSA), Kyle Game Park, and other areas

4.7.1 *Black rhinoceros*

Six animals were located in the CpSA, of which five 5 were dehorned. One adult cow was located with a 1 month old male calf, three adult males and an additional adult female were dehorned. The average induction time, using standard doses of etorphine and xylazine, were 3.98 ± 0.56 minutes. Animals were down for 46.7 ± 4.08 minutes, and reversal took 63.3 ± 3.96 seconds, using naltrexone.

4.7.2 *White rhinoceros*

Eight white rhino (three male, five females; seven adults, one calf) were captured, dehorned and crated for relocation to Kyle National Park game area. All animals were immobilised with a mixture of M99 (4.0mg) and detomidine (18-20mg) with induction times ranging from 3-6 minutes. Animals were walked into crates after the administration of 12mg M50-50 (IV). Complete reversal was achieved using 25mg Naltrexone prior to release from the crate. One animal was walked 50 meters to a crate with 45mg Nalorphine (20mg initially, followed by 10mg, 5mg and 10mg). Some animals remain to be dehorned in the Game area (n=3). Total population in the Park maybe 14 animals.

4.8 Chiredzi River Conservancy

During a 3 week period, seven black rhinos were immobilised in the Chiredzi River Conservancy (seven adults, four males and three females). This operation was carried out entirely on the ground with trackers, and an average of 1 rhino/day was immobilised.

5. Discussion

5.1 Chemical Immobilisation

The dehorning programme for 1991, 1992 and the early part of 1993 has afforded the opportunity to further evaluate (efficacy, safety) and to redefine (new drugs and combinations, improved dose rates) chemical immobilisation methods used on white and black rhinos, in the field. Of particular significance has been the re-evaluation of chemical immobilisation methods used on the white rhino.

5.1.1 *White rhinoceros*

The Natal Parks Board (NPB) in the Republic of South Africa, has been responsible for the success story in the recovery of the southern white rhino from low numbers in the 1920's, and repopulation of former range in the 1960's (Player, 1967). Innovative and far-sighted programmes initiated at that time resulted in research and development of chemical immobilisation methods for the white rhino. These methods have been refined and improved with the development of more concentrated opioids, and therefore, smaller dart volumes increasing projectile accuracy and reducing the risk of abscess formation. Based on this pioneering work by individuals in South Africa, recommendations have been made for chemical immobilisation of white rhinos (Flamand et al., 1984) and include the use of etorphine (0.5-2.0mg), fentanyl (10-30mg), combined with hyoscine (50mg). More

recently, others have reported on white rhino immobilisations in Zimbabwe (Booth and Coetsee, 1988).

Chemical immobilization of free-ranging white rhinos is carried out for capture, with transfer to boma holding facilities and, in some instances, relocation to game ranches or other African countries or overseas, for medical reasons (for example, snare and fight wounds), for research purposes and recently for conservation dehorning. In many of these instances, immobilisation is followed by short-term anaesthesia, rapid reversal and release back into a free-ranging situation or transfer to a crate for transport to holding bomas. Evaluation of the literature (1971-1988) reveals a lack of detailed analyses and appraisal of drug combinations used on free-ranging white rhinos, especially for extended anesthesia. Experience gained in the chemical immobilisation of the black rhinos (*Diceros bicornis*) (Morkel 1989; Kock, 1992) has resulted in the use of high doses of opioids, with rapid induction times, reduced stress, trauma and a reduction in costs (for example, helicopter time). The single most important factor has been a willingness to research and experiment with higher drug doses (opioids) and different drug combinations (sedatives mixed with hyaluronidase), compared to previous reports (Flammand et al., 1984; Booth and Coetsee, 1988).

During the 1991 white rhino dehorning program, it became apparent during the early stages of this operation that dehorning, with the collection of ancillary research data required total down times of 30-40 minutes. Immobilisation of white rhinos, in large numbers in 1991, allowed the evaluation of currently recommended drug combinations (Flamand et al. 1984) and new combinations. Results from 1991, suggested that the etorphine/xylazine combination was superior for induction of white rhinos (smooth and short time to first signs), and provided good muscle relaxation during recumbency. The initial doses of etorphine (4-5 mg) and xylazine (150-200 mg) provided rapid induction and anesthesia, characterised by normal respiratory rates. Thirteen animals were immobilized with etorphine (2 mg) and fentanyl (20-30 mg), a combination recommended by NPB. This combination produced rapid and smooth induction, although not as consistently good as the etorphine/xylazine mixture. Recumbent animals appeared relaxed but some showed paddling movements, and pulse rates were often rapid and bounding. Etorphine was used alone to immobilize young calves and some subadults (0.5-1mg), resulting in a smooth and unstressful induction with good muscle relaxation. Young calves exhibited significant temperature rises under etorphine sedation, despite cooling with water and provision of shade.

In evaluating the drug combinations used, dose rates and the mortalities that occurred during 1991, several important factors and existing constraints need to be considered:

* the use of higher doses of etorphine and xylazine always carries a risk of respiratory depression but other researchers have reported (Heard et al., 1992) that prolonged etorphine immobilisation and recumbency has been associated with hypoxemia (poor oxygenation), hypercapnia (shallow and rapid breathing), and apparent hypertension (high blood pressure) in a white rhino immobilised in captivity. Of particular significance is that these findings were apparent even with low doses of etorphine (1.5-2mg).

* in the dehorning program, two out of the three mortalities occurred > 40 minutes into the dehorning procedure. Mortalities occurred under all drug combinations. With all these drug combinations the respiratory rate was often normal, although respiration was shallow and progressively worsening hypoxemia was noted in some animals (especially large bulls and cows), which was confirmed by cyanotic blood samples.

* even following modification of the drug protocol with a dosage reduction (of both M99 and xylazine), hypoxemia (which developed over time) was still a concern in many individuals. Etorphine in the white rhino can produce significant muscle rigidity, tremors, and leg paddling, making an animal difficult to work with. It can also result in rapid body temperature rises, compounding existing hypoxemia.

* the massive size of the white rhino (body weight 1500-2300kg) with a very large digestive tract (especially the hind-gut), was a significant factor in reducing the ability of the recumbent animal to oxygenate adequately over a prolonged period of recumbency. As a large perissodactylid, the white rhino would be expected to experience the same adverse effects of recumbency and anaesthesia observed in the horse and other large mammals, for example, the elephant.

Data collected and evaluated from the 1991 operation suggested that M99/xylazine might be superior to M99/fentanyl, for immobilization and prolonged recumbency in the white rhino. The mortalities in 1991 were unfortunate but because prolonged recumbency was necessary for horn removal and data collection, it was apparent that animals were at risk of shock and cardiovascular system collapse, brought on by inadequate oxygenation. A subjective assessment of anaesthesia suggested that this could occur under different drug combinations. Although concern was expressed with the higher drug doses this did not appear to be a prime factor leading to mortality, rather the prolonged recumbency (> 40 minutes) and from subsequent immobilisation data, the tendency of white rhinos towards hypoventilation and hypoxemia under anaesthesia, even under low doses of etorphine were major contributory factors.

In 1992, several innovative approaches were developed to allow a more scientific and objective evaluation of chemical immobilisation of white rhino. A research project was implemented with two American Researchers joining the dehorning team to evaluate the field application of pulse oximetry in rhinos (see *Innovative Research-pulse oximetry*, below). Although rhinos had died from all different combinations of drugs, it was felt that the M99/detomidine mixture had promise. In 1992, Dr Pete Morkel had used it on northern White rhinos (*Ceratotherium simum cottoni*) in Garamba National Park, Zaire, with success. Therefore, the majority of immobilisations carried out in 1992/1993 were with M99/detomidine (n=64), and a few with M99/xylazine (n=10). Evaluation of these mixtures was carried out by combining the 1991/1992 data (Table 4). The M99/detomidine mixture proved superior in most respects.

Although there were no statistically significant differences in induction times amongst the 3 drug combinations, M99/detomidine induction was smoother and appeared to be more rapid (Table 4), the quality of anesthesia was excellent based on pulse rate, pulse oximetry (S_aO_2) (Table 19), muscle relaxation and absence of rigidity/paddling (M99 alone is excluded in this discussion as it was used effectively on subadults and calves, who were most often standing

next to their mothers). The pulse rate in rhinos immobilised with M99/detomidine was significantly lower than with the other two combinations and M99 alone (Table 4). The pulse palpated normally, as was auscultation of the heart, indicating good cardiac output. The temperature associated with M99/detomidine was lower than with the other combinations. Recommendations for dosages are given in **6. Conclusions, 6.2 Immobilisation Procedures now Established.**

Innovative Research-pulse oximetry: In order to evaluate anaesthesia in the white rhino more scientifically **Drs Jack Allen** and **Walter Boyce** (from San Diego Wild Animal Park and University California, Davis, USA) provided expertise in a technique termed pulse oximetry, during a 6 week research project in 1992. Patient monitoring with pulse oximetry (N-10, Pulse Oximeter, Nellcor Incorporated, Hayward, California 94545, USA) was therefore utilised in the 1992 exercise.

Pulse oximeters provide a continuous, non-invasive display of estimated arterial oxygen saturation (S_aO_2) and heart rate.The most reliable and accessible location for the pulse oximeter sensor was found to be the ear. Patient preparation was necessary to get consistent recordings. A scalpel blade (#10) was used to gently (no haemorrhage) scrape away the superficial epithelial cells in a small patch on both sides of the ear. This small area was then considered to be properly prepared for the pulse oximeter sensor.

Observations made on ten immobilized (M99/detomidine) white rhino revealed that the S_aO_2 would consistently range between 40-60%. The respiratory rate ranged from 6-10 (breaths/min.) and heart rate 60-100 (beats/min.). Clinically, the chest excursions associated with each respiratory effort appeared to be shallow with a relatively small amount of air moved. These early physiological observations suggested that the immobilised rhino in sternal recumbency were undergoing significant hypoxemia. This occurred with all drug combinations. Monitoring of rhino soon after the administration of naltrexone (IV) and as they attempted to stand, revealed a S_aO_2 of 85-90%, which may represent baseline values.

Print 9: Immobilised white rhino bull, Hwange National Park. Note pulse oximeter, with sensor attached to ear, under hat.

These findings confirmed that anaesthesia of white rhino carries a risk of medical complications, therefore, evaluation of emergency drugs to attempt to counteract the hypoxemia was undertaken. Nalorphine (Nalorphine hydrobromide, Centaur Labs, Pty., Ltd., Johannesburg, RSA) at 10-20mg was administered IV. An increase in respiratory rate and relative S_aO_2 was observed (Table 19). This was due to the partial antagonism of M99 resulting in an increase in ventilatory drive and improved oxygenation. With the use of nalorphine, a 20-25% increase in S_aO_2 was noted. This was confirmed by blood samples showing more normal colour. The result was a more stable anaesthesia, less risk of complications. The pulse oximeter could be checked regularly during the dehorning and, if it indicated problems, appropriate action could be taken.

Nubain (Nulbuphine hydrochloride), an opioid agonist (with analgesic effects) and antagonist properties one-fourth the potency of nalorphine, was tested as a substitute to nalorphine. The preliminary results were promising, with 2-3 times the milligram amount of Nubain required to produce similar effects (of nalorphine).

Table 19: Drug dosages and physiological data obtained from five immobilised white rhinos in sternal recumbency.

Rhino Age	1 adult	2 adult	3 calf	4 calf	5 adult
M99/detomidine (mg)	4.2/14	4/14	1/3	1/2	4/14
Naltrexone (mg)	75	50	50	50	75
Pre-Nalorphine					
Heart rate[a] (beats/min.)	53	58	73	89	56
Respiratory rate (breaths/min.)	4	4	4	8	4
SaO_2 (%)[a]	60	58	41	60	55
Post-nalorphine					
Heart rate[a] (beats/min.)	44	55	71	77	59
Respiratory rate (breaths/min.)	8	10	8	10	10
SaO_2 (%)[a]	76	78	55	82	83

[a] Pulse Oximetry data.

Drug Reversal: Reversal of M99 with the standard narcotic reversal agent, diprenorphine (M50-50), often results in incomplete antagonism, in the white rhino. Rhinos are often depressed, wander aimlessly for several hours and do not respond well to adverse stimuli. The reason for this partial antagonism is not clear as M50-50 works well with the black rhino. Narcotic recycling may be a contributory factor. Complete antagonism is important, especially when dealing with cow/calf combinations. Young calves (< 12 month old) are vulnerable to predation by hyenas (*Crocuta crocuta*) and lion (*Panthera leo*) if separated from their mothers. If either mother or calf is unable to respond to a threat due to partial narcosis, there would be a high risk of the calf being killed and/or the mother injured.

In 1992, naltrexone was evaluated as an antagonist for M99. Naltrexone, like naloxone, is a pure antagonist resulting in complete reversal of the narcotic effects. The advantage of naltrexone is that the half life is 12-24 hours. Therefore, it would prevent narcotic recycling, with less chance of complications with cow/calf combinations. Between 50-75mg of naltrexone, given IV was adequate in reversing 4-4.5mg M99. On occasion, 125mg was given, but it did not seem to produce better results over lower doses. In the Matobo National Park exercise, an average reversal time using naltrexone was 104 ± 7 seconds (range 55-215 seconds). The time to arousal was consistent (90-100 seconds) and this was important with cow/calf combinations. The calf was always reversed 10-20 seconds ahead of the

mother. This ensured that the calf stayed near the mother and they both left the scene together. If the mother was aroused before the calf, she would leave the scene without the calf, especially if the reversal was incomplete, and the cow was disorientated.

5.1.2 *Black rhinoceros*

Drug performance: Immobilisation times reported from previous black rhino capture operations have ranged from 6-21 minutes and 5-156 minutes (Booth and Coetsee, 1988) and 2-110 minutes (median of 13.5 min.) (Kock et al., 1990). Modifications in the drug protocol in recent years has resulted in a major improvement in induction times and reduction in stress (Kock, 1992). In addition, with correct dart placement, rhinos become recumbent within 500-1000 meters, reducing the chances of trauma. The need to chase and rope rhinos is no longer necessary and is undesirable.

Induction times of 3.9, 5.5, 4.2 and 4.6 minutes for Hwange NP, Chizarira NP, Save Valley Conservancy and the Lower Zambezi Valley, respectively are impressive when compared to previously reported induction times (Booth and Coetsee, Kock et al., 1989). The 0.6% mortality rate associated directly with 165 immobilisations is a direct result of the rapid induction times and experience. The use of M99/detomidine produced good anaesthesia but induction times were slower (6.8 minutes).

Cow/calf combinations and Drug Reversal: In Hwange NP, 20 female black rhino with subadults or calves were immobilised. Ten of these involved the capture of females with calves of 2-10 months old. No mortalities were experienced and all calves were reunited with their mothers, either at reversal or within 1 hour. The calves were either immobilised with M99 alone next to their mothers, or hand captured and given M99 intravenously. Excellent anaesthesia was achieved by filling a tuberculin syringe with 9.8mg/ml M99, emptying the syringe of M99, then filling the empty syringe with sterile water.

Print 10: Black rhino cow and calf soon after administration of reversal drug and arousal from anaesthesia, after dehorning of the cow, Hwange NP, 1992.

The key to ensuring that these very young calves stayed with their mothers was reversal with either naloxone (25mg) or naltrexone (25mg)(the latter being preferred). The calf was always given the antagonist (IV) 20 seconds ahead of the mother. After the antagonist was administered to the mother, the dehorning team moved out of sight during recovery. This was done to prevent the calf mistaking a member of the team as a mother rhino!

5.2 Dehorning Tools and Procedure

5.2.1 *Retrospective evaluation of horn cutting technique*

Normal horn regrowth: Nineteen white rhino were reimmobilised in Hwange NP to measure horn regrowth and evaluate form of regrowth. Normal regrowth was roughly cylindrical (Print 16) but evidence of cracking was seen in several horns (see 5.3 **Research and Monitoring Program**). This normal regrowth was related to the correct cutting technique with the chainsaw during dehorning. Evidence of rubbing and shaping of horns was present.

Abnormal regrowth: This was evaluated and defined by developing 4 categories of scoring for regrowth (see Diag. 2 and 3, Prints 13-20):

Score 1 was normal regrowth.
Score 2 was abnormal regrowth with central cavitation, with outer walls intact, occasionally with a central plug.
Score 3 was partial cavitation with incomplete walls.
Score 4 was undercutting with top of the horn intact.

These abnormalities appeared to be directly related to cutting technique and exposure of the germinal area at the base of the horn. For the development of abnormal horn regrowth scored as 2, the sequence of events are likely as follows: exposure of the germinal area results in infection, introduced either by rubbing or mud. This focus of infection, which cannot drain due to the presence of solid horn on the outside (Diagram 2 and 3; Print 17, 18, 19 and 20), results in the development of a cavity or failure of horn regrowth centrally.

None of the regrowth abnormalities appeared to have affected the health of the rhino. In fact, in many instances, scar tissue was present with evidence of normal horn underneath. With these abnormalities it appears that normal horn regrowth would be achieved in time, but further monitoring needs to be carried out. Radio-collars were placed on some adult white rhino with abnormal horn regrowth.

The correct cutting technique for dehorning must involve initial cuts approximately 6cm above the base of the horn. These can be angled or horizontal. The chainsaw blade should then be used to shave the horn to conform as close to the skull as possible (Print 13, 14 and 15). The shaving should be stopped as soon as droplets of blood appear centrally but the area must be solid when pressurised by a finger. Shaving further will result in exposure of the germinal area.

Print 11 and 12: Dehorning technique using a chain-saw, white rhino bull, Hwange National Park, 1992.

Print 13: Appearance of horn after dehorning in a black rhino, Hwange National Park, 1992. Note small amount of blood centrally on front horn. Area is still solid and will not cavitate.

Print 14: Immobilised black rhino cow and calf, Hwange National Park, 1992. Calf will be given reversal drug 20 seconds ahead of the cow and in most instances will remain with the mother.

Print 15: Normal profile of black rhino horn after cutting with a chain-saw, Hwange National Park, 1992. Note close conformity of horn to nasal area in an attempt to reduce incentive for poachers.

Print 16: Normal horn regrowth after 1 year in a white rhino, Hwange National Park, 1992.

Print 17: Score 2-abnormal horn regrowth with central cavitation (see Diagrams 2 and 3), white rhino, Hwange National Park, 1992.

Print 18: Removal of abnormal horn regrowth in white rhino. Viewed from the underside, note central plug.

Print 19: Score 3-abnormal horn regrowth in a white rhino. Partial cavitation and splitting

Print 20: Score 4-abnormal horn regrowth in a white rhino. Undercutting from the anterior edge.

5.3 **Research and Monitoring Program** *(by Janet Rachlow)*

5.3.1 *Overview and research aims*

A research and monitoring program was initiated in 1991 prior to starting horn removal on the white rhino in Hwange National Park. This research is being conducted by Janet Rachlow (PhD Graduate student, University of Nevada, Reno, USA) in collaboration with a Namibian study, directed by Dr Joel Berger, involving both dehorned and horned desert black rhino. The aims of these two programs are:

* to document rates and form of horn regrowth,

* to gather information regarding poaching activity and rhino survival to assist in evaluation of the effectiveness of horn removal in lowering poaching risk,

* to investigate intra- and inter-specific behavioural interactions of dehorned rhino,

* to examine natural variation in horn and body sizes as they relate to dominance and reproductive performance.

5.3.2 *Horn Regrowth: rates and form*

Linear rates of horn regrowth were measured for white rhino adults immobilised in 1992, approximately one year after horn removal (Table 20).

Table 20: HWANGE NATIONAL PARK: White rhino (*Ceratotherium simum*) horn regrowth data, measured approximately 1 year after dehorning.

	n	Front horn (cm/yr)	n	Rear horn (cm/yr)
Age/sex				
Adults	14	6.7	14	2.9
Male	7	6.8	7	3.4
Female	7	7.0	7	2.5

Average regrowth rates for adults did not differ significantly between the sexes for either anterior (males: n = 7, x = 6.8 cm/yr; females: n = 7, x = 7.0 cm/yr) or posterior horns (males: x = 3.4 cm/yr, females: x = 2.5 cm/yr). Rates of regrowth for all adults (n = 14) differed significantly between anterior (x = 6.7 cm/yr) and posterior (x = 2.7 cm/yr) horns. Thus, total horn regrown by white rhino adults averaged 9.6 cm/yr. Berger (1992) reported mean rates of regrowth (summed for both horns) for desert black rhinos in Namibia as 8.7 cm/yr and 13.3 cm/yr for adults and juveniles, respectively; no significant differences were detected between the sexes. Although we observed some evidence of rubbing of horn bases one year after horn removal in white rhinos, most horn wear was restricted to the lateral surfaces. Therefore, measured changes in horn length closely reflect rates of horn regrowth.

Regrowth rates for adult white rhino in the first year were slightly greater than intrinsic rates of horn growth (growth of new horn versus change in horn length, which is influenced by horn wear and breakage) reported for the intact anterior horns of white rhino in South Africa (Pienaar, Hall-Martin and Hitchins 1992); growth rates were not measured for posterior horns in that study. Similarly, regrowth for the anterior horns of adult black rhino in Namibia exceeded the reported growth rates for black rhino in South Africa. Numerous factors may affect horn growth and regrowth including habitat, age of adults, and nutritional status. Available samples do not permit a statistical comparison of growth and regrowth.

The key measure of interest in horn regrowth is the mass and hence, monetary value, of the horns. Converting measurements into mass values, we found that adult males (n = 38) carried an average mass of 6.24 kg while females (n = 45) supported 5.10 kg before horn removal. Over 90% of horn was removed from adult males and over 93% from females. Based on regrowth measured in the first year, mean annual mass produced by adults is 0.56 kg and 0.45 kg for males and females, respectively. The value of horn regrowth at different time intervals is difficult to calculate. Currently poachers selling whole horns in Zambia realise only about US$100 per horn (T Milliken, pers. comm.), but it remains to be seen if partial horns could be sold for even that amount. At some point horn regrowth will become attractive to poachers, but initially dehorning appears to be a disincentive, as in Hwange NP poachers refrained from taking horn stubs on at least <u>two</u> occasions. If there were a legal market for rhino horn, it would be possible to calculate a specific value for horn regrowth, but until a valid unit price is established any attempt is speculative.

The shape of horns one year following horn removal was roughly cylindrical. Horn wear has begun to produce a more conical shape to the horns of black rhino 3 to 4 years after dehorning (Berger, pers. comm.). Some white rhino immobilised 10-13 months later exhibited slight abnormality in the shape of regrowth at the base (see 5.2 Dehorning Tools and Procedure).

5.3.3 Poaching and population monitoring

Monitoring of poaching activity both before and after the horn removal operations is necessary to evaluate the effectiveness of this strategy in lowering poaching risk. Rhino poaching only became a serious problem in Hwange National Park's Main Camp region, where 94% of the white rhino are located, in 1990. In that year, 10 carcasses of rhino (both black and white) were found, some close to main tourist routes. A total of four dehorned white rhino plus one calf have been killed in three poaching incursions during the first year following completion of the 1991 dehorning operation in Hwange Park.

Incursion # 1: This incident occurred very near the Main Camp tourist facilities, and within 1 km of a game-viewing platform. Poachers opened fire on a group of four rhino (one cow with a 7-month old calf and two subadult males) habituated to humans due to their proximity to the rest camp. One subadult (#98) was killed, from which poachers removed the flat horn bases and ear-tag, the calf (#100) was found 2-300m away with horns intact, and the remaining two animals escaped with bullet wounds from which they have recovered. The carcass of the calf was largely destroyed by hyaena and we were not able to determine if it suffered bullet wounds or died from predation after being separated from the group. In either case the death can be attributed to the poaching incursion. Poachers did not pursue the wounded animals.

Print 21: Poached dehorned white rhino bull (No. 43), Ngweshala Pan area, Hwange National Park, 1992. Note removal of back-strap muscles, an unusual occurrence with poachers. Meat was smoked and dried to be sold in Zambia.

Incursion #2: During a second incursion in January 1992, an additional two dehorned bulls (#38 and #43) were killed in a mixed teak woodland. Ear-tags, meat, and the posterior horn bases were removed from each of the rhino by poachers, but the anterior horn bases were not taken. National Parks scouts identified the footprints of the poachers indicating that they had followed a third rhino, approached and circled the animal within 100 m without killing it. From that location, the poachers headed directly out of the Park.

Incursion #3: While radio-tracking collared rhino from fixed-wing aircraft in early August 1992, we found bull # 63 poached. Scouts identified spoor of this animal indicating that he had been wounded at least 2 km from the location of the carcass. Poachers removed the horn bases, ear-tag, and radio-collar from which they cut the belting

material; the transmitter was located several hundred meters away. This animal was killed in mixed teak woodland with varying densities of understory. There is no way of knowing if the poachers realized that this animal was dehorned before shooting, however, they recovered relatively little horn for their efforts.

Additional Poached Rhino: Carcasses of two other poached white rhino were located during an aerial game survey in November 1992. Scouts estimated the carcasses to be several months old, and we were unable to identify the animals. The nasal bones of both animals had been cut by poachers, and it was not possible to determine if they had been dehorned. In 1993, a further three dehorned white rhinos have been poached.

Other Causes of Mortalities: One female lost her 3-4 month old calf (#50) in September 1991 within 2 months of her dehorning. The carcass was not located, and hence, the cause of death is unknown. Survivorship rates of white rhino in Hwange Park have not been documented, however, Owen-Smith (1973) suggested that calf mortality was 3.5% per annum in Umfolozi, South Africa. Two carcasses of dehorned white rhino were located in Hwange during July 1992. One adult bull (#60) appeared to have been wounded by a train (a railway forms much of the eastern border of the Park). Veterinarian examination indicated that his left humerus was severely fractured. The carcass of an adult female (#55) was located from a helicopter with horn bases and ear-tag remaining, suggesting that it was a natural mortality.

Population Summary: The first female dehorned in 1991 gave birth to a healthy calf less than 4 months later. At least one other female has calved within the first year following horn removal and two cows immobilized in September 1992 appear to be late in gestation. During the first year after completion of the 1991 dehorning exercises, 12.7% of the known white rhino in Hwange Park have died, 8.9% due to poaching (including the two unidentified poached animals). These values are based only on known births and mortalities. Much of Hwange Park was surveyed from both a helicopter and a fixed-wing aircraft during the second phase of horn removal in 1992, and if poaching losses were significantly higher than known, it is likely that carcasses would have been located. Monitoring of survival and reproduction will continue for the next two years. The use of telemetry equipment will be invaluable in documenting movements and survivorship.

Discussion: For horn removal to be most effective in deterring poaching, it must be known by poachers, and the persons who fund them, that horns have been removed from all or most rhinos within an area. Following the 1991 dehorning operation, 84% of the white rhino in the Main Camp region of Hwange Park were dehorned. Including the few black rhino that inhabit this region of the Park, the proportion of both species dehorned in the first year was approximately 76%. Distribution of educational materials in local languages has been undertaken by the DNPWLM and the Zimbabwe Wildlife Society to advertise the dehorning operations in Zimbabwe and Zambia.* Some rhino were killed, probably by uninformed poachers, following the dehorning operations in 1991. In the first poaching incursion of 1992, poachers wounded, but did not pursue two rhino after removing the horn bases from a dehorned animal. Likewise, there is evidence that a second gang of poachers followed and approached an adult rhino to within 100m

* (See p.2)

without shooting, after having killed two dehorned rhino with little reward. In both of these cases, poachers appeared to give up hunting after discovering how little horn remained on their quarry.

Monitoring of poaching activity and rhino survival is ongoing in Hwange to help answer questions about the effectiveness of dehorning as a deterrent to poaching. The number of rhino killed per poaching incursion in the Main Camp region of Hwange Park has dropped from 2.0 in 1990 to 0.5 in 1992 (through 15 Nov. 92), while the number of known incursions has tripled. This decrease in hunting success may, in part, be related to a decrease in the number of rhino due to poaching. Based on known carcasses, approximately 18% of the total rhino population (black and white) in the Main Camp region have been poached during 1990-92. Even if the number of rhino killed is twice the number of carcasses recovered, this reduction in numbers of 36% is insufficient to explain a four-fold decrease in hunting success. These data, along with that of poacher behaviour, are suggestive that poaching risk is lower for dehorned rhino versus those with intact horns. Continued collection of information on illegal activity along with the anti-poaching effort will be necessary in gaining a more complete understanding of the demographic consequences of horn removal.

5.3.4 *Radio-collaring and identification*

In the past, the placing of radio-collars on both black and white rhinos has been difficult. This has been due, in part, to the anatomy of the neck area. The use of stiff leather collars has resulted in damage to the ears of the rhino, and in some cases, the cutting off of the ears. In other instances, the collar has not stayed on for very long. For example, the collar comes off after being caught by the thick vegetation that is the preferred habitat of the black rhino.

Print 22: Immobilised white rhino bull with stretchable radio-collar, Hwange National Park, 1992. Note original leather, rivets and stretchable material covered with UV resistant acrylic canvas. Collar is folded and rivetted just behind the ears.

The development of a new collaring technique was needed, and Dr Pete Morkel pioneered the use of a stretchable, woven material. The original leather of the collar (Telonics Inc., Mesa, Arizona, USA) was cut so that a quarter remained, with the radio-transmitter and aerial present. The stretchable material was then doubled and attached to the leather by first placing a glue, then stitching, followed by rivetting.

In the field, the collar was then measured against the immobile rhino and the circle completed by rivetting and gluing the material to the leather. The fit of the collar was tight around the neck, but with enough stretch remaining for growth and freedom of movement. The collar is then placed over the head of the animal and fitted snugly (Print 22). There should be no movement of the collar around the neck. On occasion the collar was folded back behind the ears and the fold rivetted to make the collar more "animal friendly". One adult bull was reimmobilised approximately 3 months after the collar was attached, and the collar was found to be in good condition and still on the animal.

In April 1993, ten out of 12 collars were located. Six had torn the stretchable material, three had slipped off and the other was still on a rhino (> 6 months). It is evident that the concept of a stretchable collar is sound but stronger material will have to be utilised. Work continues on radio-collaring in 1993.

Print 23: Trovan transponder reader being used to read ID number of transponder placed under the skin in front of the ear of a black rhino, Matusadona NP, 1992.

In 1992, a passive transponder system (Trovan Inc.) was adopted to aid in identification of rhino. These 11mm x 2.2mm rice grain shaped transponders each have a unique code, that once programmed at manufacture, cannot be altered. The individual transponder was placed subcutaneously using a special implanter. The site chosen was 3-5cm in front of the left ear, under the skin of the rhino's forehead. This site was chosen because it was thought to be an area that may be left by predators or scavengers (in the first few days). The importance of this, was an ability to ID the rhino if it died naturally or was killed by poachers. We would then be able to determine if it had been dehorned. Scavengers will quickly chew off ears, therefore ear tagging or notching would not be effective. In some cases, poachers have removed ear tags and cut off ears. The Trovan transponder system was found to be easy to implant and the use of a hand-held portable reader (with data storage capabilities) allowed rapid identification (Print 23).

5.3.5 *Behavioural work*

Methods: Most of the white rhinos in Hwange inhabit mixed teak woodlands bordering long, winding grasslands, called "vleis". Numerous vleis are located in the southeastern region of the Park where the study is centered. Monitoring work, including night time observations at waterholes and tracking during daylight hours, began in November 1991. Additionally, we have developed a collection of photographs of footprints to aid in identification of individual rhino. During July - September 1992, seven dehorned rhinos (five males and two females) were fitted with radio-collars, and five rhinos (three males and two females) were collared and left with horns intact. These horned control individuals are located deep within the Park where poachers entering the area would be likely to encounter several dehorned rhino before reaching horned animals. We will be observing the horned rhino closely to record interactions among horned animals and between horned and dehorned rhino. Horns will be removed from these rhino in 1993, and observations continued to assess changes in behaviour following horn removal.

Predators and Calf Survivorship: The relative importance of predation as a factor of calf mortality and of horns in maternal defense is unknown and requires attention. Several females accompanied by young calves at the time of horn removal have been observed with the calves at heel over one year later. One cow lost a calf within 2 months of her horn removal, but the carcass was not located for examination. The absence of ears and tails has been noted for several populations of black rhino, in which some were born earless (Goddard 1969) while others exhibited mutilation and scarring suggestive of predator attacks (Hitchins 1986), and indeed, hyaena have been observed attacking black rhino calves (Kruuk 1972, Sillero-Zubiri and Gottelli 1991). Interestingly, Hitchins (1986) noted a complete lack of these signs of predation on white rhino in Natal, South Africa. Of the 89 white rhino immobilised in Hwange NP throughout these operations, 15.7% had tears or pieces missing from at least one ear and/or portions of their tails missing. Because it is possible that ears may be torn during intra-specific aggressive encounters, particularly among males, we calculated this same percentage among females and subadult males and found that 10.1% exhibit ear or tail damage. Five animals (5.6%) were missing most of at least one ear or most of the tail; it is unlikely that these injuries resulted from intra-specific interactions or environmental damage, and thus, they serve as a

conservative estimate of the proportion of the white rhino population in Hwange that has suffered predator attacks. Sex differences in response of rhino to predators, as well as differences between females with and without calves will be used in addressing questions about the importance of predation risk and calf mortality. We are currently collecting information on interactions with predators at waterholes.

Territoriality, Dominance and Reproduction: The importance of horn size in social contexts is unknown. We have observed several aggressive interactions between dehorned rhinos, and one encounter between a "hornless" territorial male and a horned intruder. The hornless rhino was the first to initiate horn-to-horn contact and dominated the horned individual. Additionally, at least four large, territorial males maintained territory ownership after being dehorned in 1991, even though there were several males in the area still sporting intact horns. Several of the large-bodied males exhibiting territorial behavior in the study have been radio-collared, and continued observation of their movements and interactions with both horned and hornless rhino will be invaluable in gaining an understanding of the relationship between horn and body sizes and social dominance.

6. Conclusions

6.1 Mortalities associated with dehorning

With improvements in technique and drug combinations used to chemically immobilise white and black rhinos, based on data collected in Zimbabwe during the period 1991-1993 (> 300 individual rhino immobilisations), the overall mortality rate for a dehorning operation will probably be < 2%. The mortality rate for white rhino immobilisations (associated with prolonged recumbency) will be < 3.5%, and black rhino immobilisations < 1%. It is likely, over time, that the overall mortality rate will approach < 1%, especially for white rhinos. These figures are in stark contrast to recent reports using mortality rates of 9% in modelling exercises evaluating dehorning of African rhinos (Milner-Gulland et al., 1992). This report states: "As dehorning carries a risk of rhino mortality, it is unsustainable as an anti-poaching measure". If the authors had used a mortality rate of < 3% the results of the model would have invalidated their 1992 conclusions.

6.2 Immobilisation procedures now established

Critical evaluation of various drug combinations used to chemically immobilise white rhinos, during the conservation dehorning programme in Zimbabwe, has enabled more specific recommendations to be made as to choice of drug combinations. Although M99/xylazine, M99/fentanyl and M99/detomidine produce similar induction times, the latter appears to be smoother and more rapid. If the purpose of immobilisation is for quick anaesthesia and reversal, all combinations could be recommended as effective and safe. Hyoscine mixed with the opioid, as recommended by the Natal Parks Board does not appear to be necessary. A higher dose of etorphine ensures a smooth and rapid induction in the white rhino, reducing stress and chances of trauma during induction but partial antagonism of the opioid must be carried out to ensure adequate oxygenation during prolonged immobilisation and recumbency. The quality of anesthesia, especially with regards muscle relaxation,

tractability and pulse rate, with M99/detomidine was considered superior to the other combinations, especially for prolonged immobilisation. All drug combinations produced degrees of cardiovascular system compromise, evidenced by low S_aO_2.

In light of these field results, a dose rate of 3.0-4.2 mg etorphine (subadult to large bull) combined with 12-20 mg detomidine and hyaluronidase (1500IU) can be recommended for the chemical immobilisation of the white rhino. A standard protocol should involve the administration of 10-20 mg nalorphine (or 20-40 mg nulbuphine) IV as soon as possible after recumbency. These will counteract respiratory depression and hypoxemia with a 20-25% increase in S_aO_2 within 5 minutes. This will not result in arousal and the quality of anaesthesia will remain excellent.

Immobilisation procedures for the black rhino in Zimbabwe, have been improved and refined since 1989. Etorphine (M99), 3.0-4.0mg with 100mg xylazine and 1500IU hyalase is recommended. The use of other adjunct sedative/tranquilliser drugs, such as azaperone or detomidine, will result in the addition of 1-2 minutes on induction times. The use of low doses of etorphine (Booth and Coetsee, 1989) are no longer recommended to immobilise adult rhino in the free-ranging situation. Doses for subadults and calves will need to be adjusted downwards, as will doses for compromised animals (disease, trauma etc.).

It is recommended that naltrexone be used as a standard reversal agent for both black and white rhinos. For each 1mg of etorphine, 12-25mg of naltrexone appears to result in complete antagonism of the effects of the narcotic. The use of M50-50 or naloxone in the black rhino is effective, but will result in incomplete reversal in the white rhino. With naltrexone in the white rhino, reversal will be consistent (time to arousal and standing) and complete.

6.3 Numbers and Distributions

In 1990, when the Zimbabwe Black Rhino National Conservation Strategy was first formulated, there were eight Intensive Protection Zones (IPZs), designated for high priority protection in the Wildlife Estate areas of Zimbabwe (ZBRCS, 1992). In the last two years, the number of IPZs has been reduced to three, and include Hwange National Park (HNP), Matusadona National Park (MNP), and Chizarira National Park (ChzNP). Matobo National Park (MatNP) has now been designated an IPZ. Only HNP and MatNP have significant numbers of black (and white) rhinos left that are viable; and populations could expand significantly if adequately protected. MNP has a population of black rhinos that may be viable, but the numbers are low and a sudden crash (disease, poaching, natural disaster) would be a catastrophic.

MNP should be an area that can be protected, but it requires a conservation commitment from Government. ChzNP is in a similar situation as MNP, but is considered by many to be a more difficult area to protect. A recommendation might be to secure MNP and then relocate rhinos from ChzNP to Matusadona. The DNPWLM is currently developing several high-technology, but practical monitoring projects, for MNP and HNP. These pilot projects will allow monitoring of rhinos on a 24 hour basis and other large mammals, as well as improving DNPWLM staff deployment. The monitoring will be performed remotely, with a base station, equipped with a radio and computer link.

6.4 Cost of dehorning

The cost of a dehorning exercise (with full complement of helicopter and aircraft) appears to have a direct relationship to the density of the rhino population, and the experience of the dehorning team. A low density rhino population will result in an escalation of costs due to difficulties in locating animals (even with ground tracking, fixed-wing support is necessary and judicious use of the helicopter is essential). When a helicopter and fixed-wing are used in an operation, costs will tend to escalate. The most cost effective operations will be those carried out entirely on the ground, with only tracker support but time constraints would be a major limiting factor. This type of operation would apply to small, known populations in confined areas. Dehorning cost per animal varies between US$350-US$1800. Costs of dehorning in three different areas of Zimbabwe will be evaluated and presented, namely Hwange NP, Matobo NP (1992 and 1993), and the Chiredzi River Conservancy.

In Zimbabwe dollars (April 1993) the average costs in terms of drugs of immobilising black and white rhinos are as follows: Black rhino Z$120-160/animal (average Z$140/animal); White rhino Z$160-200/animal (average $160/animal).

For each animal the cost of other drugs such as nalorphine, naltrexone, antibiotics and wound treatment ointments is as follows: Black rhino Z$100/animal; White rhino Z$140/animal.

Total costs, therefore, amount to: Black rhino Z$240; White rhino $320. Lost or broken darts are costed at approximately Z$120/dart. On average loss and damage to darts approaches 50-60% over time. Manpower costs were calculated at Z$1600 per day for professional input and mileage for vehicles at Z$6 per kilometre.

Costing of operations by areas: (April 1993 values)

A. Hwange National Park:

69 black rhinoceros immobilized and dehorned	57 adults x Z$140 12 calves x Z$100	Z$7,980 Z$1,200
Medical drugs	69 x Z$100	Z$6,900
37 white rhinoceros immobilized and dehorned	37 adults x Z$180	Z$6,660
Medical drugs	37 x Z$140	Z$5,180
Lost darts		Z$6,000
Helicopter hours	146 x Z$2790/hour	Z$407,340
Fixed-wing hours	200 x Z$200/hour	Z$40,000
Fuel (Jet A1) Fuel (AvGas)	73 drums x Z$300/drum 40 drums x Z$530/drum	Z$21,900 Z$21,200
Manpower costs		Z$115,500
Mileage		Z$12,000
Scouts T and S		Z$5,000
10% Contingency		Z$65,686
	TOTAL =	**Z$ 722,546.00**

Dehorning cost per rhino=**Z$6,816** in Hwange NP **(US$1099)**

B. **Matobo National Park** (1992)

1 black rhinoceros immobilized and dehorned	1 adult x Z$160	Z$140
Medical drugs	1 x Z$100	Z$100
31 white rhinoceros immobilized and dehorned	31 adults x Z$180	Z$5,580
Lost darts		Z$600
Medical drugs	31 x Z$140	Z$4,340
Helicopter hours	14 x Z$2790/hour	Z$39,060
Fuel (Jet A1)	7 drums x Z$300/drum	Z$2,100
Manpower		Z$10,000
Mileage		Z$3,000
10% Contingency		Z$6,492
		TOTAL = Z$ 71,412

Dehorning cost per rhino=**Z$2,164**
in Matobo NP, 1992 **(US$350)**

c. **Matobo National Park** (1993)

8 black rhinoceros immobilized and dehorned	8 adults x Z$160	Z$1280
Medical drugs	8 x Z$100	Z$800
Helicopter hours	16 x Z$2790/hour	Z$44,640
Fuel (Jet A1)	8 drums x Z$300/drum	Z$2,400
Manpower		Z$25,600
Mileage		Z$6,000
10% Contingency		Z$8,072
		TOTAL =Z$ 88,792

Dehorning cost per rhino=**Z$11,099**
in Matobo NP, 1993 **(US$1790)**

Note: With the Matobo NP operation in 1993, of the 16 hours of helicopter time, seven hours were spent, after dehorning eight animals, trying to locate three black rhino that were supposed to be within the Game Park. Both ground tracking and helicopter flying failed to locate them (there was no fixed-wing). The operation was stopped at this stage as costs were escalating without any returns.

Deduction of this seven hours of helicopter time gives a more realistic cost per rhino of Z$8658 (US$1396). Constraints included thick vegetation and grass cover hampering tracking, lack of confirmed sightings of the three rhinos within the last three months, and the use of the helicopter to provide rapid deployment of scouts and trackers. With a higher density of rhinos, costs will be reduced (see MatNP, 1992).

d. **Chiredzi River Conservancy** (ChRC) (this operation was entirely ground based, with Dr Anderson, trackers and no aerial support)

7 black rhinoceros immobilised and dehorned	7 adults x Z$160	Z$1,120
Medical drugs	7 x Z$100	Z$700,000
Manpower		Z$17,600
Mileage		Z$6,000
10% Contingency		Z$2,542
	TOTAL =	**Z$27,962**

Dehorning cost per rhino = Z$3995 in ChRC 1992 (US$644)

Note: This operation took a total of 3 weeks (11 days actually looking for rhinos) to complete and required extensive ground work to locate rhinos. Despite the relatively low cost ratio for dehorning, this method would probably be impractical for large wild populations and crisis situations. Compare the cost of US$644/rhino for seven animals in a 3 week (11 day) period, to the cost of US$350/rhino for 33 animals in 5 days for the Matobo NP operation (1992). Using a helicopter, based on the Matobo NP data, 6.6 (7) rhinos/day could potentially be dehorned, and 0.6 (1) rhino/day using ground methods (this would also be influenced by animal density and terrain factors).

6.5 Effectiveness as an Anti-Poaching Measure and Law Enforcement

In the space of 22 months, only six dehorned white rhino have been killed by poachers (known deaths). The number of incursions into Hwange National Park tripled in 1992, but the number of rhinos killed dropped from 2.0 to 0.5 per incursion. There were no incursions in 8 months in Matusadona National Park, following dehorning. Eleven dehorned black rhinos are known to have died from poacher's bullets throughout the country up to 31st March 1993, with two dying from other causes, in the space of 11 months. Contrast this with the 52 horned rhino that died between September 1991 and January 1992 (a 4 month period), throughout Zimbabwe, and an estimated loss rate of > 100 per year.

Poachers are not rewarded by the middle-man in Zambia per kilogram of horn, rather by size of horn. Maximum prices paid for a large horn appear to be approximately US$ 350 (TRAFFIC, Milliken, pers. comm.). On this basis, there is no doubt that the quality of horn (size and shape) is important. The removal of cracked, roughened stubs from a dehorned rhino represents no safe or long term investment, and may make a poacher consider the risks more seriously before entering Zimbabwe. The ultimate effects of this psychological aspect of dehorning have yet to be determined.

Dehorning will never reduce the risk of a rhino being killed by poachers to zero. But, it has provided a breathing space, which must be filled by a recognition on the part of Government, of the urgency of the crisis. The 3 remaining IPZs must be considered priority areas for increasing staffing levels, transferring the most professional and competent individuals; *without this commitment, dehorning will ultimately fail.* **

6.6 The Rhino horn trade and conservation politics

In Africa, the black rhino has declined faster than any other large terrestrial mammal in recent times: from a continental estimate of 65,000 in 1970, possibly as few as 2,400 remain today. Only the white rhino population of southern Africa seems secure for the moment, numbering approximately 5,500 animals. This decline has been entirely due to poaching of rhinos for their horns, to satisfy an illegal trade in the Far East, principally in China, both Koreas, Taiwan and the other overseas Chinese communities in Southeast Asia. Poaching also continues due to lack of acceptance of innovative approaches to the problem by International Conservation Organisations, and a lack of effective finance and commitment by African Governments to protect the species of Wildlife Estate Lands.

** *As of April 1993, there has been no increase in law enforcement in the remaining IPZs, in fact there has been a reduction.*

Print 24: Black rhino horns, chips and shavings removed by a dehorning team.

Strategies pursued so far to stem the decline of the world's rhinos have essentially relied on two basic components (A Report to the CITES Animals Committee on Trade in Rhino Horn, TRAFFIC Network, July 1992): in range states, the emphasis has been on increasing local anti-poaching and law enforcement capabilities to stem rhino losses in the wild (clearly a failure in Zimbabwe); and in consuming nations the focus has been on reducing demand for rhinoceros products (again, clearly a failure after 17 years of CITES Appendix 1 listing, rhinos are <u>still</u> being slaughtered at an unsustainable rate). Conservation and political (green) rhetoric gives the impression that the trade has almost been halted, but the question asked by managers and field staff of range states, again, is: "*Are rhinos no longer being slaughtered on the African continent*" due to all the work in halting the trade? The answer is NO! Despite these commendable efforts by conservation organisations, with promises by Taiwan to ban internal trade, the trade now flourishes entirely unreported in official trade statistics, and can be quantified only by estimating stockpiles in consumer countries and counting the carcasses of poached rhinos in range states (TRAFFIC, July 1992). Organisations such as TRAFFIC International have recognised the critical need, in rhino conservation, to move beyond the narrow scope of orthodox conservation strategies and to consider the full spectrum of available options to enhance rhino conservation worldwide.

6.7 **The future**

There is no doubt, under the current situation in Zimbabwe, that a dehorned rhino is at a significantly lower risk of being killed by a poacher, than if the rhino still had horns. Dehorning is recognised as a crisis management strategy, but in Zimbabwe's situation dehorning was the <u>only</u> option open in the face of an unsustainable attrition rate by poachers on the existing black rhino population. Despite the fact that Zimbabwe's black rhino numbers are between 300-450, there is some hope for the future. The DNPWLM knows exactly how bad the situation is, and is in a position to consolidate. The majority of rhinos in Zimbabwe have been dehorned. There is no doubt that little quality horn is going back across the border to Zambia.

Many positive aspects of dehorning have emerged including:

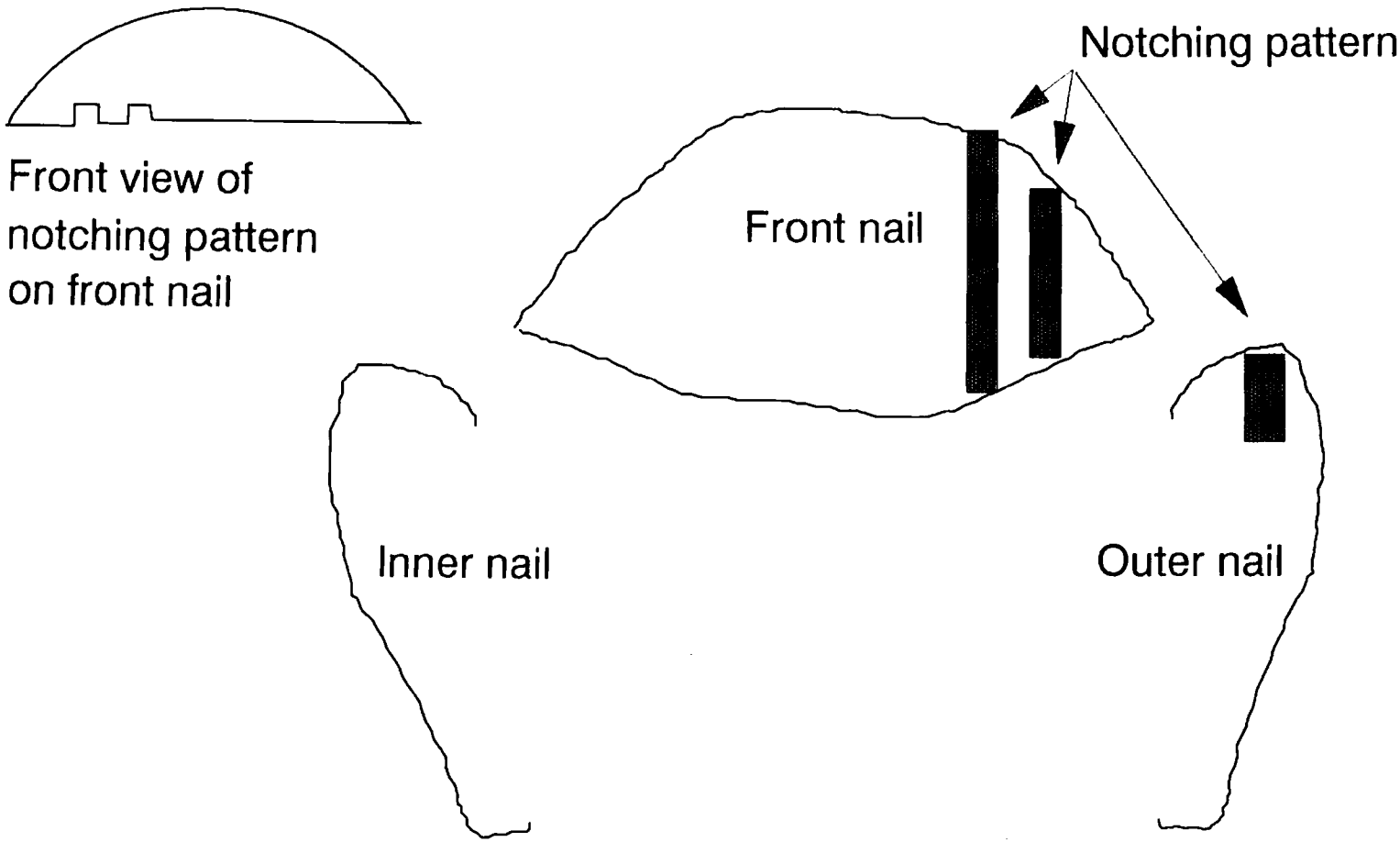
* development of "state of the art" immobilisation methods,
* increased knowledge of behavioural aspects of black and white rhinos,
* collection of biological samples for disease, stress and genetic evaluation,
* improved identification, remote monitoring methods, and improved demographic information.

Dehorning is a viable, safe and innovative conservation strategy, *but it cannot stand alone.* It is evident that dehorned rhinos will continue to die (Zimbabwe has lost 11 black and 6 white dehorned rhinos since May 1991), but this is a significant improvement when compared to previous poaching statistics of horned rhinos. If Zimbabwe is unable to stop the poachers killing rhinos, then there will be some grim satisfaction for those individuals working in the field, that the poachers will carry very little reward back to Zambia for considerable effort. This may, ultimately, produce results.

Print 25: Do these two animals, cow No 48 and her calf No 49, have a future in the wilds of Zimbabwe after dehorning?

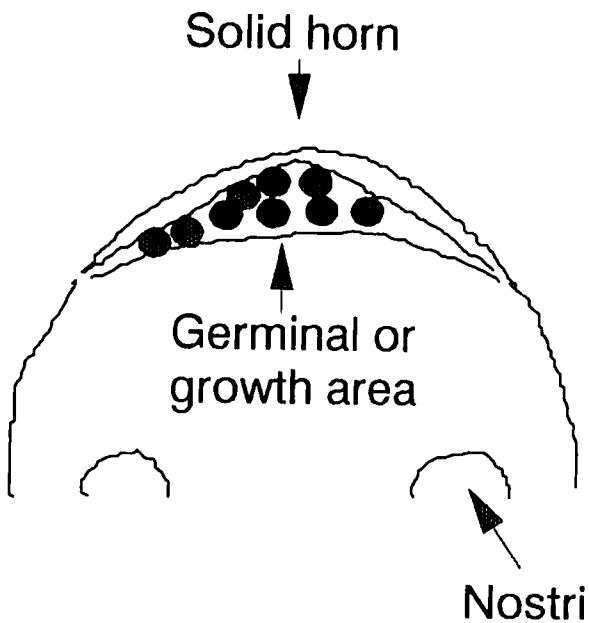
Diagrams and Figures

Diagram 1: NOTCHING PATTERN USED TO IDENTIFY A PREVIOUSLY DEHORNED BLACK RHINO



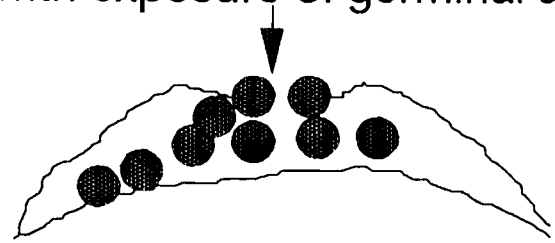
Underside of left rear foot of a black rhino

Diagram 2: SEQUENCE OF EVENTS LEADING TO ABNORMAL HORN REGROWTH

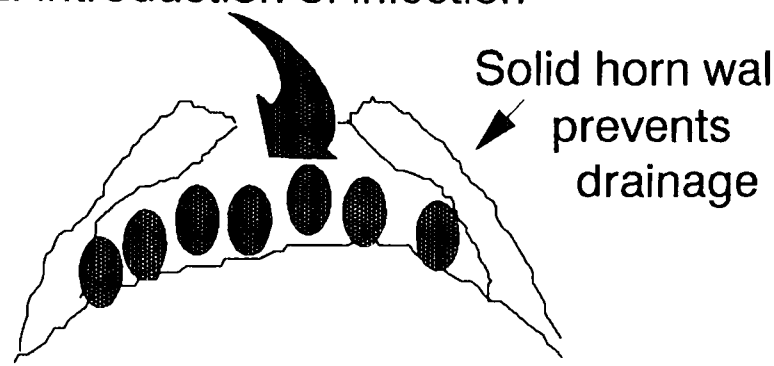


FRONT VIEW OF HORN
WITH NORMAL CUT, WITHOUT EXPOSURE OF GERMINAL AREA

1. Incorrect cutting technique with exposure of germinal area



2. Introduction of infection



3. Central cavitation

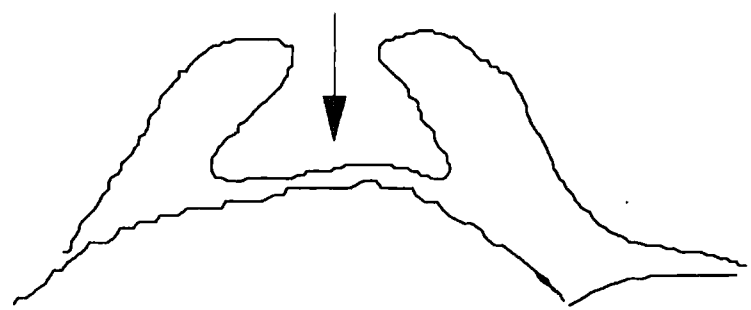
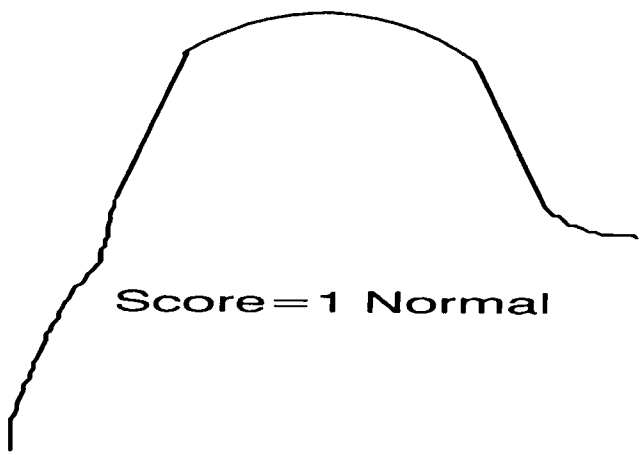
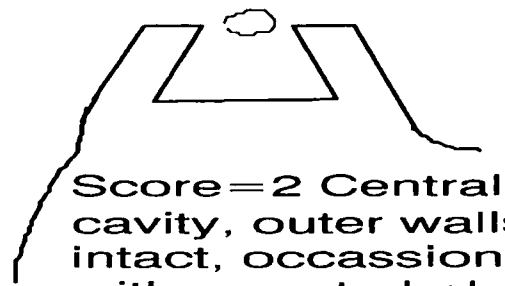


Diagram 3: HORN REGROWTH CHARACTERISTICS FOR WHITE RHINO

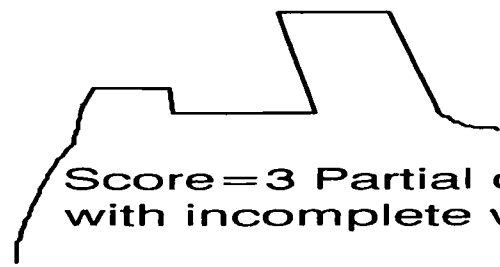
Normal regrowth of
front horn = 6.7cm/yr
Rear horn = 2.9cm/yr



Score = 1 Normal



Score = 2 Central cavity, outer walls intact, occassionally with a central plug



Score = 3 Partial cavity with incomplete walls

Score = 4 Undercutting with top of horn intact or vertical split present

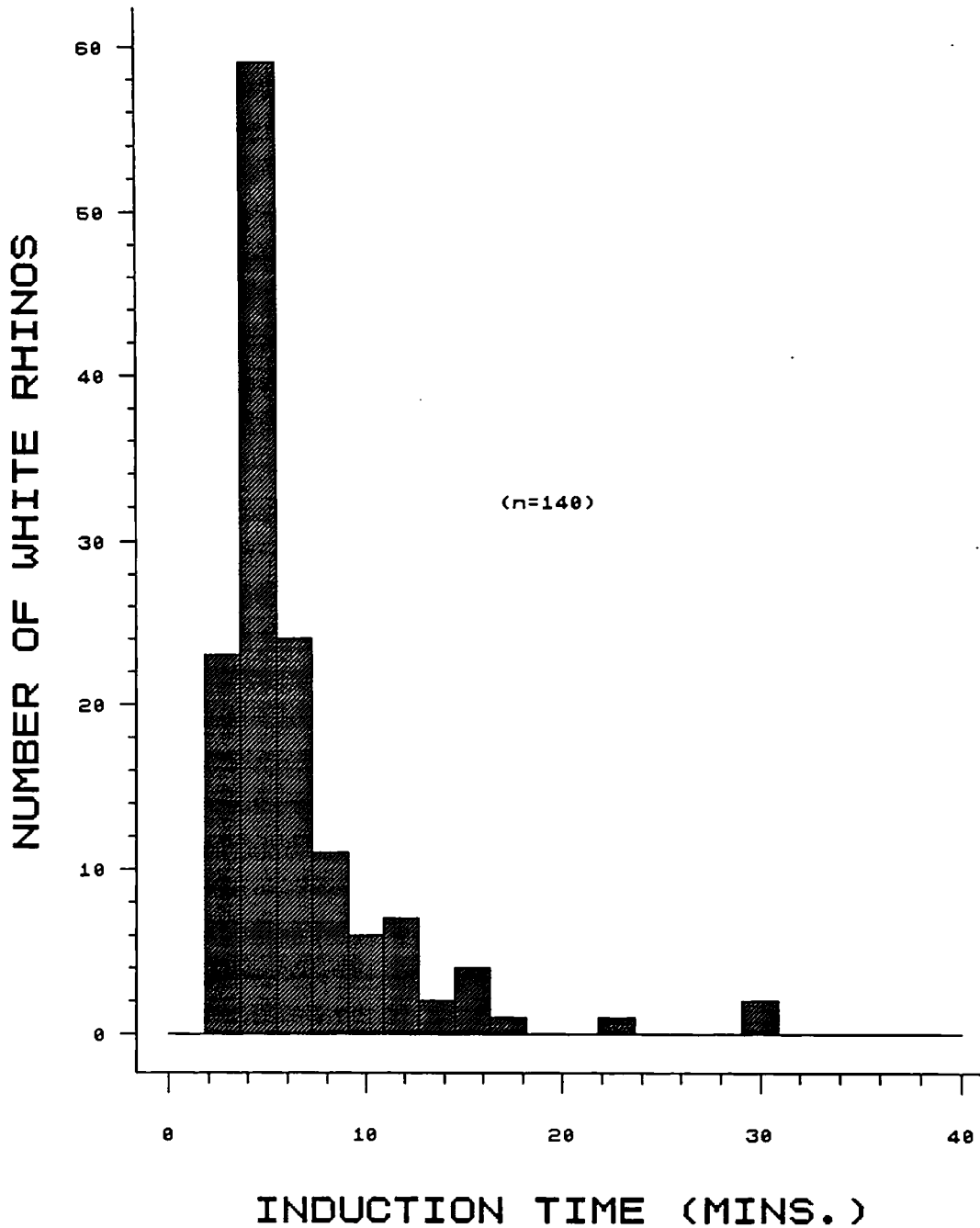


Figure 1: Distribution of induction times for white rhinos immobilised with either M99/fentanyl (n=13), M99/xylazine (n=55), M99/detomidine (n=59) or M99 alone (n=12), in Hwange and Matobo National Parks.

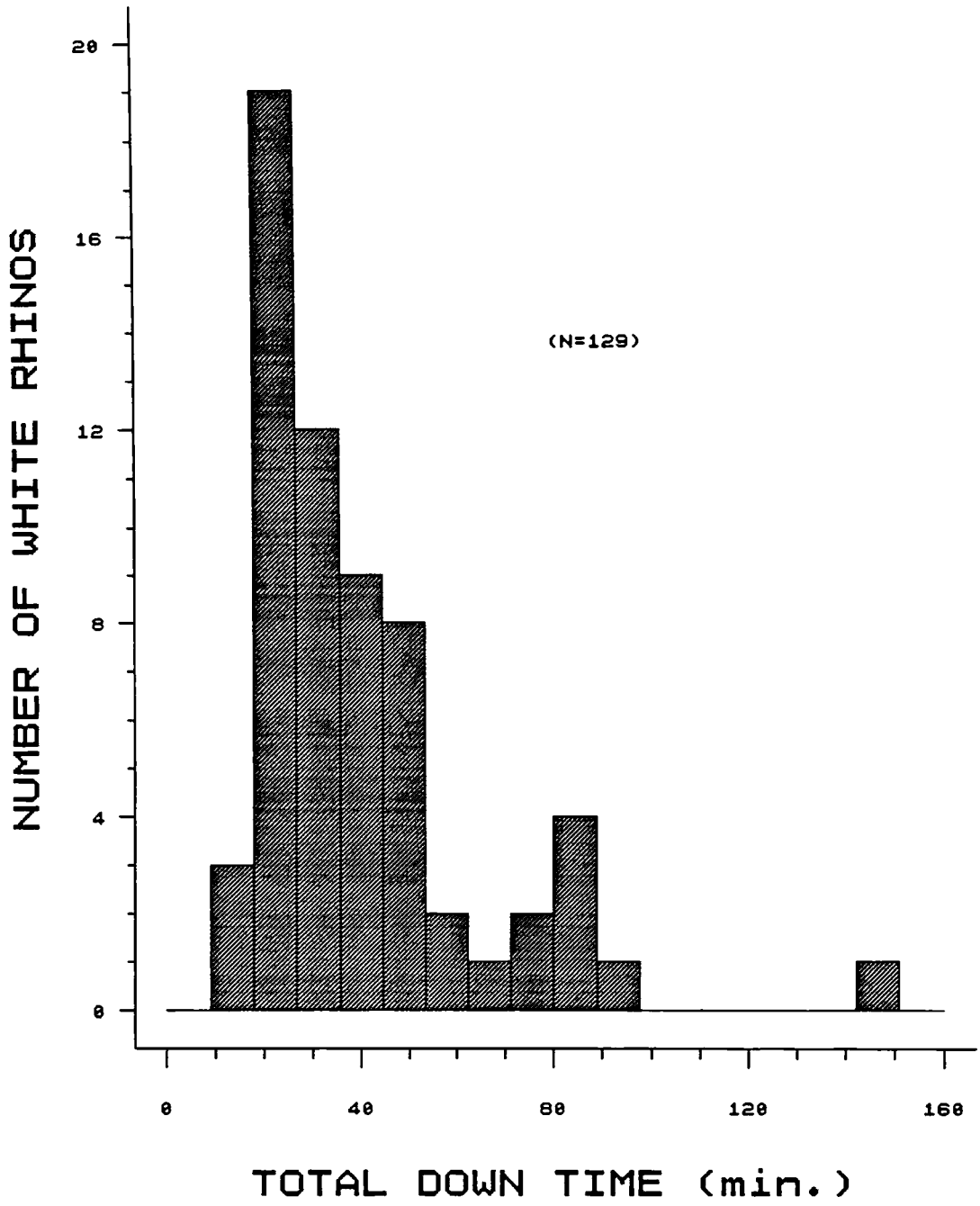


Figure 2: Distribution of total down times for white rhinos immobilised with either M99/fentanyl (n=13), M99/xylazine (n=55), M99/detomidine (n=59) or M99 alone (n=12), in Hwange and Matobo National Parks, 1991/1992. Total down time is measured from the time the animal becomes recumbent, until it stands following reversal of the narcotic.

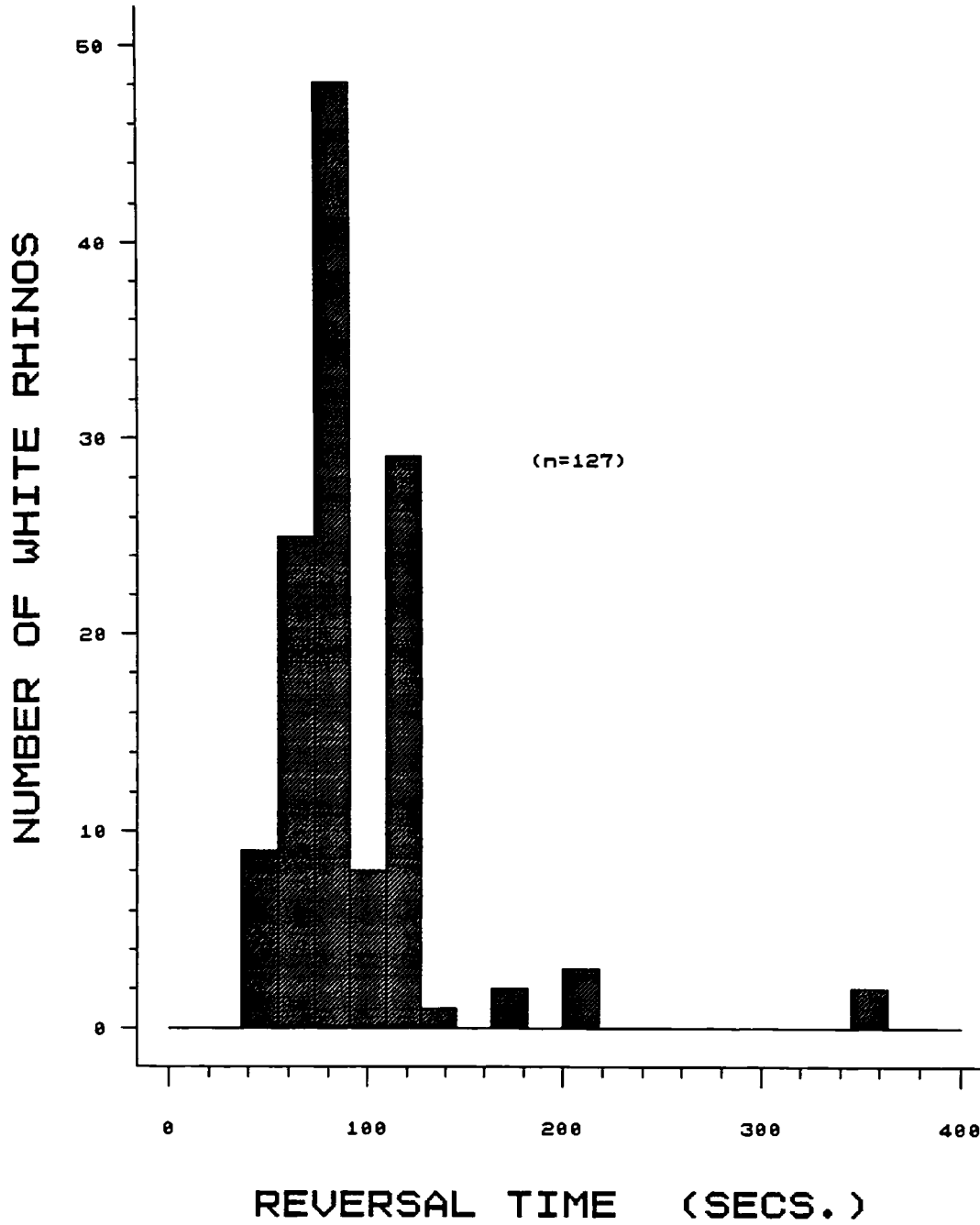


Figure 3: Distribution of reversal times for white rhinos immobilised with either M99/fentanyl (n=13), M99/xylazine (n=55), M99/detomidine (n=59) or M99 alone (n=12), in Hwange and Matobo National Parks, 1991/1992. Reversal was achieved with either naloxone (IV) with M50-50 (IM) (n=71) or naltrexone (IV) (n=73).

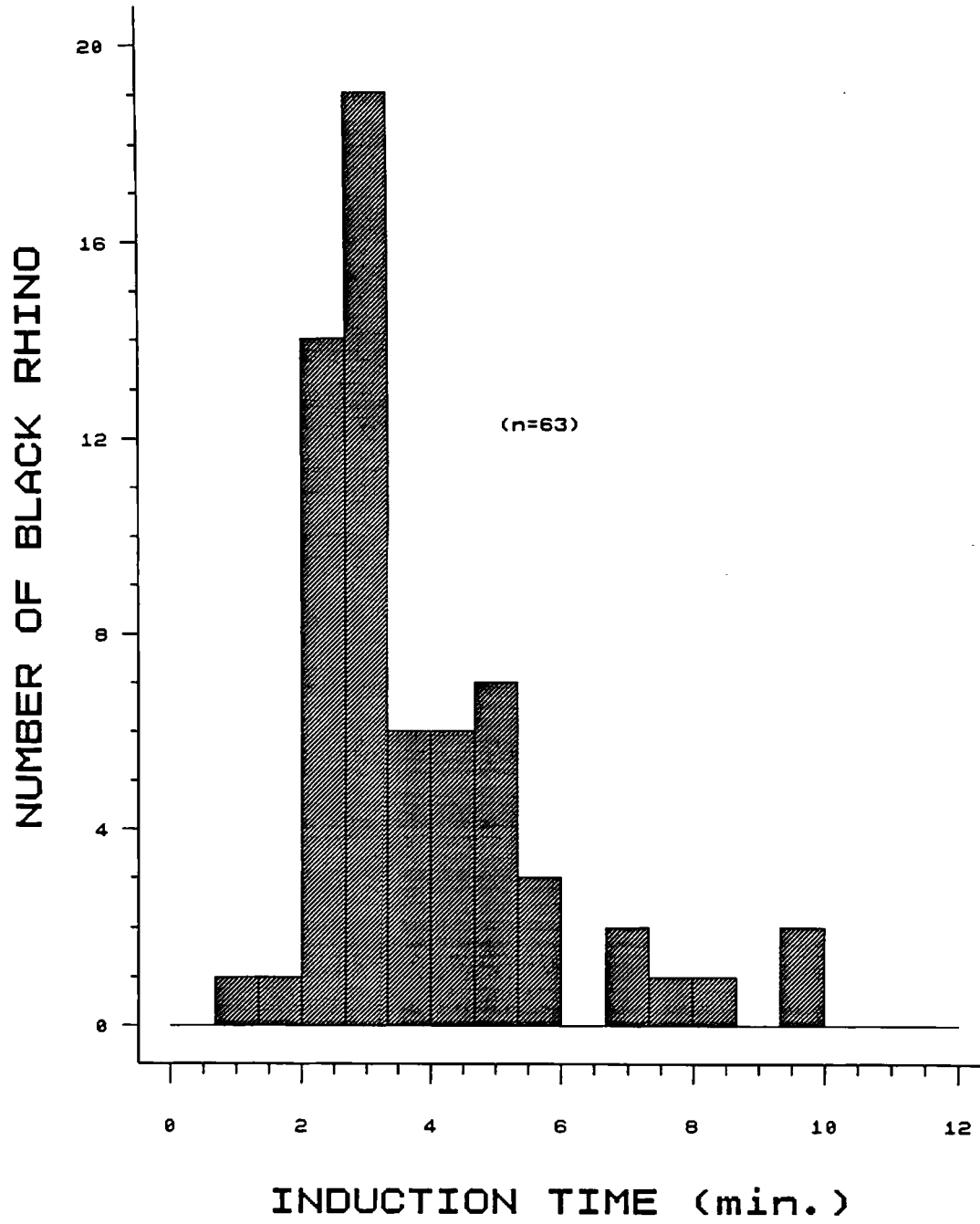


Figure 4: Distribution of induction times for black rhinos immobilised with M99/xylazine (n=63) in Hwange National Park, 1992.

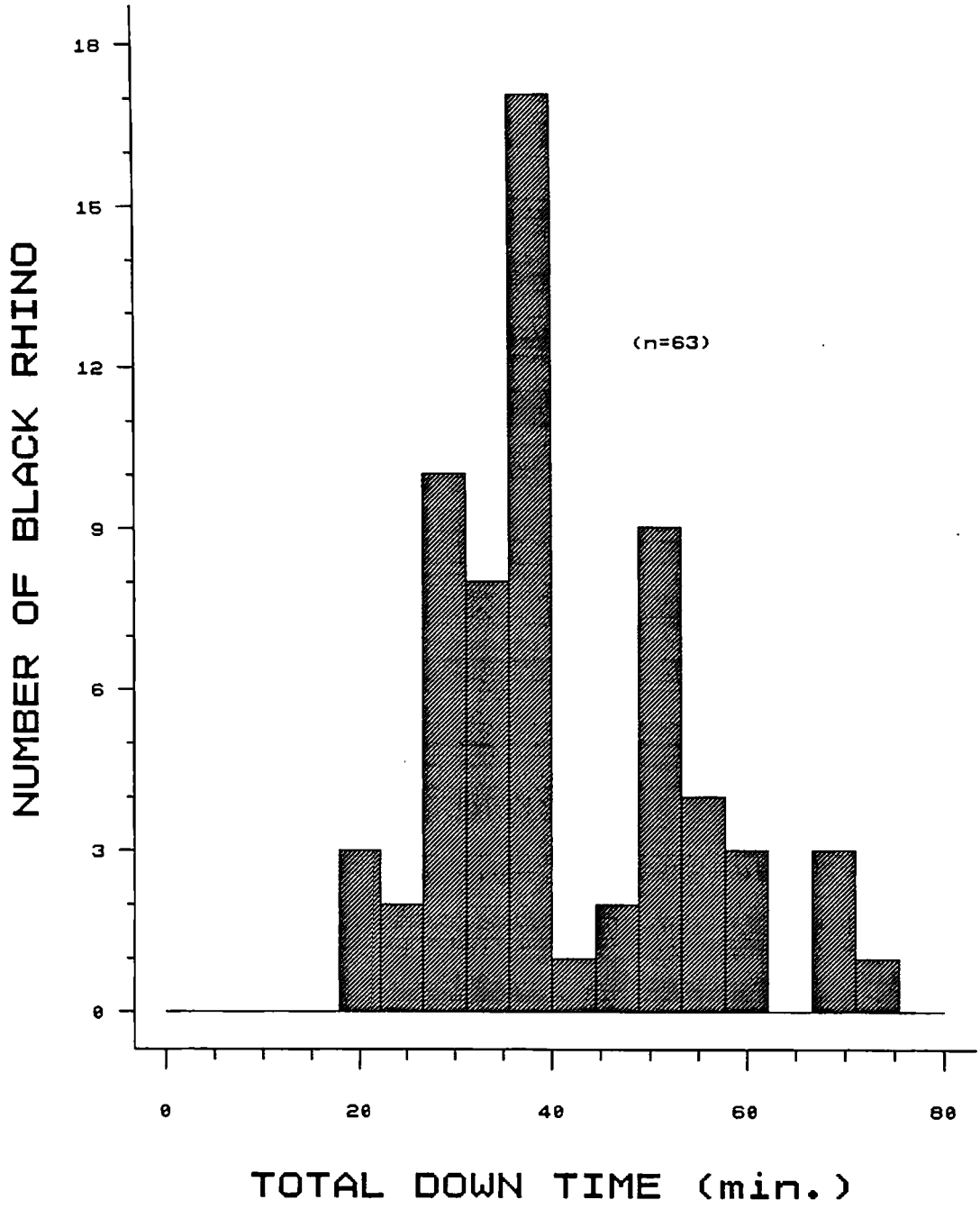


Figure 5: Distribution of total down times for black rhinos immobilised with M99/xylazine (n=63) in Hwange National Park, 1992. Total down time is measured from the time the animal becomes recumbent, until it stands following reversal of the narcotic.

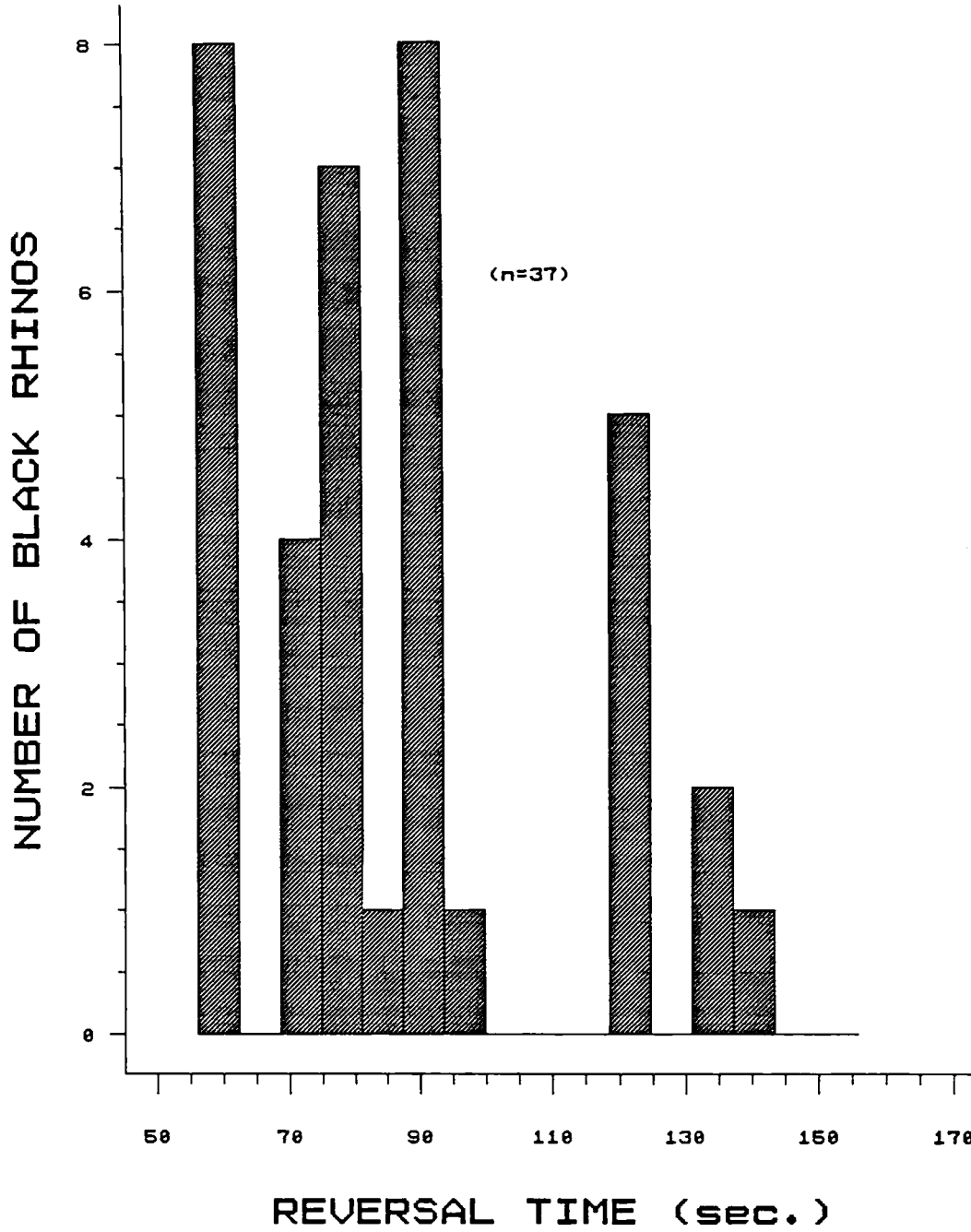


Figure 6: Distribution of reversal times for black rhinos immobilised with M99/xylazine (n=63) in Hwange National Park 1992. Reversal was achieved with naltrexone (IV).

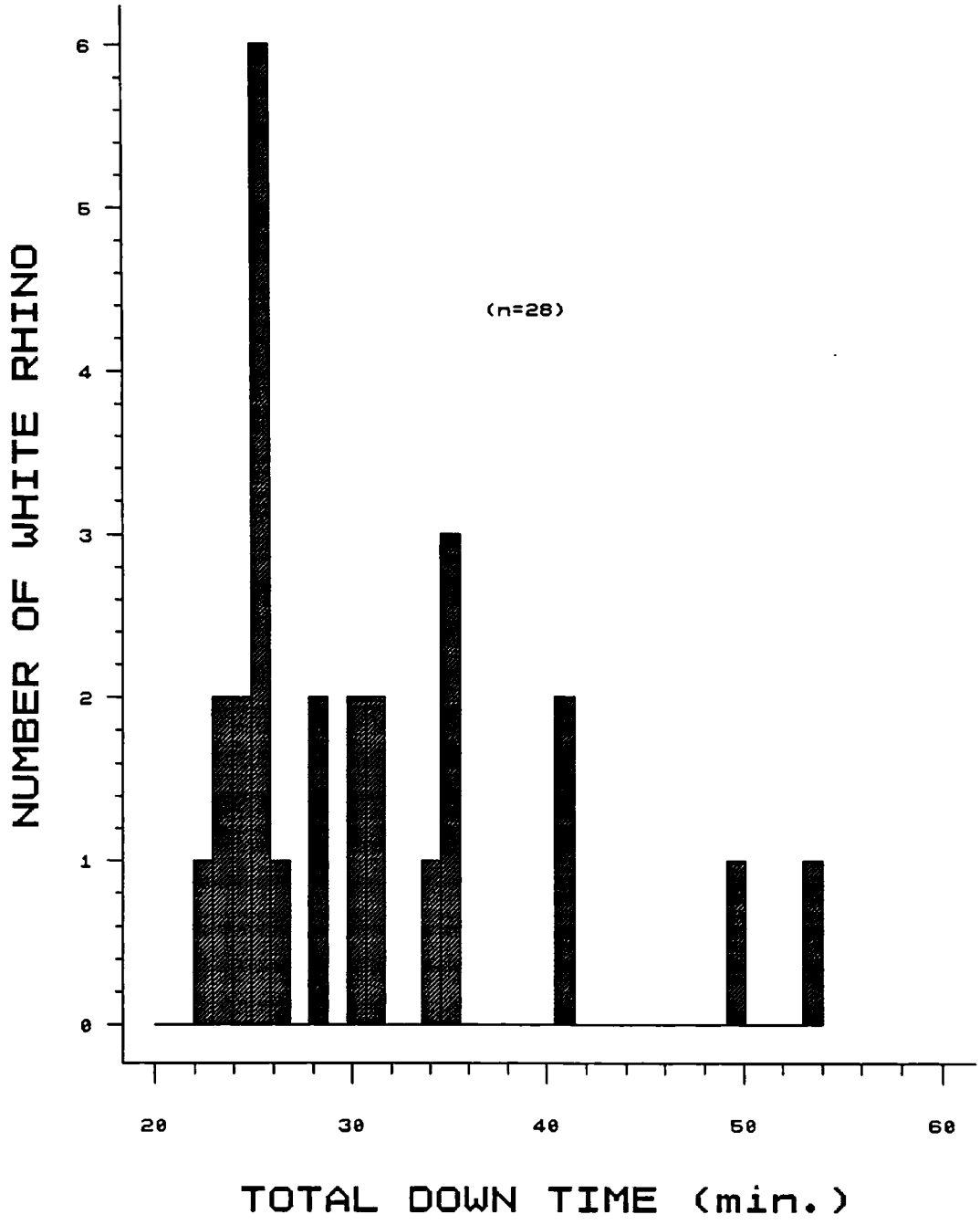


Figure 7: Distribution of total down times for white rhinos immobilised with M99/detomidine (n=31) in Matobo National Park, 1992.

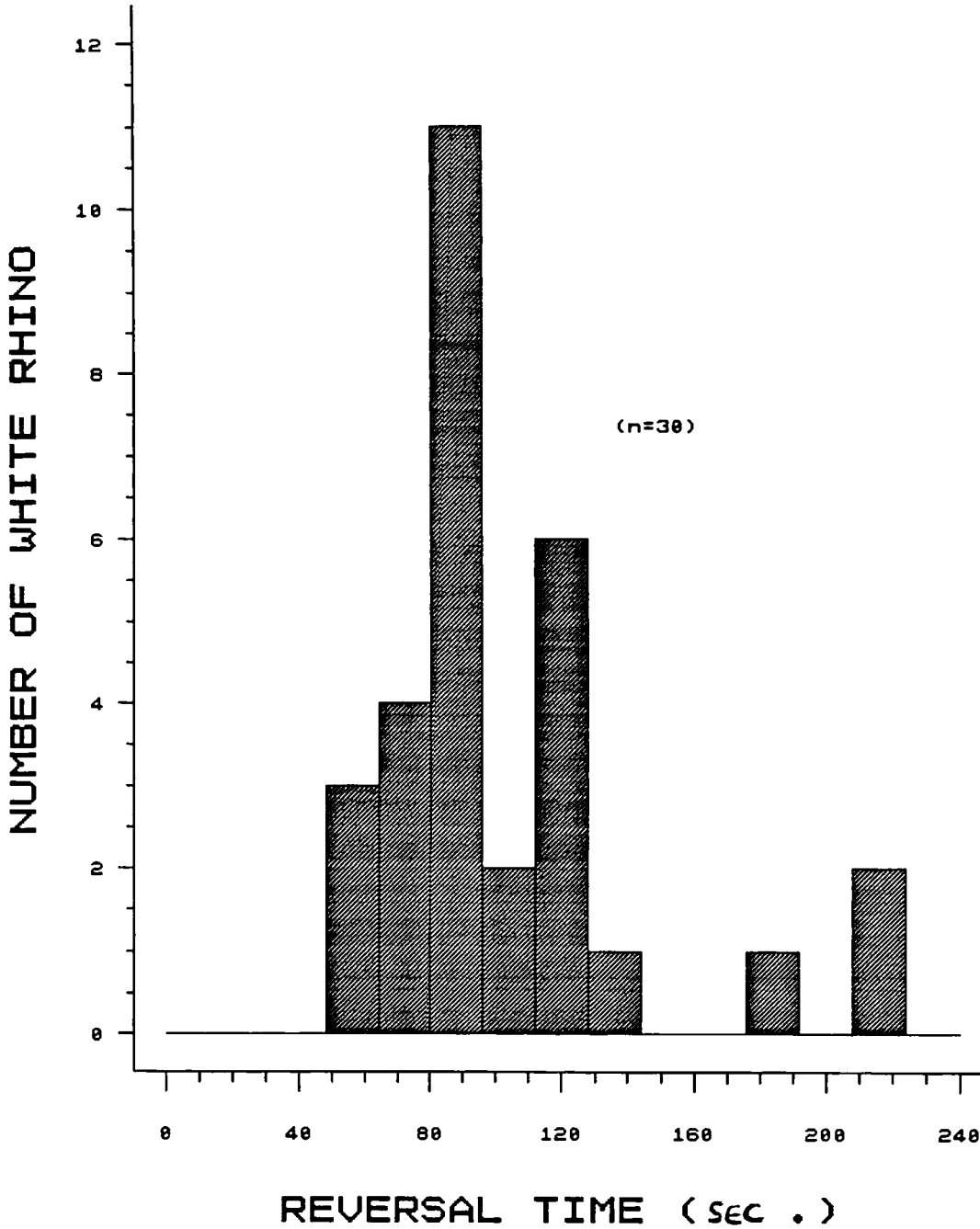


Figure 8: Distribution of reversal times for white rhinos immobilised with M99/detomidine (n=31) in Matobo National Park, 1992. Reversal was achieved using naltrexone (IV).

Appendices

Appendix 1.

Financial Assistance and Equipment:
International (USA, Australia, UK, Switzerland, New Zealand)

Financial:	Amount (Z$)
WWF International	500,000
Bass Foundation	150,000
NORAD	100,000
BRITISH ODA	200,000
CIDA	30,000
IBRF	Various inputs
Australian High Commission	25,000
IWVS Inc.	14,000
SAVE Australia	12,000
Sylvanus Charitable Trust	40,000
Friends of Conservation (FOC)	16,000
LightHouse Films (UK)	16,000
EleFriends (Australia)	9,000
Elkington Associates	3,200
Tina Dalton/Gary Speer	Helicopter hours
Columbus Zoo	3,000
Kyle Good	30,000
Julie Taylor/Brian Stevens	350

Equipment/Project support:

European Commission: Salary and operating costs, including transport and veterinary equipment for TA Veterinarian

International Wildlife Veterinary Services Inc.: Equipment, administrative, and logistical support

IBRF: Helicopter (US$500,000) plus numerous other inputs and assistance

SAVE Australia (NSW branch, Sydney): Considerable equipment support for the Veterinary Unit, DNPWLM. Nicholas Duncan, President, SAVE continues to provide moral, financial and logistical support

New Zealand High Commission: 3 x ground to air radios

Australian High Commission: AUS$50,000 for Matusadona Remote Sensing Project

Zoological Parks Board, New South Wales, Australia: Various inputs

Beit Trust: transport and recovery vehicles, fixed-wing, personnel (with special thanks to Raoul du Toit)

John Blythe-Wood: Helicopter hire and generator

Frankfurt Zoological Society and Dr Faust: Various inputs, including specific funding for Janet Rachlow

InfoPet: Trovan Transponders and 2 readers

Nellcor Incorporated: Pulse Oximeter (thanks to Jack Allen and Walter Boyce)

Cotswold Camping: Dart gun (1) and rhino darts (100)

Local (NGOs, Safari Operators etc.)

Financial and Administrative:

Zambezi Society: Handling of funds and logistical support
(Dick Pitman and Barbie Pickering)

Matusadona Operators Association 100,000

Appendix 2.

Data sheet used to collect immobilisation, horn, age, sex and other data from black and white rhinos.

BLACK RHINO IMMOBILIZATION DATA SHEET

Rhino ref. no. _____

Officer: _____ Date: _____ Location: _____ Map grid ref: _____

SEX: *M/F* Age: *Adult/Subadult/Calf* Guess age: _____ months/years Condition: *1/2/3/4/5*

With any other rhino? *None* *Adult*
Male *Subadult (2-4 yrs)*
Female *Calf (<2 yrs)*

Lactating? *No/Yes/Unknown*

Darting method: *ground/helicopter* Drugs: M99 _____ Xyl _____ Hyalase _____ Other _____

Distance run before darting: _____km after dart 1 _____km
after dart 2 _____km
after dart 3 _____km

Time to immobilization: after dart 1 _____ mins
after dart 2 _____ mins
after dart 3 _____ mins

Degree of stress: *mild/moderate/severe*

Period of immobilization _____ mins

Body dimensions (cm):

Straight shoulder ht. _____

Spine (base skull-base tail) _____

Front foot diameter _____

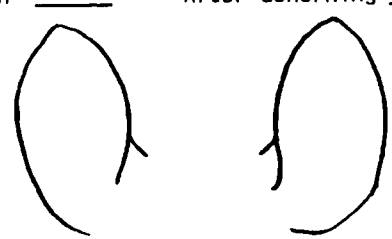
Rear foot diameter _____

Neck girth _____

Chest girth _____

Front horn _____ After dehorning _____

Rear horn _____ After dehorning _____



Any particular features? _____

Transponders: Location _____ Code _____ Can stick code labels on back.

Location _____ Code _____

Blood collection? _____

Notes _____

Appendix 3.

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