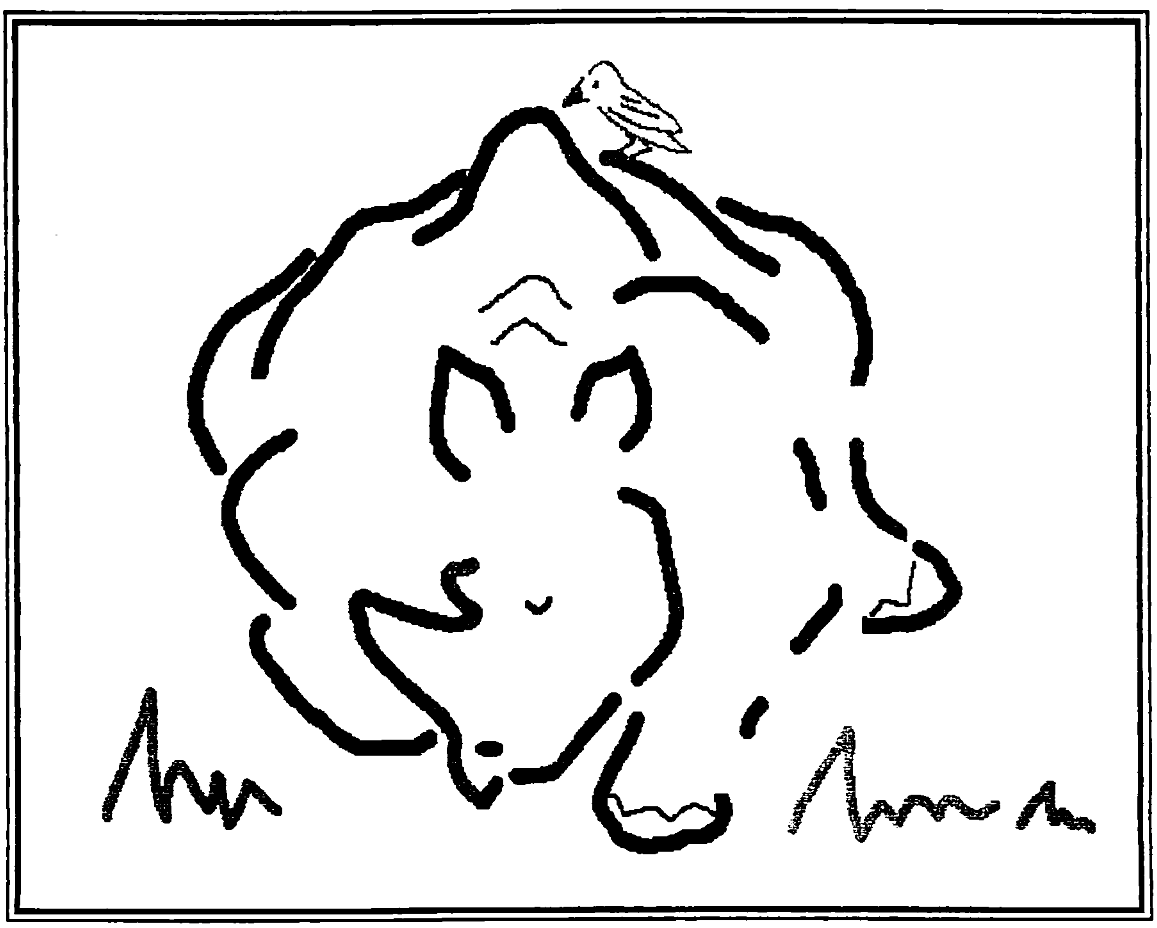
RHINOWATCH REPORT

THE DENSITY, DISTRIBUTION AND RANGING OF THE BLACK RHINO *(Diceros bicornis)* IN THE SINAMATELLA INTENSIVE PROTECTION ZONE (IPZ) HWANGE NATIONAL PARK, ZIMBABWE

Sky Alibhai & Zoë Jewell
Rhinowatch
Sinamatella Camp
P Bag WK5941, Hwange, Zimbabwe

Stewart Towindo
Area Ecologist, Sinamatella IPZ
Department of National Parks and Wild Life Management (DNPWLM)
P Bag WK 5941, Hwange. Zimbabwe

December 1996



Black Rhino
Zoë Jewell, 1996

CONFIDENTIAL

This report contains data on the number, distribution and other aspects of the ecology of the black rhino from 1992 to 1996 in the Sinamatella IPZ, Hwange National Park. Since the information contained in this report is of a highly sensitive nature, this document is confidential and meant for a limited and specified distribution. This document should not be photocopied without the permission of Rhinowatch or DNPWLM.

SUMMARY

1. At the end of 1995, the black rhino population in Africa was estimated at 2408.

2. In Zimbabwe, the population estimate for the black rhino in October 1996 was 324, with 202 in Conservancies and 122 on state land.

3. The black rhino population estimate for the Sinamatella IPZ in October 1996 was 62.

4. The mean annual birth rate for the Sinamatella IPZ from 1992-5 was 13.29%.

5. The mean annual rate of population increase from 1992-5 was 11.18%.

6. The mean births/female/annum from 1992-5 was 0.27.

7. The mean intercalving interval (n=9) was 42.5±6.64 months with the shortest interval being 21 months.

8. Projections for population growth (based on the exponential with a rate of increase of 11.2%) indicated that the Sinamatella population will be 114 in 5 years, 199 in 10 years and 349 in 15 years.

9. Out of 23 known births from 1992- September 1996, 15 were born in the dry season (May-October) and eight in the wet season (November-April).

10. From September 1993-September 1996 a total of 71 carcasses were collected from the IPZ.

11. Carcass recovery rate was estimated at 56%.

12. There have been no known mortalities from poaching activity since the establishment of the IPZ in September 1993.

13. Ranging patterns of 39 black rhino were determined from visual fixes using the minimum convex polygon method. Of these, 11 black rhino were shown to be ranging outside the IPZ. Extrapolating to the whole IPZ population, it was estimated that there are 18-20 black rhino on the periphery which range outside the boundaries of the IPZ.

14. In order to quantify home range analysis, it was established that a minimum of 20 fixes was required.

15. Based on above, mean range size for males (n=5) was 96.24±18.74 km^2 (max.=146.12 km^2) and for females (n=13) it was 87.42±22.18 km^2 (max.=282.40 km^2).

16. In general wet season ranges for both males and females were smaller than dry season ranges, the difference being more pronounced in males.

17. From July 1994-September 1996, a total of 839 observations were made of 39 black rhino in the IPZ. 17 males were observed on 251 occasions and 22 females on 588 occasions.

18. Data on social interactions between sexes, subadults and juveniles was analysed.

19. Of the 23 calves known to have been born to dams dehorned from 1992-5, only three calves were lost, suggesting that dehorning had no significant effect on calf survival.

20. Preliminary data suggested that intensive management (boma holding, and frequent immobilisation) compromised the reproductive capacity of female black rhino. Mean number of calves per female surviving to > 3 mths was 0.14 for the intensively managed group and 0.62 for the non-intensively managed group.

21. There was tentative evidence that females immobilised in the first trimester of pregnancy were likely to abort their calves.

22. Overall, about 60% of all standard radio-collars fitted (strap variety) came off within 12 months. Collar loss was relatively higher in males than females.

23. A cost-benefit analysis was carried out for various options with regard to black rhino management policy.

24. A 10-year course of action was recommended for the Sinamatella IPZ with the aim of developing a long-term, sustainable strategy for black rhino conservation and managment, and one which optimised local expertise. It was suggested that the most important and immediate action should be the boosting of scout numbers to the recommended one scout/20 km^2. It was also suggested that peripheral animals, which are most at risk and are not protected by

anti-poaching patrols, should be radio-collared.

25. Regular aerial and ground monitoring of both collared and uncollared black rhino should continue.

26. A photographic spoor technique for identification of individual black rhino being developed by Rhinowatch and DNPWLM should be fully implemented by the end of 1997. A report on the development of the spoor technique will be published separately.

CONTENTS

PAGE

TABLES AND FIGURES

TABLE PAGE

FIGURES PAGE

1 INTRODUCTION

1.1 THE PROJECT BACKGROUND

In 1970, an estimated 65,000 black rhino were distributed across Africa, extending from Senegal in the far west to Somalia in the east and covering large areas of East Africa, all the way into Angola, Botswana, Namibia, Zambia, Mozambique, Zimbabwe and South Africa. However, by 1987 this population had been decimated to less than 4,000 (Cumming *et al.*, 1990), and 1993 estimates suggested that the world population of this magnificent animal was less than 2500 (Redmond, 1993). Fig. 1 shows the 1995 world population estimate to be 2408 (Brooks, 1996). Brooks (1996) points out that although this figure is lower than the African Rhino Specialist Group estimates for 1992 and 1993, the 1995 estimate excludes speculative guesstimates, which account roughly for the difference. He also points out that while the black rhino population trend is now stable, this is largely due to a combined increase of the South African and Namibian populations of 308 rhinos since 1993. The black rhino has been lost from much of its original range, and only three countries are now thought to have growing populations - Namibia, South Africa and Kenya. However, Conybeare (1995) reported that overall the Zimbabwean population was also growing.

The black rhino (*Diceros bicornis)* is the sole survivor of a genus whose first representatives appeared on earth about five million years ago. The use of rhino horn by humans was first recorded in China around 2600 B.C. (Nowell *et al*, 1992). In the last twenty five years, representing less than one second in a 24 hour representative history of the species, the demand for rhino horn, primarily as an ingredient in traditional oriental medicine, has vastly outpaced sustainable supply. The horn is used primarily in Asian countries as an ingredient in traditional medicines, but has also been used extensively for making ceremonial dagger handles in the Yemen. Although the black rhino is protected from legal international trade under CITES Appendix I, the black market value of the African horn to the retailer is currently as much as $10,286 a kilogramme and there is thus a strong financial incentive to poach the horn (Bradley-Martin, 1993). A recent haul of poached black and white rhino horn in London (Streeter, 1996) yielded one horn with an estimated market value of US$150,000. The result of the uncontrolled trade in rhino horn is that this magnificent species is now faced with possible extinction.

Many different approaches have been used globally, in attempts to protect the remaining

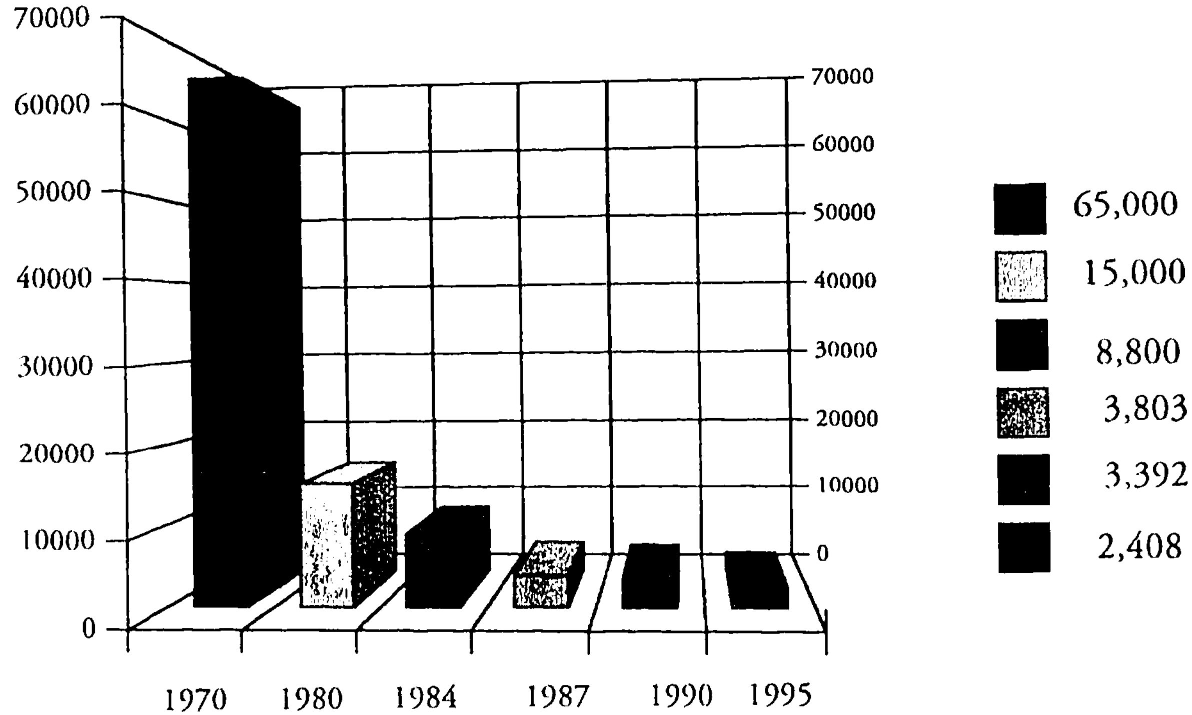


Fig. 1. World black rhino population 1970-1995

animals. Despite much effort, control of the illegal international trade in rhino horn has proved difficult, partly because of the difficulty in tracing the trade routes and also because the use of rhino horn is culturally-entrenched. Although recently some progress seems to have been made in this area, it is not sufficient to guarantee the future safety of the rhino. Protecting existing populations *in situ* has proved to be the only successful method of conserving these animals, and has been most successful where animals have been locally translocated to areas small enough to patrol and fence adequately (Leader-Williams, 1993). Effective protection of a low-density population in a large area is only feasible if sufficient financial resources are available or the poaching threat is small. Nevertheless, whether in game reserves, or larger areas, the effective protection of animals *in situ* is many times more cost-effective than attempts at protection through captive breeding (Leader-Williams, 1993; Alibhai & Jewell, 1994b). Given that attempts at controlling the illegal trade in rhino horn might not succeed before the wild population has been eliminated, and that captive breeding replacement rates for the black rhino are running at a value of O% after almost 15 years of attempts at captive breeding (Farst & Foose, 1996), it is vital that urgent attention be focused on protection of this species *in situ.*

In order to implement an effective management strategy for any *in situ* population, it is essential to have accurate, current information on the abundance and distribution of that population. Any strategy implemented without such information could constitute a waste of valuable and often scarce resources. Despite the threatened status of all five of the rhino species, relatively little reliable census data for any of these species has been available, and many conservation policy decisions have been based on "guesstimates" (Cumming *et al,* 1990). Rhinowatch was established in 1990 with the aim of providing reliable census data for rhino populations to those authorities responsible for formulating rhino conservation policies.

In 1990 Zimbabwe was thought to have more than half of the world population of black rhino, 1754 animals (Cumming *et al,* 1990), and was considered the last stronghold for this species. However, the population has declined very dramatically since then and, although as Table 1 shows, the most significant decline occured from 1991 to 1993, it was evident from field reports that numbers were already declining in 1988. It is unlikely that this dramatic decline can be attributed entirely to poaching activity. According to Cumming *et al* (1990), the estimates (Table 1) were based on non-specific and generally unreliable surveys, which in some cases had been carried out many years earlier. It was quite obvious that there was a need for reliable scientific data on the numbers and distribution of black rhino in different parts of Zimbabwe, as underlined by Cumming *et al* (1990). In 1992, Rhinowatch, in conjunction with

	1970	1975	1985	1988	1989	1990	1991	1993	1995	1996
STATE LAND	739-1476	860	1605	1532-1682	2026	1740	1845	125	NA	122
PRIVATE LAND	10?	0	0	159	162	14	150	160	188	202
TOTAL	739-1476	860	1650	1691-1841	2188	1754	2095	285	NA	324
SOURCE	A	A	A	A	B	C	B	A	NA	D

TABLE 1. Estimates for the Zimbabwean black rhino population 1970 to1996.

A. du Toit, R. 1993. Rhino Conservation in Zimbabwe. Unpubl. pp 45.
B. DNPWLM. 1992. Zimbabwe Black Rhino Conservation Strategy.
C. Cumming, D.H.M. *et al*. 1990. African Elephants and Rhinos - Status Survey and Conservation Action Plan. IUCN/SSCAfrican Elephant and Rhino Specialist Group Publ. pp 72.
D. Rhinowatch for Sinamatella IPZ numbers and Matipani (pers. comm.) for rest

the Zimbabwean Department of National Parks and Wild Life Management (DNPWLM) undertook a thorough ground census of the black rhino (Alibhai & Jewell, 1993), and other large mammals (Alibhai & Jewell, 1994a) in the Chirisa Safari Area and the Sengwa Wildlife Research Area. The resulting information on population density and distribution in this area was then made available to the DNPWLM for the updating of the appropriate management strategies.

As a result of this survey the previous black rhino population estimate for the Chirisa Safari Area of approximately 100 (du Toit, 1989), 130 ± 74 (Towindo, 1990) and 350 (Cumming *et al*, 1990, for Chirisa Safari Area and Chizarira National Park) was revised to a dramatically reduced 15 ± 3. This decline in the Chirisa Safari Area population was echoed on many Parks and Wild Life estates, and as a result the estimated population for black rhino in Zimbabwe in 1992 dropped from 1700 to less than 300 animals (du Toit 1993.) Recent estimates (Brooks, 1996) suggest that the population of black rhino in Zimbabwe may be around 315 animals, although Conybeare (1995) estimated a figure of 291, but did not correct for the estimated population of the Sinamatella IPZ at the end of 1995. The present black rhino population in Zimbabwe is estimated at 324, with 202 animals on private land and 122 in the IPZs (Fig. 2).

In 1993 the DNPWLM of Zimbabwe formulated an emergency rhino action plan (Department of National Parks, 1993) which designated four areas as intensive protection zones (IPZ) for black rhino. The emergency plan proposed that all black rhino on the Parks and Wild Life estate be translocated into the four newly created IPZ's where they would be intensively protected. The four designated IPZ's are; Matobo, which lies within the boundaries of Matobo National Park; Matusadona, which lies within Matusadona National Park; Sinamatella, which lies within Hwange National Park and Deka Safari Area; and Chipinge, which lies within the Chipinge Safari Area. The Sinamatella IPZ, in Hwange National Park and Deka Safari Area, is the largest designated IPZ at approximately 1,500 km^2 , has the single largest black rhino population in Zimbabwe and is one of the three IUCN rated key black rhino populations in Zimbabwe. It is also the only IPZ with the potential for IPZ size increase - which could take place within Hwange National Park, Deka Safari Area and Matetsi Safari Area. In 1992/3 12 animals were translocated into the Sinamatella IPZ from various outlying areas, including Chizarira National Park and Sikumi Forest Area, to consolidate the population already present.

In 1994 Rhinowatch, in conjunction with the DNPWLM, carried out a systematic ground

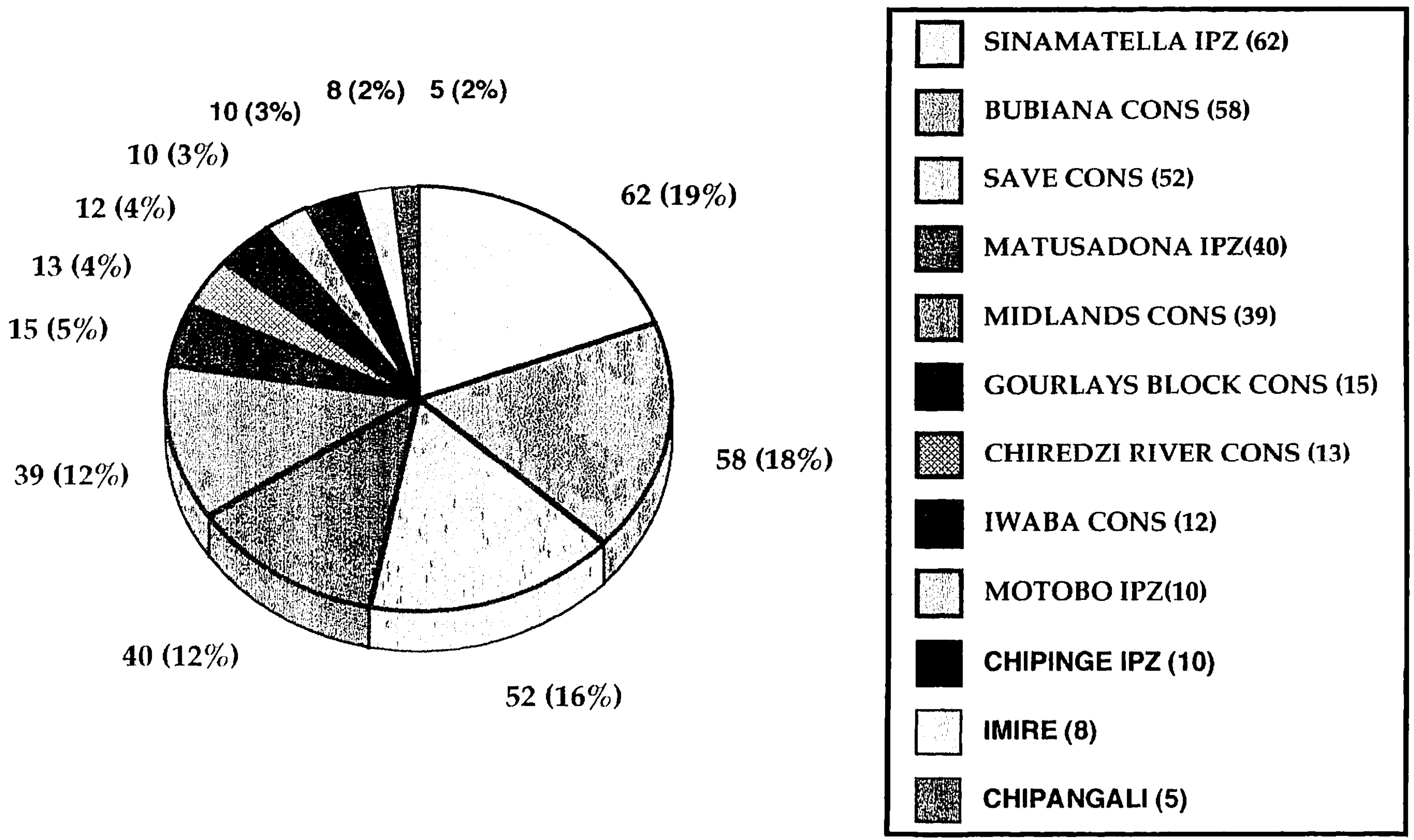


Fig. 2. October 1996 estimates of black rhino numbers in conservancies/private land (Matipani pers. comm.) and on state land in Zimbabwe. Total population estimate = 324 (the estimate does not include the few rhinos on state land outside the IPZs).

survey of black rhino in the newly formed Sinamatella IPZ to establish a baseline figure for the population from which demographic indicators could be taken in future to monitor the succe of the IPZ concept (Alibhai *et al*, 1995). The estimated population of 55±5 animals for this IPZ showed it not only to be the most significant population of black rhino on National Parks Estate, but also the largest contiguous population of black rhino in Zimbabwe. Furthermore, no recent evidence of poaching of rhino was found which was consistent with the increased protection afforded to the population through the implementation of the IPZ concept. In the same year a census was undertaken of the other large mammal species in the IPZ (Alibhai *et al*, 1996)

In an attempt to protect and monitor the Sinamatella population the DNPWLM dehorned and radio-collared black rhinos on several occasions over the period 1992-5. In September/October 1992 the Veterinary Unit of the DNPWLM undertook a dehorning operation in the Sinamatella IPZ. Sixty-nine black rhino were immobilised and, of these, 58 animals dehorned (Kock & Atkinson, 1993) and in September/October 1994 (Veterinary Unit report 1995) they repeated the de-horning operation during which 35 animals were radio-collared primarily for the monitoring and protection of the animals by the anti-poaching units. However, this also afforded an opportunity to study the ranging and distribution of the population in greater depth than had previously been possible. In November/December 1995 (Veterinary Unit report 1996) the Veterinary Unit immobilised 32 animals and fitted 27 new radio-collars. However, none of these animals were dehorned and since then no further dehorning and/or radio collaring has taken place.

In 1995 Rhinowatch, in conjunction with the DNPWLM, began a long-term study of the ecology and behaviour of the black rhino in the Sinamatella IPZ. Initially it was considered most urgent that data was gathered on the distribution and ranging behaviour of the animals in order for the DNPWLM to be able to assess the security of the population and the success of the IPZ strategy.

1.2 THE PROJECT AIMS

The primary and immediate aim of the Rhinowatch project in 1995/6 was to monitor the distribution and movement patterns of the black rhino in the Sinamatella IPZ. This was done for two equally important reasons. First, it was imperative that this information was available to the Warden at Sinamatella so that the anti-poaching patrols could be deployed in the most effective manner. Second, it was important from a scientific and management point of view, and for the purposes of future management, to begin to provide information on the spatial distribution patterns and habitat utilisation of this young and growing black rhino population. By doing this, the project was attempting to meet with management requirements, whilst at the same time fulfilling research aims.

The third aim was to begin to gather data on the biology of this endangered species in the Sinamatella IPZ, in particular data on reproductive ecology (birth rates, calf survival, inter-calving intervals etc.) and general aspects of population dynamics (population growth rates, recruitment rates, dispersal etc.). Also, since a number of animals had radio-transmitter collars, it was hoped that it would be possible to collect data on social interactions between individuals.

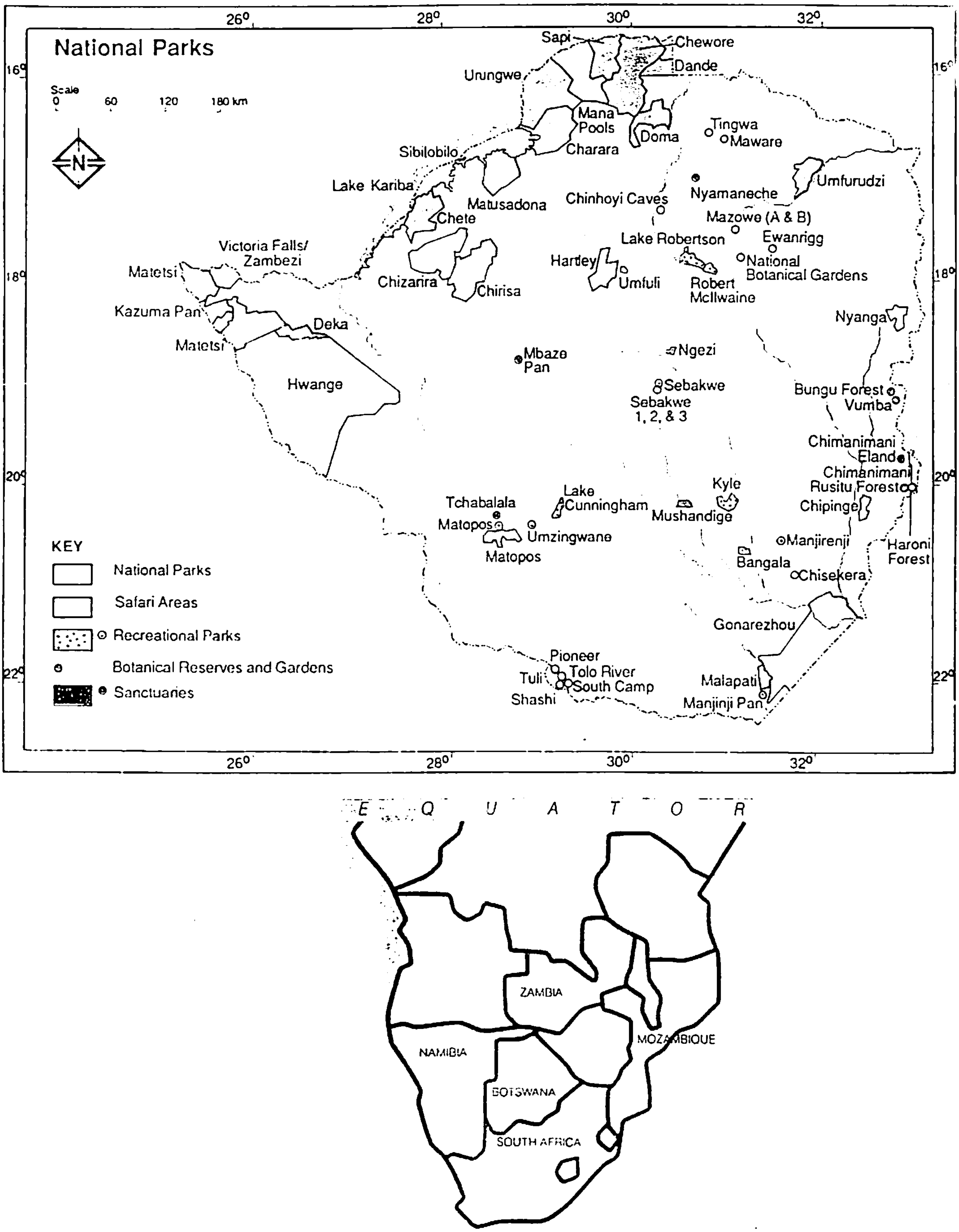
A third aim was to begin to develop a non-invasive, cost-effective and sustainable technique for the identification and monitoring of individual black rhino using spoor analysis.

1.3 THE STUDY AREA

The Sinamatella area was gazetted as part of Hwange National Park in 1952, before which parts of the area were commercially farmed (Tafangenyasha & Campbell, 1995). It was identified as a primary site for an Intensive Protection Zone (IPZ) in the Black Rhino Emergency Plan of 1993 (DNPWLM, 1993). It was also recognised in the Hwange National Park Plan (Jones, 1992), as an area in which a study was required on the density and distribution of rhino because of the very limited data available.

The Sinamatella IPZ lies within the Hwange National Park and adjacent Deka Safari Area in North Western Zimbabwe (Fig 3).

Sinamatella Intensive Protection Zone is an area of 1530 km^2 which extends from approximately 18° 23' to 18° 48' S and 26° 05' to 26° 40' E, and incorporates northern parts of Hwange National Park and western and southern parts of the Deka Safari Area. Altitude ranges from 840m on the Deka river to 1153m at Bumbuzi, and the area has a mean annual rainfall of 572mm, ranging from 138 to 955mm (Tafangenyasha & Campbell, 1995). The area contains several geological types including pre-cambrian rocks, karoo sediments, kalahari



MAP OF ZIMBABWE SHOWING HWANGE NATIONAL PARK

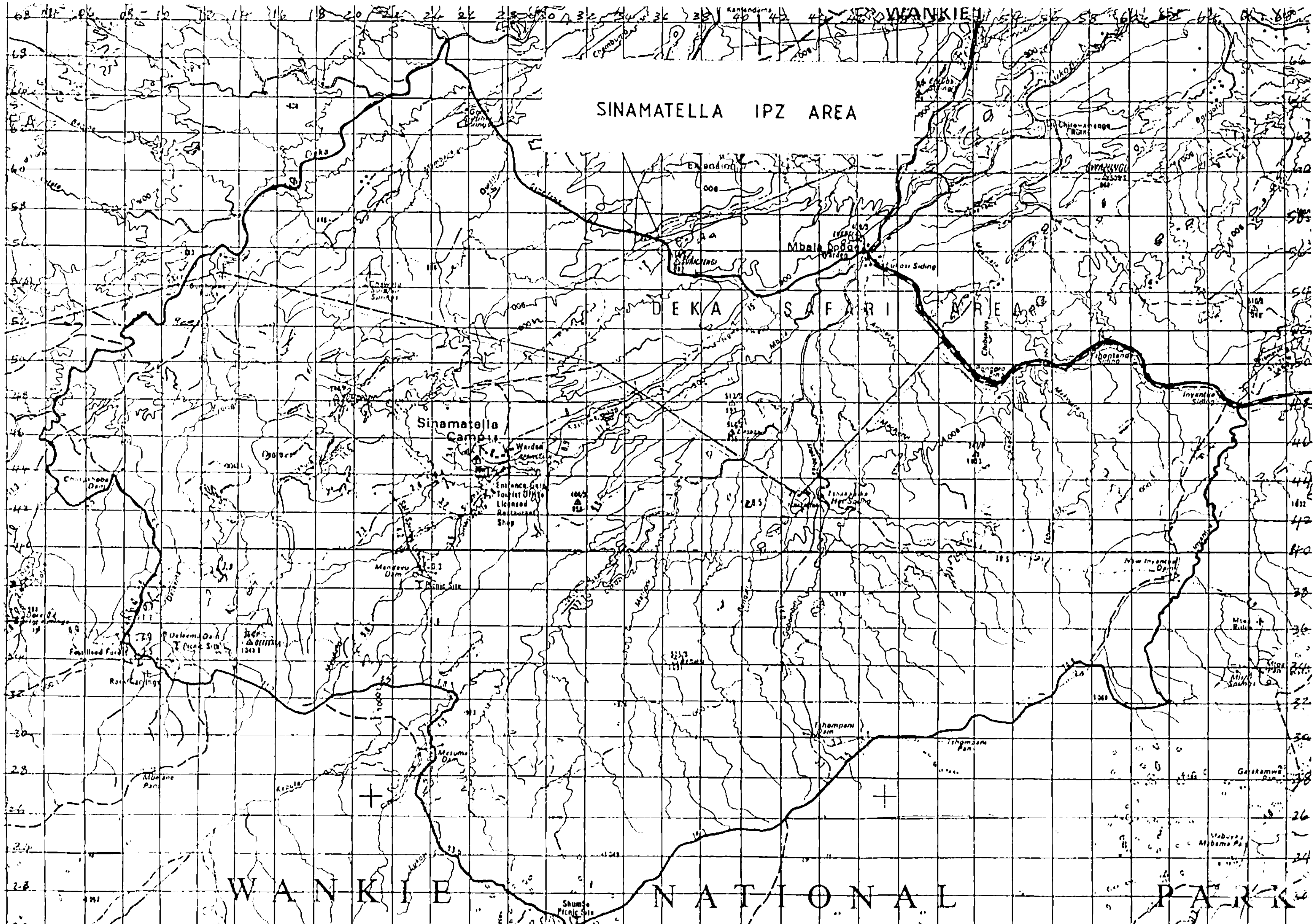
Fig. 3

sands and batoka basalt. Woody vegetation types (Rogers, 1993) include *Combretum sp.* and *Boscia angustifolia* open scrub and thicket on Lower Karoo sandstone, *Colophospermum mopane* and *Terminalia prunioides* woodland on mudstones, *Colophospermum mopane* and *Acacia sp.* woodland adjacent to riverine vegetation, *Diospyros mespiliformis* and *Combretum mossambicense* riverine vegetation, *Colophospermum mopane* and *Commiphora marlothii* mixed woodland on scree slopes and *Combretum elaeagnoides* and *Diospyros quilioensis* thicket on the escarpments (Rogers, 1993). The IPZ is drained primarily by the Deka river on the northern and western boundary, the Lukosi centrally, and the Inyantue river on the eastern boundary. The rainy season runs approximately from October until March, and rivers and watercourses are usually dry 2-3 months after the end of the rains. Water is then only available in the natural springs and man-made dams and waterpoints.

Rhinowatch is based at Sinamatella Camp which is centrally situated in the IPZ (Figs. 4 & 5).

1.4 THE HISTORY OF THE BLACK RHINO IN THE STUDY AREA

The black rhino is indigenous in the study area, where it was recorded by many early European hunters and explorers. Balfour (1991) writes that Selous recounted that black and white rhino were "practically exterminated" in all the countries between the Limpopo and Zambezi rivers between 1872 and 1890. This was due partly to sport hunting and partly to the trade in rhino horn. This was undoubtedly greatly increased due to the appearance of firearms bought into Africa by Europeans in the 1800's. The population began therefore to decline dramatically from the latter half of the 19th century. There were a few sightings in the 1940's of black rhino in the area which is now the Sinamatella IPZ, although one of these animals was shot by a local farmer who apparently mistook it for an eland. The first attempts to re-establish the population were made in the 1960's and early 1970's. (Herbert & Austen, 1972, Booth et al, 1983). In 1961 *Operation Noah* began a translocation of animals out of the newly flooded Lake Kariba. Further translocations were made throughout the 1960's and early 70's from other parts of what was then Rhodesia (du Toit, 1989b). This strategy appeared to be successful, because in 1988 the black rhino population in Hwange NP, the Deka SA and Matetsi NP was estimated to be 250 (Tatham & Taylor, 1989). However, in 1988 a renewed wave of poaching for horn began in earnest in the region, after the population in the Zambezi Valley had been dramatically depleted. 78 animals were reported poached from the region between 1988 and 1993. Using the estimated carcass recovery percentage of 56% for the Sinamatella IPZ



TOPOGRAPHICAL MAP OF THE SINAMATELLA I.P.Z.

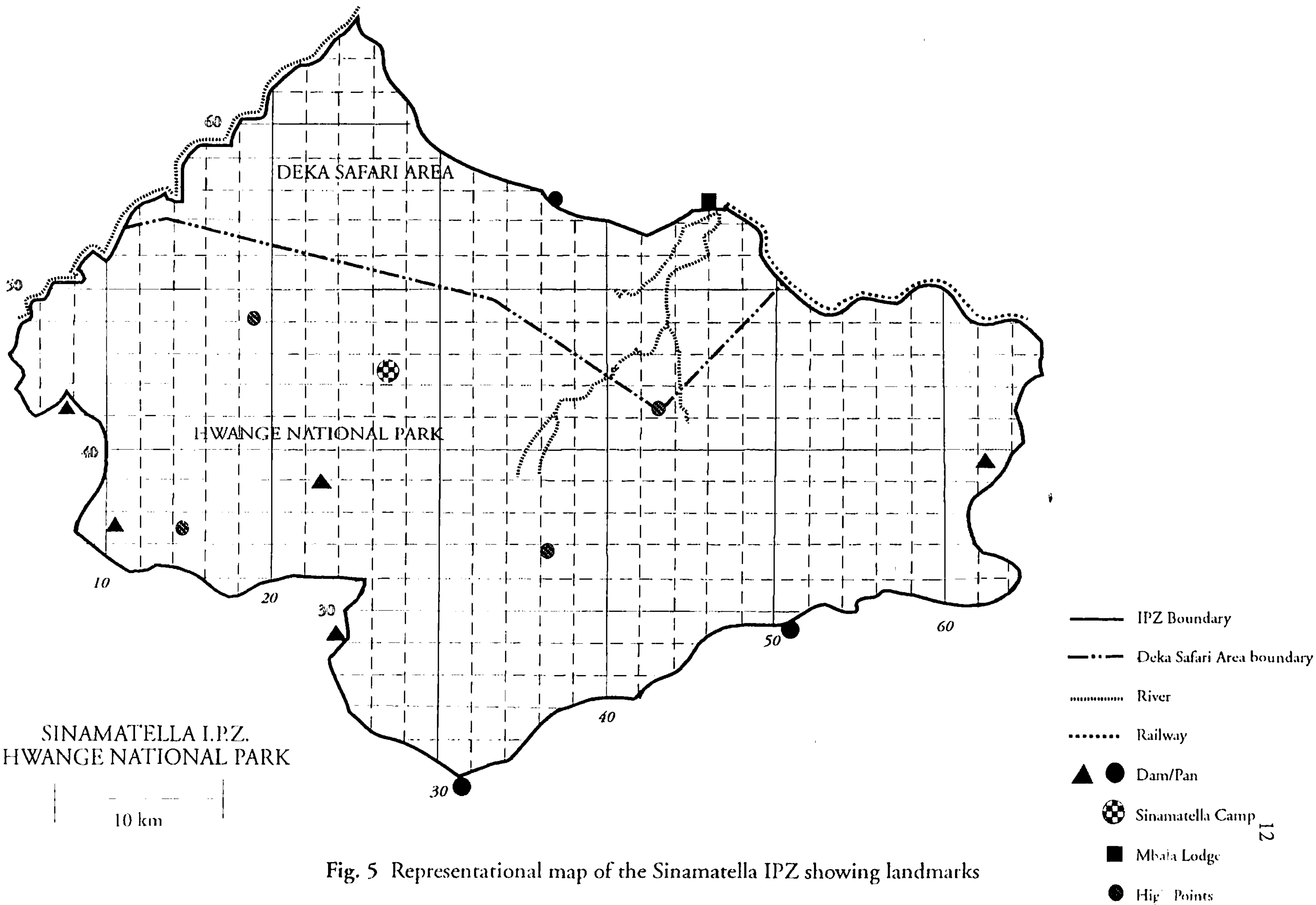


Fig. 5 Representational map of the Sinamatella IPZ showing landmarks

(see below) this would suggest that more than 140 animals were actually poached during this period. Since the creation of the Intensive Protection Zone at Sinamatella there has been no reported poaching, and animals have been introduced from other areas of the country - in 1992/3 12 animals were introduced from outside the current IPZ, primarily from Chizarira and Sikumi Forest Areas.

2 METHODS

Several methods were used over the period 1994-6 to gather data about the demography, distribution, ranging behaviour (movement patterns) and social interactions of the population.

2.1 RADIO-TRACKING

2.1.1 Collaring and telemetry equipment

The radio-collaring of black rhino in the Sinamatella IPZ was carried out by the Veterinary Unit of DNPWLM using a helicopter, a fixed wing plane and ground support, on three different occasions in 1992, 1994 and 1995 (Kock & Atkinson, 1993; Veterinary Unit 1995 & 1996). Several translocated animals were radio-collared and dehorned in 1993. Resin housed Telonics transmitters were fitted on the rhinos using two different designs of collars, strap (1992, 1994 & 1995) and hose (1994). The transmitters which emitted signals continuously, were equipped with mortality indicators which started trasmitting signals more rapidly when inactive for 5-6 hours. The radio signals were picked up using three Telonics receivers, one TR4, and two TR2 receivers equipped with scanning units. Both vehicle-adapted omni-directional antennae and heavy duty directional antennae were used for signal detection. Small portable and flexible mono headphones were used which enabled the tracker to keep one ear open for environmental cues. In October 1996, there were 17 black rhino with effective radio-collars in the Sinamatella IPZ.

2.1.2 Aerial tracking method

Approximately every three to four weeks (variable) during the study period, the DNPWLM conducted an aerial census using a fixed wing light aircraft or small helicopter with fixed antenna to collect locstats for collared rhino on the ground. This data was included in the radio-tracking database. Animals were occasionally sighted which had no collars, and were recorded. Collars which had fallen off were retrieved. During aerial tracking, locstats were recorded by the observer using familiarity of the terrain and at times using Global Positioning Systems (Trimble Ensign or Garmin).

2.1.3 Ground tracking method

Rhinowatch tracking teams together with DNPWLM Scouts operated each day from the Sinamatella base throughout the study period. On occasion, fly camps were established to enable ground coverage of the more peripheral areas of the IPZ. Teams operated from trucks using omni-directional antennae where appropriate and the direction of the signal ascertained using the directional antenna and a compass. A fade-out technique was used to increase the accuracy of the directional estimate. Using this technique, the highest signal intensity and therefore the most accurate estimation of the direction of the animal, was taken to be mid-way between points at which the signal faded out either side of the range. The compass bearing was read and recorded. Several different bearings were taken from different positions, until a field triangulation calculation could estimate the position of the animal. The angle of declination (8°) was subtracted from the bearing reading for plotting on the map. Readings were taken as close together in time as was practicable.

For purposes of visualising the animal, proximity could be accurately gauged by the intensity of the signal, generally a very loud signal being received when within approximately 1 km of the animal. The animals were always approached quietly from downwind, with the aim of causing them minimum disturbance and making good behavioural observations. At all bearing and observations points, locstats were recorded with Trimble Ensign Global Positioning Systems accurate to ±60metres.

2.2 ESTIMATION OF RHINO POSITION BY TRIANGULATION, AND ASSESSMENT OF ACCURACY BY COMPARISON WITH OBSERVED POSITION.

Because many animals were initially radio-collared after the operations in 1994 and 1995, and radio-tracking was also fairly time-consuming (the location of a signal and subsequent tracking of an animal often took several hours depending on terrain) it was important that an appropriate technique be used for the rapid and reliable estimation of animal position. For the preliminary investigation in 1995/6 this was done using simple geometric triangulation on 1:50,000 maps. Controls on accuracy were made by placing transmitter collars at known locations and estimating position from a minimum of three different locations. Bearings received from the transmitter were plotted on maps. making a deduction of 8° from each bearing before plotting to allow for the angle of declination, and calculations of estimated position of the animal made as follows:

1. Where three or more bearing lines intersected exactly, the point of intersection was taken as the estimated position.

2. Where three or more bearing lines came together to form an approximately equilateral triangle, the mid point of the triangle was taken as the estimated position. Where the shortest side of the triangle was less than half the length of each of the two longer sides, the Priddel Method was used and the mid-point of the shortest side was taken as the estimated position (Pyke & O'Connor, 1990).

3. Where more than three bearing lines produced more than one triangle, or polygon of intersection, the smallest shape produced by the most lines was taken and the midpoint used as the estimated position

4. Where the lines did not intersect, or where insufficient bearings were available, no estimated position was calculated.

To estimate the reliability and accuracy of this triangulation method, an estimated position was compared with the known (observed) position of the animal from radio-tracking. The accuracy of the estimated position was classified as below:

A = Estimated position was ≤ 1 km of observed position.
B = Estimated position > 1 km but ≤ 2 km from observed position.
C = Estimated position > 2 km from observed position, or no estimated position obtained because bearings did not cross.

Data was further analysed to test the significance of other variables:

a different animals, to allow for possible differences in the transmitter strength, and the variability of terrain occupied by different animals
b different trackers, to allow for individual expertise.
c means of the distances between all the contributary bearings and the estimated position of the animal, to allow for the proximity to the animal when bearings were taken.

2.3 HOME RANGE ANALYSIS

The minimum convex polygon technique (Harris *et al.*, 1990) was used to calculate home ranges for collared animals, using visual fixes acquired from aerial and ground radio-tracking, and ground spoor tracking. This technique was chosen because it is the only home range technique which is easily comparable between studies. It is also more robust than other techniques when the number of fixes is low, as was the case for several animals.

Ranges which included all fixes obtained over the study period were plotted by size, for all animals. The increase in range size by number of fixes was calculated for the population in an attempt to ascertain at what number of fixes a reasonable estimation of range could be made. Range sizes in wet and dry seasons were calculated for males and females and comparisons made. Range overlaps in wet and dry seasons were calculated to ascertain whether there was significant drift in range between these seasons.

Wildtrak software for the Apple Macintosh was used for the analysis (Todd, 1993).

2.4 SPOOR ANALYSIS

2.4.1 Tracking by spoor

It became clear throughout the study period that radio-collars were a temporary solution to the problem of monitoring the population. The number of animals with radio-collars represented up to 50% at maximum of the total estimated population, and declined rapidly over the research period, either through failure of the transmitter, or, more commonly, loss of the collar from the animal. It was evident that it would be necessary to develop other techniques for locating the animals, which could be complementary to the radio-collaring programme, or operate alone if no collars were available. First amongst these was the tracking and subsequent identification of animals by their spoor.

Rhino spoor was located and tracked using the field skills of the scouts of the DNPWLM. In favourable conditions, there was little difficulty in locating and following fresh spoor.

2.4.2 Identification of individual animals by spoor recognition

du Toit (1989) described the identification of individual rhino by analysis of spoor, on the basis that each animal had a unique spoor print. Provided the same foot was used to compare prints, it was shown to be possible to identify animals in the field by means of their spoor print.

In 1992 Rhinowatch began to develop a new technique for the identification of animals using spoor analysis (Alibhai & Jewell, 1993). This technique was refined in 1994 (Alibhai *et al.*, 1995) and further refined in 1995/6 for development of a photographic spoor analysis technique for censusing and monitoring of individual black rhino. Initial trials are very promising and the results will be published in a separate report.

Spoor seen were recorded in one of the three designated age categories, but only fresh and more detailed spoor, predominantly category A , were used. (Towindo, 1990).

2.5 DEMOGRAPHIC DATA COLLECTION

During each of the radio-collaring operations, data recorded by the Veterinary Unit and collated by Rhinowatch formed the initial basis of population data subsequently gathered on the ground through radio-collaring and spoor work by Rhinowatch and DNPWLM staff.

Specific information about the sex and approximate age of individuals in the population, and the reproductive status of females was collected over the entire study period by aerial and ground radio-tracking and by spoor tracking. An estimated age of some adults was made by the Veterinary team according to dentition (Hitchins, 1978) although some doubts have subsequently arisen about the accuracy of these estimations. The time that a new calf was first seen was recorded and the ageing of the calves and sub-adult animals was based on the system of measuring the animal against the dam when standing side by side after du Toit (pers. comm.) who modified the method previously devised by Hitchins (1970). Adcock (1996) devised a modified system of ageing based on Hitchins (1970), but this relied to a greater degree on horn shape and size, and was impracticable in the dehorned Sinamatella population.

Estimates were made of the annual rates of increase and the mean annual rate of increase for the period 1992-1995. The value of the mean annual rate of increase was then used to make projections of the rates of population growth based on the exponential model. Estimates for the "carrying capacity" of black rhino in the IPZ were made using densities from published studies. For the purpose of future management, the time taken to reach the "carrying capacity" was estimated. For populations occuring in confined areas, such a projection would be based on the logistic model, assuming that as the population approaches carrying capacity, the rate of population growth would slow down until the asymptote is reached when the growth rate would be zero. However, the Sinamatella IPZ lies within the Hwange National Park and Deka Safari Area. There are no fences to restrict the population which means that as the population expands, it is likely that animals will begin to disperse into areas outside the IPZ. The logistic model is inappropriate in this situation hence, the calculation of time projections to reach the "carrying capacity" were based on the exponential model.

2.6 BEHAVIOURAL AND ECOLOGICAL DATA FROM DIRECT OBSERVATION

Animals were observed in the field for as long as possible without disturbing them. Notes were made of the different categories of activities. When individuals were seen with other black rhino, in each case an attempt was made to identify the rhino. Data on social interactions was recorded in the field and then put on a data base at Sinamatella. Where animals were found resting during the middle of the day, as was often the case, observations on behaviour were limited.

2.7 CARCASS DISTRIBUTION

During the field work, rhino carcasses found in the field were brought back to Sinamatella. The exact location of each carcass was determined using GPSs. Information about carcass location, approximate age of the animal and the age of the carcass was recorded on a data base.

2.8 COLLECTION OF DATA ON ECONOMIC COSTS OF VARIOUS MANAGEMENT OPTIONS FOR PROTECTING AND MONITORING THE BLACK RHINO IN THE SINAMATELLA IPZ

An attempt was made to assess the economic costs of the various options for protecting and monitoring the black rhino in the Sinamatella IPZ. A table was then compiled to compare the costs and benefits of the methods, and a 10-year plan designed to incorporate the best options over that time period.

2.9 METHODS OF DATA ANALYSIS

All information was recorded on observation sheets in the field and entered into 4D 1st relational database on a computer at Sinamatella. Each animal was identified as far as possible using a base code adopted by the Veterinary Unit in 1992 and 1994 (Veterinary Unit, 1993 & 1995). To facilitate the recognition of maternal lineage, Rhinowatch developed a new code. Statistical analysis was done using JMP software (SAS Institute), graphing using Deltagraph Pro, and mapping using Aldus Freehand and Wildtrak, all designed for Apple Macintosh. Analysis of demographic projections was carried out on an ICL computer at Sinamatella.

3 RESULTS

3.1 DEMOGRAPHY AND REPRODUCTIVE DATA ON THE BLACK RHINO POPULATION IN THE SINAMATELLA IPZ

3.1.1 Population composition 1992-5

Fig. 6 shows the population composition from 1992 - 5 based on known animals as identified by Rhinowatch and the Veterinary Unit. During the collaring operation, the Veterinary Unit immobilised a certain proportion of the IPZ population which constitutes a sample of the entire population. The sample size varied each year according to the amount of time spent by the Veterinary Unit at Sinamatella. Hence, the actual number of animals in Fig. 6 (and Table 2) does not indicate a trend in population size of black rhino in the IPZ. However, the composition of the known population remained fairly consistent during the study period and, although adult females consistently out-numbered adult males in each of the four years, the overall ratio was not significantly different from the expected 1:1 ($\sum$ chisquare = 5.98, df = 3, p > 0.05). The composition of the population indicates that the male: female ratio varied from a maximum of 1:3 in 1993 (small sample size)to almost parity, 1:1.19 in 1992.

3.1.2 The % mean annual birth rate and % mean annual rate of increase 1992-5

The % annual birth rate was calculated as the number of calves born in one year as a percentage of the total known population at the beginning of that year. The % annual rate of increase was calculated from the annual birth rate adjusted for known mortalities occurring in that year (Caughley, 1977). The mean rate of increase and the mean annual birth rate were calculated for the period 1992-5. Table 2 shows a mean annual birth rate of 13.29% and a mean annual rate of increase of 11.18% in the known Sinamatella IPZ black rhino population in the period 1992-5. The mean annual rates of increase varied from 4.87% in 1994 to 15.15% in 1995. This wide variation was partly due to the fact that in some years the sample size was very small, particularly in 1993 when the collaring/dehorning operation lasted a very short period. Obviously it is not appropriate to place emphasis on a single population growth rate for any one year in a species which has such a long inter-calving interval. Rather, a mean should be taken from several years.

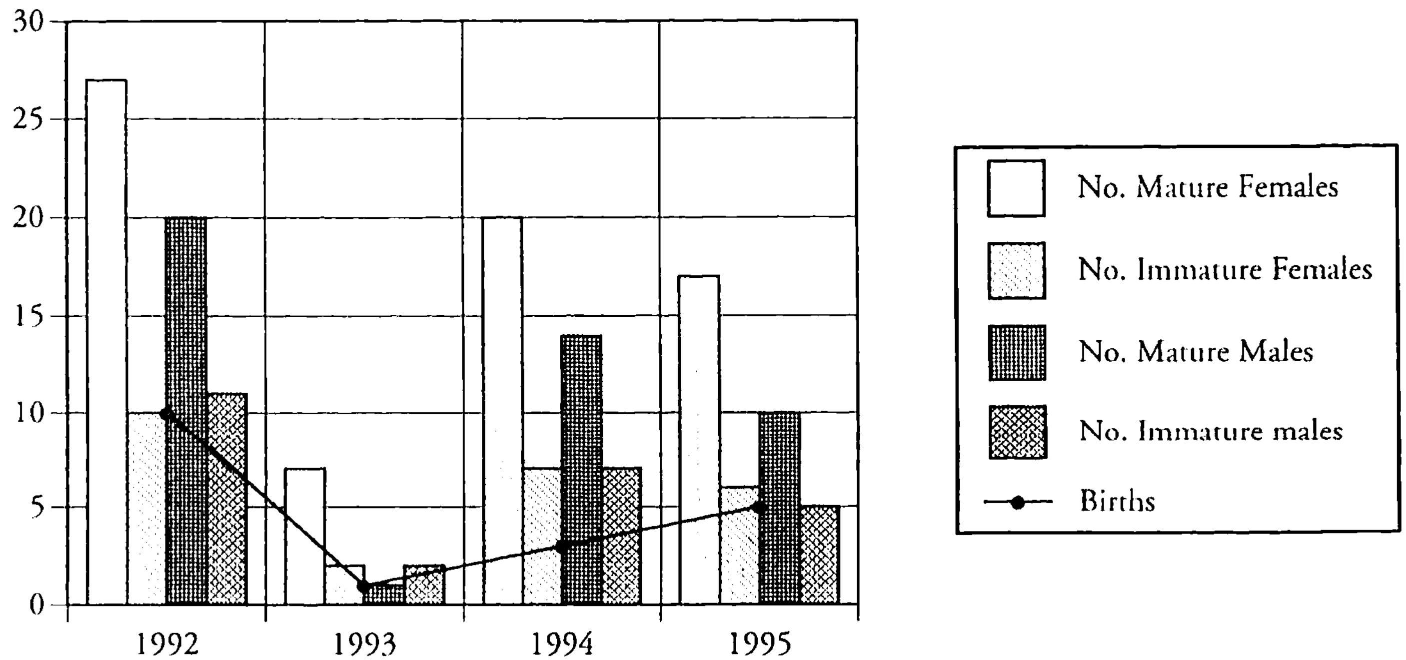


Fig. 6 Numbers of mature and immature males and females and numbers of births from 1992-95 in the Sinamatella IPZ.

	1992	1993	1994	1995	
no. of adult black rhino recorded	58	11	41	33	
no. of calves born	10	1	3	5	
% birth rate	17.24	9.09	7.32	15.15	
no. of known natural mortalities	2	0	1	0	
% annual rate of increase	13.79	9.09	4.87	15.15	
% mean annual birth rate 1992-5					13.29
% mean annual rate of increase 1992-5					11.18

Table 2. Total number of black rhino recorded in the Sinamatella IPZ, number of calves known to be born, number of natural mortalities known, % mean annual birth rate and % mean annual rate of increase from 1992-95.

3.1.3 Number of births per mature female 1992-5

Table 3 shows the number of calves born per mature female per annum for the years 1992-5 and the mean over that period. The figure of 0.27 mean births per mature female per annum indicates that out of every 100 mature females in the population, an estimated 27 would be expected to give birth each year. This is a more accurate indicator of reproductive performance than population growth, which does not take into account sex ratio or the reproductive state of all the females (i.e. ratio of mature/immature) in the population.

3.1.4 Age at maturity of females

There were only two occasions on which it was possible to get a reliable estimate of the age at which a female first produced a calf. On both occasions, these females were still with their mother when first identified. One female was aged at 42 months on 28/08/92 and was observed with her calf on 02/08/95. If the ageing of both the mother and calf(carried out by the staff of the Veterinary Unit of DNPWLM) is assumed to be correct, then allowing for a gestation period of 15 months, that female conceived when she was 63 months old. The second female was also identified as being approximately 42 months old and its estimated age of first conception was 60 months. In both cases the animals were aged as sub-adults whilst still with the dam, and estimating the age of a sub-adult is acknowledged to be difficult, especially in a dehorned population. Nevertheless, it is likely that these estimated ages of conception are accurate to ± 6 months.

3.1.5 Inter-calving intervals for females in the Sinamatella IPZ 1992-5

Inter-calving interval is a demographic feature which is an indicator of the rate at which the population is growing. Generally the lower the figure the faster the population growth. Table 4 shows the inter-calving interval in months between births for those animals for whom reliable calving dates were available in the Sinamatella IPZ. The black rhino has a gestation period of approx. 15 months. The mean intercalving interval recorded was 42.5 ± 6.64 months, ranging from a minimum of 21 months to a maximum of 80.

3.1.6 Projected growth rate and times to reach estimated "carrying capacity" of the black rhino population in the IPZ

	1992	1993	1994	1995	
No. of mature females recorded	27	7	20	17	
No. of calves born	10	1	3	5	
No. of births per mature female per annum	0.37	0.14	0.15	0.29	
Mean births per mature female per annum (1992-95)					0.27

Table 3. Numbers of mature females recorded, numbers of calves born and the number of births per mature female from 1992-95.

Calving Interval (months) (n=9)
48
64
80
25
24
21
38
33
50
mean=42.56 ± 6.64

Table 4. Inter-calving intervals identified in the Sinamatella IPZ from nine females 1992-96

Table 5 shows the projected growth of the population based on different estimated rates of annual increase. The examples taken are based on the current mean annual rate of increase in the Sinamatella IPZ (11.2%) and the maximum annual rate of increase recorded during this period (15.2%). Lower rates of 5% and 7.5% are included as being more representative of other populations in Southern Africa (Adcock, 1996). If the current mean rate of growth is maintained, it is estimated that the population will be 114 animals in 5 years. The rates are calculated on the exponential model.

Fig. 7 shows projected estimates of population increase of black rhino based on different rates of annual increase in the Sinamatella IPZ. Projections are again calculated using the exponential model.

Table 6 shows the projected number of years for the black rhino population in the Sinamatella IPZ to reach the "carrying capacity" of 150 (at a density of 1 rhino per 10 km^2) and "carrying capacity" of 450 (at a density of 3 rhino per 10 km^2). Density estimates for black rhino were taken from du Toit (1994). This table shows that if the current rate of population increase is maintained, it will take approximately 7.5 years for the lower "carrying capacity" estimate to be reached, and 18 years for the upper limit to be reached. These projections are based on the exponential model of population growth given that there is no physical boundary to the IPZ and suitable black rhino habitat adjoins the IPZ for expansion of the population. The exponential model predicts population growth assuming constant maximum growth rate. The logistic model makes allowance for reduction of population growth as carrying capacity is approached. In the case of the Sinamatella IPZ, because there is no physical boundary the population growth is not likely to decrease as "carrying capacity" for the IPZ is reached, since the population can instead expand into outlying areas. For this reason the exponential model has been used in the calculations below.

Fig. 8 shows graphically the annual rate of increase against years to reach the two different estimates of "carrying capacity".

3.1.7 Seasonality of calving in the IPZ 1992-5

Fig. 9 shows the distribution of births of black rhino calves by month in the Sinamatella IPZ. From January 1992 to September 1996, a total of 23 calves were known to have been born in the IPZ. Since the sample size was limited, it is difficult to draw any conclusions about trends

% Annual Rate of Increase	5 Years	10 Years	15 Years	20 Years
5	83	107	138	177
7.5	95	138	200	291
10	107	177	291	480
11.2	114	199	349	610
15.2	139	297	635	1359

Table 5. Projected growth of the black rhino population based on different annual rates of increase in the Sinamatella IPZ.

% mean annual rate of increase in Sinamatella IPZ from 1992-5 = 11.2% and maximum annual rate of increase recorded in this period = 15.2%. Other rates are used for comparison. Analysis based on 65 animals in the Sinamatella IPZ at the end of 1996 and projections based on the exponential model.

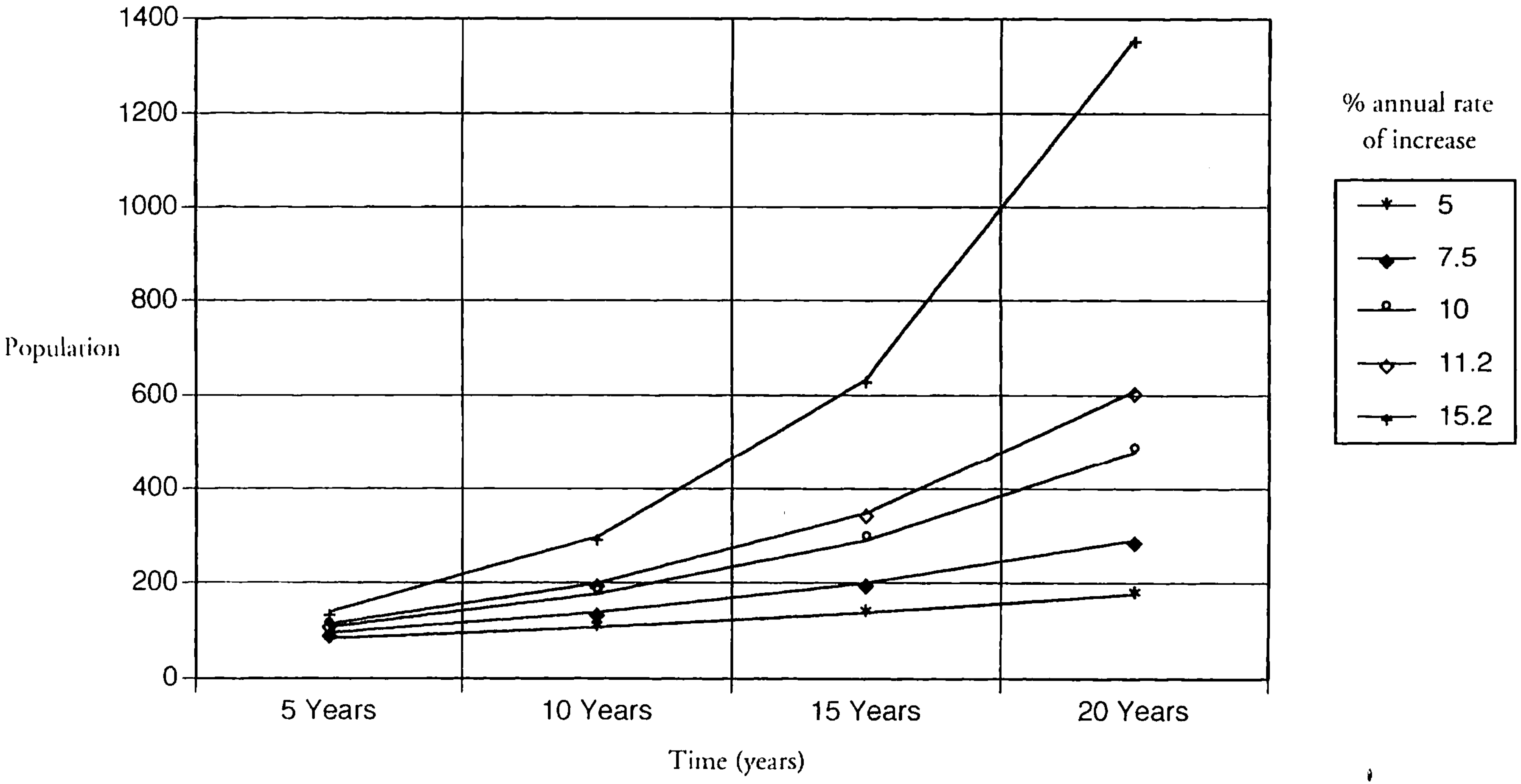


Fig. 7. Projected estimates of population increase of black rhino based on different rates of annual increase in the Sinamatella IPZ.

Projections calculated using the exponential model. Mean annual rate of increase for the Sinamatella population from 1992-5 = 11.2%. Analysis based on 65 animals at the end of 1996 and projections based on the exponential model.

% Annual Rate of Increase	No. of years to reach 150	No. of years to reach 450
5	16.7	38.7
7.5	11.2	25.8
10	8.36	19.34
11.2	7.5	17.3
15.2	5.5	12.7

Table 6. Projected number of years for the black rhino population in the Sinamatella IPZ to reach the carrying capacity of 150 (density of rhinos at $1/10\ km^2$) and carrying capacity of 450 (density of rhinos at $3/10\ km^2$).

Density estimates for black rhino from du Toit (1994). % mean annual rate of increase in Sinamatella IPZ from 1992-5 = 11.2% and maximum annual rate of increase = 15.2%

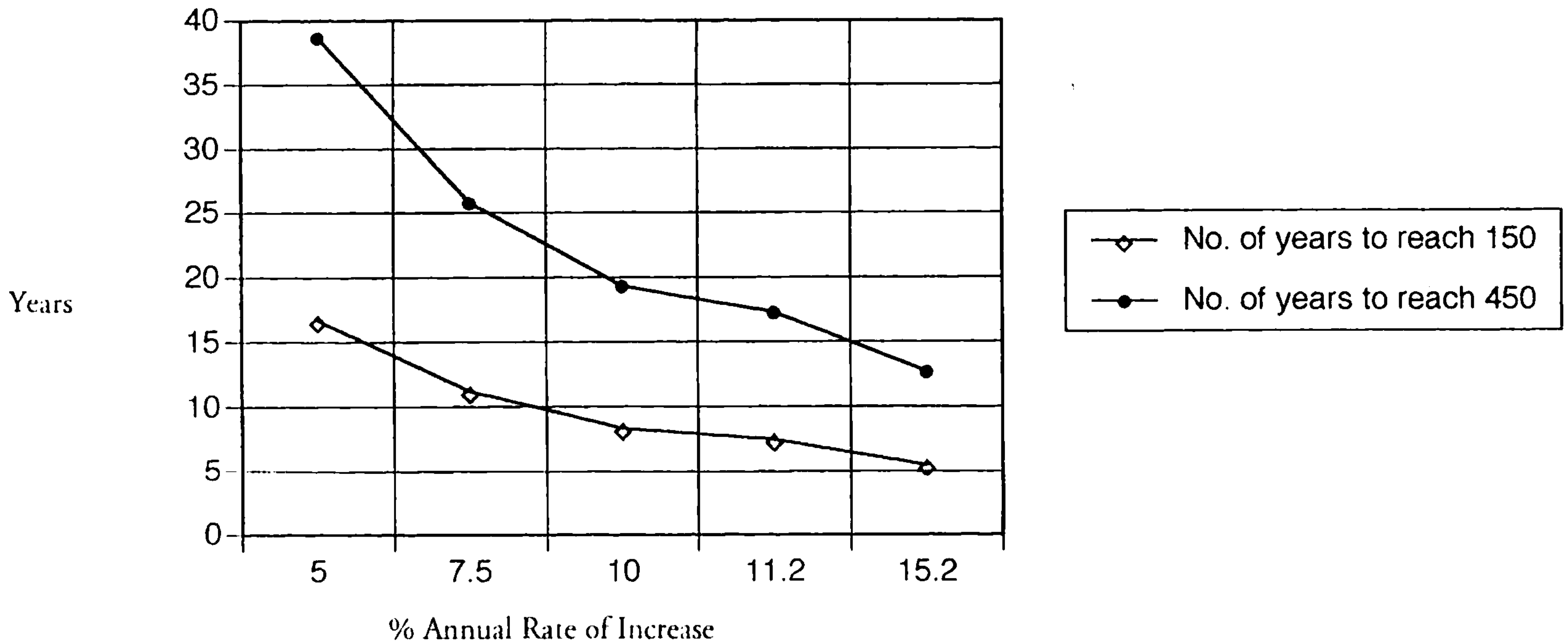


Fig. 8 Projected number of years for the black rhino population in the Sinamatella IPZ to reach the "carrying capacity" of 150 (density of rhinos at 1/10 km^2) and carrying capacity of 450 (density of rhinos at 3/10 km^2).

Density estimates for black rhino from du Toit (1994).

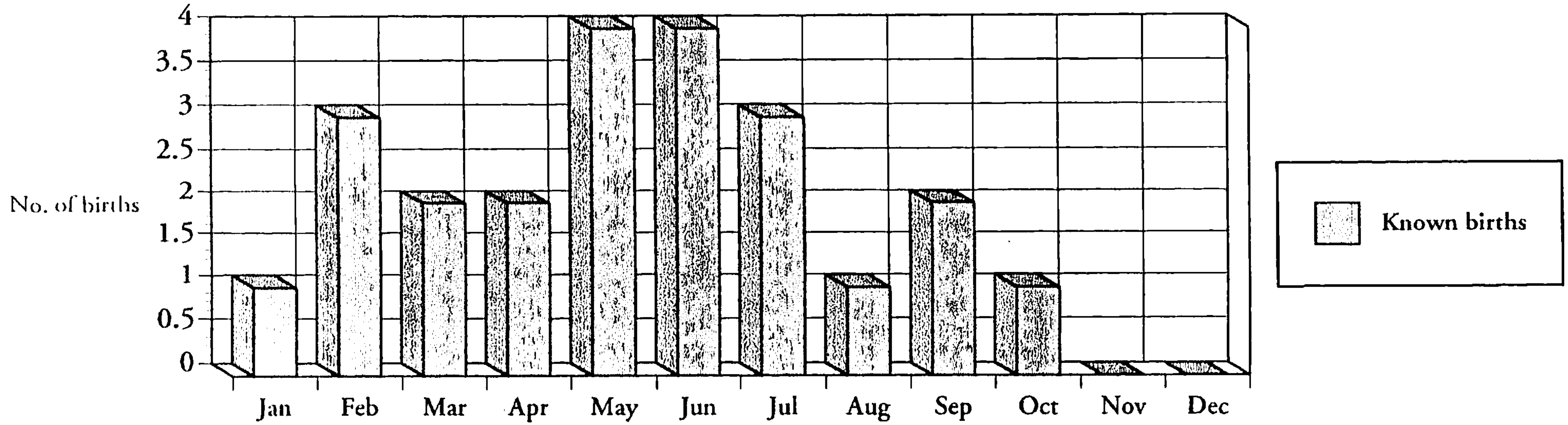


Fig. 9 Number of known births per month in the Sinamatella IPZ from January 1992 -September 1996 (n = 23).

but as Fig. 10 shows, there were more births in the dry season (May - October inclusive) compared with the wet seasons (November - April inclusive). However, this difference was not statistically significant ($\sum$ chisquare = 2.35, df = 1, $p > 0.05$).

3.2 CARCASS RECOVERY IN THE SINAMATELLA IPZ 1994-6

The locstats for all rhino carcasses found in the IPZ were recorded before the carcasses were brought back to Sinamatella. The carcasses were located by scouts of DNPWLM on regular patrols and/or by Rhinowatch teams.

Fig. 11 shows the distribution of recovered carcasses in the Sinamatella IPZ since it was established in September 1993. The dates of recovery of the carcasses are indicated. Thirty carcasses were recovered between September 1993 and end of 1994, 28 from January - December 1995 and 13 from January - September 1996 giving a total of 71 carcasses.

Fig. 12 shows the carcass recovery by Rhinowatch and the DNPWLM separately from July 1994 to September 1996. RW recovery accounted for 13.5% of total recovery from July 94 to December 94 (6/19), 18.5% in 1995 (5/27) and 54% from 01-01-96 to 30-09-96 (7/13) respectively.

Fig. 13 shows the number of recovered carcasses of animals poached between 1992 and 1995 in the Sinamatella IPZ. This figure suggests that there has been a complete cessation of poaching activity in the Sinamatella IPZ since the formation of the IPZ. However, because the carcass recovery rate has been estimated at 56 % it is possible that 44% of carcasses have still not been found. As 10 carcasses have been recovered from animals poached during this period, the true number of animals poached is probably nearer 18. Similarly, the total number of carcasses recovered to date from animals poached in all years is 71, which represents 56% recovery. The total number poached over the last decade in the IPZ is estimated to be at least 122.

3.3 REVISED POPULATION ESTIMATE FOR THE BLACK RHINO IN THE SINAMATELLA IPZ, 1996

Table 7 shows the population estimates for Sinamatella from 1992 to the end of September

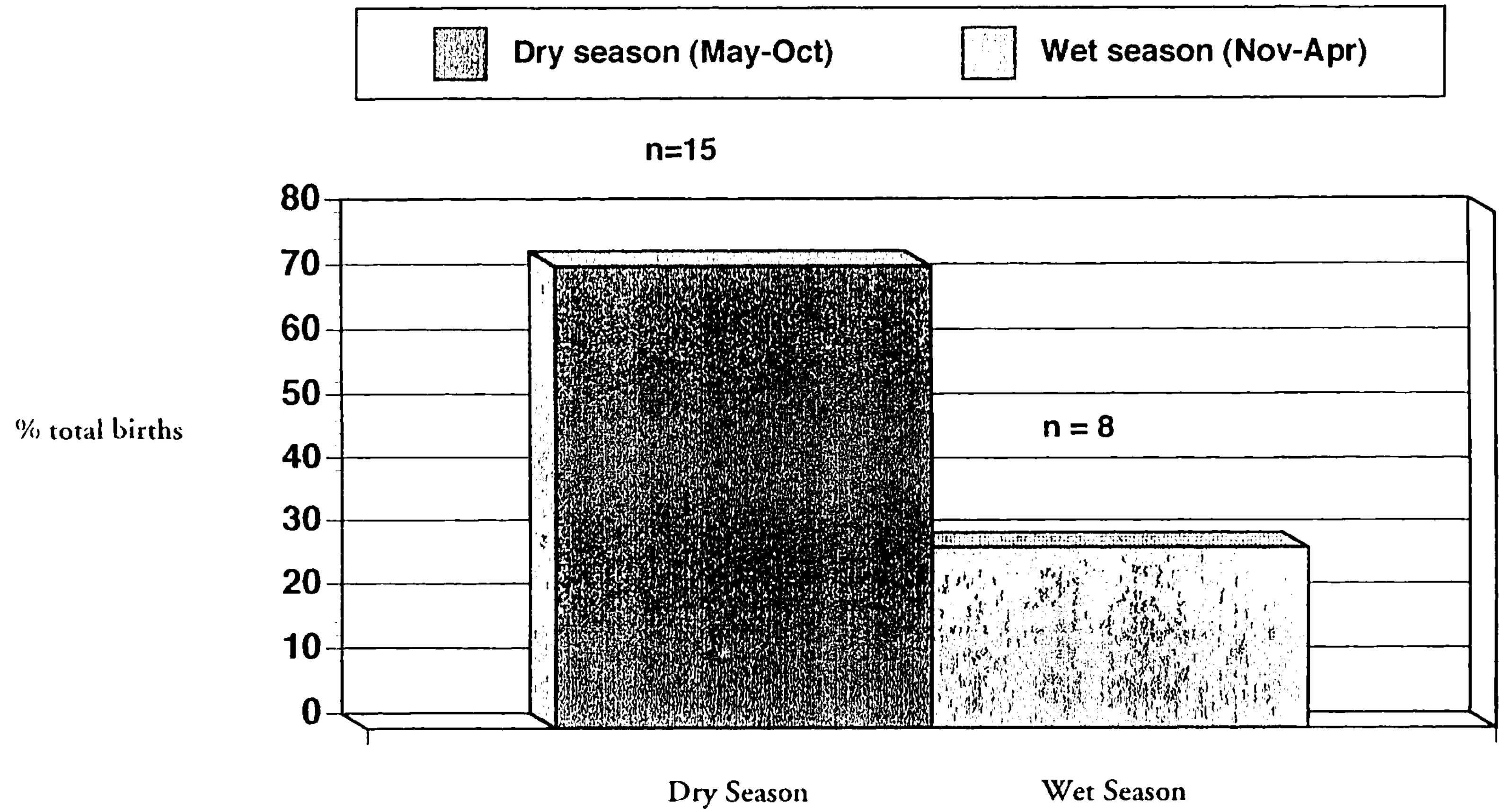


Fig. 10. % of known births in dry and wet seasons in the Sinamatella IPZ from January 1992 - September1996

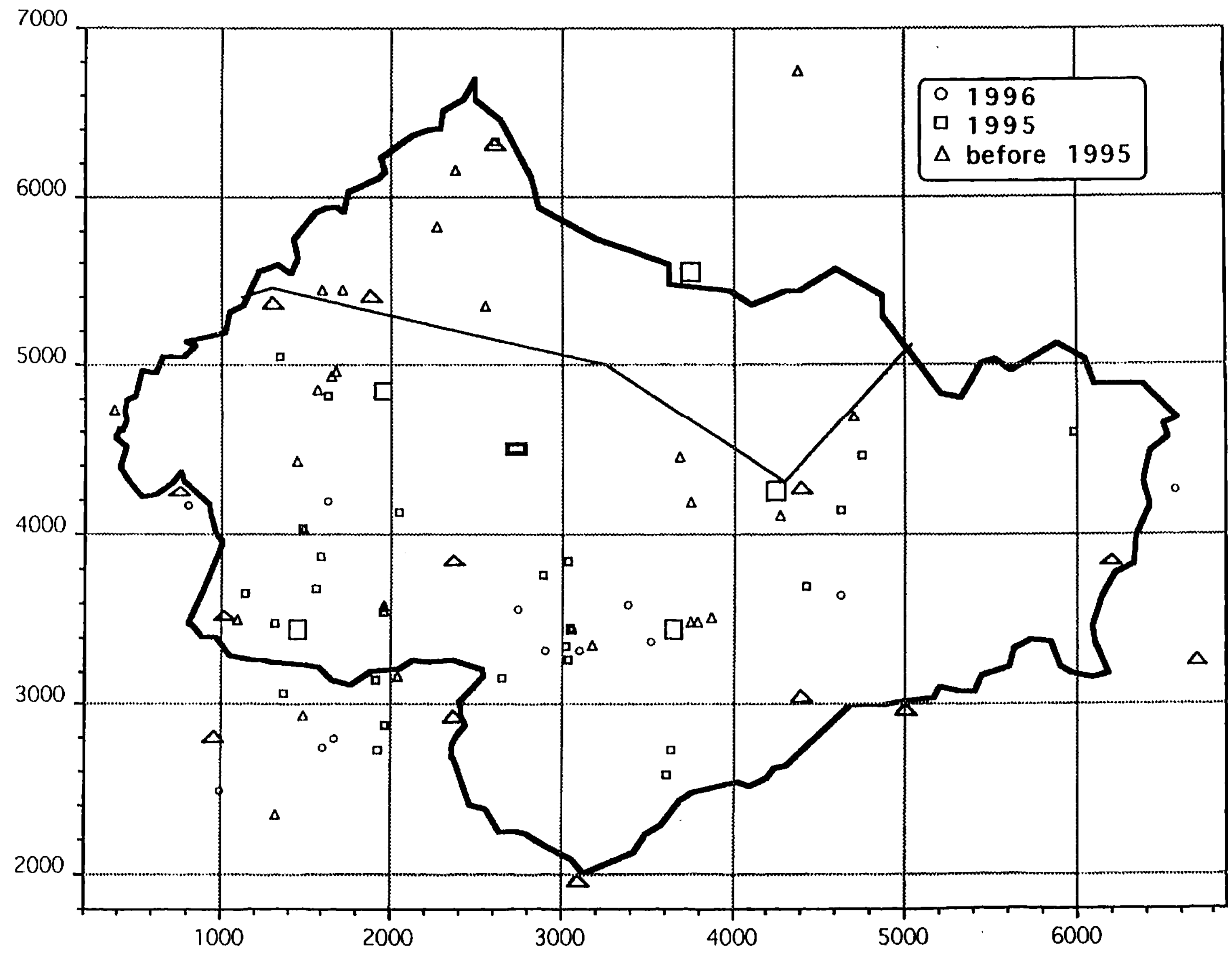


Fig. 11 Carcass recovery in the Sinamatella IPZ by date (to 2-10-96 , n=71)

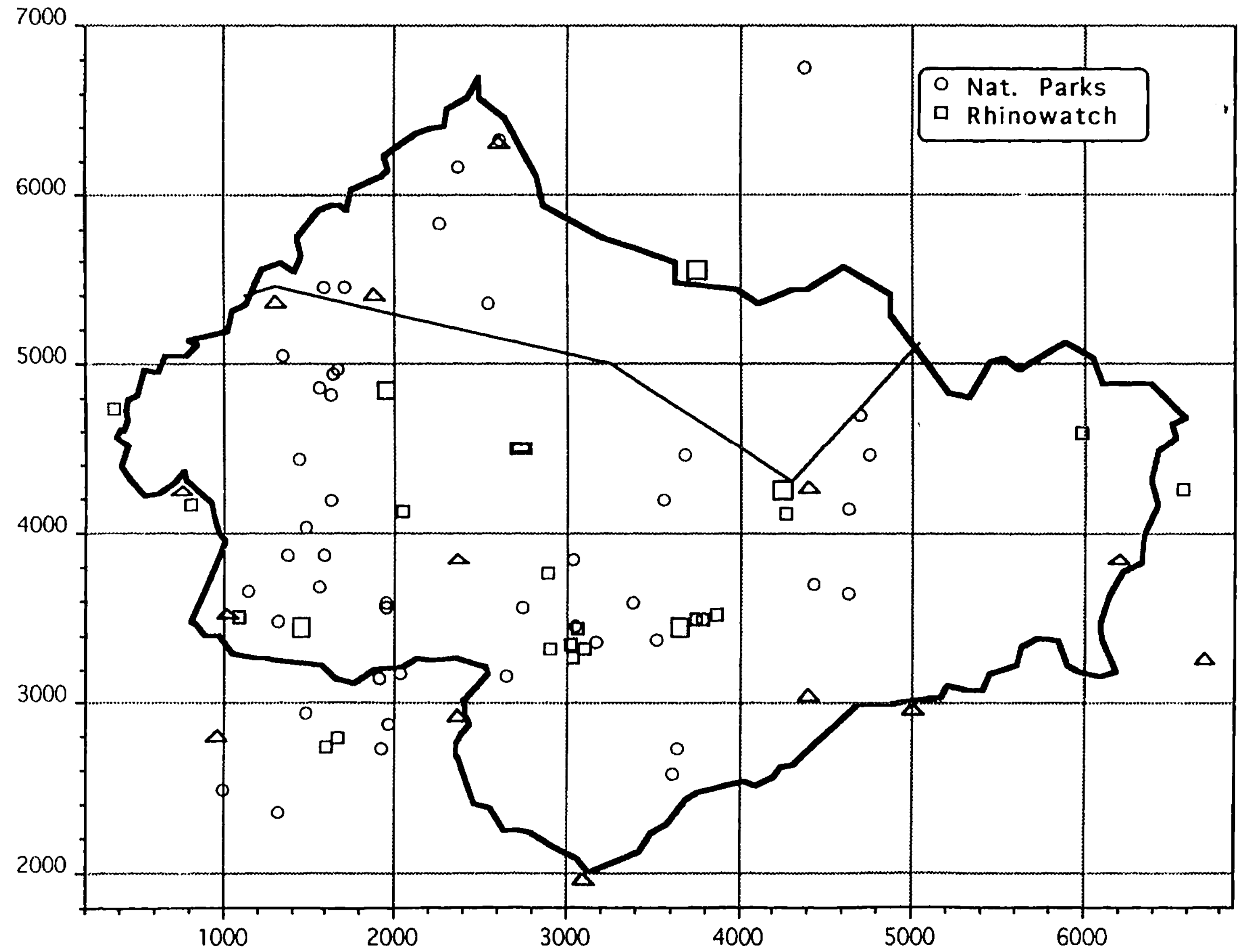


Fig. 12 Recovery of carcasses by DNPWLM and Rhinowatch July 94 - Sept. 96

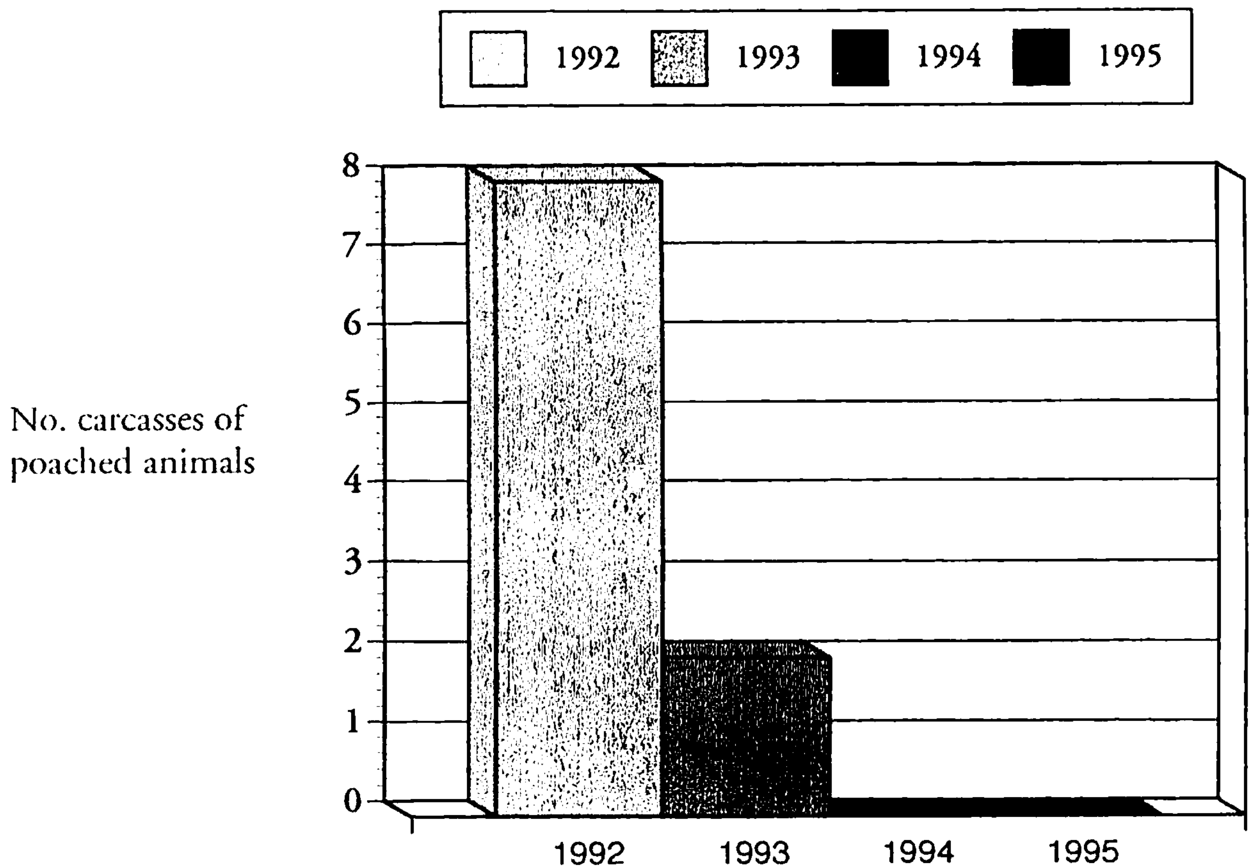


Figure 13. No. of recovered carcasses of animals poached between 1992-95 in the Sinamatella IPZ.

POPULATION STATISTICS	NUMBER
Total number of animals identified in IPZ 1992-4	77
Known mortalities 1992-4	4
Number of carcasses found from animals poached 1992-4	10
Rhinowatch ground census estimate 1994	55
Estimated recovery rate of carcasses from above (%)	56
Number of calves born 1995	5
Known mortalities 1995	0
Population estimate for Sinamatella IPZ at end of 1995	60
Number of calves born 1996 to 1-10-96	4
Known mortalities 1996 to 1-10-96	2
Population estimate for Sinamatella IPZ 1-10-96	62

TABLE 7. Population estimates of black rhino in the Sinamatella IPZ 1992-6 and estimated carcass recovery rates 1992-5.

1996. From 1992 - 1994, the Veterinary Unit of DNPWLM and Rhinowatch teams identified 77 individual black rhinos in the Sinamatella IPZ. Four of these animals are known to have died over this period and 10 carcasses of animals poached over this period were recovered. From July - November 1994, Rhinowatch carried out a ground census and estimated that the black rhino population in the Sinamatella IPZ was 55 (Alibhai *et al*, 1995). Hence at the end of this period, eight animals were still unaccounted for. Based on this, it was calculated that the carcass recovery rate was 56% (i.e. 10/18 carcasses recovered). Five calves were identified in 1995 and with no known mortalities, the population was estimated to be 60 at the end of 1995. From January - September 1996, four calves were identified but two of these have been lost, possibly to predation. There were no other known mortalities in that period so the population estimate to September 1996 was 62.

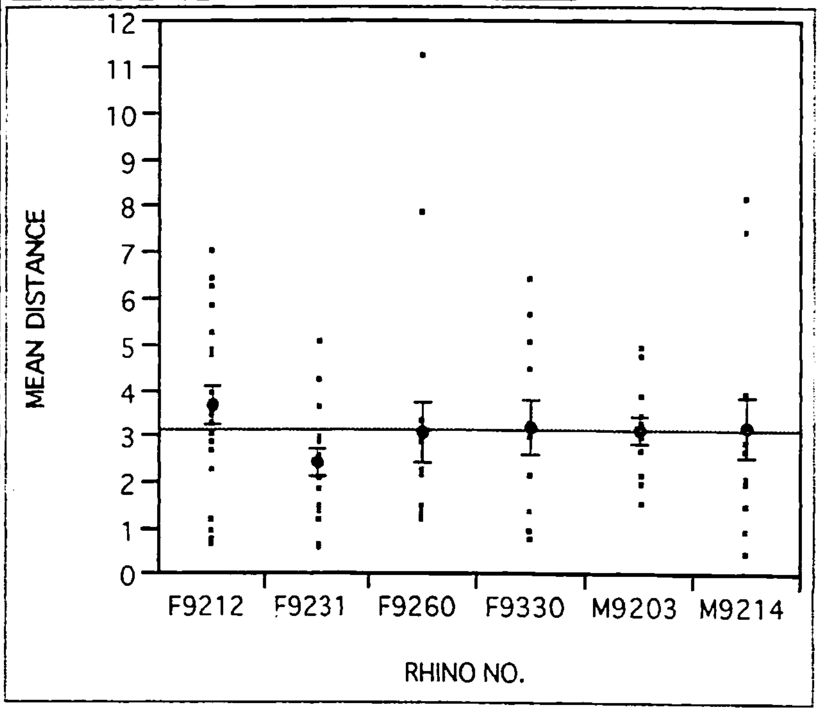
3.4 ESTIMATE OF POSITION USING THE TRIANGULATION TECHNIQUE

Since it was not possible to get a visual on a rhino during each tracking session, the method of triangulation was employed to give an estimate of the position for radio-collared animals. However, since the accuracy of the estimation might be affected by a number of variables, the significance of the variables was tested.

3.4.1. Differences between individual rhino in accuracy of estimated position

In order to eliminate the possible differences due to different rhinos i.e. whether some individuals were more difficult to track because of the terrain, or whether some radio-collars gave a better signal etc., an analysis was carried out to test to see if there were any significant differences between individuals. Fig. 14 shows the means of bearing distances for six rhinos for whom sufficient data was available. There was no significant difference between them i.e. all six rhinos were located from similar triangulated distances. Fig. 15 shows the means of differences between observed and estimated locations (O - E) of six rhinos for whom sufficient data was available. There was no significant difference between them i.e. the level of accuracy, measured in terms of the difference between observed and estimated distances, did not appear to be different for the six animals.

MEAN DISTANCE By RHINO NO.



Oneway Anova

Summary of Fit

RSquare	0.039662
RSquare Adj	-0.02112
Root Mean Square Error	2.034248
Mean of Response	3.129412
Observations (or Sum Wgts)	85

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	13.50154	2.70031	0.6525
Error	79	326.91493	4.13816	Prob>F
C Total	84	340.41647		0.6604

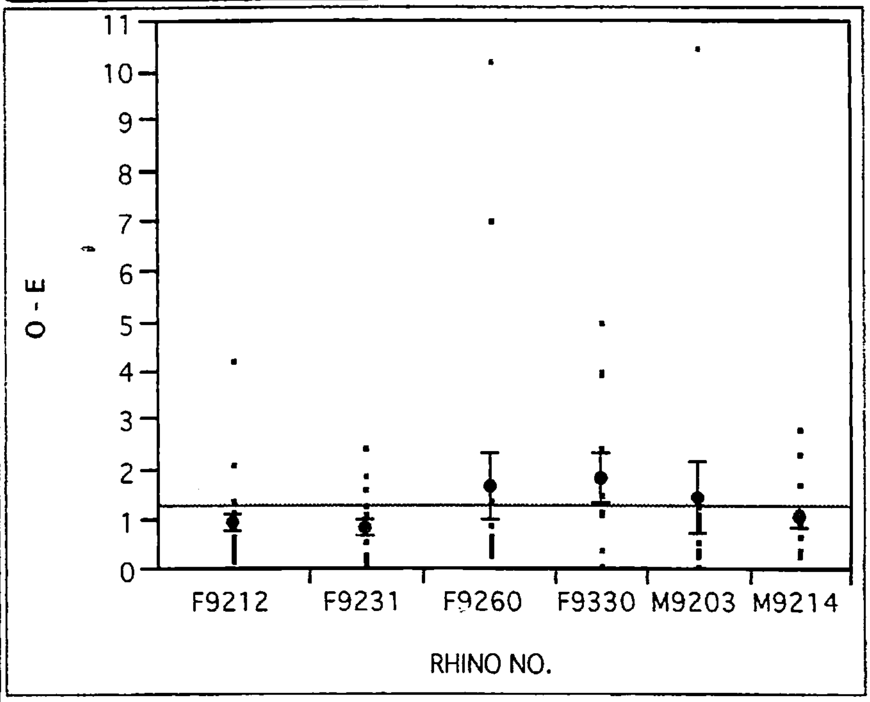
Means for Oneway Anova

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
F9212	19	3.67895	1.99181	0.45695
F9231	14	2.39286	1.32924	0.35525
F9260	16	3.05000	2.75148	0.68787
F9330	11	3.17273	2.01400	0.60724
M9203	13	3.12308	1.09328	0.30322
M9214	12	3.19167	2.41339	0.69669

Fig. 14. The means of bearing distances for six rhinos (pairwise comparison for all means NS).

O - E By RHINO NO.



Oneway Anova

Summary of Fit

RSquare	0.039531
RSquare Adj	-0.02126
Root Mean Square Error	1.836339
Mean of Response	1.282353
Observations (or Sum Wgts)	85

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	10.96437	2.19287	0.6503
Error	79	266.39916	3.37214	Prob>F
C Total	84	277.36353		0.6621

Means for Oneway Anova

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
F9212	19	0.97895	0.91929	0.21090
F9231	14	0.85714	0.74288	0.19854
F9260	16	1.67500	2.77957	0.69489
F9330	11	1.82727	1.74590	0.52641
M9203	13	1.44615	2.74609	0.76163
M9214	12	1.05833	0.80618	0.23272

Fig. 15. Means of differences between observed and estimated locations (O - E) of six rhinos (pairwise comparison for all means NS).

3.4.2. Relationship between mean of bearing distance and O - E distance.

This analysis was carried out to see if the mean bearing distance had any effect on the O - E distance. Fig. 16 shows the mean of distances of bearings from the estimated position of the rhino plotted against the difference between O - E. Althought there was a fair amount of scatter, there was a highly significant correlation. This indicates that the longer the bearing distance the less accurate the estimated position. In order to extrapolate the mean distance for an O - E value of 1 km, the correlation was examined in more detail. Fig. 17 shows that the mean distance of the bearings from the estimated position must be less than 2 km for the accuracy of the estimated position to be grade A, i.e. within 1 km of the observed position.

3.4.3. Differences between trackers.

In order to test to see if there was a significant difference between the three trackers, all O - E distances were divided into three categories: A $\leq$ 1 km, B >1 km $\leq$ 2 km and C > 2 km.
Fig. 18 shows the percentage frequency of the distances between the observed and expected positions (O - E) of the rhino as determined by triangulation as obtained by three different trackers. There was no significant difference ($\sum$ chisquare = 1.33, df = 4, $p > 0.05$).

3.5 RANGE ANALYSIS

3.5.1. Range sizes of male and female black rhinos.

Minimum convex polygon ranges were plotted for all visual locstats (ground and aerial) obtained over the entire study period (1994 - 1996). Figs. 19 to 25 show the estimated ranges of males and females in the IPZ. For convenience, the ranges have been plotted according to size category. Each map coordinate represent one visual observation for that animal. Since plots are not temporally defined, an overlap in range does not necessarily imply that the animals with spatially overlapping ranges are necessarily interacting socially.

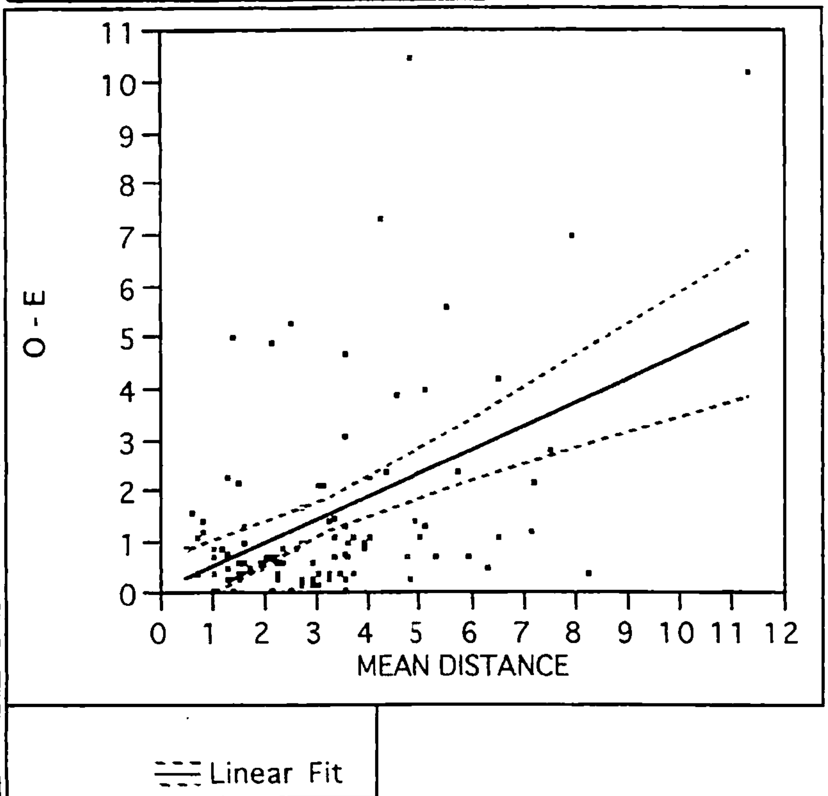
Fig. 19: Males with ranges < 50 km^2. (n=10)

Fig. 20: Males with ranges between 50 and 100 km^2. (n=3)

Fig. 21: Males with ranges between 100 and 200 km^2. (n=4)

Fig. 22: Females with ranges < 50 km^2. (n=9)

O - E By MEAN DISTANCE



Linear Fit

Summary of Fit

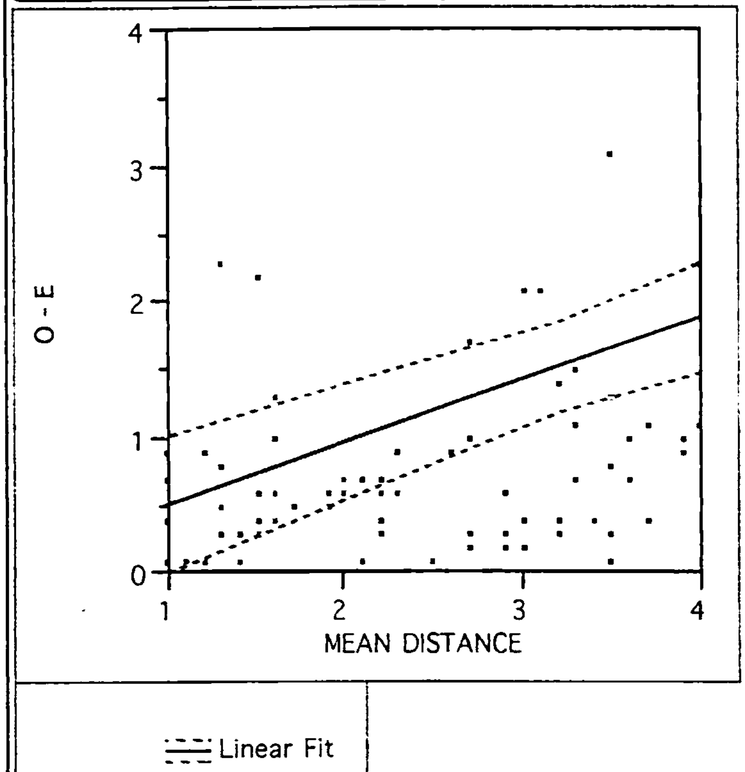
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	84.24318	84.2432	28.8767
Error	102	297.56903	2.9173	Prob>F
C Total	103	381.81221		0.0000

Parameter Estimates

Fig. 16. The mean of distances of bearings from the estimated position of rhino plotted against the difference between estimated and observed positions.

O - E By MEAN DISTANCE



Linear Fit

Summary of Fit

RSquare	0.220640
RSquare Adj	0.213000
Root Mean Square Error	1.708023
Mean of Response	1.466346
Observations (or Sum Wgts)	104

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	84.24318	84.2432	28.8767
Error	102	297.56903	2.9173	Prob>F
C Total	103	381.81221		0.0000

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0422078	0.313508	0.13	0.8932
MEAN DISTANCE	0.4621229	0.085997	5.37	0.0000

Fig. 17. The mean of distances of bearings from the estimated position of rhino plotted against the difference between estimated and observed positions (O - E). (Rescaled).

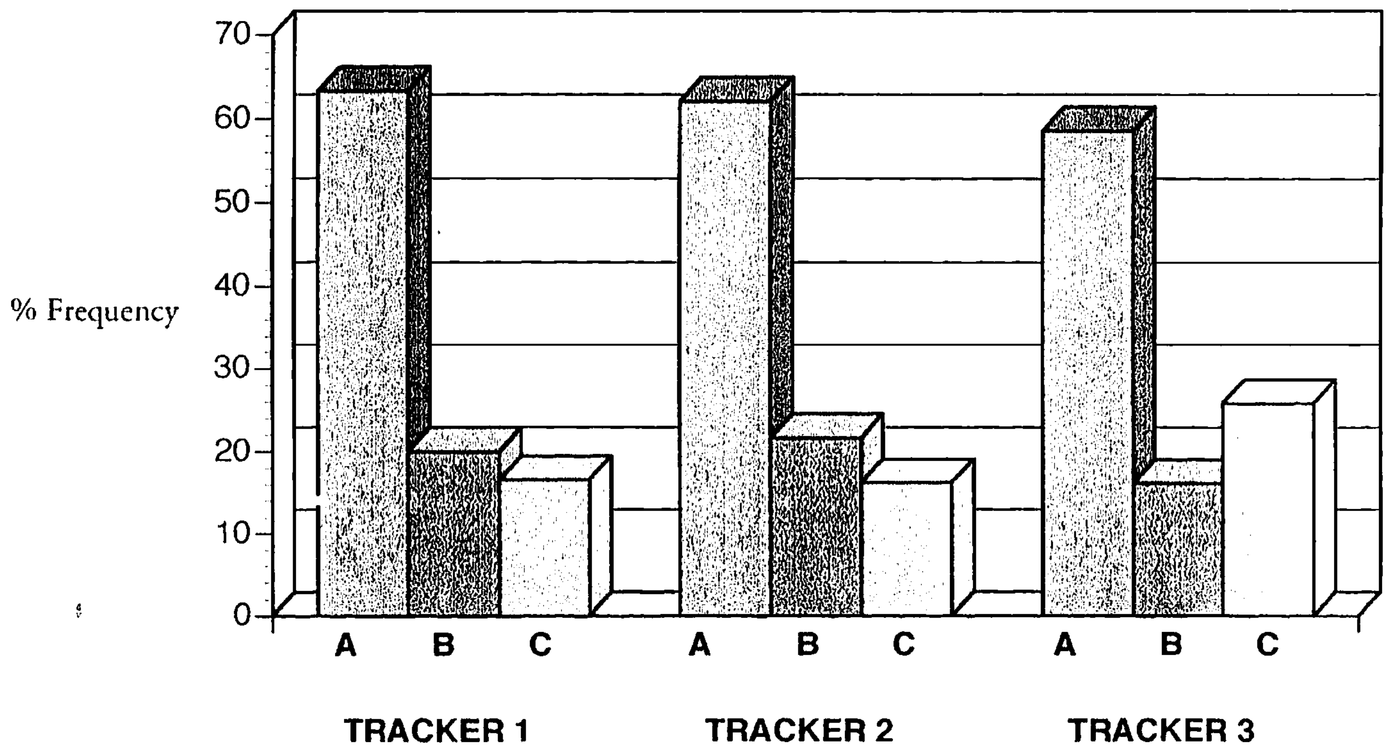


Fig. 18. Percentage frequency of the distance between the observed position of rhino and expected position as determined by triangulation as obtained by three different trackers. Category A < 1km, B 1 - 2 km and C > 2 km.

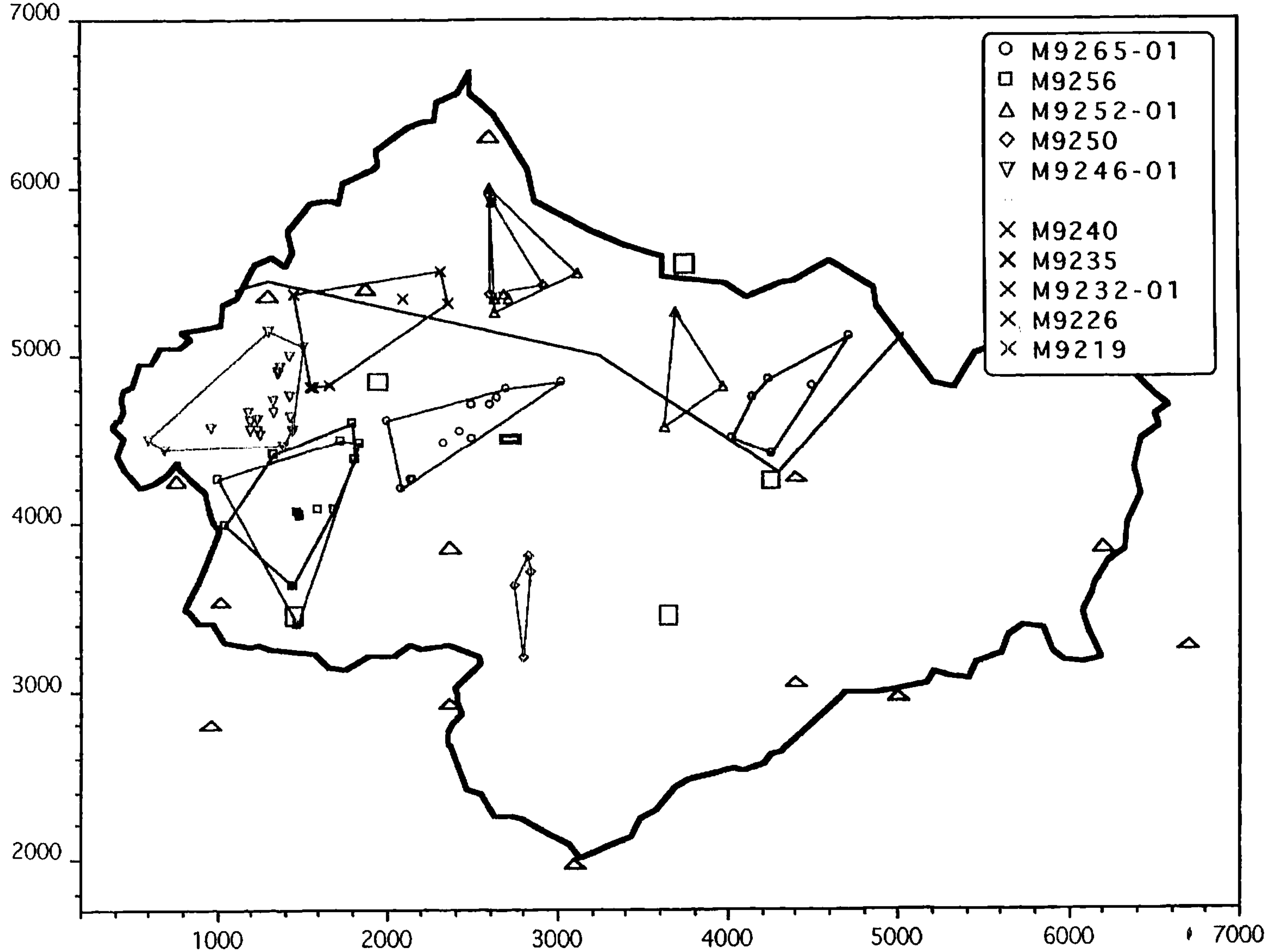


Fig. 19 Males with ranges < 50 km^2 to September 1996

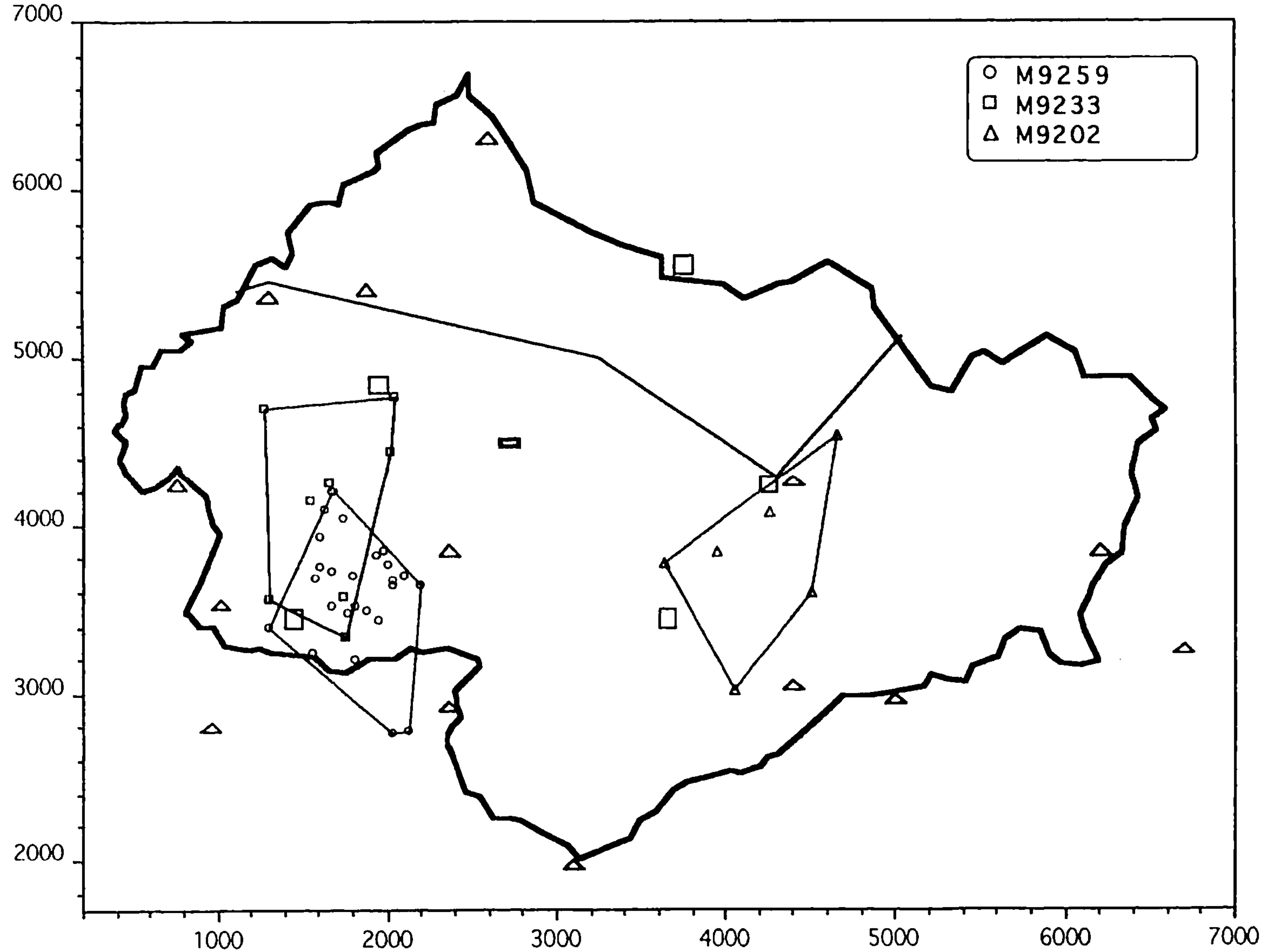


Fig. 20 Males with ranges 50-100 km² to September 1996

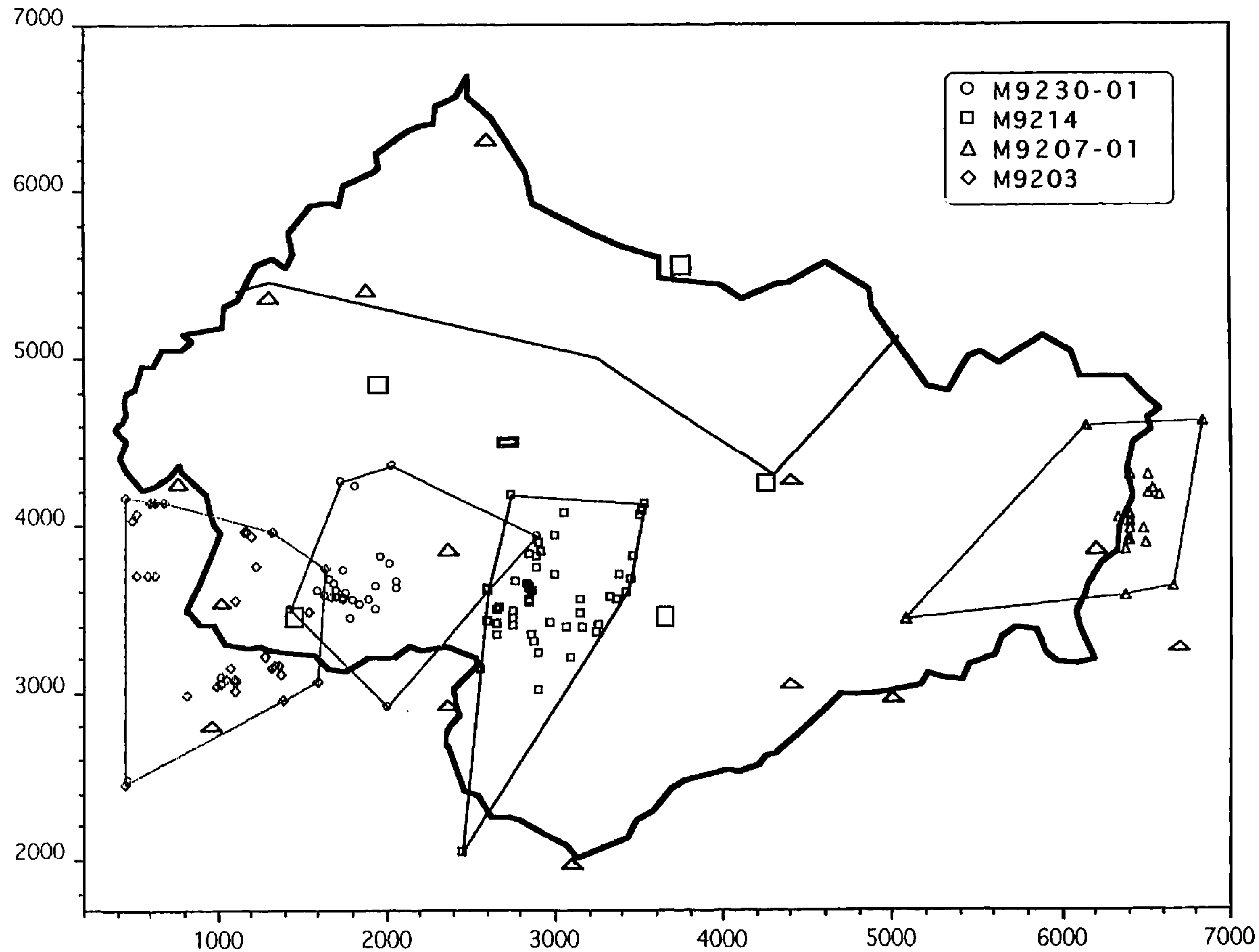


Fig. 21 Males with ranges 100-200 km² to September 1996

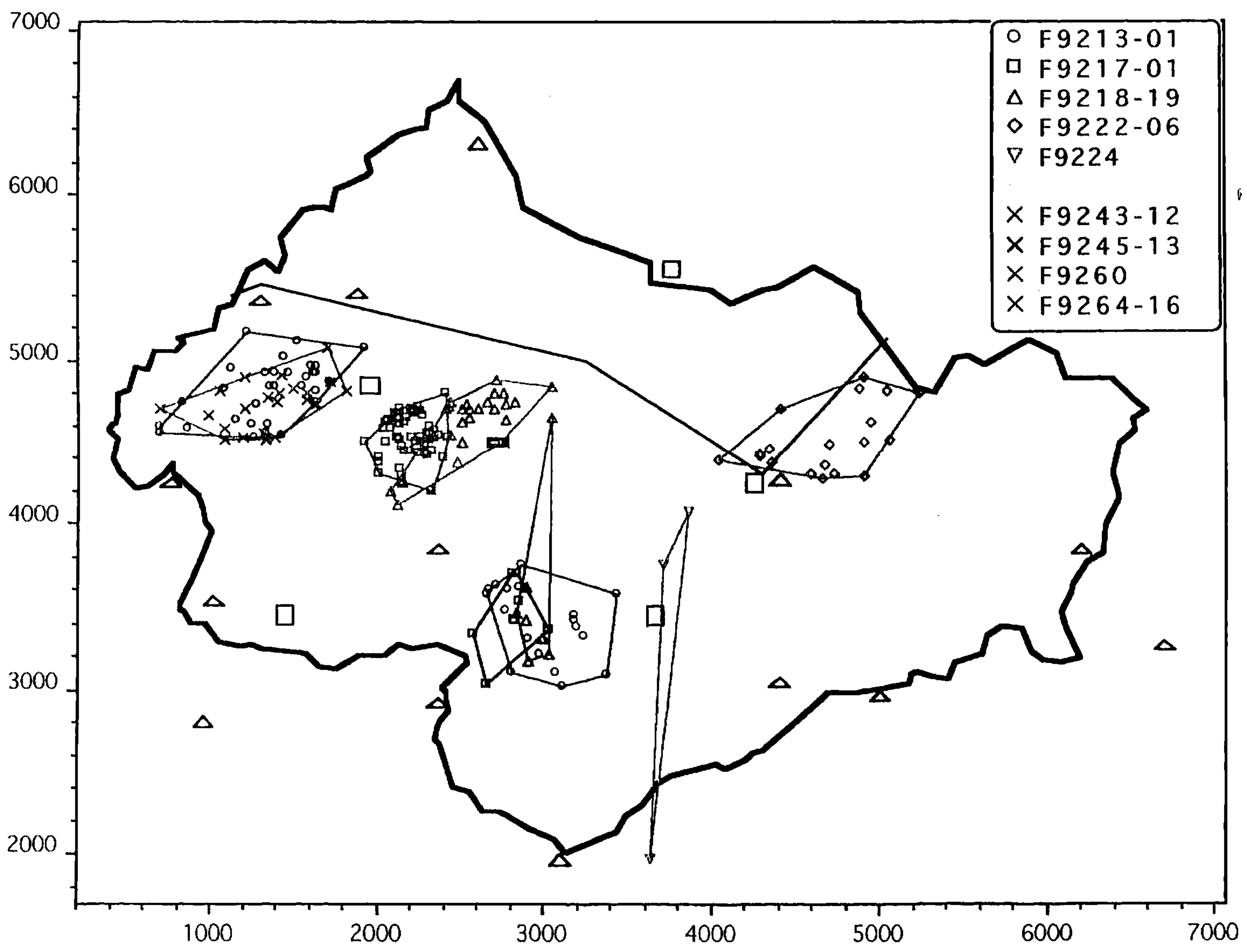


Fig. 22 Females with ranges < 50 km² to September 1996

Fig. 23: Females with ranges between 50 and 100 km^2. (n=7)

Fig. 24: Females with ranges between 100 and 200 km^2. (n=2)

Fig. 25: Females with ranges > 200 km^2. (n=4)

3.5.2. Relationship between range size and number of fixes.

Table 8 shows range sizes and number of fixes for all males in descending order of range size. Table 9 shows range sizes and number of fixes for all females in descending order of range size.

As can be seen from Tables 8 & 9, to some extent, range size appears to be dependent on the number of fixes as would be expected. For some of the animals it was quite obvious that the number of fixes was too few to allow an accurate estimate of range size. To test the relationship between range size and number of fixes, two different forms of analysis were attempted.

Firstly, in Fig. 26 , the % cumulative range was plotted against the number of fixes for 11 rhinos which had a minimum of 30 fixes. The analysis was based on the first 30 fixes for animals with > 30 fixes. The figure of 30 was chosen because looking at the relationship between cumulative % range size and number of fixes, for most animals examined, over 90% of the range had been accounted for by the time 30 fixes had been obtained. An attempt was made to discern a plateau effect as maximum range was reached. As Fig. 26 shows, the curve begins to level out at 20 fixes for the 11 animals tested.

Table 10 shows the number of fixes and the percentage increase in range size for 11 rhinos (SE - standard error of mean, CV-coefficient of variation). Only individuals with a minumum number of 30 fixes were included and for individuals with > 30 fixes only the first 30 fixes were used for calculating the percentage change in range size.

Secondly, a slightly different form of analysis was carried out to determine if there was a levelling effect. Fig. 27 shows the coefficient of variation (CV) for the cumulative change in range size plotted against the number of fixes for 11 rhinos. The curve shows that the greatest variation occurs with few fixes and of course, at the other end, the least amount of variation occurs when the maximum range size has been reached. However, the point of the analysis was to determine once again if there was a levelling effect. As fig. 27 shows, there appears to be a marked deviation at the 20 fixes stage i.e. this is the point at which the amount of variation within the cumulative range size narrows considerably.

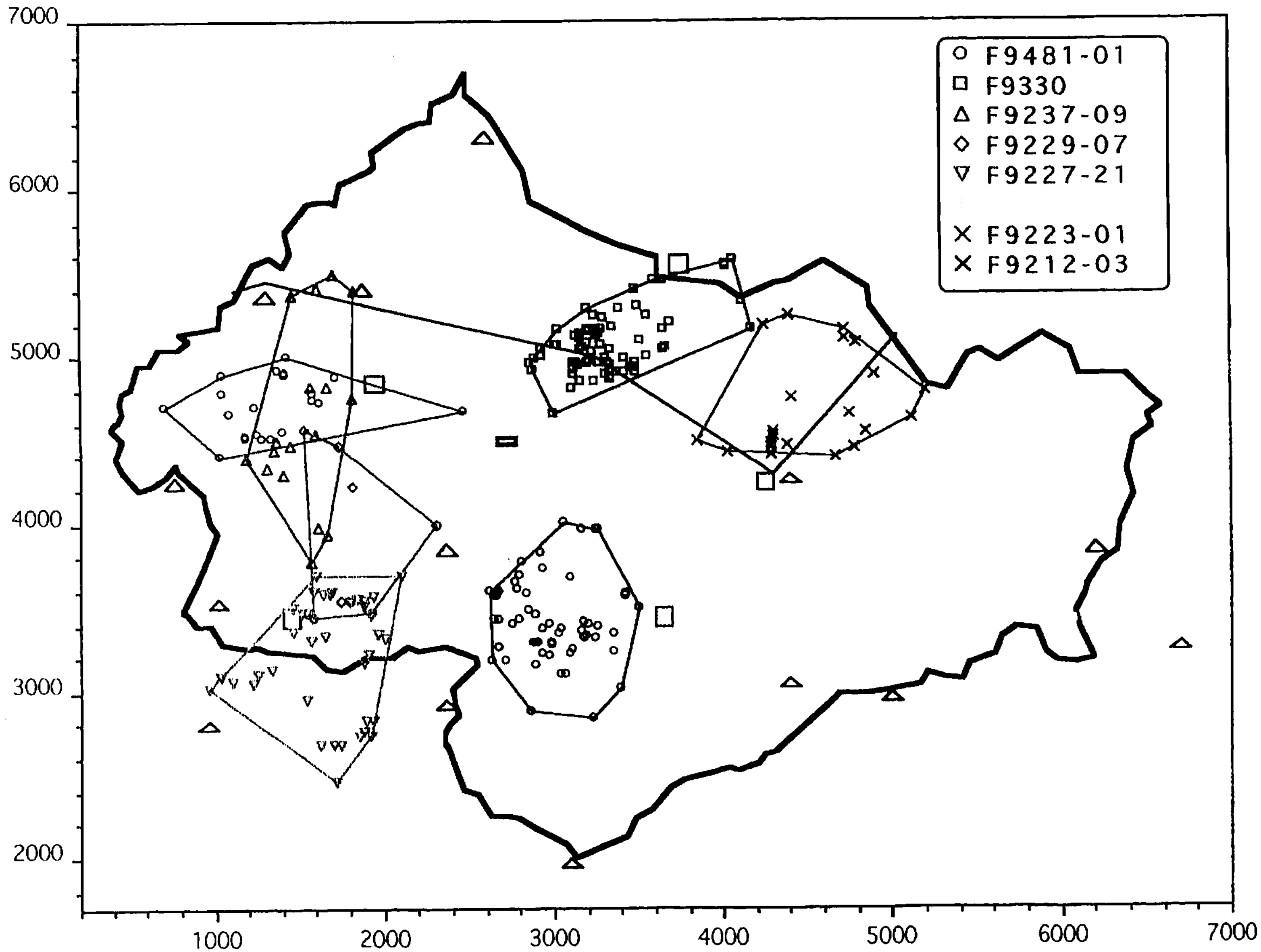


Fig. 23 Females with ranges 50-100 km2 to September 1996

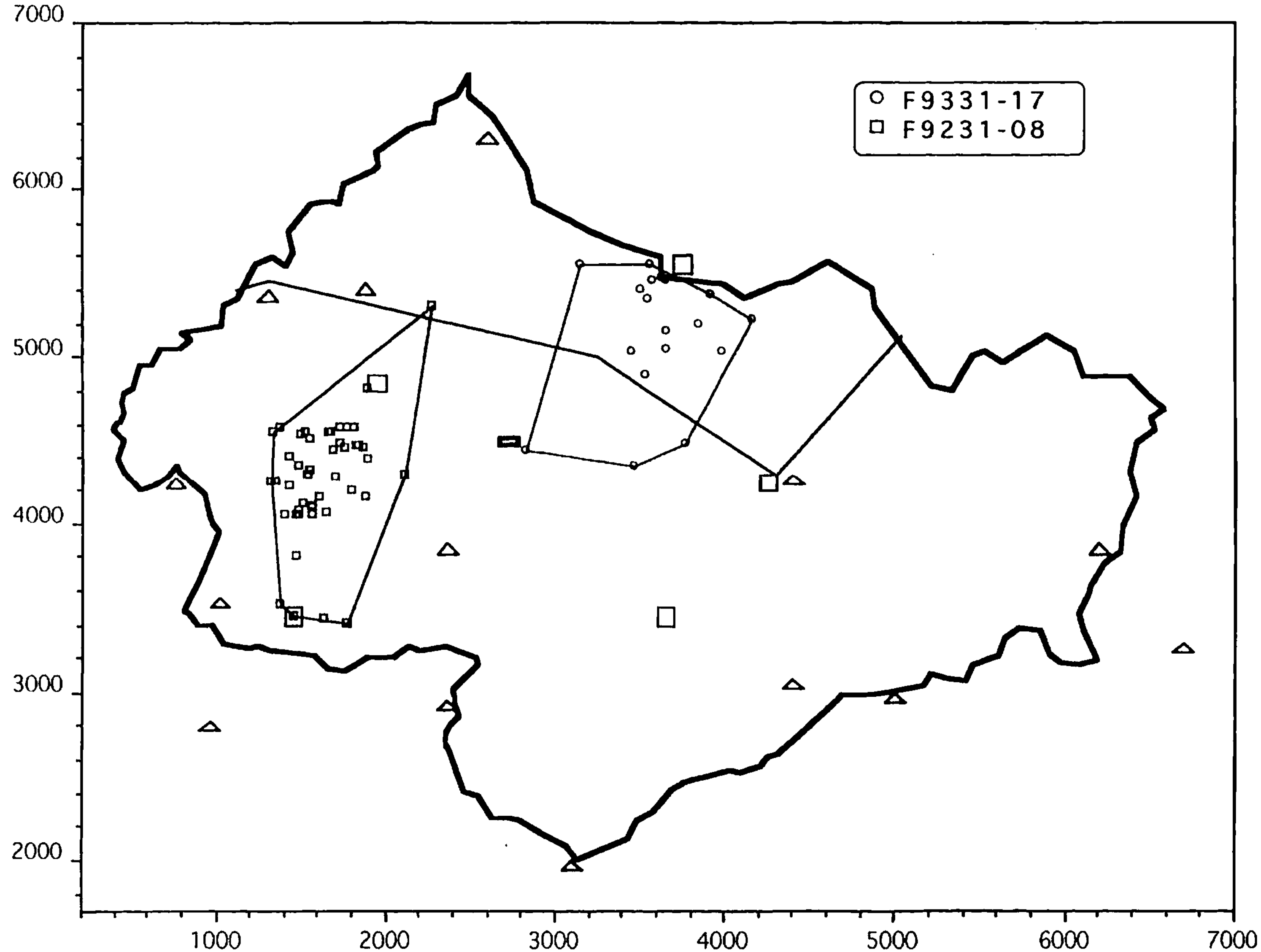


Fig. 24 Females with ranges 100-200 km² to September 1996

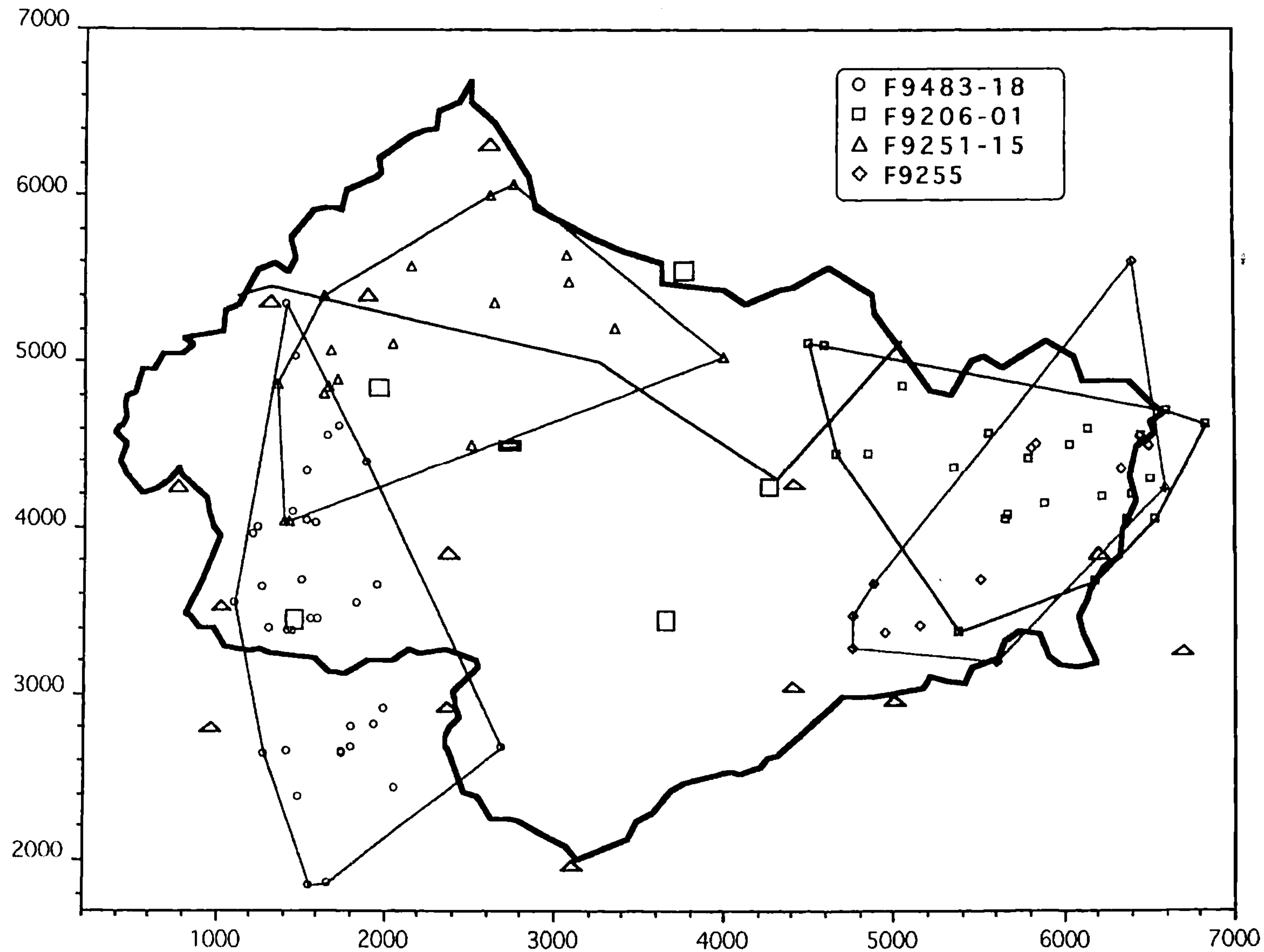


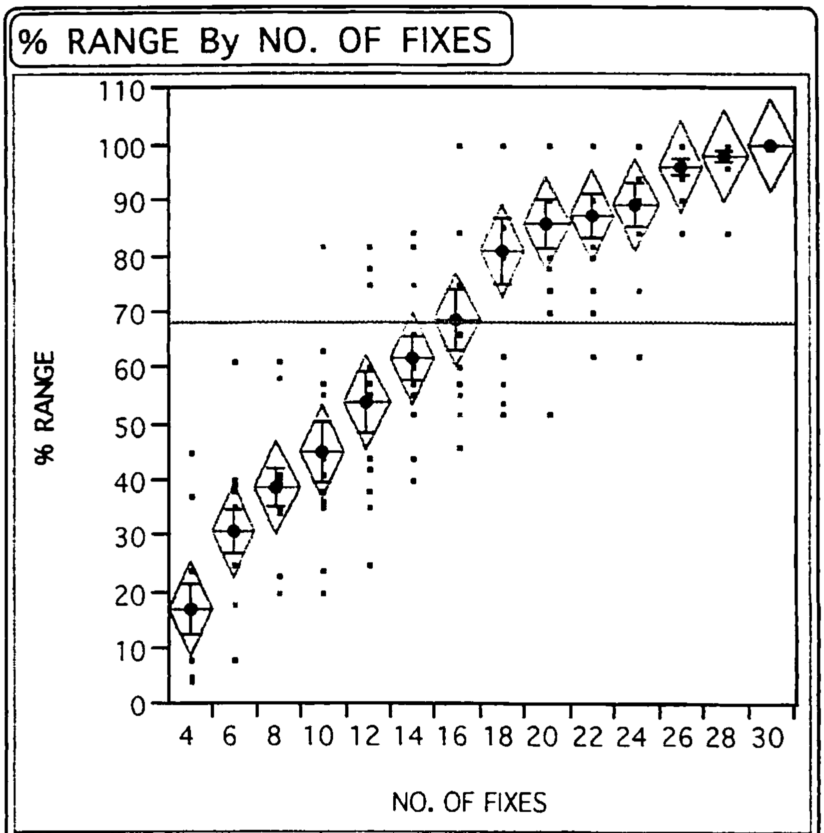
Fig. 25 Females with ranges > 200 km^2 to September 1996

RHINO NO.	RANGE SIZE	FIXES
M9203	146.12	36
M9207	117.68	19
M9230	114.71	27
M9214	110.29	51
M9233	81.80	8
M9259	72.37	26
M9202	70.78	6
M9232	42.29	7
M9256	38.10	7
M9246	37.70	21
M9240	35.81	7
M9265	23.77	12
M9252	18.44	7
M9235	16.48	6
M9226	11.10	3
M9250	9.42	4
M9219	2.97	4

Table 8 Range sizes and number of fixes for all males in descending order of range size.

RHINO NO.	RANGE SIZE	FIXES
F9483	282.4	34
F9251	279.58	18
F9206	234.71	24
F9255	201.21	15
F9331	108.15	18
F9231	102.6	45
F9227	81.62	39
F9223	75.27	21
F9212	74.4	59
F9237	69.06	17
F9330	59.9	73
F9481	55.95	22
F9229	52.91	8
F9245	46.8	33
F9222	42.43	19
F9213	41.65	22
F9243	33.15	23
F9264	28.1	29
F9260	19.85	52
F9218	16.56	7
F9217	15.54	7
F9224	13.39	3

Table 9. Range sizes and number of fixes for all females in descending order of range size.



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
4	11	17.091	15.6170	4.7087
6	11	30.636	14.3127	4.3155
8	11	38.636	12.3796	3.7326
10	11	45.000	18.0278	5.4356
12	11	53.727	18.8366	5.6795
14	11	61.545	14.3273	4.3199
16	11	68.364	18.8959	5.6973
18	11	80.909	20.8060	6.2733
20	11	85.818	16.2838	4.9098
22	11	87.091	14.1807	4.2756
24	11	88.909	13.5459	4.0842
26	11	96.091	5.3377	1.6094
28	11	97.818	4.8542	1.4636
30	11	100.000	0.0000	0.0000

FIG. 26. % cumulative range and number of fixes plotted for 11 rhinos which had a minimum of 30 fixes. Analysis based on including only the first 30 fixes for rhinos with more than 30 fixes.

NO. OF FIXES	4	6	8	10	12	14	16	18	20	22	24	26	28	30
F9212	8.00	40.00	41.00	41.00	60.00	60.00	60.00	62.00	78.00	80.00	94.00	94.00	96.00	100.00
F9227	8.00	30.00	35.00	35.00	35.00	66.00	66.00	85.00	90.00	90.00	90.00	95.00	100.00	100.00
F9231	4.00	25.00	58.00	82.00	82.00	82.00	84.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
F9245	8.00	8.00	23.00	24.00	25.00	44.00	57.00	57.00	70.00	70.00	74.00	90.00	96.00	100.00
F9260	5.00	18.00	20.00	20.00	78.00	84.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
F9264	4.00	25.00	34.00	36.00	38.00	40.00	46.00	54.00	74.00	74.00	74.00	94.00	100.00	100.00
F9330	8.00	18.00	34.00	38.00	42.00	62.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
F9483	45	61	61	63	75	75	75	80	80	82	84	84	84	100
M9203	37	39	40	57	57	57	57	100	100	100	100	100	100	100
M9214	24	35	40	44	44	52	52	52	52	62	62	100	100	100
M9230	37	38	39	55	55	55	55	100	100	100	100	100	100	100
MEAN	17.09	30.64	38.64	45.00	53.73	61.55	68.36	80.91	85.82	87.09	88.91	96.09	97.82	100.00
SE	4.71	4.32	3.73	5.44	5.68	4.32	5.70	6.27	4.91	4.28	4.08	1.61	1.46	0.00
CV	27.56	14.10	9.65	12.09	10.57	7.02	8.34	7.75	5.72	4.92	4.59	1.68	1.49	0.00

Table 10. Number of fixes and the percentage increase in range size for 11 rhinos (SE = standard error of mean, CV = coefficient of variation). Only individuals with a minimum of 30 fixes included and for individuals with more than 30 fixes, only the first 30 fixes used for calculating the percentage change in range size.

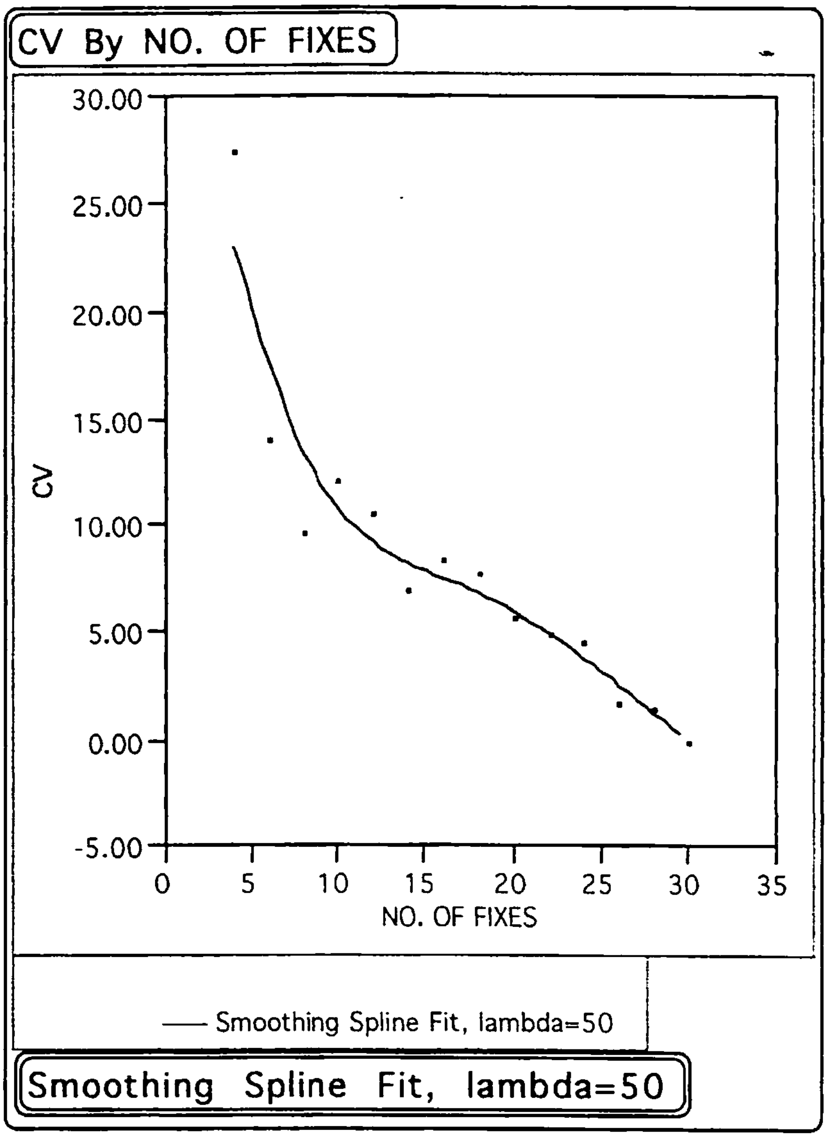


FIG. 27. The coefficient of variation (CV) for the proportional change in range size plotted against the number of fixes for 11 rhinos.

3.5.3. Range size differences between males and females.

Fig. 28 shows the mean range sizes of 13 females and 5 males with 20 or more fixes included. The mean female range was 87.4 km^2 and the mean male range 96.2 km^2. In order to test the difference between range sizes of males and females, a non-parametric test was used and as Fig. 28 shows, there was no significant difference between the range sizes.

3.5.4. Seasonal difference in range size

Fig. 29 shows a comparison of range sizes of 12 females and 5 males combined during wet and dry seasons. The mean dry season range was 67.1 km^2 and the mean wet season range 45.7 km^2. Although the dry season range appeared to be considerably larger, the difference was not statistically significant.

Fig. 30 shows a comparison of range sizes of 5 males during the wet and dry seasons. Once again, the dry season range was much greater, over twice the size of the wet season range but the difference was not statistically significant. However, the analysis was based on a very small sample size.

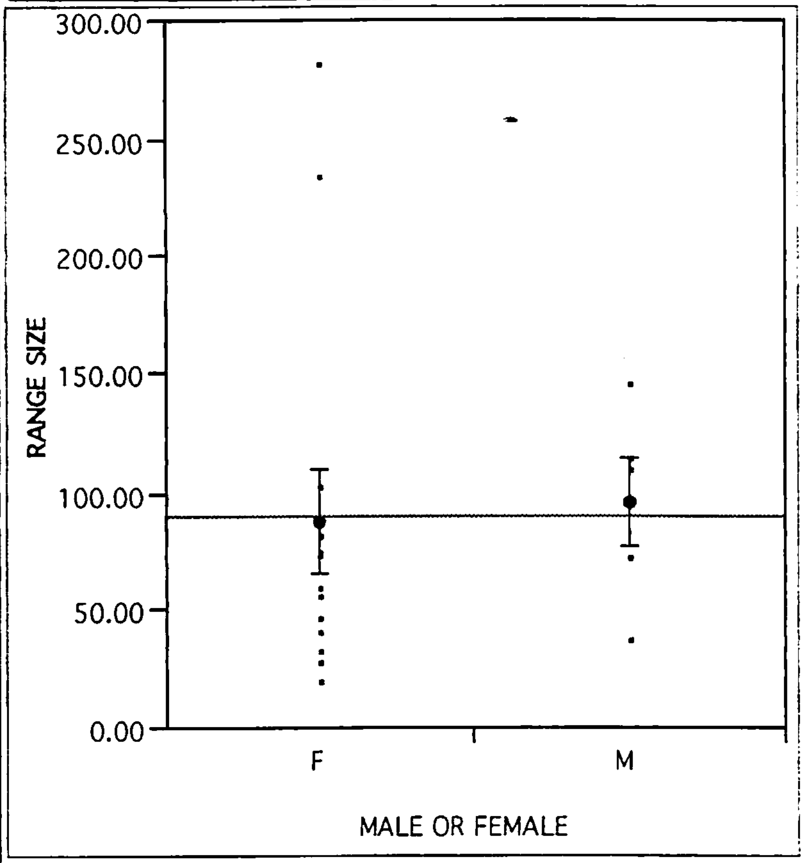
Fig. 31 shows a comparison of range sizes of 12 females during wet and dry seasons. The females also ranged over a greater distance in the dry season but in this instance, the difference was much smaller and also statistically not significant.

3.5.5. Exclusive use of ranges in dry and wet seasons.

Using Wildtrak to carry out the range analysis, it was possible to determine how much of the ranges in dry and wet seasons overlapped and how much was exclusively used during a particular season.

Fig. 32 shows the percentage use by 5 males of their two ranges, dry and wet, which were used exclusively - that is the percentage of each range which was not part of the range in the other season. Although the exclusive range used in the dry season was almost twice the size that in the wet season, the difference was not statistically significant for a two sample test. However, the analysis was based on very small sample sizes.

RANGE SIZE By MALE OR FEMALE



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
F	13	87.4154	80.0079	22.190
M	5	96.2380	41.9025	18.739

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
F	13	113	8.6923	-0.986
M	5	58	11.6000	0.986

2-Sample Test, Normal Approximation

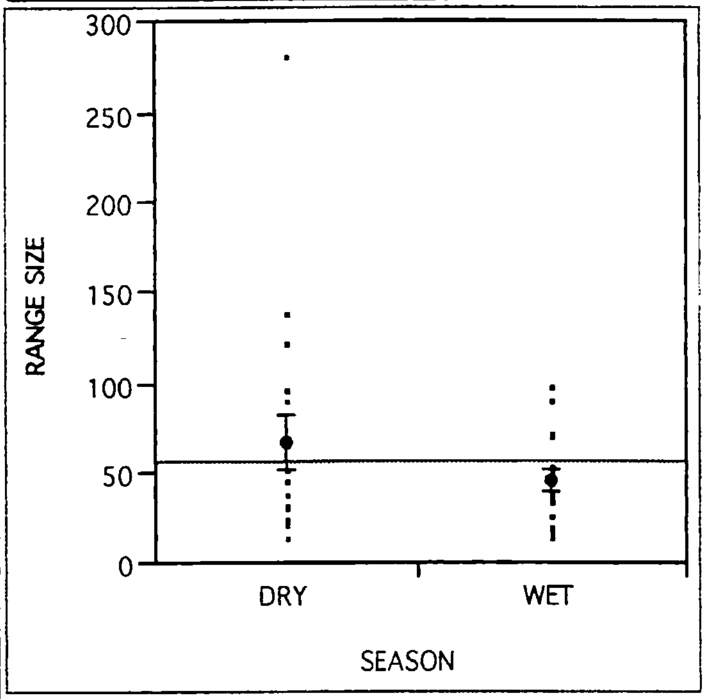
S	Z	Prob>|Z|
58	0.98573	0.3243

1-way Test, Chi-Square Approximation

ChiSquare	DF	Prob>ChiSq
1.0713	1	0.3007

Fig. 28 Mean range sizes of 13 female and 5 male rhinos (only individuals with 20 or more fixes included).

RANGE SIZE By SEASON



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
DRY	17	67.1176	66.5739	16.147
WET	17	45.7271	25.2042	6.113

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
DRY	17	312	18.3529	0.482
WET	17	283	16.6471	-0.482

2-Sample Test, Normal Approximation

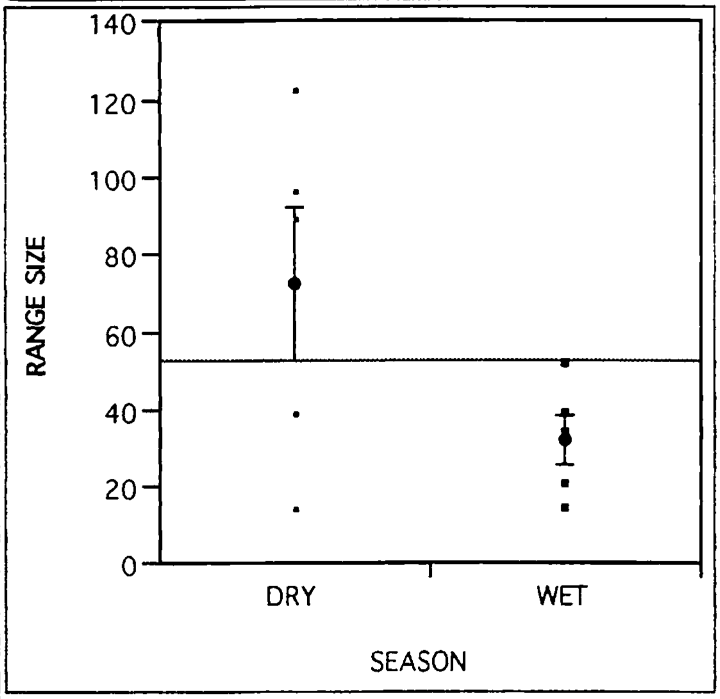
S	Z	Prob>IZI
283	-0.48221	0.6297

1-way Test, Chi-Square Approximation

ChiSquare	DF	Prob>ChiSq
0.2494	1	0.6175

Fig. 29. Comparison of range sizes of 12 females and 5 males during wet and dry seasons.

RANGE SIZE By SEASON



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
DRY	5	72.4160	44.2878	19.806
WET	5	32.2800	15.0500	6.731

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
DRY	5	34	6.80000	1.253
WET	5	21	4.20000	-1.253

2-Sample Test, Normal Approximation

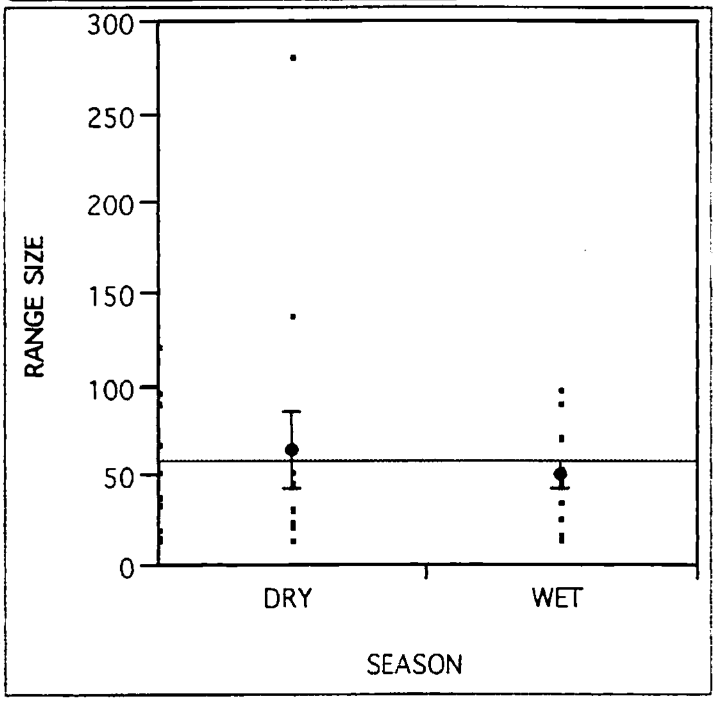
S	Z	Prob>|Z|
21	-1.25336	0.2101

1-way Test, Chi-Square Approximation

ChiSquare	DF	Prob>ChiSq
1.8436	1	0.1745

Fig. 30. Comparison of range sizes of 5 males during wet and dry seasons.

RANGE SIZE By SEASON



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
DRY	12	64.9100	75.5999	21.824
WET	12	51.3300	26.9295	7.774

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
DRY	12	142	11.8333	-0.433
WET	12	158	13.1667	0.433

2-Sample Test, Normal Approximation

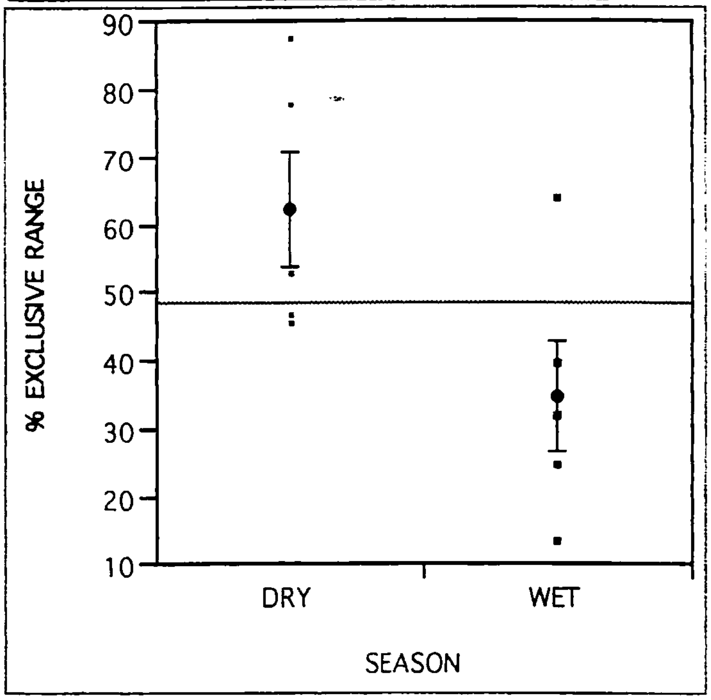
S	Z	Prob>|Z|
158	0.43301	0.6650

1-way Test, Chi-Square Approximation

ChiSquare	DF	Prob>ChiSq
0.2133	1	0.6442

Fig. 31 Comparison of range sizes of 12 females during wet and dry seasons.

% EXCLUSIVE RANGE By SEASON



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
DRY	5	62.3600	19.3461	8.6519
WET	5	34.7800	18.9530	8.4760

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
DRY	5	37	7.40000	1.880
WET	5	18	3.60000	-1.880

2-Sample Test, Normal Approximation

S	Z	Prob>IZI
18	-1.88004	0.0601

1-way Test, Chi-Square Approximation

ChiSquare	DF	Prob>ChiSq
3.9382	1	0.0472

Fig. 32 Percentage of the wet and dry ranges of five males used exclusively during that season.

Fig. 33 shows the percentage use by 12 females of their two ranges, dry and wet, which were used exclusively - that is the percentage of each range which was not part of the range in the other season. There was no significant difference in the exclusivity of seasonal ranges, with approximately 35% of the dry range exclusive to the dry season, and 38% of the wet range exclusive to the wet season.

3.5.6. Range distribution in relation to IPZ boundaries.

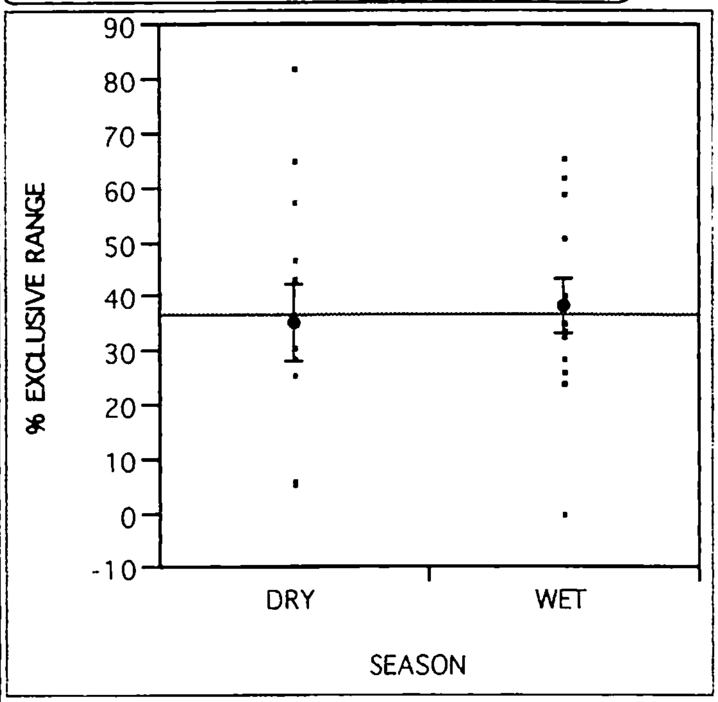
Since Sinamatella IPZ is not fenced in, it was not unexpected to find that some individuals ranged beyond the IPZ boundary. Figs. 19 - 25 show the range patterns of 39 black rhino in relation to the IPZ boundaries. In some instances, the ranges of individuals were consistently found within the confines of the IPZ boundaries. Eleven individuals had ranges which extended beyond the IPZ boundaries. Of these individuals, some had only a small part of their range outside the IPZ boundaries (e.g. M9214, Fig. 21), others had ranges equally divided inside and outside the IPZ (e.g. F9227-21, Fig. 23) and another group had a considerable part of their range outside the IPZ boundary (e.g. M9203, Fig. 21). However, for most of the animals, visuals were obtained within the boundaries of the IPZ. This was not simply a case of just tracking these animals predominantly within the IPZ boundaries. Fixes for all the animals were based on visuals on collared animals (ground and aerial tracked), and if the radio siganl for a particular individual appeared to be coming from outside the IPZ, then the animal was tracked outside the IPZ either on the ground or aerially. However, it should be pointed out that in some instances, individuals tended to 'disappear' for a while i.e. the individual could not be radio-tracked. In such cases, it was likely that the animal had made forays well outside its normal range and probably well beyond the boundaries of the IPZ.

It should be emphasised that this data is entirely based on spatial and not temporal analysis, ie an animal which has a large proportion of its range outside the IPZ might be spending a relatively short period of time there or vice versa. More data is required before a temporo-spatial analysis can be done.

3.6 SOCIAL INTERACTIONS OF BLACK RHINO IN THE SINAMATELLA IPZ

From July 1994 - September 1996, 839 observations were made on a total of 39 black rhino. A total of 17 males were observed on 251 occasions and a total of 22 females on 588 occasions.

% EXCLUSIVE RANGE By SEASON



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
DRY	12	35.1417	24.7100	7.1332
WET	12	38.2250	18.7876	5.4235

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
DRY	12	140	11.6667	-0.548
WET	12	160	13.3333	0.548

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
160	0.54848	0.5834

1-way Test, Chi-Square Approximation

ChiSquare	DF	Prob>ChiSq
0.3333	1	0.5637

Fig. 33. Percentage of the wet and dry ranges of 12 females used exclusivelyduring that season.

During these observations, which lasted from a matter of minutes duration to several hours in some cases, the activities shown by the animals was recorded. Also, if found in association with other rhino, the sex, age and identity of animals was recorded. Copulation was observed on one occasion. Figs. 34 - 38 show the social interactions between individuals of different social groups as a % of all visualisations of that group.

Fig. 34 shows the social interactions of cow with calves < 2 years old. This social group was observed on 101 occasions and the figure shows that cow with calves < 2 years old were accompanied by their calves in 100% of observations. On nine occasions, the cow was observed with its calf and another rhino. On these occasions, the cow and calf were seen six times with their previous calves, three times with other sub-adults and only once with an adult male.

Fig. 35 shows the social interactions of cows who had sub-adult calves of > 2 years. Not surprisingly, this group showed more social diversity than females with younger calves. However, the cows were still observed with their calves 80% of the time. On the other hand, the cow was seen on several occasions on its own whereas with the youger age group of calves (< 2 years) the cow was never seen on its own.

Fig. 36 shows the social interactions of single cows i.e. those females > 4 years old which did not have calves. Most of the time (92%), the cows were seen on their own and the rest of the time they were seen with adult bulls. Single females were never seen with rhinos in any other category.

Fig. 37 shows the interactions of single bulls. These animals were seen alone in 78% of observations, and with either single females, cow and calf combinations or other unidentified animals in the remaining 12% of observations. A bull was seen on at least two occasions with a young adult bull with an overlapping range.

Fig. 38 shows the interactions of sub-adults (2 - 4 years old). Sub-adults were the least likely group to be observed alone (apart from dependent calves) of all the groups. Only in 8% of observations were they alone, and in 88% with the dam. When sighted with "other" rhino (4% of observations) they were seen twice with a cow (and its calf) other than their dam, twice with another cow and unknown, once with their own dam and adult bull, and once with another sub-adult and unknown animal. Unlike the other groups, every member of the observed sub-adult group was seen on at least one occasion with at least one other animal.

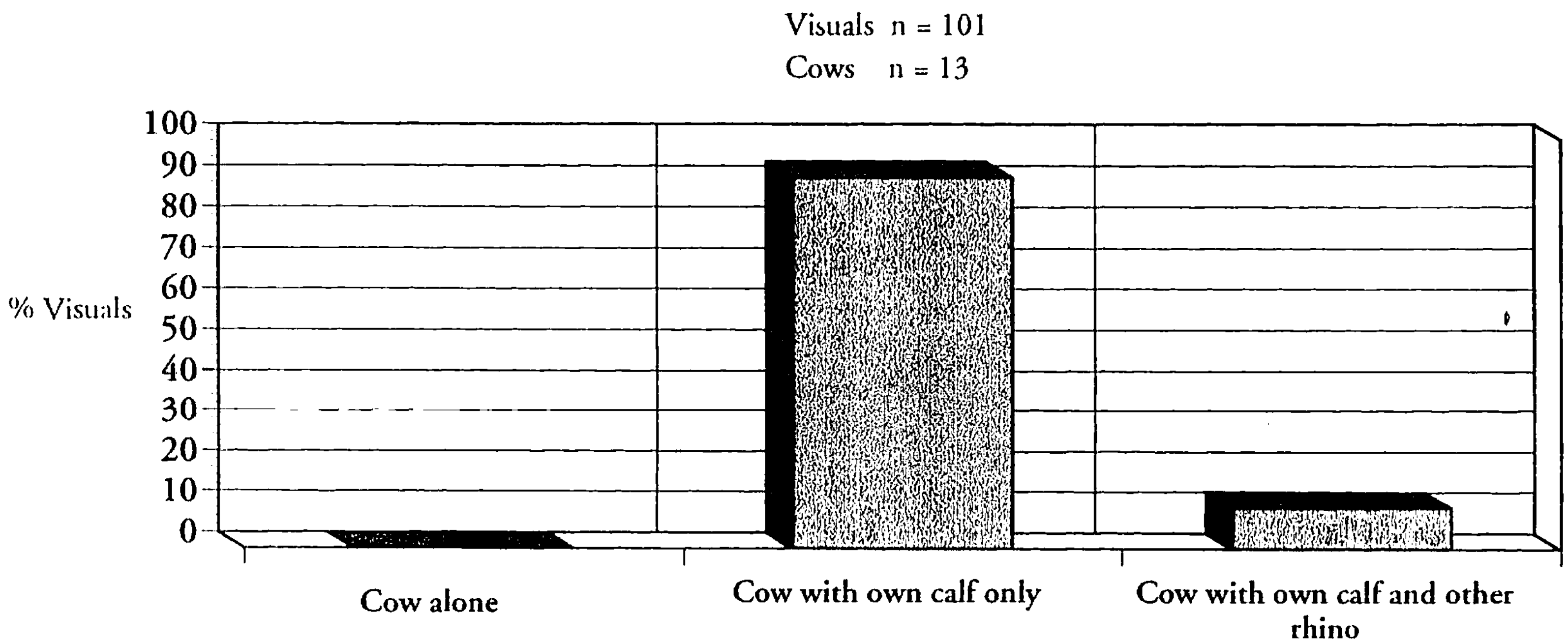


Fig. 34. Social Interactions of cows with accompanying calves of less than 2 years old . When sighted with 'other' rhino, the cow and calf were seen six times with the previous (sibling) calf, three times with other subadults and once with an adult male.

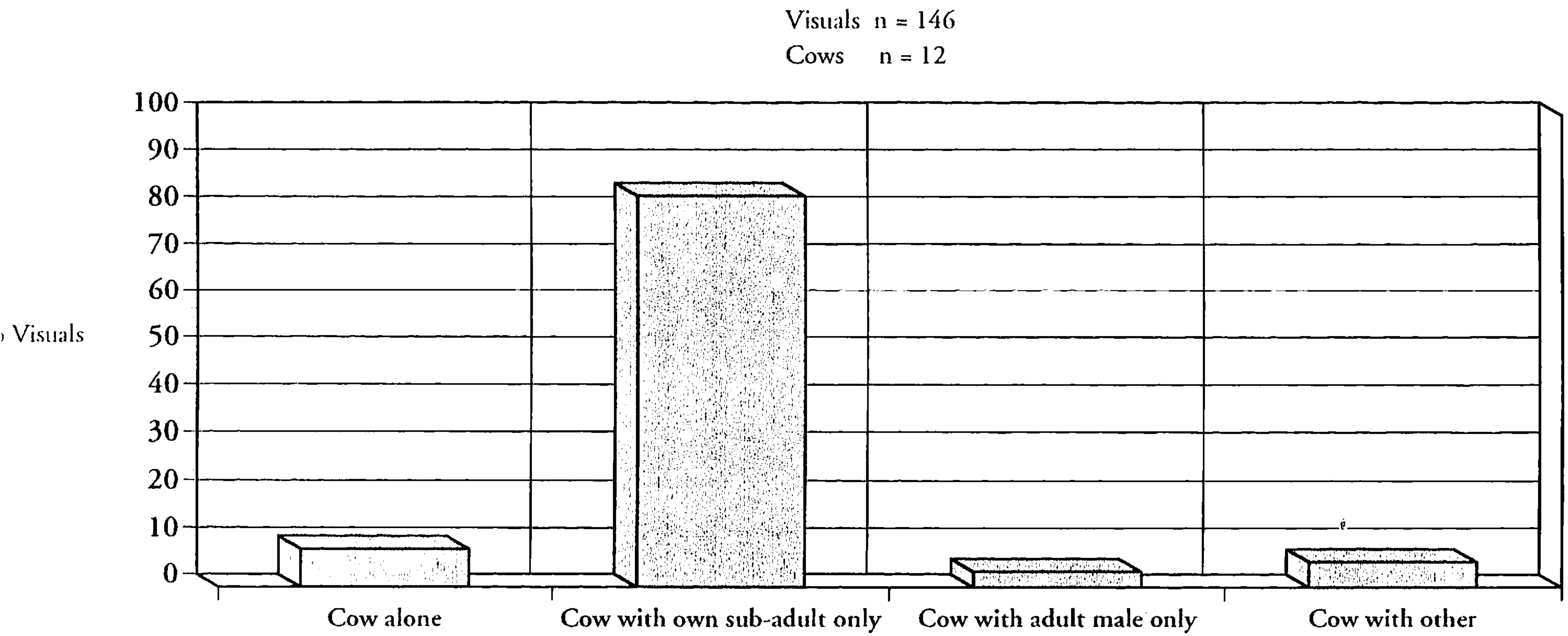


Fig. 35. Social interactions of cows with accompanying subadult calves (2 - 4 years old). When sighted with 'other' rhino, the cow was seen six times with its own calf and a male , and twice with its own calf and unknown rhinos.

Visuals n = 117
Adult females n = 6

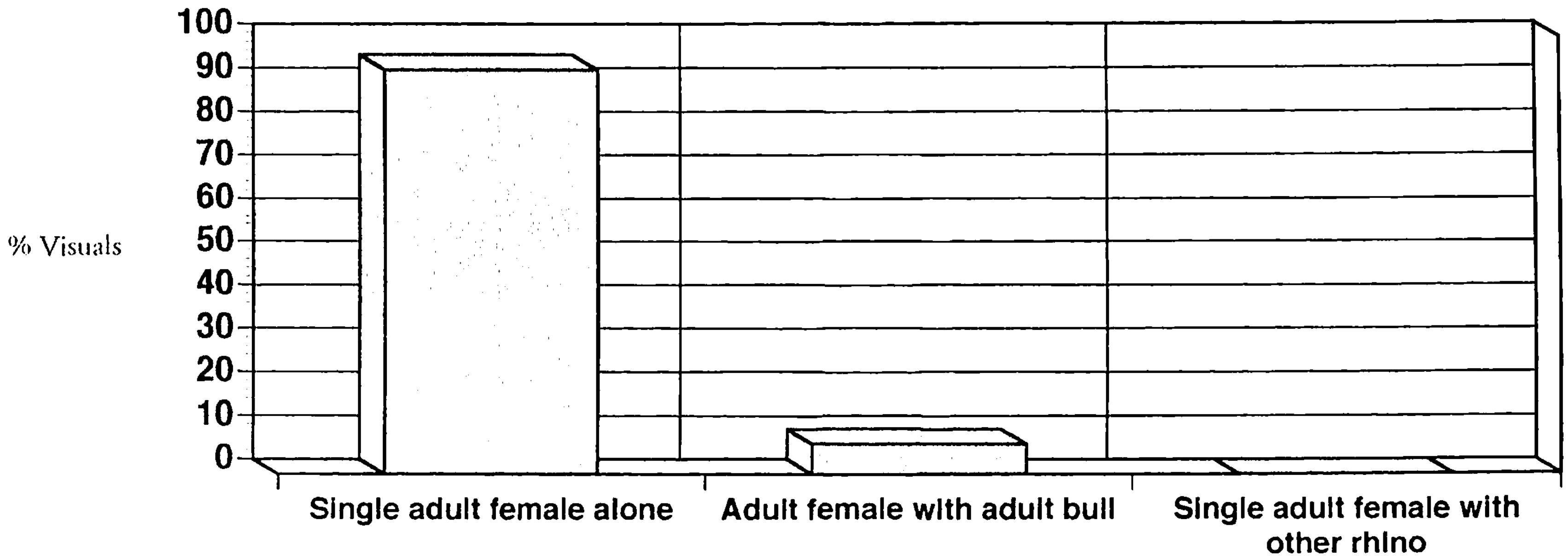


Fig. 36. Social Interactions of single adult females. Of the 117 visualisations, no single adult females were seen with animals other than adult bulls.

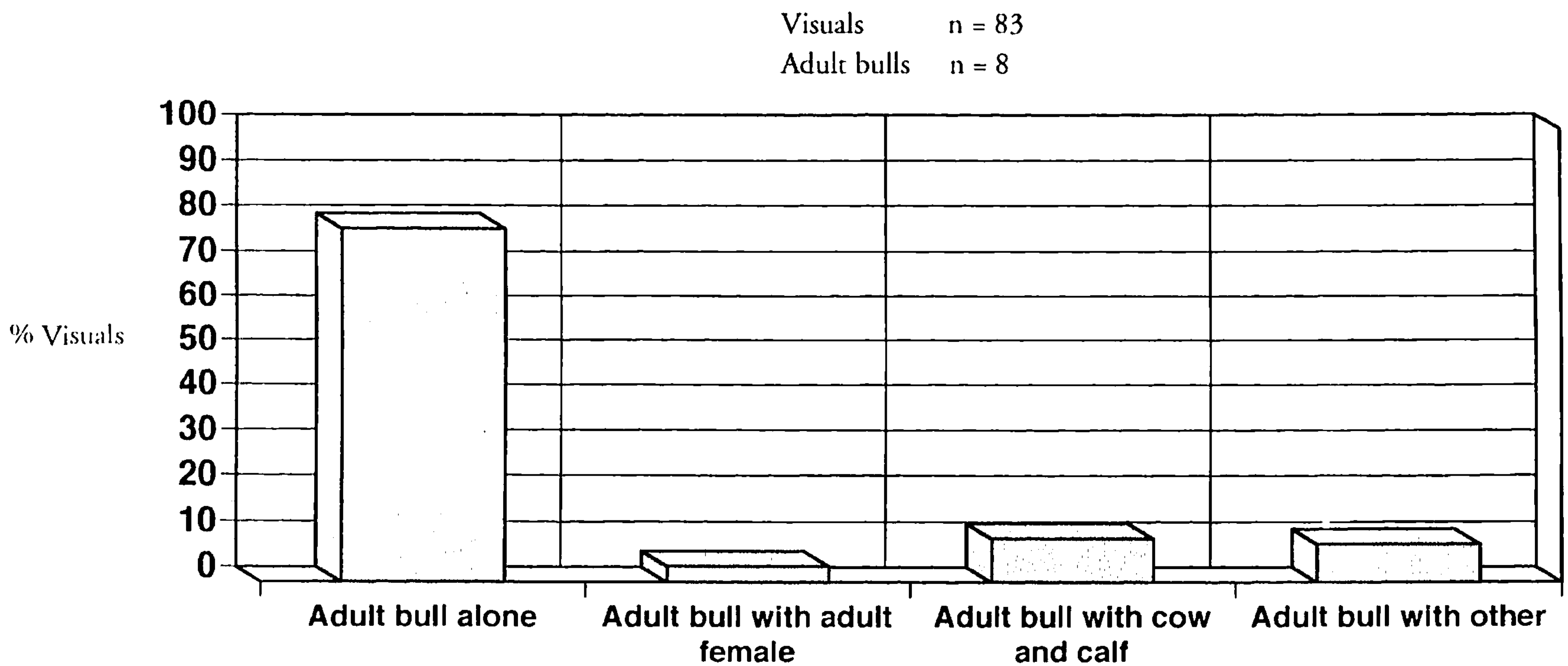


Fig. 37. Social interactions of adult bulls. When sighted with 'other' rhino, adult bulls were seen twice with subadults, once with another adult bull, once with another adult bull + cow + calf and on three occasions, adult bulls were sighted with unknown rhino.

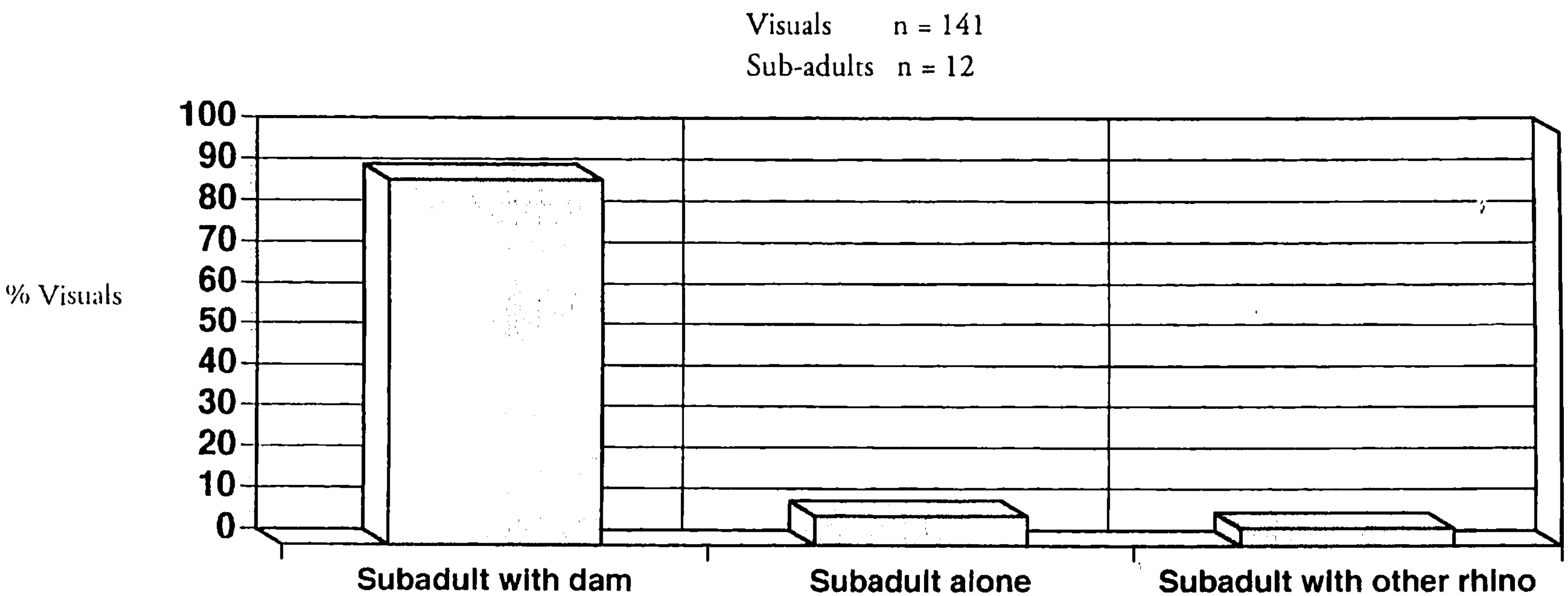


Fig. 38. Social Interactions of subadults (2-4 years old). When sighted with 'other' rhino, subadults were seen twice with a cow which was not their dam and it's calf, twice with other cow+unknown rhino, once with own dam+adult bull and once with another subadult+unknown rhino.

3.7 MANAGEMENT PROCEDURES - EFFICACY AND SAFETY

3.7.1. Dehorning - The ability of dehorned cows to protect their calves 1992-5

Fig. 39 shows the % survival of calves of different ages, whose dams who were dehorned in 1992. The figures show the subsequent survival into 1994 and 1995 of one calf who was < 3 months old when the dam was dehorned, three calves which were 3 - 5.9 months old, five calves which were 6 - 11.9 months old and two calves which were 12 - 24 months old. It is difficult to assess survival in older groups since the calf would probably have naturally left the dam two years after the 1992 dehorning took place, and would not then have been identified with the dam. In each case where a calf was not subsequently identified, neither was the dam. It is also possible that these cow/calf combinations were poached as poaching activity was quite intense in 1992.

Fig. 40 shows the % survival of calves of different ages, whose dams who were dehorned in 1994. The figures show 100% survival in all classes a year later.

These figures suggest that dehorning has not had a detrimental effect on calf survival, although it is impossible to draw firm conclusions without reference to figures on natural mortality of calves with dams who had not been dehorned. One calf was lost when < 3 months old in 1995, to a dam which had been dehorned at least 8 months previously. Two of the four 1996-born calves have been lost , both of which had dams which had not been dehorned for 24 months and thus had substantial horn re-growth. It is expected that this was natural mortality due to hyaena predation, but this has not been confirmed. In total, since 1992 a total of 23 calves have been identified in the Sinamatella IPZ. Of these, only three calves have been lost. In the rest of the cases, both the cow and calf disappeared, particularly in the case of calves born in 1992, or the calves have survived. This indicates that the proportion of calves lost to natural mortality (3/23) was 13% and the proportion lost to cows dehorned up to one year previously (1/23) was 4.4%.

3.7.2 Management effects on reproductive performance of females in the IPZ

Black rhino in the IPZ were managed both intensively and non-intensively during the study period at various times. Intensive management is defined here as immobilisation and boma-holding for up to 5 months, which may have been done for the purposes of translocation into

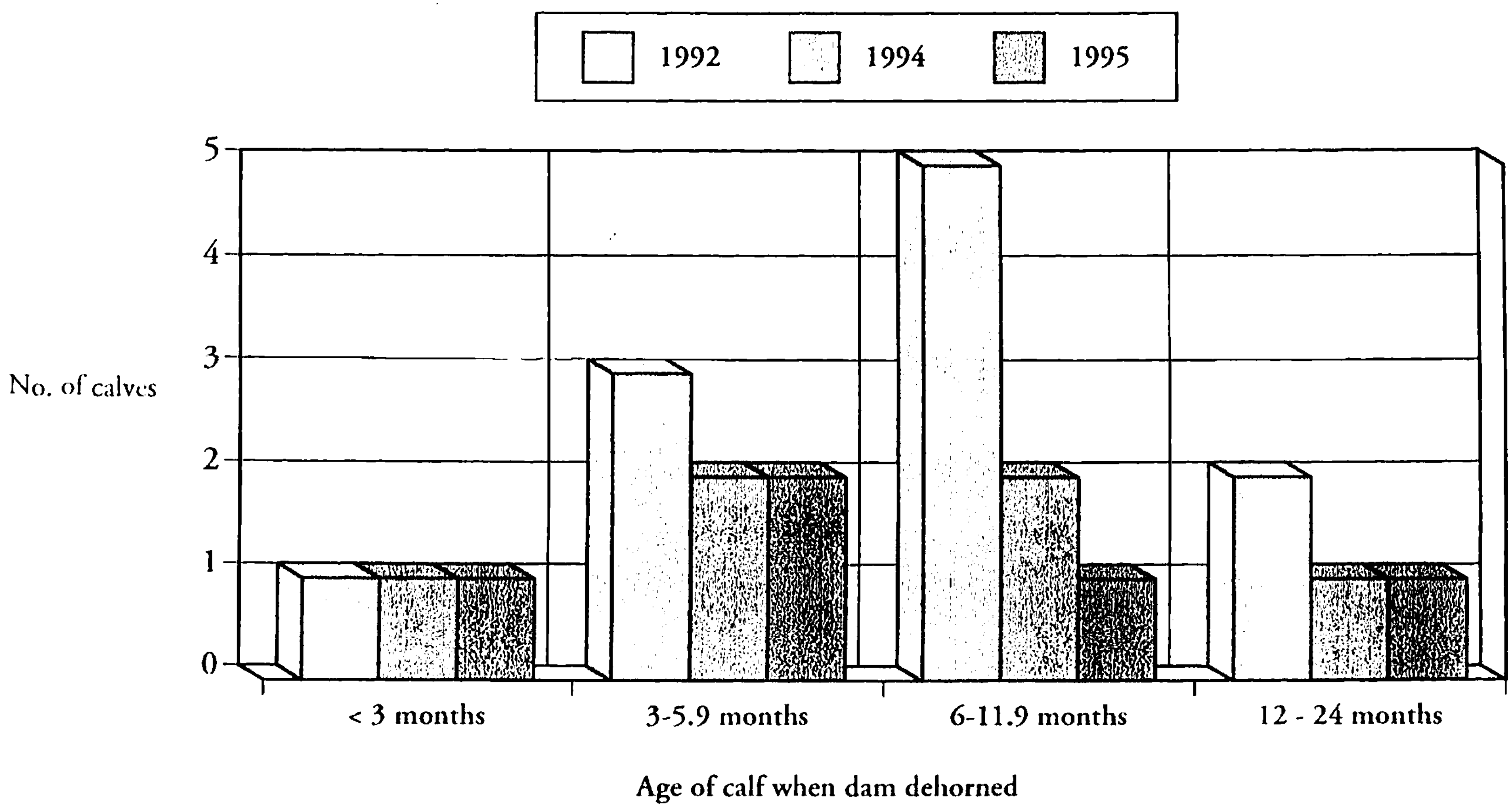


Fig. 39. Calves of different ages whose dams were dehorned in the Sinamatella IPZ in 1992, subsequently confirmed to be alive in 1994 and 1995.

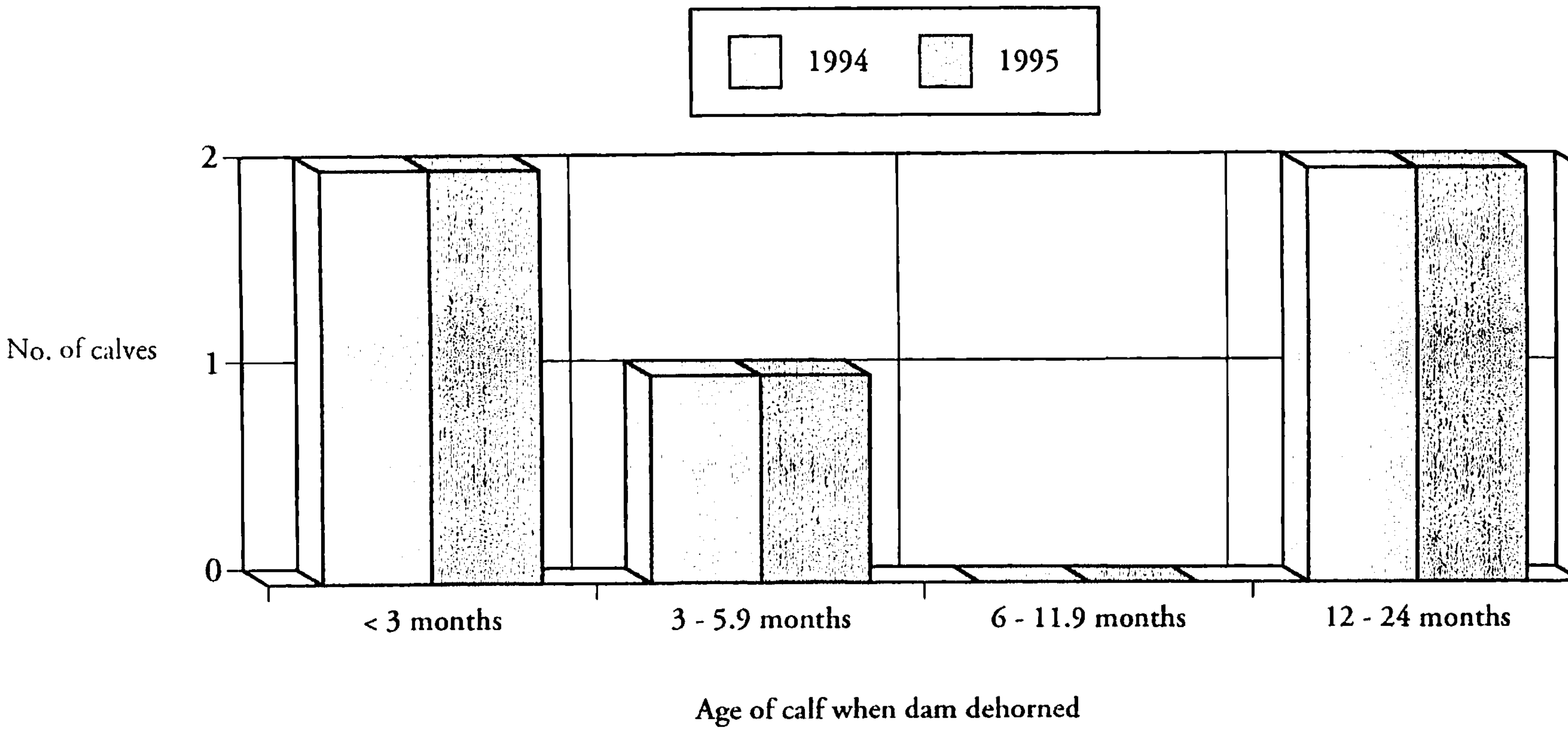


Fig. 40. Calves of different ages whose dams were dehorned in the Sinamatella IPZ in1994, subsequently confirmed to be alive in 1995

the IPZ from outside, or for collar maintainance/nutritional research on an animal from within the IPZ. Non-intensive management is defined as the immobilisation, for dehorning and/or collar fitting, of an animal in the field (*in situ*), without translocation or boma management.

3.7.2.1 Intensive management through boma holding - effect on subsequent reproductive performance

Table 11 shows a comparison of reproductive performance between the intensively and non-intensively managed groups of females in the Sinamatella IPZ. Initial data suggests that the reproductive performance and subsequent survival of calves of the intensively managed group is compromised, since the mean number of calves per female surviving to > 3 months in this group is 0.14, compared with a figure of 0.62 for the non-intensively managed group. The youngest of the intensively managed animals was observed mating in April 95, suggesting that all members of the group are sexually mature, but to date (November 1996) this animal has not calved. It can be seen that the mean number of immobilisations per animal in the intensively managed group was higher (more than twice the number) than the non-intensively managed group.

3.7.2.2 Effects of immobilisation in different stages of gestation

There is a suggestion from field experience that females in the first third of pregnancy may be more likely to abort due to the immobilisation procedure than other females (Kock, pers. comm). To test this, the number of females immobilised for management procedures at different stages of pregnancy and subsequently producing calves was compared with the expected figures, assuming no difference in subsequent calving between groups. Table 12 shows that fewer than expected females immobilised in the first third of pregnancy went on to produce calves, suggesting that they might have aborted.

3.7.3 Analysis of lifespan of radio-collars fitted in 1994 and 1995

Table 13 shows the lifespan of two different types of radio-transmitter collar placed on black rhino in the Sinamatella IPZ in 1994 and 1995. The hose collar design adopted for the majority of animals in 1994 was very unsatisfactory, with a loss of approximately 70% of collars in the first five months. The strap collar design fared better, with average loss of 25% over the first five months in 1994, 58% loss over 12 months in 1994 and 27% loss over five

	Intensively managed for up to 5 months during period 1-1-93 to 1-10-96 i.e. boma holding/translocation	Non-intensively managed during period 1-1-93 to 1-10-96
No of females in group	7	16
Mortalities (% of group)	2(29%)	0 (0%)
Calves born 1-1-93 to 1-10-96 (% increase)	2 (29%)	12(75%)
Calves surviving > 3 months (% survival)	1 (50%)	10(83%)
Mean no. calves per female surviving to >3 months	0.14	0.62
Mean no. immobilisations	5.50±0.85	2.68±0.22

Table 11. Comparison of reproductive performance of intensively and non-intensively managed females in the Sinamatella IPZ from January 1993 - September 1996

Period after conception	0-4.9 months	5-9.9 months	10-15 months
Observed number of animals immobilised subsequently producing calves	1	6	4
Expected number	3.67	3.67	3.67

Table 12. Number of females (and expected number), immobilised for management procedures at different stages of pregnancy, which subsequently went on to calve in the Sinamatella IPZ from July 1992 to September 1996 . Stage of pregnancy at immobilisation determined by back-dating from date of parturition for a 15 month pregnancy.

	Hose collars fitted in 1994	Strap collars fitted in 1994	Strap collars fitted in 1995
Total No. females fitted	14	9	17
No. collars lost within 5 months	9	1	2
No collars lost within 12 months	14	5	n/a
% collars lost within 5 months	64	11	12
% collars lost within 12 months	100	55	n/a
Total No. males fitted	14	3	9
No collars lost within 5 months	11	2	5
No collars lost within 12 months	14	2	n/a
% collars lost within 5 months	78	66	55
% collars lost within 12 months	100	66	n/a

Table 13. Lifespan of two different types of radio-transmitter collar fitted on black rhino in the Sinamatella IPZ in 1994 and 1995.

months in 1995. The table shows that strap collar lifespan was considerably lower in males than females in both 1994 and 1995.

3.8 OPTIONS FOR MONITORING OF THE BLACK RHINO IN THE SINAMATELLA IPZ

3.8.1 Three considered options - initial and repeat costs

Three options for monitoring were compared as they relate to the Sinamatella IPZ, and an assessment made of their relative merits or otherwise in providing monitoring for the black rhino in the Sinamatella IPZ. The selection and assessment of the three options was based on previous experience in the IPZ, together with one new technique which is being developed by the authors. It was considered important to make the assessment not only in terms of immediate effectiveness for the task put forward, but also in terms of cost-benefit and sustainability in the longer term.

An very important assumption was made that none of these options could be effective without the essential foundation of basic law-enforcement provided by armed scouts of the DNPWLM. A recommended 1 man per 20 km^2 of the IPZ (Department of National Parks and Wild Life Management, 1993) in the 1500 km^2 Sinamatella IPZ would require 75 scouts. Any monitoring option undertaken without effective law-enforcement is inappropriate, simply because it would be impossible to effectively protect the population. One of the options, the spoor technique, would integrally involve the law-enforcement component in the monitoring process. Radio-collaring techniques require a separate monitoring programme.

3.8.1.1 Radio-collaring entire population.

Table 14 shows that the estimated cost for monitoring 60 animals (the estimated population of the Sinamatella IPZ at end 1995) by radio-collaring would be US$104,000 initially and US$100,000 per annum thereafter.

3.8.1.2 Spoor technique.

Table 15 shows that the estimated cost for monitoring using the spoor recognition technique

OPTION 1 - MONITORING BY RADIO-COLLARING ENTIRE POPULATION	Annual est. cost (US$)
A. Purchase and fitting 60 radio-transmitter collars @ 1500 per animal	90000
B. Follow-up aerial monitoring by 2-person helicopter @ 5hrs/2 wks	10000
C. Follow-up aerial monitoring - 1 set radio-receiving equipment	4000
Est. cost for monitoring 60 animals by radio-collaring A+B+C	104000
Recurrent cost each year for this option A+B	100000

Table 14. Estimated cost of monitoring entire black rhino population of the Sinamatella IPZ by radio-collaring. Estimates based on replacement of all collars annually to allow for collar drop-off and transmitter/battery failure. Estimate does not take into account cost of ground tracking or the annual rate of population increase (11.2%) in the Sinamatella IPZ.

OPTION 2 - MONITORING BY SPOOR RECOGNITION	Annual est. cost (US$)
A. Purchase of computer equipment required for spoor analysis	20000
B. Purchase of cameras	6000
C. Purchase of films and processing	1000
Est. total cost for monitoring by spoor recognition A+B+C	27000
Recurrent cost each year for this option C	1000

Table 15. Estimated cost of monitoring the entire population of the Sinamatella IPZ by spoor recognition

being developed by Rhinowatch is US$27,000 to establish and US$1000 thereafter.

3.8.1.3 Peripheral radio-collaring.

Because animals who range outside the IPZ are more at risk from poachers, the radio-collaring of these peripheral animals alone was considered as an option. Table 16 shows that the estimated cost for monitoring peripheral animals in the IPZ using radio-collaring is US$39,000 initially and US$ 35,000 thereafter.

3.8.2 Comparison of the three options.

Table 17 attempts to make an objective comparison of the merits of each monitoring method, in terms of factors which are considered important in formulating a good monitoring strategy for the black rhino. Factors considered were initial and repeat costs, whether the method allows for gathering of immediate positional information on animals, the risk of deleterious effects, the use of local resources, the ability to gather data of ranging at night, the law-enforcement benefits and lastly, long-term sustainability of the method for monitoring the population.

3.9 RECOMMENDED 10 YEAR PLAN FOR PROTECTION AND MONITORING OF THE BLACK RHINO IN THE SINAMATELLA IPZ 1997-2006

Table 18 is a suggested 10 year plan for the protection and monitoring of the black rhino in the Sinamatella IPZ.

OPTION 3 - RADIO-COLLARING PERIPHERAL ANIMALS ONLY	Annual est. cost (US$)
A. Purchase and fitting of 20 radio-collars @ 1500 per animal	30000
B. Follow-up aerial montoring - helicopter @ 2.5 hrs/2wks	5000
C. Follow-up aerial monitoring - radio-receiving equipment	4000
Est. cost for monitoring 20 peripheral animals by radio-collaring A+B+C	39000
Recurrent cost each year for this option A+B	35000

Table 16. Estimated cost of monitoring the peripheral black rhino population of the Sinamatella IPZ by radio-collaring. Estimates based on replacement of all collars annually to allow for collar drop-off and transmitter/battery failure. Estimate does not take into account cost of ground tracking or the annual rate of population increase (11.2%) in the Sinamatella IPZ.

OPTIONS - FACTORS FOR CONSIDERATION	OPTION 1	OPTION 2	OPTION 3
Initial cost	high	medium	medium
Repeat cost	high	low	medium
Provision of immediate positions and visuals on animals	high	low	high
Risk of deleterious effect on animals from management interventions eg anaesthetic, collar trauma	yes	no	yes
Use of local resources i.e. manpower and expertise	low	high	low
Ability to gather data on ranging at night	low	high	low
Long-term sustainability for increased population	low	high	medium

Table 17. Factors for consideration when comparing options for monitoring of black rhino in the Sinamatella IPZ

YEAR	RECOMMENDED COURSES OF ACTION
1997	Immediate boosting of DNPWLM scout numbers in Sinamatella IPZ by 30 men
	Radio-collaring of peripheral animals
	Rhinowatch and DNPWLM installation of equipment and field trials using spoor
	DNPWLM and Rhinowatch continued monitoring of currently radio-collared animals
	Continued aerial monitoring of all radio-collared animals
1998	Further boosting of DNPWLM scout numbers in Sinamatella IPZ by 26 men
	Radio-collaring of peripheral animals without collars
	Rhinowatch and DNPWLM spoor monitoring technique full implementation - 1st year
	DNPWLM and Rhinowatch continued monitoring of currently radio-collared animals
	Continued aerial monitoring of all radio-collared animals
1999-2001	Re-assessment of need for collaring of peripheral animals based on population growth
	Rhinowatch and DNPWLM spoor monitoring technique full implementation
	DNPWLM and Rhinowatch continued monitoring of any radio-collared animals
	Continued aerial monitoring of all radio-collared animals
2002-2006	Assessment of black rhino population growth and distribution 1996-2000
	Assessment of scout numbers and law-enforcement success 1996-2000
	Based on the above;
	1 Consideration of extending IPZ boundaries
	2 Boosting scout population further to cover possible extension of IPZ
	3 Phasing out invasive techniques of monitoring
	4 Phasing in non-invasive and sustainable techniques of monitoring by DNPWLM
	5 Upgrading and Consolidation of transfer of technology and equipment by Rhinowatch

Table 18. Proposed 10-year integrated research and management plan for the black rhino in the Sinamatella IPZ, 1997-2006.

4 DISCUSSION

4.1 POPULATION COMPOSITION AND FEMALE PRODUCTIVITY

Adult females consistently out-numbered adult males in each of the four years, but the overall ratio was not significantly different from the expected 1:1 ($\sum$ chisquare = 5.98, df = 3, $p > 0.05$). A ratio in favour of adult females provides for optimum population growth. In a relatively large population such as the Sinamatella IPZ one might expect the sex ratio to be approximately 1:1, and the importance of sex ratio assessment is probably greater in a small reserve where lack of females might easily compromise population expansion.

4.2 MEAN ANNUAL BIRTH RATE AND MEAN ANNUAL RATE OF INCREASE

The high mean annual birth rate of 13.29% and mean annual rate of increase of 11.18% for the Sinamatella IPZ, which is one of three IUCN key black rhino populations in Zimbabwe (Emslie, 1995), and the largest IPZ, shows that the population is growing more rapidly than any other established population in Zimbabwe. In Zimbabwe the official growth target set by the DNPWLM in the (1993) Emergency Report for the Black Rhino in the newly created IPZ's was 3%. Emslie (1995) now quotes the DNPWLM's target to be 5%, and cites the Midlands conservancy populations to be showing an annual growth rate of 2.9% compared with 5.3% for the SAVE Valley conservancy. In South Africa, Adcock (1996) estimated a growth rate of around 7% for black rhino in the Kruger National Park and 8.9% for Hluhluwe/Umfolozi, both of which have substantial black rhino populations, with an average growth rate of the major black rhino populations for South Africa of around 7% (*D. bicornis minor*) and 6.8% (*D. bicornis bicornis*) respectively. Kiwia (1989) reported very high birth rates (24.2% and 24.1% respectively) for the Ngorongoro crater but noted that this was probably a result of small population size. The high mean annual rate of increase suggests that the Sinamatella IPZ has a very favourable black rhino habitat. However, it should be pointed out that the mean annual rate of increase for the period 1992-5 was calculated essentially by 'sampling' the population. From 1996, with the development of a new spoor technique to identify individual rhinos, it will be possible to track most of the animals in the IPZ and the calculation of the annual rate of increase will be based on the performance of the entire population.

4.3 AGE OF FEMALE MATURITY

Another indicator of the reproductive success of this population is the relatively young age at which females are reaching sexual maturity. Two females were estimated to be aged 6yrs 3 months years and 6 yrs 6 months respectively when they gave birth to their first calves, indicating that they conceived at 5 yrs and 5 yrs 3 months respectively. These were the only two females in the population whose own birth dates were reasonable estimations, and more data will reveal more accurately the age of maturity of more females in the population. In comparison, Adcock (1996) estimated average age at first calving in three different South African areas of 6.92 (n=3), 7.12 (n=1) and 8.12 (n=11) years. Hitchins & Anderson (1983) reported that first conception occurred between 5.08 and 11 years in Hluhluwe/Umfolozi in South Africa, but that most black rhino cows reached sexual maturity at 7 years of age. Morgan Davies (1996) estimated the age of conception of a female in the Masai Mara National Reserve to be 5.4 yrs.

4.4 INTER-CALVING INTERVAL

The mean intercalving interval recorded was 42.5 ± 6.64 months, ranging from a minimum of 21 months to a maximum of 80. For those animals whose calving dates were known (n=9), the mean of 42 months is lower than the mean for the Zimbabwean Midlands conservancies of 57 months (Emslie, 1995), but slightly higher than the SAVE valley conservancy of 38 months. Adcock (1996) reports intercalving interval averages for the different reserves/National Parks of just under 24 months to 51 months. Emslie (1995) reports that the RMG estimates of average observed inter-calving intervales for *D. b minor* and *D. b bicornis* from a sample of 108 ICI's was 35 months. Morgan-Davies (1996) reports a mean calving interval of 25.4 months (n=11) in the Masai Mara National Reserve, Kenya. Frame (1980) reported intervals of 39 months in the Serengeti Plains, Tanzania. However, as discussed later in this section, there is some concern that the four inter-calving intervals of 48 months or more in the Sinamatella may be as a result of abortion in early pregnancy due to immobilisation from previous management operations. More data is needed to assess the effects of age on inter-calving intervals, and the anaesthetic/immobilisation risk to females who are in the early stages of pregnancy.

Viv Wilson (pers. comm.) of the Chipangali Wildlife Orphanage in Bulawayo, Zimbabwe reports successive intercalving intervals of 17 months in a female whose calves have been removed at birth and hand-reared.

4.5 SEASONALITY OF CALVING

A total of 23 calves were known to have been born in the IPZ from 1992 to September 1996. Since the sample size was limited, it is difficult to draw any conclusions about trends but as Fig. 10 showed, there were more births in the dry season (May - October inclusive) compared with the wet seasons (November - April inclusive). Although this difference was not statistically significant ($\sum$ chisquare = 2.35, df = 1, $p > 0.05$), further data may clarify the situation.

Seasonality of calving in black rhino in South Africa has been reported by Hitchins & Anderson (1983) , who noted bimodal seasonal reproduction with peaks mid-summer and mid-winter. The majority of conceptions occured in October-November and April-July, with parturition peaks in January-February (19% of observed cases) and June-August (41% of observed cases) respectively. The data from Sinamatella is insufficient for deductions about possible seasonality to be made yet, although there is a suggestion that more births may be taking place in the dry season.

It is generally recognised that there are in fact three or four seasons in Zimbabwe: a cool dry season from May - mid-August, a hot dry season from mid-August - October, a warm wet season from November to March and a post-rainy season in April (Sayce, 1987). It might be useful, when more data is available on calving months, to analyse according to these seasons, with appropriate weighting. However it could be argued that any deductions made on this basis over a few years might be unreliable because of wide variations in the onset and end of these seasons.

4.6 CARCASS RECOVERY

All the recovered carcasses are estimated to have been poached before the inception of the IPZ, and there has been no evidence of poaching since 1993. Carcass recovery in the IPZ was estimated to be 56% which is consistent with an estimated 55% by Emslie (1995).

The percentage of poached skulls retrieved by Rhinowatch shows that the project is contributing significantly. In an area where scout patrols often use the same routes, it is undoubtedly useful to have ground coverage by a different group which uses varied routes.

Rhinowatch put three teams into the bush each day during the study period, whilst the Sinamatella IPZ was able to put out 6-7 patrols. This ongoing project thus increases by 33% the coverage of the IPZ for the purposes of black rhino research, law-enforcement and carcass retrieval.

4.7 OVERALL POPULATION FIGURES

Table 6 combines reproductive data with carcass recovery to produce an estimated population of 62 to 1-10-96, and an estimated carcass recovery rate of 56%. This maintains the Sinamatella IPZ as the home of the largest single black rhino population in Zimbabwe. Further more, since the IPZ is neither fenced nor has any physical boundaries, as the population expands, it is expected that the animals will disperse across the present boundary thus allowing for a continuous rapid population growth rate. However, this does mean that the size of the IPZ will have to be increased to ensure that proper protection can be provided.

4.8 TRIANGULATION

There was no significant difference either in the means of bearing distances or the O-E distances for any individual animal, which shows that any possible differences between animals in terrain occupied, collar performance or movement were not affecting triangulation data. However, the highly significant correlation between mean of distances of bearings from the estimated position of the animal and the O-E distance shows that the closer the bearings from the estimated position of the animal the more likely the estimated position to be accurate. A distance of just over 2 km was extrapolated as the maximum distance allowed of the mean value of the bearings from the estimated position, if that position was to be taken as an accurate estimation of the true position of the animal. This suggests that in the Sinamatella IPZ accurate estimation of position of an animal from many kilometers away is impracticable, and that some degree of tracking off-road into the immediate vicinity of the animal would be almost essential for the purposes of estimating position accurately. No significant difference in accuracy between three different trackers of equal experience was found.

4.9 RANGE ANALYSIS

Figures 19-25 show the enormous disparity in range size amongst different animals in the population. Tables 8 & 9 list the ranges for each animal, although it can be seen that insufficient data is available for many of the animals with relatively few fixes. Most of the studies in this field have failed to provide data on the number of fixes when estimating home ranges. An attempt was made to ascertain whether there was a minimum number of fixes which gave a reliable estimate of the home range. The cumulative percentage range was plotted against number of fixes for 11 animals which had 30 or more fixes, and the coefficient of variation (CV) for the proportional change in range size plotted against the number of fixes for these animals. In the case of the relationship between cumulative percentage range and number of fixes, the curve levelled out at 20 fixes. Similarly, when the CV was plotted against the number of fixes, the curve showed a visible inflection at 20 fixes. For those animals for whom $\geq$ 20 fixes were available, the mean female range was 87.4 km^2 and the mean male range 96.2 km^2.

Adcock (1996) reports home ranges in South Africa ranging from 10.30 to 34.63 km^2 for females and 8.22 to 39.40 km^2 for males. Range size decreased with increasing Ecological Carrying Capacity, as would be expected. Attention to range size in the Sinamatella IPZ is less likely to be a useful indicator of potential carrying capacity, since there is no physical boundary and the population can expand naturally into adjacent areas. Morgan-Davies (1996) estimated home range sizes of black rhinos in the Masai Mara National Park in Kenya with means of 51 km^2 (range 12 km^2 - 126 km^2) for females (n=5) and 42 km^2 for males (range 7 - 83 km^2) (n=7). According to the same author, in 1971/2 Mukinya (1973) estimated rhino densities to be higher and overall home range sizes were smaller, varying from 5 km^2 to 22.7 km^2 with a mean of 13.1 km^2. However, Morgan-Davies points out that the increase in home range size may also be related to a reduction in food resources through annual uncontrolled fires, or a deterioration of the environment caused by tourists, and not simply reduced rhino numbers *per se*. Frame (1980) reported home ranges varying from 43 - 133 km^2 in the Serengeti (n=8). Owen Smith (1992) notes the very large home ranges of the desert black rhino (*D. b. bicornis*) from Namibia of up to 500 km^2. Although the Sinamatella mean home ranges appear large compared with Kenyan and Tanzanian , this may simply be a factor of insufficient fixes in other estimates, and therefore unrealistically low estimates of home range.

Goddard(1967) calculated home ranges for adult females and males in two different areas. In the Ngorongoro crater the mean home range size of adult males was 15.80 km^2 with a range of 2.59 to 44.03 km^2. Adult females in the same area had a mean home range size of 15.02 km^2, ranging from 2.59-26.16 km^2. In the area near the Olduvai Gorge, adult males showed a mean home range size of 22.02 km^2 and ranged from 5.44 to 51.8 km^2. In the same area, adult females showed a mean home range size of 35.48 km^2, with a range of 3.63 to 90.65 km^2. Goddard (1967) noted a larger range during wet season, which he attributed to larger variety of palatable plants at that time of year. During the dry season animals apparently stayed close to one marshy area where these plants grow and avoided the dry area. The Sinamatella data shows no significant difference in wet and dry season size for males or females. However, the data fcr males, which was based on a small sample size, showed that males covered more than twice the area in the dry season compared with wet season. This warrants further investigation, but suggests that wet season range contracts when essential resources (water and food) are more plentiful. It is unlikely that, if this is the case, the same would not be true of females, especially when they are often accompanied by less mobile small calves. Indeed the females do show an apparent decrease in size of range during the wet season, although the difference is much smaller than the the males.

Data was analysed to investigate the distribution of wet and dry ranges to ascertain whether they were totally exclusive areas, or whether overlap occurred. There was approximately 35 - 38% overlap of the two seasonal ranges in females, with no significant difference between wet and dry. In males, however, the dry season exclusivity (62.3%) was much higher than the wet (34.7%). The partial wet season exclusivity exhibited by both males and females does however show that it is not simply a contraction of the dry season, but an actual shift in range.

The above comparison of sizes of home range is, however, of somewhat limited value since none of the above-mentioned studies actually quote the number of fixes used to determine home range size. As the analysis in the present study shows quite clearly, there is a relationship between number of fixes and home range size and home range sizes based on fewer than 20 fixes are not likely to provide reliable estimates of home range size.

Since Sinamatella IPZ is not fenced in, it was not unusual to find that some individuals had ranges which extended beyond the boundaries of the IPZ (see Figs. 19 - 25). Eleven black rhino out of a total of 39 for which range data was available had ranges which extended beyond the IPZ boundaries. Extrapolating this ratio to the entire IPZ population, it is likely that there are 18-20 peripheral animals. This has significant implications as far as security is concerned. Since patrolling by the anti-poaching units is generally confined to the area within the IPZ, it means that the animals which range outside the IPZ are potentially vulnerable. Based on ranging data available at the moment, it would appear that the area south and west of Deteema Dam is used frequently by some individuals and there is a strong case to extend the boundaries of the IPZ to cover this area. However, there are other areas on the boundaries of the IPZ which may need to be treated similarly. Once the spoor identification technique is in place, it should provide ranging data for a much larger proportion of the population (rather than just the few collared individuals at present). This will then enable us to make far more concrete recommendations with regard to the expansion of the IPZ.

Also, because all range fixes were based on diurnal radio-tracking visuals they are necessarily limiting in the true representation of the range of the animal. The identification of spoor and use of spoor fixes for range determination will greatly expand knowledge of the true range of the animals, especially as much movement is known to take place to and from water sources at night.

The distribution of ranges within the IPZ is discontinuous, the highest density appearing to be within the Bumboosie and Deteema areas. However, it is premature to make conclusions about the distribution of the population at this stage for two reasons: firstly the ranges of only 39 animals out of the total population of 62 are currently available, and secondly the population distribution was probably affected by the poaching onslaught which took place in the area before the establishment of the IPZ. In years to come data should become available on the factors which determine the distribution of the entire undisturbed population and it is anticipated that deductions might then be made about preferred habitat and range size in relation to population density. Such information would be of importance in allowing management decisions to be made about establishing other IPZ's or expanding existing ones.

4.10 SOCIAL INTERACTIONS BETWEEN BLACK RHINO

Social interactions between females with calves < 2 years and other animals showed, as expected, that such cow-calf combinations spend less time with other animals than any other social group, except single females. Sub-adults and adult bulls were more sociable groups. Two sub-adults were observed on more than one occasion with each other's dam, and her new calf, in an area where the ranges of the dams overlapped. Goddard (1967) reports that sub-adults immediately leave females on birth of new calf but this has not been found to be the case in the Sinamatella IPZ, where several females with new calves are constantly accompanied by the previous calf. It is possible that the previous calves will leave the dam at the time that the new calf is born but then return to join the group on an intermittent basis. An insight into the actual relationships between individuals can only be obtained if there is a programme of continuous monitoring.

4.11 MANAGEMENT OF THE BLACK RHINO IN THE SINAMATELLA IPZ

4.11.1 Dehorning

Milner-Gulland, Beddington and Leader-Williams (1992) calculated that dehorning has to be performed at least annually to make poaching unprofitable.

There has been much controversy over de-horning. Several reports suggest that de-horned cows are unable to protect their calves (Berger *et al.*, 1993, Berger 1994, Berger *et al.,* 1994). Sinamatella data shows that calf survival appears not to be compromised, although to be certain, one would need data on natural mortality levels of calves with horned mothers. Calves lost at Sinamatella over the last two years have all been from dams with at least 8 months horn regrowth. One 6 month old calf of a dam with 8 months of horn regrowth lost both ears and tail in what was assumed to be an attack by spotted hyaena. 12 hyeanas were observed less than 3 km from the observed position of the calf the day after the injury was first noticed. However, since the calf was not lost, the dam had presumably protected it effectively.

As regards its use as an anti-poaching measure, dehorning has been shown to be ineffective on its own. In early 1993 approximately 90 newly-dehorned white rhino were poached in Hwange National Park (DNPWLM, 1994). It is impossible to ascertain how much of a disincentive to poaching dehorning has played in areas such as Sinamatella IPZ where it has been combined with improved ground and aerial monitoring, increased law-enforcement and radio-collaring. On the other hand, many studies have shown the beneficial effect of improved ground law-enforcement alone (Martin & Vigne, 1995; Leader-Williams *et al.*, 1990; Leader-Williams & Albon, 1988).

4.11.2 Intensive management and reproductive performance

The comparison of the reproductive performance of intensively and non-intensively managed females in the Sinamatella IPZ showed that intensively managed females performed less well, with a mean number of calves per female of 0.14 compared with the non-intensively managed group of 0.69. Currently the data is based on relatively small sample sizes, but nevertheless, the possibility that intensive management may compromise reproductive performance of female black rhino should be taken seriously and investigated. If a longer-term compromise is evident then the factors which might contribute to this decline in reproductive performance, which include boma holding, translocation and more frequent immobilisation, must be investigated further. One female from the intensively managed group was observed mating in April 95 but, to date, has not produced a calf. It is not known whether this was due to abortion or simply lack of conception.

Abortion due to immobilisation of a female in early pregnancy has been noted in the field by Kock (pers.comm.) and the data from this study suggests that this may be a regular occurance. Although more data is needed about possible abortions in pregnancy, several long inter-calving intervals also suggest that there may be a significant effect. Since it is impossible to identify a pregnant female *in situ* by sight alone prior to immobilisation, there is concern that a safer method of management should be used if possible, to avoid compromise of female productivity.

Boma confinement is commonly practiced with animals which are being translocated or otherwise managed for various periods of time, with the primary rationale that boma confinement subsequently prevents the animal "bombshelling" on release into the new area (pers. comm., Tatham, English). A secondary rationale is that a "settling in" period in the boma allows the manager to check the condition of the animal and perform any desired physiological or pharmacological tests. However, due to the scarcity of quantitative data from properly followed-up free releases, it is difficult to justify boma confinement in terms of "settling" the animal prior to release. Booth (1983) relates the free-release of four black rhino adult males and two adult females taken from south of Lake Kariba to the Zambezi National Park in 1975. Sightings of the animals were made around two months later, 16 and 14 km from the release point. In seeming contractidiction of the theory that boma confinement prevents re-location to previous home-range, four resident adult black rhino in Sinamatella IPZ were released after a period of 5 months in a holding boma for nutrition trials. After release at a central point in the IPZ, three of the four animals returned directly to their original ranges on the periphery of the IPZ. One of the three animals travelled 45 km overnight to achieve this. The fourth animal was a sub-adult who established a very small new range just north of the release site. What is more, these animals were transported to the release point which was approximately 20 km from the point of confinement, an area which was totally unfamiliar to them. Paradoxically, a reported lack of dispersion after boma management may cause as many problems as perceived "bombshelling". Emslie (1995) comments that one of the major causes of post-translocation mortality is due to the fact that boma held animals do not disperse far enough after release, leading to local high density, increased contact and fighting. Free releases undertaken in the 1960's and 70's were poorly followed up. This area would be worthy of more research, especially in the light of unacceptably high translocation mortality figures. The Veterinary Unit of the DNPWLM (1995) noted that post-immobilisation stress appeared to result as much or more from boma confinement than immobilisation itself.

4.11.3 Radio-collaring

Table 13 showed the unsatisfactory lifespan of the radio-transmitter collars fitted in 1994 and 1995. Given that the battery life of the transmitter is approximately 2 years, the collars failed well before their estimated battery lifespan period ended. Given also that the cost of radio-collaring is substantial (Table 14), the cost: benefit of collaring males is questionable. In order to maintain a reasonable proportion of the population with collars, it is estimated that re-collaring would need to be repeated every 12 months. Both the costs of the operation and the possible effects of invasive management on the population suggest that this would be unwise, especially if applied to the entire population, or as a long-term policy.

It is likely that it would be difficult to design an entirely satisfactory collar for the black rhino, since the neck is wide relative to the head and thus not anatomically suited to a collar design. Difficulties were experienced by the Veterinary team (Kock, pers. comm.) in estimating the correct tightness of the collar being fitted on a recumbant animal, and allowing for possible gain/loss of condition which would make the collar tighter/looser. Lack of opportunity for sufficiently frequent visual follow-ups to permit removal of a cutting collar is also a matter of some concern.

Alternatives to radio-collaring are necessary because it will probably prove unsustainable in the long term. One of the primary perceived functions of radio-collaring is law-enforcement, but this is in fact only true when radio-collaring is backed up with reliable aerial support on 24 hour call, and sufficient scouts in the field to deter would-be poachers. Radio-collaring is, however, a very useful field tool for the rapid location and identification of individuals. If radio-collaring is found to be impracticable and unsustainable an alternative individual recognition system is of primary importance. Rhinowatch is optimistic about the success of the spoor identification technique which it is developing and the results will be presented in a separate report. However, it is recommended that this technique be used in conjunction with the radio-collaring of peripheral animals since these animals are more at risk. The main, non-invasive alternative to the spoor technique is the photography of individual animals. In open areas in Namibia and Tanzania direct photography of the animal (Cillers, 1989; Kiwia, 1989) has been used successfully. Morgan-Davies (1996) has developed a slightly more sophisticated photographic method for identifying individual black rhinos which relies on making a template of their head in profile.

4.11.4 Black rhino density, "carrying capacity" and management of an expanding population

If the current rate of growth of the Sinamatella population is sustained, it will, in theory, take between 7.5 and 17.3 years to reach 'carrying capacity', depending on the density of rhino which can be supported. These figures are based on two different estimated carrying capacities of 0.1 and 0.3 rhino per km^2 taken (du Toit, J.G., 1994). However, since then Emslie (1995) has estimated carrying capacity in the lowveld conservancies, considered good black rhino habitat, of $0.1/km^2$, and it is likely that the optimum stocking density in Sinamatella is similar. Also, the calculation of carrying capacity in an area without a physical boundary and with a good contiguous surrounding area for natural expansion of the population is less useful than it would otherwise be. However, for the sake of assessing the progress of the population, and comparison with other populations, it has been used here.

At the point where numbers have reached carrying capacity, an assessment should be made as to whether the IPZ should be expanded or whether a subset of population translocated outside. Emslie (1995) recommends population be kept at 75% of Ecological Carrying Capacity to ensure maximum growth rate, and calls the desired capacity (MPCC) Maximum Productivity Carrying Capacity. He also quotes estimated desirable stocking rates of $0.1/ km^2$ in the lowveld and $0.053/km^2$ in the midlands, which are rather lower than those of du Toit, J.G. (1994), who reports stocking densities of between 0.1 and 0.3 rhino per km^2 in Zimbabwe. du Toit, R.F. (1994) reports that densities as high as $0.25/km^2$ were common in the Zambezi

Valley before the poaching began, although more arid areas were probably as low as 0.05/km2. Hitchins and Anderson (1983) reported population densities in Hluhluwe and Umfolozi Game Reserves of 0.1/km2 in the former and a very high 0.7/km2 in the latter. Morgan-Davies (1996) reports densities of rhino of 0.1 per km2 in the Masai Mara National Park, Kenya. In 1973 in the same area it was reported (Mukinya, 1973) to be 0.14 animals/km2. Goddard (1967) reported densities of 0.15 animals/km2 in bushed woodland near the Olduvai Gorge and a higher density of 0.32 animals/km2 in the Ngorongoro crater. Frame (1980) reported a lower density of 0.05/km2 along the Seronera river along the edge of the Serengeti plains, and an even lower density of 0.02/km2 overall.

Given that the Sinamatella population is growing very rapidly at present and that it is not confined, it can be assumed that it is well short of ECC. More information about the factors which define stocking density would be available from a GIS study of the topographical data on vegetation type, water availability etc and correlation with rhino density. This would also be very important in the assessment of adjacent areas for potential expansion of the IPZ. In the expectation that the population will increase in the Sinamatella IPZ, it is important that information is available on the options for accommodating that increase, either by the less preferable option of translocation or the more desirable option of expansion of the current boundaries of the IPZ.

There are potential problems with translocating animals to new areas, because high mortalities have been reported by Adcock (1996) with newly translocated animals fighting (22% of 1994/5 deaths in the South African population) and 7.4% capture and establishment related. The report highlights problems arising from the introduction of new animals to an established area, or young animals with unestablished hierarchy into a new area. Adcock (1994) notes that rhino introduced into an already established area are at greater risk of injury due to fighting than if a group of animals are introduced together into a new area. Aggression driven by territoriality is unlikely to lead to fatalities in established animals of any species, and reports of high mortalities from fighting tend to come from introductions into new areas. Emslie (1995) reports that post-translocation mortality among black rhino translocated to the Midlands Conservancy was 15-18%, although he also reports that 44% of these deaths could be attributed to poor nutrition.

For these reasons, it would be preferable to extend the current boundaries of the Sinamatella IPZ as soon as animals are seen to be ranging permanantly outside the IPZ. However, the risk of poaching, and the danger that many animals are in one area can not be discounted, and means that a balanced approach be taken to the problem of how to proceed when MPCC is reached.

4.11.5 Future management options

The three options outlined in tables 14-16, compared in table 17 and compiled into a suggested 10 year management plan in table 18, were selected for their relevance to previous management regimes in the Sinamatella IPZ, and possible options for the future. However, as stated above, **none of these have any relevance unless implemented on a firm foundation of adequate ground law-enforcement.**

It is clear that firmly held and opposing opinions are held by different authorities on the suitability of each option for the management of the black rhino. The tables were compiled with the aim of trying to objectively quantify these options, without emotive or subjective assessment. Tables were compiled specifically for the management of the Sinamatella IPZ population by the DNPWLM, although their relevance may extend further.

The 10-year plan incorporates those features of the options which are considered most suitable. Ultimate priority was placed on the establishment of an effective, cost-effective, self-sustaining system which makes maximum use of local skill and expertise, and is not subject to the vagaries of external funding.

The overall management aim for the Sinamatella IPZ should be firstly to immediately secure the protection of the resident black rhino from any possible poaching threat, by expanding the law-enforcement effort on the ground. This has to remain as the primary mainstay of any of any conservation strategy for the black rhino anywhere in Zimbabwe. If this is not done, the future of the black rhino in Zimbabwe will always remain precarious. After all expensive radio-collaring and/or dehorning in themselves do not stop poaching. An early detection system, which can only come from heavy personnel presence on the ground, is absolutely essential. Secondly, efforts should be made to establish a cost-effective and sustainable monitoring policy, especially one which utilises and involves local expertise. An attempt is being made to put this into place in a collaborative effort between Rhinowatch and DNPWLM. This should then allow the existing population to breed, with minimum interference, as quickly as possible. If in 10 years the population has expanded substantially over the present boundaries of the IPZ it will be the well-earned privilege of the DNPWLM, who first designed and implemented the IPZ policy, to make the next significant decision about the future management of the population. The first successful steps will have been taken in the challenge to secure the future of the black rhino in Zimbabwe.

4.12 THE SIGNIFICANCE OF THE SINAMATELLA POPULATION IN THE WIDER CONTEXT OF THE GLOBAL BLACK RHINO POPULATION.

4.12.1 Is genetic diversity an issue ?

All the issues in this report are directly or indirectly connected with the future management of the Sinamatella IPZ population in Zimbabwe. In the context of the larger African black rhino population and the captive population, primarily outside Africa, the question of the importance of genetic diversity should be addressed for the future management of the species as a whole.

Metapopulation management of the black rhino has often been justified in terms of preventing loss of genetic diversity (Foose, 1993). Both Caughley (1994) and Emslie (1994) are sceptical about the percieved threat to the black rhino of decreasing genetic diversity. Emslie (1994) notes that Southern African black rhinos have a very high degree of genetic diversity, and even if it were to be otherwise, there is no direct evidence that any long-term loss of heterozygosity would necessarily translate into reduced performance of this species. Caughley (1994) notes that the greatest genetic risk to any endangered small population is that it should remain small for a long period of time. After ensuring protection, the first priority in rehabilitating an endangered population is therefore to optimise growth. Only when carrying capacity is reached in a particular area (or 75% of ECC as suggested by Emslie, (1995)) should efforts be made to either expand the area available to the population or translocate some members of the population to other areas. Theoretical conservation genetics, often espoused by captive breeding institutions as justification for moving animals regularly from one establishment to another, which coincidentally also increases gate takings and publicity, may have done a disservice to such small endangered populations in suggesting that the greatest threat to the survival of the population lies in inbreeding.

Caughley (1994) wrote, " *no instance of extinction by genetic malfunction has been reported, wheras the examples of driven extinction* (ie human activity) *are plentiful. Genetic thinking often* *intrudes where it is not relevant and where it sometimes obscures the real issues ....*"

4.12.2 The primary importance of *in situ* conservation.

In the past 15 years many attempts have been made to produce a viable black rhino population through captive breeding. Most captive breeding attempts have taken place outside Africa. Although the theory of having a population held safely from poachers outside the range country is a good one, captive breeding attempts have been beset with problems from the outset. In particular there are two fundamental areas of concern. Firstly, the overall captive population rate of growth (Farst & Foose, 1996) is running at a value of O% after almost 15 years of attempts at captive breeding, and during which time animals have been removed from *in situ* areas to boost numbers. Secondly, there has not, to date, been a single successful re-introduction of a captive-bred animal back to the wild. Indeed, given that the costs of translocation are extremely high (McKinnon, 1991) and mortality rates in translocation may approach 30% (Farst & Foose, 1996) this is not surprising. In addition, the black rhino does not fit any of the criteria laid down by Stanley-Price (1993) for an animal which may be a subject for successful re-introduction.

Another area of considerable concern is the extraordinary disparity in funding available to captive breeding and in situ projects. Alibhai and Jewell (1994b) estimated that 16 rhinos could be protected in the wild (and, as an additional benefit, every other component of the ecosystem) for every one maintained in captivity. Although not all funding sources for one area are necessarily available to the other, there is nevertheless much that could be done to re-dress the balance.

In this regard, Rabinowitz (1995) reviews the difficulties which have surrounded the conservation of the highly endangered Sumatran Rhino in Borneo, and talks of a recent US$2 million plan, based primarily on viable population theory, to save the last of this species through a combination of "wild population protection, sanctuary management, captive propagation and gene-bank technologies". He goes on to say that this plan unfortunately "ignores the fact that the *only* means likely to save the rhino in the wild involves intensive, on-the-ground protection and management activities". He berates continued focus by the international funding community on approaches to rhino conservation which rely on captive breeding and reproductive technology, and which have consistently failed to address the real issues of protecting the animals on the ground *in situ*.

There is much that the captive breeding establishment could gain from closer association with *in situ* projects; in particular study of the ecology and behaviour of the black rhino *in situ*, which would serve better the objectives of captive breeding than placing primary emphasis on the artificial manipulation of reproductive physiology. Valuable points could also be gained in terms of public credibility in the sphere of conservation. There would also be benefit to *in situ* projects from working more closely with those who are involved in captive breeding, especially in terms of fund-raising and public awareness of the plight of animals in the wild. Poaching may be the immediate cause of the decline of numbers of the black rhino in recent years, but in the final analysis, if the animal were to join the increasing ranks of the recently extinct, the charge would lie not at the feet of the poachers. It would be directed at those who failed to enable and implement the most fundamental, cost-effective and obvious of all strategies - adequate protection and monitoring *in situ*.

With international co-operation and a better balance of funding availability, those members of the global community with an interest in the black rhino might work together to ensure that the future of this magnificent animal is safeguarded.

5 ACKNOWLEDGEMENTS

This project was undertaken in conjunction with the Department of National Parks and Wild Life Management of Zimbabwe, and, in particular, the authors would like to thank the following members of the Department for their support

Mr W.K. Makombe, Acting Director, DNPWLM
Dr C. Machena, ActingDeputy Director, Research, DNPWLM
Mr E. Chidzeya, Acting Chief Ecologist
Mr D. Mutape, Provincial Warden, Matabeleland North
Mr N. English, Warden, Sinamatella IPZ

The Scouts and other staff of the Sinamatella Intensive Protection Zone.

In addition, Rhinowatch would also like to thank the following members of the Zimbabwean government for their interest and encouragement

His Excellency, Dr N. Chideya, High Commissioner for Zimbabwe, London, U.K.
Mr E. Chindori-Chininga, Deputy Minister for the Environment and Tourism

Also the following individuals, without whose support the work would not have been possible: Earthwatch staff in Oxford, UK and Boston, USA , the volunteers, and those individuals who gave so generously of their time, effort and funding; Antony Baldwin-Cashel, Tony Murdock-Eaton, Rupert Ingram, Chosa Jogi, Kris Johnson, Margot Knuth, Peter Law, Betty Power, Penny Roberts, Justin Tew and Grahame Veldsman.

Thanks are also due to several generous corporate sponsors who allowed use of equipment and services and gave much useful advice:
D.R. Hendry and Co, Hwange
ICL Africa, Harare
Kantors, Hwange
SAVE Foundation, Australia
Sebakwe Black Rhino Trust, UK
Wankie Colliery Company, Hwange

6 REFERENCES

Adcock, K. (1994) The relevance of "territorial" behaviour in black rhino to their population management. Regional Conservation goals for black rhinos in Namibia/South Africa: Proceedings of a symposium on Rhinos as Game Ranch Animals" Onderstepoort, South Africa.

Adcock, K. (1996) Status and Management of Black Rhino in South Africa and Namibia - report for the Rhino Management Group of South Africa and Namibia.

Alibhai, S. & Jewell, Z.C. (1993) Rhinowatch Survey Report: Chirisa Safari Area and Sengwa Wildlife Research Area - A Systematic Ground Survey of black rhino in 1992. Report to the Department of National Parks and Wild Life Management of Zimbabwe.

Alibhai, S. & Jewell, Z.C. (1994a) Rhinowatch Survey Report: Chirisa Safari Area and Sengwa Wildlife Research Area - A Systematic Ground Survey of Large Mammals in 1992. Report to the Department of National Parks and Wild Life Management of Zimbabwe.

Alibhai, S. & Jewell, Z.C. (1994b) Saving the last rhino: *in situ* conservation or captive-breeding? Unpubl.

Alibhai, S., Jewell, Z.C. and Towindo S. (1995) Rhinowatch Survey Report: Sinamatella Intensive Protection Zone - A Systematic Ground Survey of the black rhino (*Diceros bicornis*) in 1994. Report to the Department of National Parks and Wild Life Management of Zimbabwe.

Alibhai, S., Jewell, Z.C. and Towindo S. (1996) Rhinowatch Survey Report: Sinamatella Intensive Protection Zone - A Systematic Ground Survey of Large Mammals in 1994. Report to the Department of National Parks and Wild Life Management of Zimbabwe.

Balfour, D. & Balfour, S. (1991) Rhino. Struik Publishers, Cape Town.

Berger, J., Cunningham, C. & Gawuseb, A.A. (1994) The uncertainty of Data and Dehorning Black Rhinos. Conservation Biology 8, 1149-1152.

Berger, J., Cunningham, C., Gawuseb, A.A., & Lindeque, M., (1993) "Costs" and short-term survivorship of hornless Black Rhinos. Conservation Biology 7 (4), 920-24.

Berger,J., (1994) Science, Conservation and Black Rhinos. J. Mammalogy 75 (2), 298-308.

Booth, V.R., Jones, M.A. and Norris, N.E. (1983) Black and White rhino introductions in north-west Zimbabwe. Oryx 18 (4), 237-240.

Brooks, M. (1996) Chairman's report: African Rhino Specialist Group. Pachyderm 21, 3-4.

Caughley, G. (1977) Analysis of vertebrate populations. Wiley, New York.

Caughley, G. (1994) Directions in conservation biology. Journal of Animal Ecology 63, 215-244.

Cillers, A. (1989) Monitoring methods and techniques for censusing Black Rhino (*Diceros bicornis bicornis*) in Etosha National Park. Koedoe 32 (2), 49-60.

Conybeare, D. (1995) Report by the outgoing Rhino co-ordinator to the Dept. of National Parks and Wild Life Management of Zimbabwe. p 5.

Cumming, D.H.M., du Toit, R.F. & Stuart, S.N. (1990) African elephants and rhinos status and conservation action plan - IUCN/SSC AERSG report.

Department of National Parks (1993) Black Rhino conservation project - Emergency Plan 1993. Internal report of the Department of National Parks and Wild Life Management of Zimbabwe.

Department of National Parks (1994) Black Rhinoceros in Zimbabwe. Proceedings of workshop for field biologists held at Sinamatella Camp, Hwange National Park, 27-28 September 1994.

du Toit J. G. (1994) white and black rhinoceros as game ranch animals. Proc. Symp on Rhinos as Game Ranch Animals" Onderstepoort, South Africa. pp 111-118

du Toit, R.F. (1989) Investigations into methodology for monitoring BlackRhino Populations in Zimbabwe. WWF Zambezi Project Report. August 1989.

du Toit, R. F. (1993) Rhino conservation in Zimbabwe. Report for the DNPWLM.

Emslie, R.H. (1994) Regional Conservation goals for black rhinos in Namibia/South Africa. Proc. Symp on Rhinos as Game Ranch Animals. Onderstepoort, South Africa.

Emslie, R.H. (1995) Updated final report on the suitability of the Zimbabwe Midlands for black rhino compared with lowveld areas, taking SAVE valley as an example. IUCN SSC African Rhino Specialist Group Scientific Officer's Report to the Zimbabwe Rhino Custodians Committee and Zimbabwe Department of National Parks and Wild Life Management.

Farst, D. & Foose, T. (1996) Summary of the North American AZA SSP Program for Southern Black Rhino *Diceros bicornis minor.*

Foose, T. (1993) Global management of rhinos. Proceedings of the International Conference on Rhinoceros Biology and Conservation, San Diego (1991), 32-43.

Frame, G.W. (1980) Black rhinoceros (*Diceros bicornis* L.) sub-population on the Serengeti plains, Tanzania. Afr.J. Ecol. 18, 155-166.

Goddard, J. (1967) Home Range, Behaviour and Recruitment rates of two black rhinoceros populations. East African Wildlife Journal 5, 133-150.

Harris, S., Cresswell W.J., Forde, P.G., Trehwella, W.J., Woollard, T. & Wray, S.(1990) Home-range analysis using radio-tracking data - a review of problems and techniques particularly as applied to the study of mammals. Mammal Rev. 20 (2&3), 97-123.

Herbert, H.J. & Austen, B. (1972) The Past and Present Distribution of the Black and Square Lipped Rhinoceros in the Wankie National Park. Arnoldia 26 (5), 1-6

Hitchins, P.M. (1970) Field Criteria for Ageing Immature Balck Rhinoceroses: *Diceros bicornis* L. Lammergeyer 12, 48-55.

Hitchins, P.M. (1978) Age determination of the Black Rhinoceros (*Diceros bicornis* Linn.) in Zululand. S Afr. J. Wildl. Res. 8, 71-80.

Hitchins, P.M., Anderson, J.L. (1983) Reproduction and Population characteristics and the management of the Black Rhino (*Diceros bicornis minor*) in the Hluhluwe/Corridor/Umfolozi Game Reserve complex. S. Afr. J. Wildl. Res. 13 (3), 78-85.

Jones, M.A.. (1992) Hwange National Park Management Plan. Report for the Department of National Parks and Wild Life Management of Zimbabwe.

Kiwia, H.D. (1989) Black Rhinoceros (*Diceros bicornis*): population size and structure in the Ngorongoro crater, Tanzania. Afr. J. Ecol. 27, 1-6.

Kock, M.D. & Atkinson, M. (1993) Report on dehorning of black (*Diceros bicornis*) and white (*Ceratotherium simum*) rhinoceroses in Zimbabwe. Report to the DNPWLM of Zimbabwe.

Krebs, C. J. (1989). Ecological Methods. Harper & Row, N.Y.

Leader-Williams, N. (1993). Theory and pragmatism in the conservation of rhinos. Proceedings of the International Conference on Rhinoceros Biology and Conservation, San Diego (1991), 69 - 82.

Leader-Williams, N. and Albon, S.D. (1988) Allocation of resources for conservation. Nature 336, 533-535.

Leader-Williams, N., Albon, S.D., and Berry, P.S.M. (1990) Illegal expolitation of Black Rhinoceros and elephant populations: patterns of decline, law enforcement and patrol effort in Luangwa Valley, Zambia. J. Appl. Ecol. 27, 1055-1087.

MacKinnon, K. (1991) How about letting them breed by themselves? BBC Wildlife Magazine 9, (7), 454-455

Martin, E. B. (1993). The present-day trade routes and markets for rhinoceros products. Proc. International Conference on Rhinoceros Biology and Conservation, San Diego (1991), 1 - 10.

Martin, E.B. (1995) Nepal's Rhinos - one of the greatest conservation success stories. Pachyderm 20, 10-25.

Milner Gulland, E.J., Beddington, J.R., and Leader-Williams, N. (1992) Dehorning African Rhinos - a model of optimal frequency and profitability. Proc. R. Soc. Lond (B) 249, 83-87.

Morgan-Davies, M. (1996) Status of the Black Rhino in the Masai Mara National Reserve, Kenya. Pachyderm 21, 38-45.

Mukinya, J.G. (1973) Density, distribution, population structure and social organisation of the black rhinoceros in Masai Mara Game Reserve. E. Afr. Wildl. J. 11, 385-400.

Nowell, K., Chyi Wei-Lien and Pei Chia-Jai (1992) The horns of a dilemma: The market for rhino horn in Taiwan. Traffic International, Cambridge, England.

Owen-Smith, R.N. (1992) Megaherbivores. Cambridge University Press.

Pyke, G.H. & O'Connor, P.J. (1990) The accuracy of a Radiotracking System for monitoring Honeyeater movements. Aust. Wildl. Res. 17, 501-9.

Rabinowitz, A. (1995) Helping a Species Go Extinct: The Sumatran Rhino in Borneo. Conservation Biology 9 (3), 482-488.

Redmond, I. (1993) Sir Peter's Paradox. BBC Wildlife Magazine 11 (2), 42-44.

Rogers, C.M.L. (1993) A woody vegetation survey of Hwange National Park. Report prepared for the Department of National Parks and Wild Life Management of Zimbabwe.

Sayce, K. (Ed.) (1987) Tabex Encyclopaedia Zimbabwe. Quest Publishing, Harare.

Stanley-Price, M.R. (1993) What will it take to save the Rhino?. Proceedings of the International Conference on Rhinoceros Biology and Conservation, San Diego (1991), 48-68.

Streeter, M. (1996) Record haul of rhino horn is seized. Independent Newspaper, London (4-9-96).

Tafangenyasha, C. & Campbell, B.M. (1995) Past human activities in the Sinamatella area of

Hwange National Park, Zimbabwe. J. Appl. Science in Southern Africa 1 (1), 63-71.

Tatham, G. H. & Taylor, R. D. (1989) The conservation and protection of the black rhinoceros, *Diceros bicornis*, in Zimbabwe. Koedoe 32, 31-42.

Todd, I. (1993) Wildtrak non-parametric home range analysis for the Macintosh. Dept. of Zoology, University of Oxford, UK.

Towindo, S. (1990) Black rhino survey II in the Sengwa Wildlife Research Area. Unpubl.

Veterinary Unit (1995). Immobilisation, dehorning, radio-collaring/monitoring, and health problems of black and white rhinoceroses in the Matobo, Sinamatella and Matusadona Intensive Protection Zones. Report by the Veterinary Unit, Department of National Parks and Wild Life Management of Zimbabwe.

Veterinary Unit (1996) Immobilisation and radio-collaring of black rhinoceros in the Sinamatella Intensive Protection Zone (IPZ), Hwange National Park and Matusadona National Park IPZ. Report by the Veterinary Unit, Department of National Parks and Wild Life Management of Zimbabwe.