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FACTORS AFFECTING THE DISTRIBUTION AND SURVIVAL OF BLACK RHINOCEROS (*DICEROS BICORNIS* L.) IN RHODESIA

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Presented to the University of Rhodesia as a thesis for the Certificate in Field Ecology.

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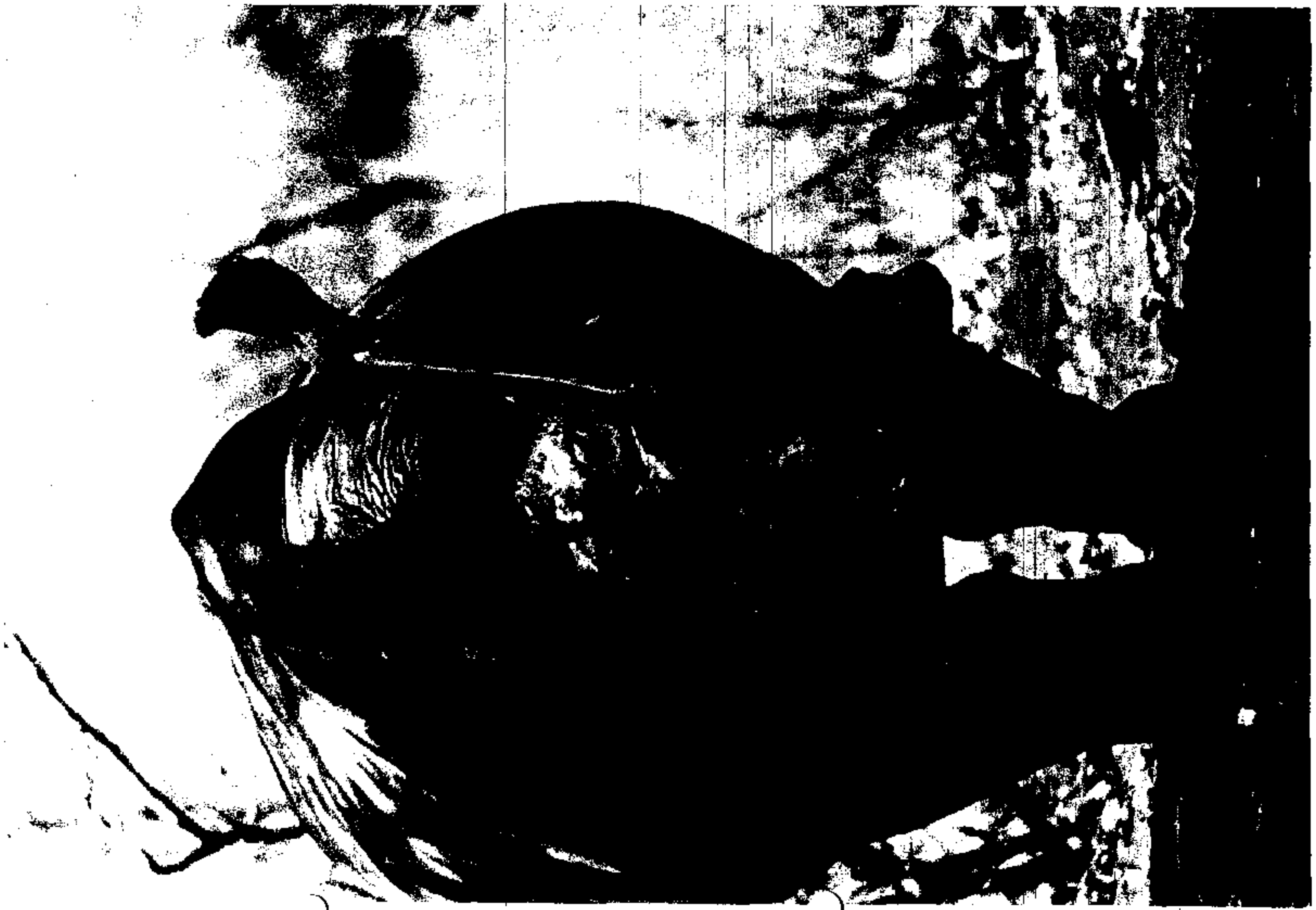

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1. ABSTRACT.

The past and present distribution of Black Rhinoceros (*Diceros bicornis* L.) in Rhodesia was examined and it is concluded that the species occupied and still exists in a wide range of environments. Three different and relatively undisturbed habitats were studied wherein population densities and relative (lateral) cover factors were assessed.

A new technique for measuring lateral cover is explained and relative cover factors for each habitat are determined. Correlations were made between relative cover factors and population densities and the results show a significant relationship between population density and available thicket cover and also an inverse relationship between each animals requirement for cover and available cover in the habitat.

Observations from several areas, made during capture operations, were brought into perspective and are discussed. These include feeding habits, water requirements, behaviour, reproduction, interspecific relationships, survival and predation.

2. INTRODUCTION.

Past records indicate that the Black Rhinoceros (*Diceros bicornis L.*), hereafter referred to as rhino, occurred throughout Rhodesia in good numbers. The present distribution shows a drastic reduction of the former range of this species and there are indications that still further contraction of its range is occurring; ultimately rhino will probably only occur in the game reserves of Chewore, Mana Pools, Matusadona, Chete, Chizarira, Gona-re-Zhou (re-introduced) and in the northern part of Wankie National Park (re-introduced). In some of these game reserves, however, the species is not secure.

The survival of the rhino in Rhodesia will depend upon a thorough understanding of its ecology and proper management of the sanctuaries to which they will be finally confined. The objectives of this study are to determine factors which affect the distribution and survival of the rhino in Rhodesia with a view to a better understanding of the problems attached to the re-establishment of breeding nuclei in areas of the species former range and the correct management of populations in existing sanctuaries.

Roth (1967) recorded the distribution of rhino from 1865 to 1965; Wild and Fernandes (1967) produced a vegetation map of Rhodesia (The Flora Zambesiaca); and the Rhodesian Surveyor-General has produced maps detailing the country's average rainfall (1958) and altitudes (1965). This literature enabled me to correlate the broad environmental factors associated with the past and present distribution of rhino in Rhodesia.

Goddard (1966 & 7), Roth and Child (1967), Child (1968), R.Schenkel and L.Schenkel-Hulliger (1969) and Hitchins (1970), have produced papers on various facets on the ecology with others interested in the study of this species, particularly Hitchins (Hluhluwe Game Reserve) in this respect, and others, has also contributed to the paper.

3. APPROACH TO THE PROJECT.

During the two year period of this study, I had to prepare and execute Black Rhino Capture Operations in the Chipinga, Gokwe, Shamva and Mount Darwin districts of Rhodesia in addition to my normal station duties. Protracted absences from my home station precluded any form of local study and it is mainly for this reason that I confined my investigations to the rhino.

The nearest undisturbed rhino populations are 700 miles from my home station and as the area in which captured rhino were released into the Gona-re-Zhou during 1970 & 1971, is situated 100 miles north of it, detailed study of this species from my home station was not possible. In addition, the arduous nature of the work whilst capture operations were in progress precluded any detailed study of habitats, although several other problems were investigated. As this paper deals primarily with the subject of habitat, it is necessary to outline my approach to this study.

I have conducted rhino capture operations annually since 1964 (with the exception of 1966) and certain observations made during this work were considered worthy of further investigation. The most striking observation was an apparent increase in population density with an increase in available habitat cover. The main part of this study, therefore, is an investigation into this aspect of the rhino's ecology.

The problems attached to such an investigation included the assessment of the numerical size of several rhino populations in habitats suitable for comparison and the defining of home-ranges. In view of the time available to complete this study and the distances involved between suitable study areas and my home station, the determination of these factors in a completely new study was considered to be impractical. I found it necessary, therefore, to utilise my records and previous reports on capture operations as a foundation for this study.

Studies relating to rhino population densities, home-range sizes and habitat cover assessments were confined to the Binga District where three areas, Sizemba, Chininga and Manzituba, provided the diverse habitat types required. All three of these areas are well-known to me and both the rhino population size and the composite area occupied by the sedentary population units, in each area, had already been determined. For comparisons to be made between population densities and habitat cover factors, all that was necessary was that the cover factor in each habitat should be measured. All three study areas were re-visited in October, 1970, at the height of the hot-dry season, when a full week was spent in measuring the cover in these areas.

Quantitative feeding records were kept during the capture operations at Mfurudzi and Ruya during June, July and August, 1970, and these have been compared with subjective observations in other areas in Rhodesia.

Although only three habitats have been selected for the primary study in this paper, varied data on a wide range of subjects have been collected from several areas in the country and therefore a good cross-section of conditions has been examined, with comparisons being made where possible. This has enabled me, in the time available, to indicate the broader habitat requirements of the species instead of merely the narrow record from just one habitat.

In addition to the primary objective of this study, viz. to correlate and determine the intensity of the relationship between rhino population densities and habitat cover, this paper also sets out to discuss and give results of research into several other factors affecting the distribution and survival of rhino in Rhodesia.

4. STUDY AREAS.

(1). The three main study areas in the Binga District, Sizemba, Chininga and Manzituba, were chosen to measure the intensity of the relationship between rhino population densities and available cover in the habitat, because :-

(i). The three areas are not extensive in size, varying between (approx.) 15 and 30 square miles in area.

(ii). They are habitats which supported a known rhino population (42, 15 and 5 respectively) and in which the dry-season area occupied by the sedentary units was also known; the foundation information for this study was therefore already to hand.

(iii). Each of the three areas comprises a different habitat type and the diverse cover conditions provided a basis for comparison.

(iv). All three areas had been subjected to similar ecological pressures resultant from the creation of Lake Kariba, at the time of the study; this includes disturbance by man.

(v). I have spent five years in the Binga District (1964 - 68) and know all three areas intimately. In two of the areas, Sizemba and Chiñinga, almost the entire rhino population had been captured and the third, Manzituba, was the most important sector of the Chizarira Game Reserve for which I was responsible.

The locations of these three study areas are shown in Fig 1..

(2). The three main study areas are described as follows.

(i). Sizemba.

This area is 17.83 square miles in extent and is situated in Tribal Trust Land, west of the Sengwa River mouth on the shores of Lake Kariba. It is bounded by the flooded Sengwa River, Lake Kariba, broken hill country and African settlement. See Appendix 1., Map No. 2..

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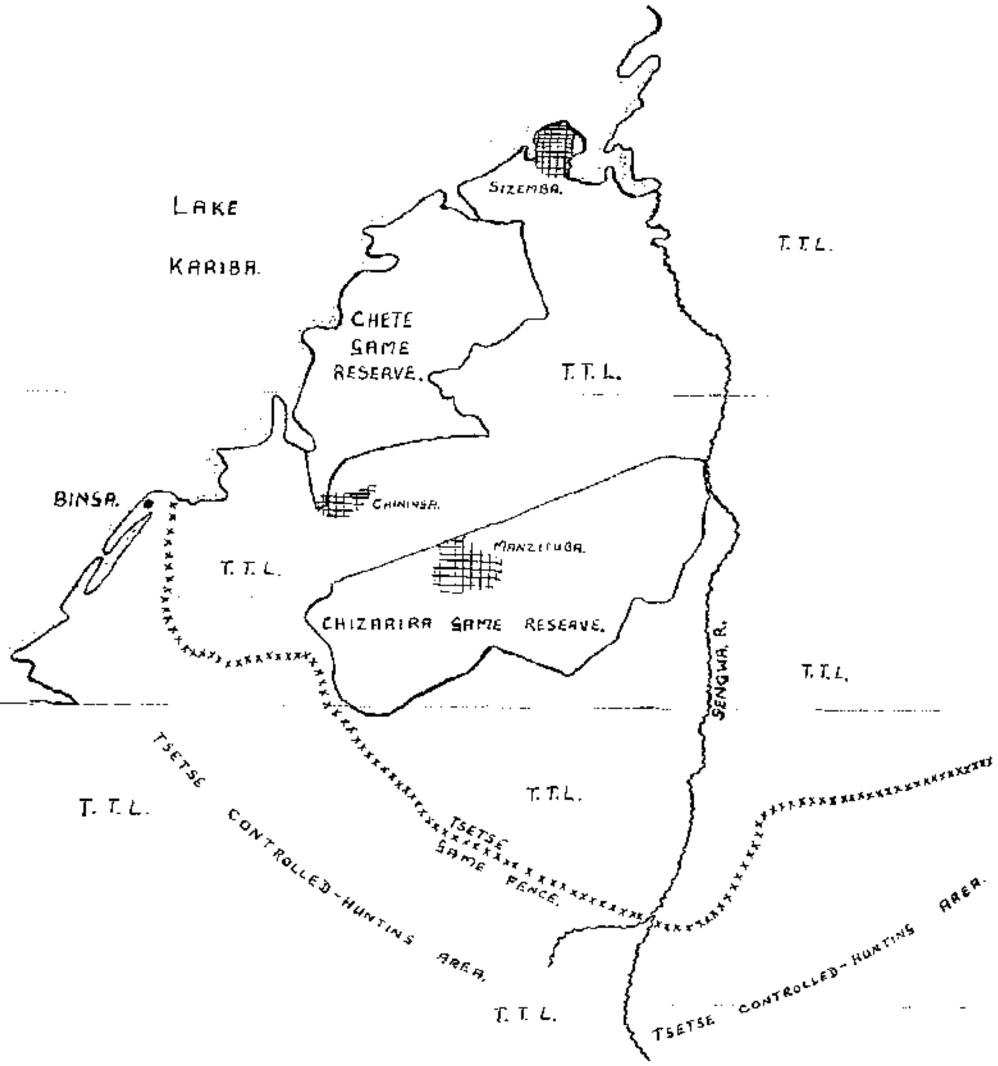
Binga District showing the position of Study Areas in relation to Lake Kariba, the Game Reserves of Chete and Chizarira, the Tribal Trust Lands, the Tsetse Controlled-Hunting Areas and the Tsetse Game Fence. (1964-68).



LEGEND.

= DEMARCATION OF STUDY AREA.

T.T.L. : TRIBAL TRUST LAND.

SCALE : 1 : 1,000,000.

Three fishing grounds, bush-cleared before the lake filled, are situated on the lake shore boundary and these result in a not inconsiderable pedestrian traffic along the south-eastern perimeter to the area; African fish buyers, in vehicles, also occasionally use this same route.

The habitat is generally flat, with occasional broken ridges and the vegetation can be categorised into three basic types :-

(a). Deciduous *Commiphora/Combretum* thicket (Wild and Fernandes (1967) - Flora Zambesiaca type 12.), hereafter described as " thicket ".

(b). *Colophospermum mopane* woodland (Wild and Fernandes (1967) - Flora Zambesiaca type 35.), hereafter described as " woodland ".

(c). *Colophospermum* Rock Scrub, hereafter described as " scrub ". This comprises stunted and small trees of *C. mopane*, growing on rocky ridges with *Terminalia prunioides*, *Diospyros quiloensis*, *Combretum apiculatum* and *Combretum elaeagnoides* growing in association. There is no equivalent description of this association in the Flora Zambesiaca (Wild and Fernandes (1967).), although it is probably closer to type 35., than to any other.

These three vegetation categories are demarcated on Map No. 2., in Appendix 1., having been traced from an aerial photographic mosaic following a ground check in October, 1970.

The " home-range " limit demarcated on the above-mentioned map, shows the extent of the movement of individuals within the population at the height of the dry-season.

There is no permanent water inside the area but the maximum distance to water on the perimeter is less than 5 kilometers (3 miles).

Three roads traverse the area, but only one (along the south-eastern perimeter) was used to any extent.

Other game in the area included 3-400 elephant approximately 600 buffalo and also eland, kudu, impala and zebra. There were 5 or 6 lions which visited the area regularly and hyenas were abundant. The elephant population was undoubtedly too high for the area, as degradation of the habitat was noticeable.

Rhino capture operations, in which I participated, were mounted in 1964 and 1965, in this area. A total of six months was spent in the area during these operations, in July, August and September of each year, i.e., during the latter part of the cold-dry season and the first part of the hot-dry season. During this period a total of 38 rhino were captured and only four were left behind, making the total population in the area, 42..

Only one African family lived inside the habitat and poaching at the time of the operations was minimal. Anti-poaching police work was maintained in and around this area during all seasons, by myself and my African staff.

(ii). Chininga.

This area is 15.18 square miles in extent and is situated inland from Lake Kariba, on the Chininga River, in Tribal Trust Land. It is lightly broken country with thicket occurring on the sandy soils on the crests of the ridges. The vegetation can be broken down into the same three categories as are found at Sizemba but there are definite differences in the character of the scrub and thicket categories which alters the lateral cover factors in the habitats :-

(a). At Chininga, the thicket is basically of the Commiphora/Combretum type but is occurs as a woodland with a continuous canopy above the height of 6 meters, with a well-developed understorey. At Sizemba, the thicket occurs as a dense mat of bush growing to a maximum height of 6 meters and with irregularly spaced, emergent trees between 6 and 10 meters in height, growing in the thicket at various densities. This results in a considerable reduction in the lateral cover at

Chininga, compared with that found at Sizemba, in this vegetation category. (See Fig. 7.).

(b). Gardenia resiniflua occurs as a major species in the scrub at Chininga whereas at Sizemba this species is relatively unimportant. This difference in species occrrence has resulted in 50% more cover being recorded in the scrub vegetation at Chininga compared with that found at Sizemba in the same category. (See Fig. 7.).

The Chininga River holds permanent water in four pools and one of its tributaries, the Kasanzi, has a further two pools; a seventh water-hole is situated to the north-west of the habitat on the Makandabwe River and this also served the rhino population in this area. The maximum distance from water in this habitat is less than 5 kilometers (3 miles.).

One road, parallel to and less than half-a-kilometer from the Chininga River, ran through the area and up until 1968, when the rhino population assessment was made, only 5 to 10 vehicles used this road each day.

Game in the rhino habitat was not abundant. Only about 30 elephant and less than 50 buffalo lived in the area during the hot-dry season, although numbers increased during the wet season. Kudu were quite common, impala occurred in the woodland areas along the rivers and zebra oould be found along the northern boundary of the habitat area in very broken country.

A total of five months was spent in this area on capture operations during 1967 and 1968, at the end of the cold-dry season and during most of the Hot-Dry season. During this period 10 rhino were captured, three died as a result of drug problems or the vicissitudes of the hunting and two were not caught, making the total rhino population for the area, 15..

No African families lived in the habitat and the nearest African habitation was 6½ kilometers (approx. 4 miles.) distant. Poaching was minimal and anti-poaching policework was maintained.

(iii). Manzituba.

This area is 31.61 square miles in extent and is situated approximately 25 miles inland from Lake Kariba on the Chizarira plateau. Manzituba can be described as the heart of the Chizarira Game Reserve and provides a major habitat for many species of game. Being situated in a game reserve, this area is the only study area which comprised a complete and gazetted sanctuary and which did not fall within the Tribal Trust Lands.

The study area is bounded on the north side by precipitous cliffs which fall away from the main plateau in the game reserve, to Tribal Trust Lands 2,000 feet below, from which there is only limited access. The other three sides of the study area comprise rolling hill country, all part of the game reserve. See Appendix 1., Map No. 4..

The vegetation can be categorised into three types:-

(a). Julbernardia globiflora woodland with Brachystegia boehmii represented as a sub-dominant. (Wild & Fernandes (1967) - Flora zambesiaca type 30.).

(b). Scrub woodland of the above type in a state of retrogressive succession (Damage caused by fire and elephant feeding - Thomson W.R., Depantmental Report of Woodland Degradation, 1965.). Hereafter called scrub.

(c). Vlei country along the drainage lines where Hyparrhenia spp. occur as the dominant grass. Sponges and springs occur on some of the vleis and there are permanent streams in the area, fed by the springs. The maximum distance from water is only about 4 kilometers (2½ miles). These vleis, however, were so small in comparative size with the other two vegetation types, that they were completely ignored as a category of vegetation for measurement.

No roads disturbed the area and there was no pedestrian traffic through the area other than anti-poaching game scout patrols.

As a result of constant observations at Manzituba, both by myself and my African staff stationed there, it was concluded that only 5 rhino occupied the habitat. Other game in the area includes influxes of elephant (normally less than 100 at any one time)and up to 200 buffalo, both species which move in and out of the area throughout the year; resident herds of sable, zebra, kudu, tsessebe, impala and reedbuck also occur in fair numbers.

No Africans lived in the area until a small resident game scout force was established on the edge of Manzituba in 1966; the nearest tribal African habitation was about 10 kilometers (approx. 6 miles) distant.

No poaching occurred as the area was very heavily patrolled by both European and African staff of the Department of National Parks & Wild Life Management.

(3). All three areas have been affected by the creation of Lake Kariba in several ways :-

(i). The flooding of the rich Zambesi valley habitats forced game populations there to move back from the rising waters of the lake and these displaced animals had to find new home-ranges in the predominantly broken country south of the lake, in which there was a less rich type of vegetation and where there was already an established game regime.

(ii). Prior to the formation of Lake Kariba, African settlement in the district was concentrated along the Zambesi River and interference with game in the hinterland was minimal. When the lake filled, however, 30,000 Batonka tribesmen were moved away from the Zambesi and resettled on the very limited alluvial soils which occurred sporadically along some of the major rivers. They removed the vegetation from these soils, to accommodate their crops and they occupied the principal water-holes; by these actions, the Batonka thus came into direct biological competition with the game.

(iii). The game reserves of Chete and Chizarira, amounting to 1,000 square miles out of a total of 6,000 square miles which comprises the district, were created in 1963 to accommodate the game animals which had hitherto enjoyed free range over the entire area, plus large tracts of country now inundated by the lake, which filled to capacity that same year. The game reserves have no alluvial valleys and have little to commend them in the way of vegetation. The Manzituba area of the Chizarira, which receives additional protection as a result of Batonka superstition, provided the only suitable major habitat for several species.

(iv). Game throughout the district was therefore under increased inter- and/or intra-specific pressures. Poaching became progressively more severe and those species which were able to, began to reorganise themselves in the district. Elephant and buffalo began to range further afield, spreading southwards towards the farming areas and this movement, probably combined with increased vehicle and pedestrian traffic, began to influence the spread of tsetse-fly. In 1964, anti-tsetse control measures were implemented and game fences were erected around the main game populations of the district. To the south of this game fence elephant, buffalo, kudu, bushbuck, bushpig and warthog were systematically eliminated and other species, including the rhino, were often killed by the African hunters without authority.

Fig 1., shows the relative position of the three main study areas and the two game reserves of Chete and Chizarira, in relation to Lake Kariba and the tsetse game fences.

(v). Because the Batonka people had been moved from their traditional homes on the Zambesi River alluvia, Government gave special consideration to their problems in the new settlement areas. These problems included the raiding of their crops by elephant and buffalo. These two species were consequently destroyed in considerable numbers, north of the tsetse game fence also.

It can be seen that game in the district was subjected to pressures from all sides, including severe culling from the centre of the game-population area too. However, two areas within the Tribal Trust Lands resisted settlement by the Batonka and formed sanctuaries for game. These were at Sizemba and Chininga, where depredations by game on Batonka crops was so heavy as to discourage would-be agriculturalists from settlement. The government ministry responsible for the Batonka assisted in preserving these sanctuaries also, by discouraging settlement and I instituted anti-poaching work in both these areas, besides the work carried out in the game reserves themselves, to give added protection to the rhino populations. Poaching remained light in these areas for other reasons also; game was so plentiful during the first five years following the resettlement that Batonka tribesmen did not have to venture far from their homes to obtain meat and had no reason to move into any of the study areas to search for game.

It is believed, therefore, that Sizemba and Chininga contained rhino populations consistent with the carrying-capacity of the habitat and that the animals in these two areas, were little affected by Batonka poaching. It is further believed that had there been an over-population of rhino some signs of intra-specific competition would have been noticed during the capture operations but none were found.

Manzituba is the best protected of the three areas and, although it has rhino populations on three sides from which to draw recruits, its rhino population has not altered noticeably since 1964. I believe, therefore, that this study area also contains a rhino population consistent with its carrying capacity, i.e., it is fully stocked.

(4). Data for studies other than those concerned with correlations between relative-cover-factors and rhino-population-densities, came from various other areas in Rhodesia. These include :-

(a). Mfurudzi in the Shamva District. This is an area of rolling hills and valleys with high ranges rising sharply to elevations 1,000 - 1,500 feet above the surrounding countryside. The vegetation consists of open woodland with small trees wherein Brachystegia boehmii and Julbernardia globiflora appear as dominants (Wild & Fernandes (1967) - Flora Zambesiaca type 29.).

In June and July of 1970, I conducted rhino capture operations in this area.

(b). Ruya in the Mount Darwin District. This is a mixed habitat in broken granite country with Sterculia spp., Adansonia digitata, Terminalia sericea, Colophospermum mopane, and Julbernardia globiflora well represented; Brachystegia boehmii only occurred at one point in the south-west of the area whilst some Commiphora-Combretum thicket was also in evidence, (The vegetation appears to be an inter-phase between Wild & Fernandes (1967) - Flora Zambesiaca types 47, 49 and 29 with some of type 12 included.).

I conducted rhino capture operations in this area during August, 1970.

(c). Pohwe and Tende in the Gokwe District. The vegetation of both these areas was similar but Tende was a little more broken than Pohwe. The vegetation consisted of extensive areas of Commiphora-Combretum thicket (Wild & Fernandes (1967) - Flora Zambesiaca type 12.), interspersed with predominantly Brachystegia boehmii woodland on the ridges and Colophospermum mopane woodland on the lower lying ground, (Wild and Fernandes (1967) - Flora Zambesiaca types 29 and 35.).

Rhino capture operations were mounted in these areas in November, 1969.

(d). Chipangayi in the Chipinga District. There were two rhino cows left from this population, the others having been poached out over the years. Onw of the these animals had taken up residence in the flat country near the Sabi River where the vegetation was either riparian or Acacia woodland (Wild and Fernandes (1967) - Flora Zambesiaca type 48), mainly *A. tortillis* . The other one had retired into the escarpment country which was extremely broken, steep and to most people, inaccessible; the vegetation here was largely *Julbernardia globiflora* and *Brachystegia boehmii* with *Brachystegia glaucescens* well represented (Wild and Fernandes (1967) - Flora Zambesiaca type 30.).

These rhino were captured one in May 1969 and the other in November, 1969..

Areas (a),(b),(c) and (d) are marked on Map No. 1., Appendix 1.. Other general information was obtained from the Gona-re-Zhou, where rhinos were introduced in 1969, 1970 and 1971 and which is marked on this same map, and from the Binga District in general, which is shown in Fig. 1..

5. METHODS.

(1). The Basic Environmental Factors which probably affected the Rhino in its Past Distribution.

This assessment was achieved by extracting facts contained in the following literature.

(i). " White and Black Rhinoceros in Rhodesia." - Roth (1967). (See Appendix 1. Map No. 1.).

(ii). " Vegetation Map of the Flora Zambesiaca Area." - Wild and Fernandes (1967).

(iii). "Rhodesia's Average Rainfall Areas." - Rhodesian Government - Surveyor General's Office (1958).

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This information has been compared with and broadened by my personal observations in Rhodesia and also from visits to Hluhluwe Game Reserve (Natal) and Addo National Park (Cape Province) in South Africa, made during the course of this study.

(2). The Home-Range Assessment of Rhino Populations in the three main study areas of Sizemba, Chininga and Manzituba.

During several years of close association with rhino, I have found that their home-ranges vary with the seasons, i.e., the Hot-Wet Season (November to March), the Cold-Dry Season (April to July) and the Hot-Dry Season (August to October). During the Hot-Dry Season cover is reduced when deciduous trees shed their leaves, the succulence of food supplies is at its lowest level, waterholes are restricted in number, temperatures are at their highest and both inter- and intra-specific pressures are at a maximum. It is during this season that rhino experience most stress and their home-ranges are, by necessity, contracted in area. Home-range assessments were, therefore, made during this period because they reflect the minimum requirements of the species.

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It was not possible to determine the home-range of each individual animal in the three rhino populations under study; a prerequisite for accurate determination of population density levels. This could have been accomplished under different circumstances, using biotelemetric techniques but it would have taken several years and considerable expense to complete and I had neither the time nor the resources to undertake such a study. However, I was able to ascertain the outer limits of movement of the populations as a whole, in all three study areas,and this " population home-range " (hereafter referred to as " home-range ") has been accepted as a parameter to compare population density levels in the three study areas.

This rather unorthodox method of " home-range " assessment is, nevertheless, still considered a valid parameter because of the clearly defined limits of each populations area of movement during the Hot-Dry Season, the rhino's sedentary behaviour pattern and the very small areas of overlap with adjacent sedentary populations which was observed at Chininga and at Manzituba, in the vicinity of waterholes. This parameter was also the only one at my disposal.

The Sizemba home-range size was determined only after six months of exhaustive tracking of the animals during the Hot-Dry Seasons of 1964 and 1965.

The Chininga home-range size was determined under similar conditions during 1967 and 1968.

The home-range at Manzituba was defined from personal observations on five known rhino and their spoor, over a four-year period (1964 - 1968), substantiated by regular observations by reliable African game scouts.

The three home-ranges thus determined, were demarcated on 1 : 25,000 aerial mosaic photographs from which maps were traced. The different vegetation categories similarly marked and committed to these maps.(Appendix 1., Maps No.s 2, 3 and 4.). I subsequently measured the home-ranges and different vegetation types, using a planimeter, and converted the measurements to units of square miles.

(3). <u>The Measurement of Relative Cover Factors at Sizemba, Chininga and Manzituba; Population Assessment and Density Levels ; and Method of Correlation between these Factors.</u>

(i). <u>Cover Measurement.</u>

Observations throughout the country have indicated that both population density and home-range size differ according to the nature of the habitat. Rhino living in open country appear to range over a far wider area than those in thicket country and population density appears to increase as the habitat cover increases. No one, however, appears to have measured this although Goddard (1967), Schenkel (1969) and Hitchins (pers. comm.) all mention thicket as comprising at least part of the species habitat (which is not the case at Manzituba.). It was apparent, therefore, that in evaluating the habitat of the rhino, it would be essential to measure the cover factors in each study area.

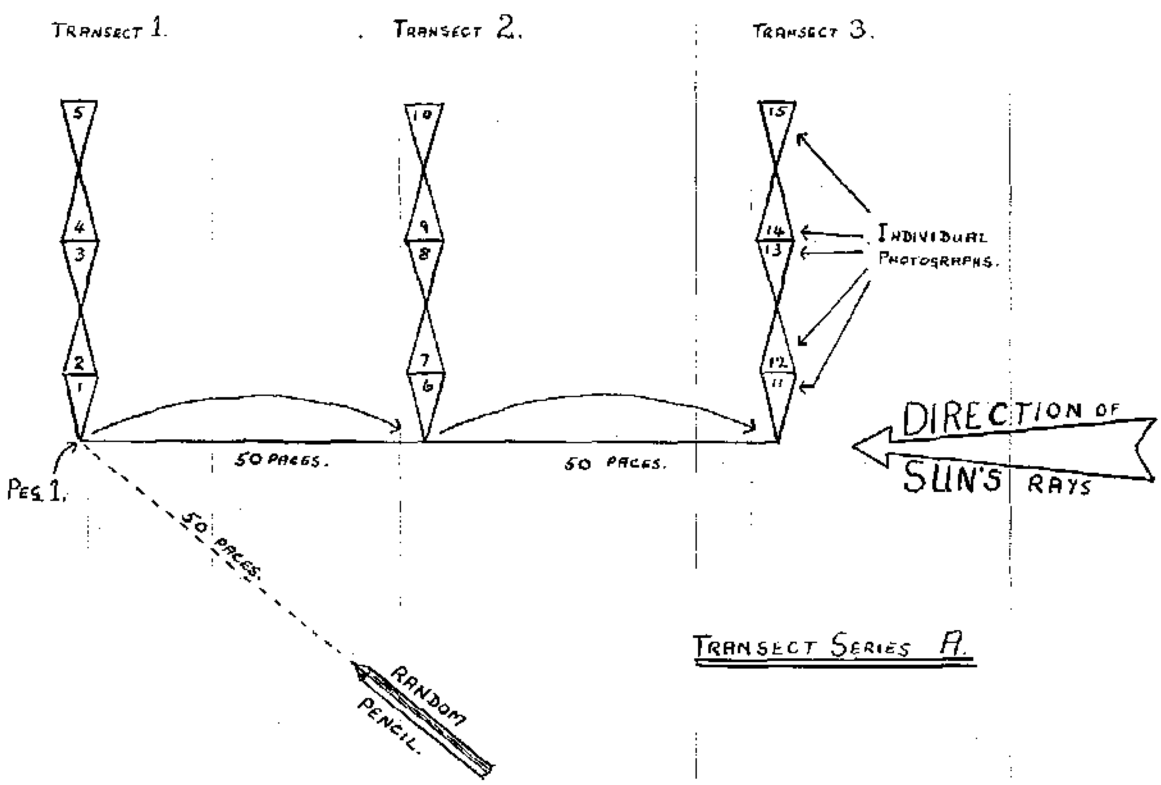
Basal cover and canopy cover are minor in importance when considering protection for an animal like the rhino. Lateral cover, or " obstruction to vision " , is the important factor since it is this form of cover which affords the rhino protection from predators. Wight (1938), in the Manual of " Wild Life Management Techniques ", describes the use of a " density board " to measure the lateral density or cover factor, but this method was tried and found to be unsuitable for this study. In fact, no conformable technique could be found to measure the lateral cover under the varied conditions found in the three study areas. It was therefor necessary to devise a new technique to resolve the problem.

It was decided that since a rhino stands less than two meters in height, even with it's head erect, only the cover factor up to this height is pertinent to the study. Several techniques were tried and discarded but finally one was tested and found to be both accurate quantitatively and practical.

The technique involved the use of a reflex camera with a 5.5 cm. lens, a tripod, a cotton-sheet screen and colour-slide film. Three transect lines, each 25 meters long and 50 meters apart, were set up in the vegetation to be measured (See Fig. 2 .). On each transect, six pegs were driven into the ground at 5 meter intervals and the camera was set up over the first peg. The sheet screen, in size,over 2 meters high and almost 3 meters wide, with rigid poles at either end, was set up centrally over the second peg. A small black line marked on the bottom centre of the sheet and arranged so that it was placed over the peg, acted as a guide to centralise the image in the camera's view-finder. A small board bearing a serial number to identify the photograph, was then held in view at the edge of the screen and a photograph was taken.(See Fig. 3.). The camera was then positioned over Peg No. 3, the serial number on the board was changed and a second photograph was taken of the reverse side of the screen. The screen was then moved to Peg No. 4 and, without moving the tripod, the camera was turned to face the screen and a third photograph was taken. The camera was then moved to Peg No. 5 and another photograph was taken of the screen from that position. The fifth, and last, photograph on the transect was taken from Peg No. 5 with the screen in place on Peg No. 6.. Five photographs

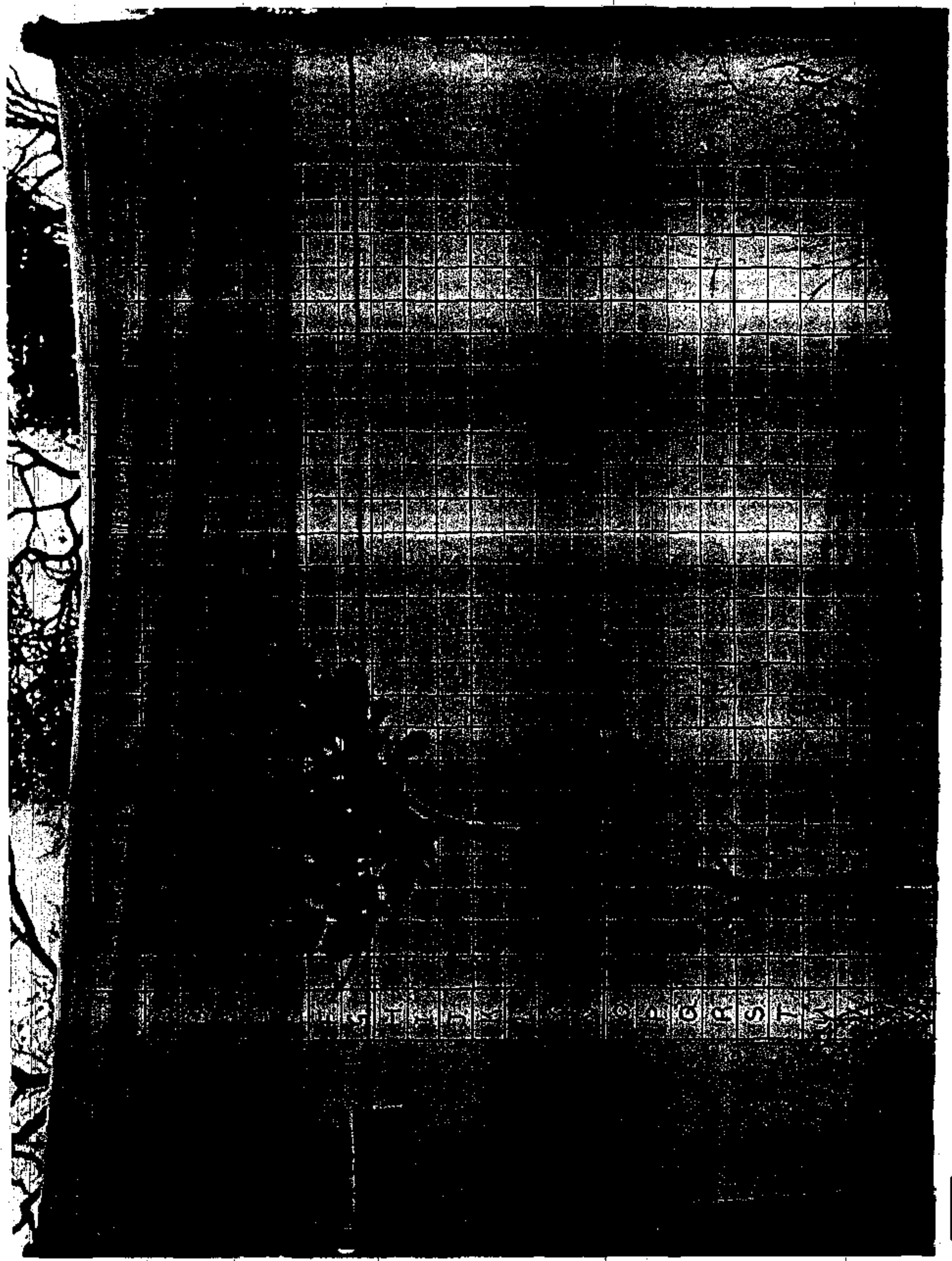
Fig. 2

METHOD OF SETTING UP A TRANSECT SERIES FOR ANALYSIS OF LATERAL COVER BY THE PHOTOGRAPHIC TECHNIQUE.



Peg 1. was determined by throwing a pencil into the air and measuring 50 paces from its position on the ground, in the direction dictated by its point. The sheet screen was then placed over peg 1. and orientated until it lay parallel with the rays of the sun. Transect 1. was set up at a 90° angle to this sheet and to the right of the direction dictated by the random pencil. Transect 2. was set up parallel to transect 1. at a distance of 50 paces to its right. Transect 3. was determined in a like manner.

FIG. 3.



A sample photograph showing the quadrat rectangle and the 600 x 4 cm quadrats. The small board on the left indicates the photograph serial number.

were thus taken, at five meter intervals, to record the cover factors over a 25 meter transect. (See Fig. 4 .).

The sheet-screen was merely used to offer a background over a measured distance and in no way represents a set measurement from which data can be taken: the recordable data is that part of the photograph which falls within the triangle formed by the camera and two points on the screen which are one meter on either side of the centre point, multiplied by the height of the sample, an arbitrary two meters. The distance of 5 meters between pegs was decided upon because at that range the 2 meter height requirement of the sample corresponded with the size of the photograph. An arbitrary 2 meter width was given to the sample size to facilitate quantitative assessment later.

Prior to taking the samples, the vegetation types of each study area were demarcated on aerial mosaic photographs and scattered arbitrary sample sites, within the main vegetation patterns, were chosen. In order that completely random samples could be achieved and to guarantee that I was not subconsciously influenced by the vegetation, the transect line was selected by an African assistant who threw a pencil into the air and marked where it had fallen: the transect line began at a point 50 paces from the pencil in the direction dictated by its point, where Peg No. 1., of the first transect of that series, was inserted.

Previous trials had taught me that shadows could often be confused with branches, when the photographs were being analysed. In order to obviate such confusion, the transect line was laid out at 90° to the direction of the sun's rays so they were always parallel with the screen thus eliminating any possibility of shadows being cast onto the screen, either from the front, or through the screen from behind. The transect line was then marked off, using a compass, with a taught line from Peg No. 1. and five pegs inserted along this line, at five were thus taken, at five meter intervals, to record the cover factors over a 25 meter transect. (See Fig. 4 .).

The sheet-screen was merely used to offer a background over a measured distance and in no way represents a set measurement from which data can be taken: the recordable data is that part of the photograph which falls within the triangle formed by the camera and two points on the screen which are one meter on either side of the centre point, multiplied by the height of the sample, an arbitrary two meters. The distance of 5 meters between pegs was decided upon because at that range the 2 meter height requirement of the sample corresponded with the size of the photograph. An arbitrary 2 meter width was given to the sample size to facilitate quantitative assessment later.

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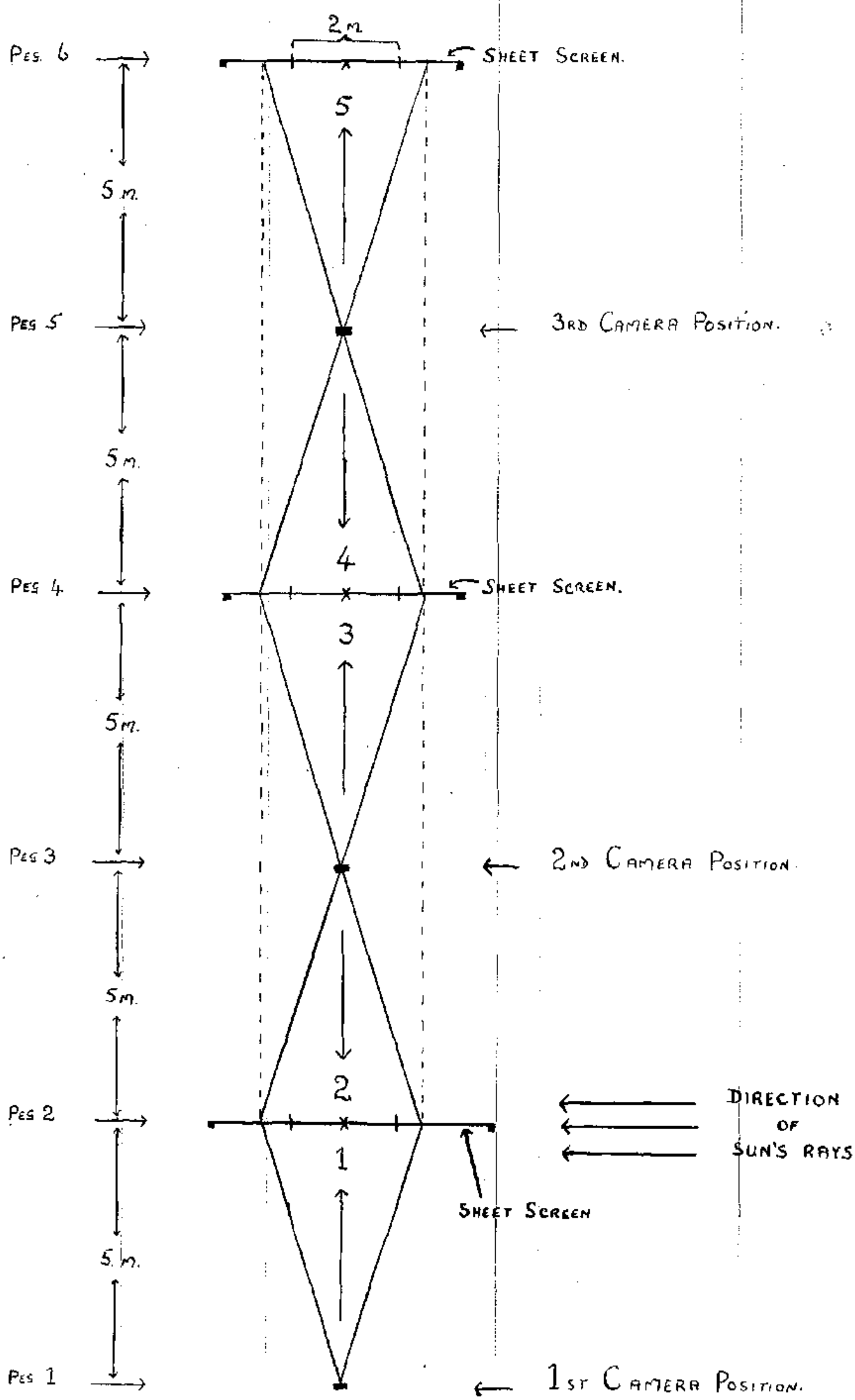
Fig. 4.

Diagrammatic Representation of Lateral Cover Transect showing the position of pegs and the positioning of camera and screen when taking the five transect photographs. The two metre quadrat length is shown.



meter intervals, completed the transect. The direction of the line from Peg No.1. was predetermined to the right of the direction dictated by the random pencil.

The position of the base peg for the second transect was determined by measuring off 50 paces from Peg No. 1., at 90° to, and to the right of, Transect No.1.. The second transect, therefor, ran parallel with the first. Transect No.3. was set up in a like manner from the base peg of Transect No.2.. (See Fig. 2 .).

A total of 330 photographs were taken to complete the overall assessment of the three study areas. Each transect series of 15 photographs was represented by a letter (A - X) and each photograph by a number (1 - 15). A list of these, detailing the vegetation categories measured, appears in Appendix 5 ..

Analysis of the colour slides was achieved in the following manner.

(i). A " viewing screen ", in excess of 1 meter square, was made out of hardboard and painted white. A rectangle 100 cms. wide and 96 cms. high, subdivided into 600 quadrats, each 4 cms. square, 24 vertically and 25 horizontally, was marked on this viewing screen in thin black lines. (The sample size was reduced from 25 to 24 quadrats in height to facilitate calculations.).

(ii). A test colour slide was made, taken against the " cotton field screen " at the requisite distance of 5 meters, on which was clearly shown two markers on the " cotton field screen " exactly two meters apart, each one meter from the centre line, i.e., the two markers outlined the width selected for the sample.

(iii). The test slide was placed in a slide projector and the image was directed onto the viewing screen whereon were marked the quadrats. The projector was moved backwards or forwards until the two markers on the test slide coincided with the two vertical lines marking the outer limits of the quadrat rectangle, i.e., until all 25 of the horizontal quadrats were contained, exactly, between the two markers. The projector was then adjusted vertically until the base of the photographic test sample, represented by the bottom of the " cotton field screen " in the slide, coincided with the base line of the quadrat rectangle on the " viewing screen ".

(iv)(a). The viewing screen and projector were then left in this position and the transect sample slides were fed through the machine. Only that part of the slide image which fell within the quadrat rectangle was considered for analysis.

(b). Cover has been interpreted as vegetation which is likely to assist in breaking up the outline of a rhino and not necessarily only that which completely obscures it; an animal does not have to be completely removed from sight to be effectively " hidden " by cover. Consequently, if any vegetation on the sample slide covered any part of a quadrat on the viewing screen, that quadrat was accepted as representing cover.

(c). A record sheet with 600 quadrats corresponding to those marked on the viewing screen, was used to cataloque the results of the cover analysis. As each slide appeared on the viewing screen, the area covered by the quadrat rectangle was assessed for approximate cover. If the cover was estimated at less than 50%, where any 4 cm. quadrat contained vegetation the corresponding quadrat on the record sheet was marked with and " x "; if the cover was estimated at greater than 50%, those quadrats which contained no vegetation were marked with a " o ". In this way only a maximum of 300 quadrats out of the total 600 had to be marked. The "o's" and " x's" were later added up and the necessary calculations made to achieve a percentage cover measurement. See sample photograph in Fig 3 . and its assessment in Fig. 5 ..

When analysing the photographs, the question arose

Fig. 5

BLACK RHINO RESEARCH

OBSERVER: W.R. THOMSON

"LATERAL COVER ASSESSMENT BY PHOTOGRAPHIC TECHNIQUE"

BELT TRANSECT NO. D.

PHOTOGRAPH NO. 1

STUDY AREA: ...TUBA

DATE: 5.16.70.

COVER ASSESSMENT

1. MAX. POSSIBLE COVER = 600
2. RECORDED COVER = 126
3. % COVER 21%

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	TOTALS
A									X																	1
B			X				X	X	X				X													5
C		X	X	X	X	X	X	X	X	X	X	X	X	X												13
D		X	X	X	X	X	X	X	X	X	X	X	X	X												13
E		X	X	X	X	X	X	X	X	X	X	X	X	X												13
F	X	X	X	X	X	X	X	X	X	X	X															11
G	X	X	X	X	X	X	X	X	X	X																10
H			X	X	X	X	X	X	X																	7
I			X	X	X	X		X																		5
J					X	X																				2
K				X	X	X																				3
L				X	X																					2
M				X	X				X																	3
N				X	X				X	X	X															5
O				X			X	X	X	X	X															6
P		X	X	X		X	X	X																		6
Q		X	X	X	X	X																				5
R		X	X	X	X	X																				5
S			X	X	X																					3
T			X	X																						2
U			X	X																						2
V			X	X																						2
W				X																						1
X				X																						1

GRAND TOTAL = 126

THE QUANTITATIVE MEASUREMENT of SAMPLE PHOTO SHOWN IN FIG. 3

as to whether or not to consider grass (where it occurred) as cover. At the time of the vegetation measurement, half the Manzituba habitat had been burnt off; this has been an annual occurrence for many years and the area is regularly devoid of most of its grass cover from July to December. Notwithstanding the fact that rhino do use heavy Hyparrhenia grass as cover, when it is available, because this cover is not stable and is regularly burnt off in most areas where it occurs during the season of minimum resources, the Hot-Dry Season, it is not a reliable or permanent retreat for the species and it was therefore decided to exclude grass as a measurement of cover. Irrespective of the occurrence of grass for cover, however, I have not observed that it strongly affects the rhino carrying-capacity of a habitat like the woody and more stable vegetation does; heavy grass cover must, however, not be excluded as a probable variable when determining possible factors influencing carrying capacities in various habitats. The grass extant at Sizemba and Chininga was negligible and consequently this problem only applied to Manzituba.

The results from the photographic quadrats enabled me to calculate the mean cover measurements and the relative cover factors in each ofthe vegetation categories, thicket, scrub and woodland, in the three study areas :-

(i). Mean Cover Measurements for each vegetation category in each of the three study areas, was achieved by adding together the percentage measurements from all the photographic samples in the vegetation type being measured (irrespective of their transect distinctions) and dividing this total by the number of photographs used in the calculation.

(ii). Relative Cover Factors were calculated by multiplying the mean cover measurements by the area measurement of the respective vegetation categories, which answer was then divided by the area measurement of the appropriate study area home-range. This reduced the cover factors of each vegetation category to a relative number per square mile, thus permitting direct comparison between the habitats.

(ii). <u>Population Assessment and Density Levels.</u>

Assessment of the rhino populations at Sizemba and Chininga was achieved by capturing the bulk of the populations (in 1964 & 65 and 1967 & 68, respectively) and translocating the animals to other areas. The animals, in both these populations, which were not caught were, however, well-known individually from numerous unsuccessful contacts during capture operations and I believe that the population figures for these two areas are unquestionably accurate.

The rhino at Manzituba were observed by myself and my European and African staff over a four year period (1964 - 1968). There are only five individuals in this population and all were well-known to observers who regularly supplied me with reports concerning their movements. An aerial count, carried out at my request in October,1970, supported my visual ground assessment.

Density Levels for the rhino populations in each study area were calculated by dividing the number of animals in each population bythe measured home-range area. Density was calculated on a basis of numbers of rhino per square mile.

(iii). <u>Method of Correlation between Relative Cover Factors and Rhino Population Densities in the Study Areas.</u>

Four graphs were constructed to correlate the R.C.F's (Relative Cover Factors) with the rhino population densities in the three study areas. The four graphs are identical in construction; three represent the R.C.F.'s found in the three vegetation categories in each of the study areas, while the fourth represents an overall cover evaluation in the three study areas derived by adding together the R.C.F's of the different vegetation categories in the respective habitats.

The abscissa on each of these graphs was divided into four equal parts and the three central points thus created along this axis, were allocated one to each study area. Two ordinates were constructed on either end of this abscissa, the left one detailing rhino density and the other, R.C.F.. Rhino density is represented by a solid line, which remains constant in all four graphs and the R.C.F. for each vegetation category is represented by a broken line. (See Fig. 8. (a),(b),(c) and (d).). This graphic method reduced the two variates to a proper basis for comparison.

Mathematical calculations of the data enabled me to make a further correlation, this time between the overall R.C.F. in each habitat and the amount of cover available to each rhino in the respective areas; this latter factor was achieved by dividing the overall R.C.F. in each habitat bythe respective rhino population numbers. In this case a simple graph was used to show the correlation (See Fig 9.).

(4). Vegetation Frequency Ratings.

When making distinctions between the vegetation structures in different study areas, or the importance of some other factor, e.g., the relative frequencies to which certain vegetation species are subjected to feeding by rhino in different habitats, it has been necessary, in the absence of more detailed data, to allocate an abundance or frequency value to some observations in order to achieve a degree of crude quantitative measurement. In many cases such a rating is all the accuracy required to differentiate between observations and it is unlikely that a more accurate measurement would have achieved any better result.

Table I . details the values of the rating adopted.

To explain this more fully, the following examples are given.

(i). If a tree species is rated " 5 " in a habitat, it is a dominant or very abundant species in that habitat.

(ii). If a tree has a feeding value of " 3 ", it is

TABLE 1.

VEGETATION FREQUENCY RATINGS

RATING	VALUE
5	Dominant or Very Abundant
4	Common or Abundant
3	Not uncommon or Frequent
2	Uncommon or Infrequent
1	Rare

fed upon frequently by the rhino or, in another context, it is not uncommon to find this species being fed upon by rhino.

(iii). Feeding preferences in a habitat, or between habitats, can be compared by using these ratings, e.g., If a tree has an occurrence rating of " 3 " in a habitat and a feeding value of " 5 ", it will have a greater feeding preference rating than another species which has an occurrence rating of " 3 ", or more, and a feeding value of less than " 5 ". A feeding preference rating, based on this criterion, was achieved for each food species at Mfurudzi and Ruya, by dividing the quantitative feeding records by the occurrence rating of the respective vegetation species in the two habitats.

(5). The Feeding Habits of Rhino at Mfurudzi and Ruya, with Comparative Observations from other areas in Rhodesia.

Rhinos are " stick-browsers " as opposed to " leaf-browsers " although they do occasionally graze when the grass is new and fresh (e.g., regenerating grass tussocks after a burn). The sticks eaten are alive, in the case of perennial woody species, and either alive or dead and dessicated, in the case of some annual weeds. The sizes of sticks eaten vary from 1 or 2 mm. to 30 mm. in diameter and they are cleanly cut off by the rhinos teeth, as opposed to being torn off as is the case when elephant feed. Rhino feeding signs are therefore very distinctive and to the experienced eye they can not only be easily distinguished from the feeding signs of other game species, but successive feeding signs on a single bush can be detected for the current and preceding two years. Consequently, the detection of fresh feeding signs is not difficult.

Quantitative feeding records were kept during the Mfurudzi and Ruya Capture Operations, in June, July and August, 1970. These were obtained by tabulating the number of sticks and the different vegetation species fed upon by the rhino, recorded during the tracking work which preceded capture; only fresh observations from the current day's feed were noted. Records consisted only of the actual number of sticks bitten off and while no weight assessment was possible, the measurement taken provided a method whereby a preference rating could be obtained.

A total of 22 days were spent obtaining these records during which time an equivalent number of adult rhino were tracked. The duration of each day's tracking varied from six to ten hours which period determined the duration of the time spent in recording the feeding data.

Subjective feeding observations from other areas have been used as a comparison to illustrate the rhino's varied feeding habits and preferences.

(6). <u>The Water Requirements of Rhino related to Diurnal Ambient Temperatures and other observation related to the Rhino's Drinking Habits.</u>

No quantitative data are available on the water requirements of rhino, but the nature of hunting operations was such that 300 - 500 observations on a large number of animals, made over a seven year period and in ten localities, have enabled me to subjectively assess the rhinos pattern of drinking habits related to diurnal ambient temperatures. These and other observations related to the rhino's drinking habits are pertinent to a study of this nature.

(7). <u>The Rhino's Attitude in Repose in Relation to the Direction of the Wind.</u>

Ranges at which rhino were darted at Sizemba were nromally between 8 and 13 yards. There was considerable danger to the hunter, therefore, and to complicate the problem it became apparent that rhino always seemed to lie down with their tails facing into the wind thus precluding any possibility of and approach towards the buttocks of a resting rhino from downwind. This habit was first noticed in 1964 and subsequent observations from different parts of Rhodesia indicated that the habit was widespread, so I decided to [illegible] of this tendency during operations in 1970.

During the Mfurudzi and Ruya operations (1970), where hunting conditions permitted analysis of resting sites, the direction in which resting rhino faced was initially noted. After each rhino had been flushed from its place of rest, the location itself was examined and a record made of the direction in which the wind (or breeze) left the site :-

(i). A line was drawn on the ground, through the middle of the resting site, aligned with the direction previously taken up by the longitudinal axis of the rhino's body. This was easily determined by the initial visual observation and by the spoor indications left in the sandy soils normally found in such sites.

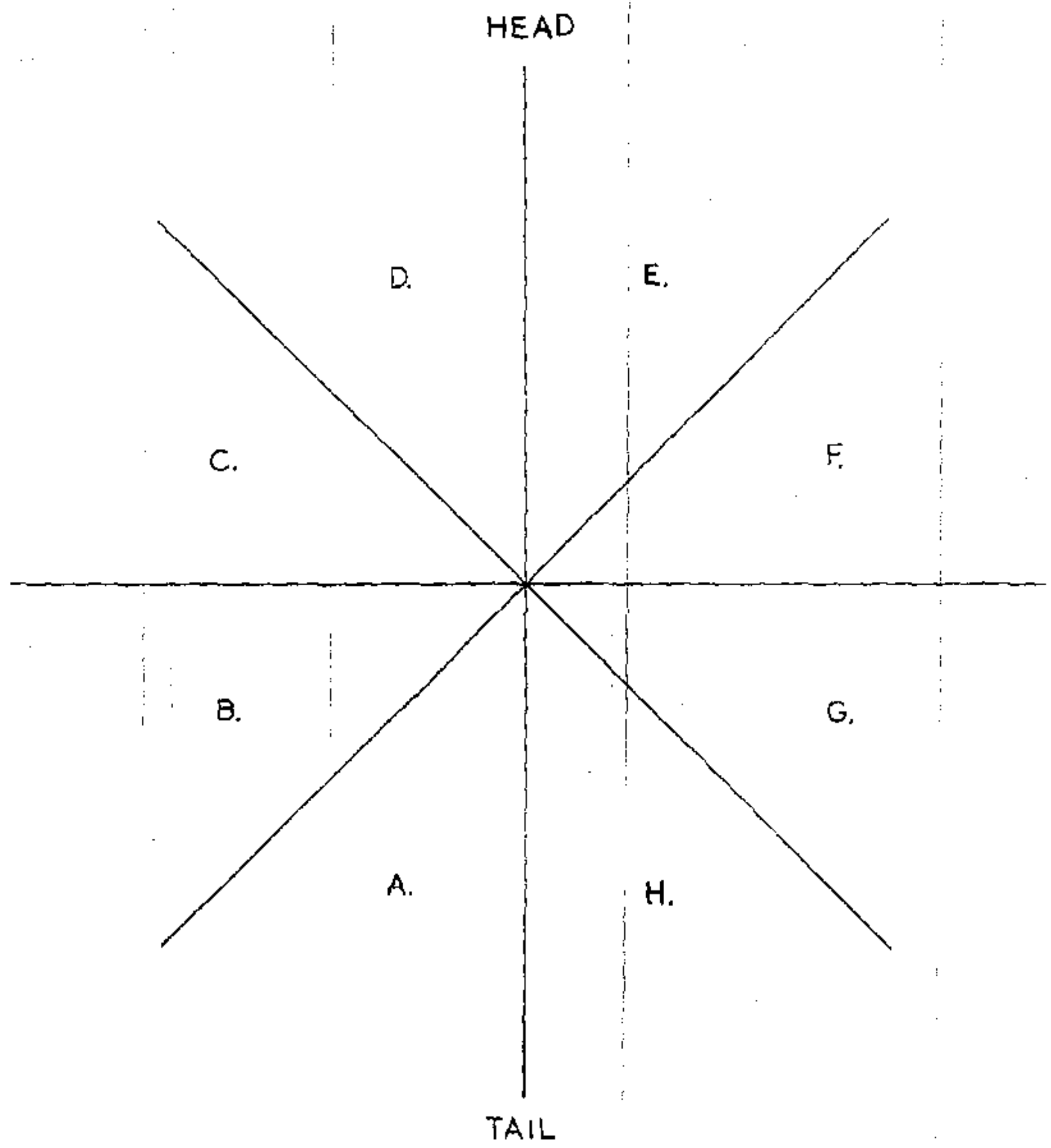
(ii). A second line was then drawn across the resting site (and so also across the first line), at right-angles to the first line, thus dividing the resting site into four sectors. Each of these quadrants was then again divided thus reducing the resting site to eight symmetrical, radial sectors whose centre point was in the centre of the location. Each octant was then given a letter identification. (See Fig 6 .).

(iii). A small ash-bag, containing fine white woodash, was then held over the resting site and a puff of ash was released from the ashbag in the centre of the position. The sector from which the ash-cloud left the area was tabulated on a record sheet. This process was repeated every 10 seconds until a total of 25 recordings had been obtained for each site.

(8). <u>Observations supporting several factors which affect the Rhino's Distribution and Survival</u>.

A considerable number of observations relating directly to the rhino's distribution, dispersal and survival have been accummulated during capture operations and these have been used to substantiate corroborating observations made during 1970. No definite technique was used in making these observations other than assiduous tracking of the animals and

FIG. 6.



ANGULAR SUBDIVISION OF RHINO RESTING SITE FOR WIND DIRECTION MEASUREMENT industrious recording. As an example, a number of observation records, quoted as they occurred, appear in Appendix 2., and these are used in support of statements and observations made in the text.

6. RESULTS.

(1). The Basic Environmental Factors which probably affected the Rhino in its Past Distribution.

Since 1865, records indicate that rhino have occurred in Rhodesia between altitudes of 600 feet and 6,000 feet above sea level (Roth - 1967 and Surveyor-General - 1965). Their distribution covered all rainfall belts from 12 - 16 ins. per annum to 40 - 44 ins. per annum (Roth - 1967 and Surveyor-General - 1958). Correlations between the past distribution (Roth - 1967), the present distribution (See Appendix 1., Map No. 1.) and the Vegetation Map of the Flora Zambesiaca Area (Wild and Fernandes - 1967) show that rhino were associated with at least fifteen different broad vegetation types; these are listed below and the types quoted are those listed in the Flora Zambesiaca. In making this correlation it has been accepted that, although the character of the vegetation has been altered by agricultural practices in recent years, there has been no general change in the basic vegetation climax areas in the past 100 years.

In their past distribution rhino have been associated with the following vegetation types.

(i). Thicket.

(a). Commiphora - Combretum (type 12.).

(ii). Tree Savannah.

(a). Commiphora - Combretum (type 46.).

(b). Terminalia sericea (type 47.).

(c). Acacia spp. (type 48.).

(d). Colophospermum (type 50.).

(iii). Woodland and Savannah Woodland.

(a). Baikiaea (type 16.).

(b). Brachystegia spiciformis on Kalahari sands (type 19.).

(c). Brachystegia spiciformis and Julbernardia globiflora (type 23.).

(d). Brachystegia boehmii (type 26.).

(e). Brachystegia boehmii and

Brachystegia allenii (type 29.).

(f). Colophospermum (type 35.).

(g). Julbernardia globiflora (type 30.).

(h). Parinari curatellifolia (type 39.).

(iv). Scrub Savannah.

(a). Colophospermum (type 61.).

(v). Grassland.

(a). Loudetia (type 65.).

(b). Hyparrhenia (type 67.).

The past distribution shows that the species occurred in a wide range of environments.

The present distribution indicates that the rhino still occurs in a wide range of different environments but they are now largely confined to areas below 3,000 feet above sea level although some do occur between the 3,000 and 3,500 foot contours, e.g.,on the Chizarira Plateau (Appendix 1., Map No.1. - 1970 Distribution and Surveyor-General - 1965.); to rainfall belts below the 30 ins. per annum level (Appendix 1., Map No.1 - 1970 Distribution and Surveyor-General - 1958.); and to the broad vegetation belts as follows (Appendix 1., Map No.1. - 1970 Distribution and Wild and Fernandes - 1967.).

(i). Thicket.

(a). Commiphora-Combretum (type 12.).

(ii). Tree Savannah.

(a). Colophospermum (type 50.).(Gona-re-Zhou - re-introduced 1969,70 & 71.).

(iii). Woodland and Savannah Woodland.

(a). Brachystegia boehmii and

Brachystegia allenii (type 29.).

(b). Julbernardia globiflora (type 30.).

(c). Colophospermum (type 35.).

(iv). Grassland.

(a). Hyparrhenia (type 67.).

There are a number of other factors concerning the nature of rhino habitats, which have not been measured, but which can be discussed objectively :-

(i). Temperature: In Rhodesia rhino now occur in the hotter parts of the country where temperatures can vary between approximately 30°F. and up to 120°F.. They seem to tolerate these extremes of temperature very well and as the species has occurred in historical times from the cold regions of Cape Province in South Africa (Le Roux - pers. comm.), throughout hot, tropical Africa and at cold, high altitudes on the East African mountains (Wood - pers. comm.), it is doubtful if this factor is very important in the selection, by rhino, of their habitats in this country.

(ii). Substrate: Rhino habitats occur in a wide range of substrate types from the sandy soils associated with Commiphora-Combretum thickets, to the extreme boulder-strewn slopes of the steep Chipinga escarpment habitat. They appear to live quite happily in fairly broken country but tend to avoid those areas which are relatively continuous, broken rock underfoot. Rhino from rocky habitats show considerable wear of their toe-nails and the pads of their feet when compared with other rhino living in less stoney terrain, so very rocky country may not be entirely suitable for the species even if they have proved sufficiently adaptable to be able to occupy such country.

(iii). Topogtaphy: Rhino occur in very flat country as well as in the steep and broken terrain associated with mountain escarpments and they seem very adaptable to topographic changes even between the observed hot-dry season home-range area and the hot-wet season home-range area of a single population, e.g., the Manzituba population extends its hot-dry season home-range, which is relatively flat, rolling country, to the broken talus-scarp of the Chizarira foothills during the rains, a difference in substrate, topography and 1,000 feet in altitude. The last rhino in the Chipangayi population , on the other hand, had by force of circumstance, adapted itself to a diurnal movement from its day-time retreats on the very steep slopes of the broken Chipinga escarpment, to the flat valley floor, 1,500 feet below, where it obtained water at night. In these examples, the species again shows its adaptability but I believe the less strenuous existence associated with the flatter-type habitat is more suitable than that found at Chipangayi, for example.

(2). <u>The Home-Range Assessment of Rhino Populations in the three main study areas of Sizemba, Chininga and Manzituba.</u>

The home-ranges of the three rhino populations at Sizemba, Chininga and Manzituba and the different vegetation types in each area, have been demarcated on Maps No. 2, 3 & 4 in Appendix 1.. The home-ranges measured 17.83 sq. miles, 15.18 sq. miles and 31.61 sq. miles, respectively. In these habitats, the respective home-ranges were further subdivided to measure the different vegetation categories :-

(i). Sizemba.

(a). Thicket. 5.09 sq. miles. (28 %).

(b). Scrub. 5.29 sq. miles. (30 %).

(c). Woodland. 7.55 sq. miles. (42 %).

(ii). Chininga.

(a). Thicket. 2.10 sq. miles. (14 %).

(b). Scrub. 6.54 sq. miles. (43 %).

(c). Woodland. 6.54 sq. miles. (43 %).

(iii). Manzituba.

(a). Thicket. 0.00 sq. miles. (0 %).

(b). Scrub. 16.41 sq. miles. (52 %).

(c). Woodland. 15.20 sq. miles. (48 %).

These results have been tabulated with other data and can be found in column (b)., of Table 2 ..

One point requires further clarification here; It will be noted that at Chininga the vegetation categories of " scrub " and " woodland " are of an equal amount. This was the result of both categories being interspersed with each other in such small units, generally, that they were indistinguishable, accurately, on the aerial mosaic photographs even with a ground check. An assessment on the ground and an appraisal of the aerial mosaics showed that there was an approximate

TABLE 2.

	a.	b.		c.	d.	e.	f.
	Vegetation Type.	Area. sq.mls.	%	Relative Cover Factor.	Rhino Population.	Rhino Density / sq. mile.	Relative Cover Factors per Rhino.
	Thicket.	5.09	28	22.5			
[redacted]	Scrub.	5.29	30	6.4	42	2.3	15.8
	Woodland.	7.55	42	7.4			
	Overall.	17.83	100	36.3			
	Thicket.	2.10	14	[illegible]			
[redacted]	Scrub.	6.54	43	14.2	15	1.0	27.3
	Woodland.	6.54	43	9.7			
	Overall.	15.18	100	27.3			
	Thicket.	0.00	0	0.0			
[redacted]	Scrub.	[illegible]	52	5.2	5	0.2	69.4
	Woodland.	[illegible]	48	[illegible]			
	Overall.	[illegible]	100	[illegible]			

equal amount of each category in the habitat and consequently the balance of the measured home-range area (after the " thicket " area had been deducted) was divided equally between these two categories.

I considered that it was necessary to show further distinction between the vegetation categories of the three study areas but they were so dissimilar in many ways that suitable parameters were difficult to find. Rather than try to completely align the different vegetation types, therefore, I decided to merely catalogue occurrence ratings of the vegetation in these habitats and to allow this record to stand without attempting to quantitatively analyse the results. As explained in the description of the study areas, the " scrub " at Sizemba and Chininga is more closely aligned with the Colophospermum woodland parts of the same habitats, than any other vegetation type listed in the Flora Zambesiaca (Wild & Fernandes - 1967.), and that the " scrub " at Manzituba is, in reality, decimated Julbernardia/Brachystegia boehmii woodland which is also represented in its climax form in the same habitat. Two broad categories were therefore chosen to record the occurrence of the 25 major species in the three habitats, viz., at Sizemba and Chininga " thicket " and " open " were selected and at Manzituba " woodland " and " open " were chosen; height recordings of > 6m. and <6m. represent an arbitrary measurement greater of lesser than 6 meters in height. (See Table 3.)

Ratings in all these assessments as per Table 1..

TABLE 3 .

A comparison of the vegetation in the three study areas of Sizemba, Chininga and Manzituba. Only 25 of the most common species are included.

Ratings as detailed in Table 1 .

	SIZEMBA				CHININGA				MANZITUBA			
	Thkt		Open		Thkt		Open		Wdld		Open	
SPECIES	<6m	>6m	<6m	>6m	<6m	>6m	<6m	>6m	<6m	>6m	<6m	>6m
Acacia tortillis.	-	-	2	1	-	-	2	2	-	-	-	-
Adansonia digitata.	-	3	-	3	-	3	-	3	-	-	-	1
Berchemia discolor.	1	3	-	-	-	-	-	1	-	-	-	-
Boscia albitrunca.	3	-	-	-	3	-	-	-	-	-	-	-
Boscia matabelensis.	2	-	4	-	2	-	4	-	-	-	-	-
Brachystegia boehmii.	-	-	-	-	-	-	-	-	3	5	5	1
Burkea africana.	-	-	-	-	-	-	-	-	2	3	3	1
Colophospermum mopane.	1	3	5	5	2	4	5	5	-	-	2	3
Combretum apiculatum.	5	-	3	-	5	-	3	-	-	-	1	-
Combretum elaeagnoides.	5	-	3	-	5	-	3	-	-	-	1	-
Combretum fragrans.	-	-	-	-	-	-	-	-	-	-	3	-
Commiphora spp..	5	3	3	2	5	3	3	2	-	-	-	-
Diospyros quiloensis.	3	2	3	1	3	1	3	1	1	-	1	-
Gardenia resiniflua.	1	-	2	-	3	-	5	-	-	-	-	-
Guibortia conjugata.	-	-	-	-	1	3	-	-	-	-	-	-
Julbernadia globiflora.	-	-	-	-	-	-	1	1	3	5	5	1
Parinari curatellifolia.	-	-	-	-	-	-	-	-	2	3	2	2
Periconsis												

Diospyros quiloensis.	3	2	3	1	3	1	3	1	1	-	1	-
Gardenia resiniflua.	1	-	2	-	3	-	5	-	-	-	-	-
Guibortia conjugata.	-	-	-	-	1	3	-	-	-	-	-	-
Julbernadia globiflora.	-	-	-	-	-	-	1	1	3	5	5	1
Parinari curatellifolia.	-	-	-	-	-	-	-	-	2	3	2	2
Pericopsis angolensis.	-	-	-	-	-	-	-	-	2	3	2	2
Popowia obovata.	3	-	-	-	4	-	2	-	-	-	-	-
Pseudolachnostylis maprouneafolia.	-	-	-	-	-	-	-	-	5	1	2	-
Pteleopsis anisoptera.	4	2	-	-	3	2	-	-	-	-	-	-
Pterocarpus angolensis.	-	-	-	-	1	1	-	-	1	2	-	-
Pterocarpus antunesii.	2	3	-	-	2	2	-	-	-	-	-	-
Strychnos innocua.	4	2	2	-	4	3	2	-	-	-	-	-
Terminalia prunoides.	-	-	4	-	-	-	4	-	-	-	-	-

Thkt = Commiphora - Combretum Thicket.

Open = Open category of habitat. At Sizemba and Chininga this is described as Colophospermum Rock Scrub and Colophospermum Woodland; at Manzituba, as Decimated Julbernadia Woodland.

Wdld = Woodland.

<6m = Less than 6 metres in height.

>6m = Greater than 6 metres in height.

(3). The Measurement of Relative Cover Factors at Sizemba, Chininga and Manzituba; Population Assessment and Density Levels; and Correlations between these Factors.

(i). Cover.

The results of the lateral cover measurement obtained by the photographic technique are contained in Table 4 ., together with the statistical treatment of these figures. Calculated Confidence Intervals at the 95% probability level, qualifying the mean values obtained, are shown in Fig 7 ..

The measurements of 79.75% and 52.80%, respectively, show the relative differences resultant from the dissimilar character of the *Commiphora-Combretum* thicket at Sizemba and Chininga, which were explained in the description of these two study areas. This adequately demonstrates the differences associated with the thicket cover which rendered these two areas worthy of comparative analysis although they are otherwise of a descriptively similar vegetative nature.

The relative differences between the vegetation categories in all three study areas, as shown in Fig 7 ., demonstrates that the major distinction between them is related to the cover provided by " thicket ". The differences in cover afforded by the " scrub " and " woodland " categories are rendered unimportant by reason of their comparable measurements and overlapping confidence intervals.

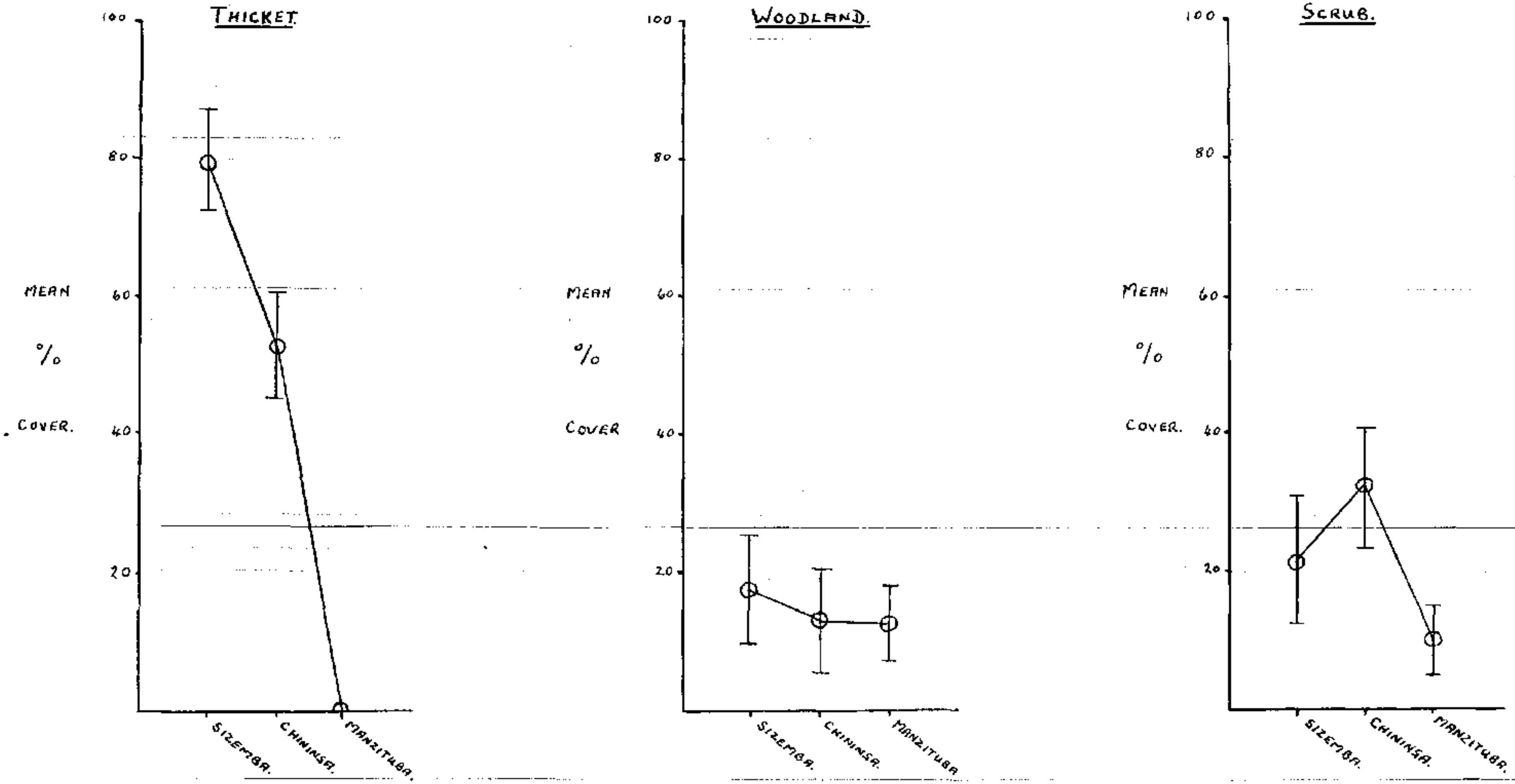
The relative cover factors calculated from the cover measurements of the different vegetation categories in the three study areas and the respective area measurements

[redacted]

Study Area	Cover-type	% Cover	$S\bar{x}$	Degrees of Freedom	t-values (@ 95% Prob.)	Confidence Interval (@ 95% Prob.)
Sizembe	Thicket	79.75	3.62	44	2.015	7.2943
	Scrub	21.66	4.53	29	2.045	9.2659
	Woodland	17.59	3.73	29	2.045	7.6279
Chininga	Thicket	52.60	3.68	44	2.015	7.4052
	Scrub	32.62	4.38	44	2.015	8.8257
	Woodland	15.00	3.72	29	2.045	7.6074
Manzituba	Thicket	-	-	-	-	-
	Scrub	10.07	2.37	44	2.015	4.7756
	Woodland	12.43	2.68	59	2.000	5.3600

Statistical results of the cover evaluations in the three study areas of Sizembe, Chininga and Manzituba.

TABLE 4.



COMPARATIVE RESULTS OF LATERAL COVER MEASUREMENTS IN THE STUDY AREAS OF SIZEMBA, CHININSA AND MANZITUBA.

VERTICAL LINES ON EACH SIDE OF THE PLOTTED MEAN-PERCENTAGE POINTS GIVE THE 95 % CONFIDENCE INTERVAL.

FIG. 7.

FIG. 7.

of these vegetation types, are contained in column (c)., of Table 2 .. These will be brought into perspective when correlations are made later in the paper.

(ii). Population Assessments and Density Levels.

As previously explained (p.28.), the rhino population figures for Sizemba and Chininga were already known at the start of the study, as a result of capture operations conducted in 1964 & 65 and 1967 & 68, respectively. The population figures are 42 and 15, respectively, and a breakdown of these numbers, into sex and age classifications, is contained in Table 5 ..

Manzituba is the heart of the Chizarira Game Reserve and the population there was well-known over the four year period, 1965 - 68. In 1967 there was a young bull, an old bull, a cow and a large heifer calf. The following year the cow and her calf separated when a new calf was born and an immigrant subadult cow was noticed in the home-range area, but it is not known if this animal took up residence as no further record of her came to light. In 1969 the old bull died (Wright - pers. comm.) and Williams (pers. comm.) estimates the resident population in 1970 to be 5 or 6 with a possible further two animals from adjacent populations sharing waterholes on the periphery of the home-range.

The Manzituba population was checked in 1970, but I only actually saw the old cow and her 30 month old calf. The Department of National Parks & Wild Life Management assisted

Table 5.

	SIZEMBA	CHININGA
Captured		
Adult bulls	16	5
Adult cows	14	4
Subadult bulls	2	-
Subadult cows	1	2
Calves - bulls	-	1*
Calves - cows	5	1
Not Captured		
Adult bulls	1	1
Adult cows	2	-
Subadult bulls	-	-
Subadult cows	1	-
Calves - bulls	-	-
Calves - cows	-	1
TOTAL	42	15

* Found dead (See observation 6, Appendix 2)

6.

me by flying a special aerial survey of the Manzituba area to check my ground assessment figures: The flight was carried out by the pilot and an observer on the 5th October, 1970, in a PA 18 Super Cub Aircraft. The Chizarira is very open country with little continuous canopy in the woodland area, with practically no understory, and at the time of the count much of the area (c. 70%) had been burnt off. As the count was undertaken in such a small area, under such open conditions and at a time of day (during the late afternoon) when the rhino are normally feeding in the open, I expected a 100% count. However, only three animals were counted in the main habitat area and a further single animal in the vicinity of a waterhole on the edge of the home-range area, which may or may not have been part of the study group. Despite my optimism for an accurate count under such good conditions, Goddard (1967) states " Even under the most ideal conditions, only 50% of the (Rhino) population was detected by observers in an aircraft ", so it is felt that the aerial count did give support to my ground estimate of 5 animals.

The overall figures for the rhino populations in the three study areas are contained in column (d). of Table 2 .. Density levels were achieved by dividing the population figures by the relative area measurements of the three study areas, which reduced them to a relative number of rhinos per square mile; these figures are 2.3, 1.0 and 0.2 rhinos per square mile for Sizemba, Chininga and Manzituba, respectively, and are contained in column (e)., of Table 2 ..

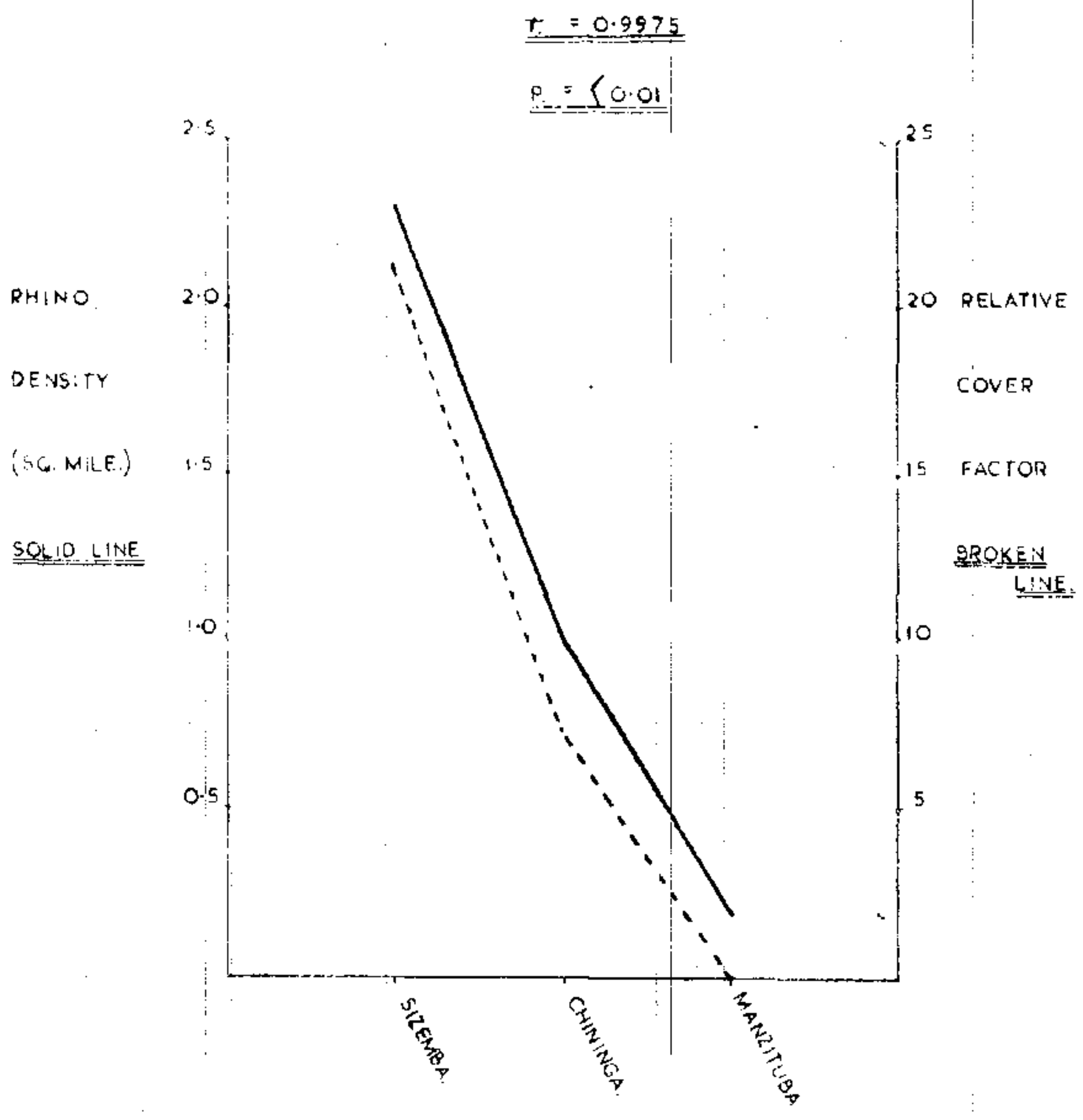
(iii). <u>Correlations between Relative Cover Factors and Population Density Levels.</u>

Correlations between the Relative Cover Factors in each study area, considered separately for each vegetation category and jointly as an overall habitat assessment, appear in Fig 8.(a),(b),(c) & (d)..

The correlation between rhino density and Thicket R.C.F. proved highly significant with a correlation coefficient of +0.9975 giving a probability for a perfect positive correlation greater than 99%. Similar correlations between rhino densities and Scrub, Woodland and Overall R.C.F.s, gave respective coefficients of -0.01346 (p =$>$0.1), + 0.8782 (p =$>$0.1) and + 0.9546 (p =$<$0.05). Of these, only the correlation made using the Overall R.C.F. is within the acceptable 95% significance level, but in view of the poor correlations made in the Scrub and Woodland categories, it can be seen that the significance level achieved with the Overall R.C.F. was only possible as a direct result of the high significance attached to the Thicket R.C.F. correlation. This demonstrates the influence that Thicket cover has in determining the rhino carrying capacity of a habitat.

However, irrespective of the importance of thicket cover in a rhino habitat, the fact that rhino live in habitats completely devoid of thicket, e.g., Mangituba, indicates that the other cover factors may be of some importance too. Consequently a further correlation was made between the Overall R.C.F. in each study area and the amount of cover

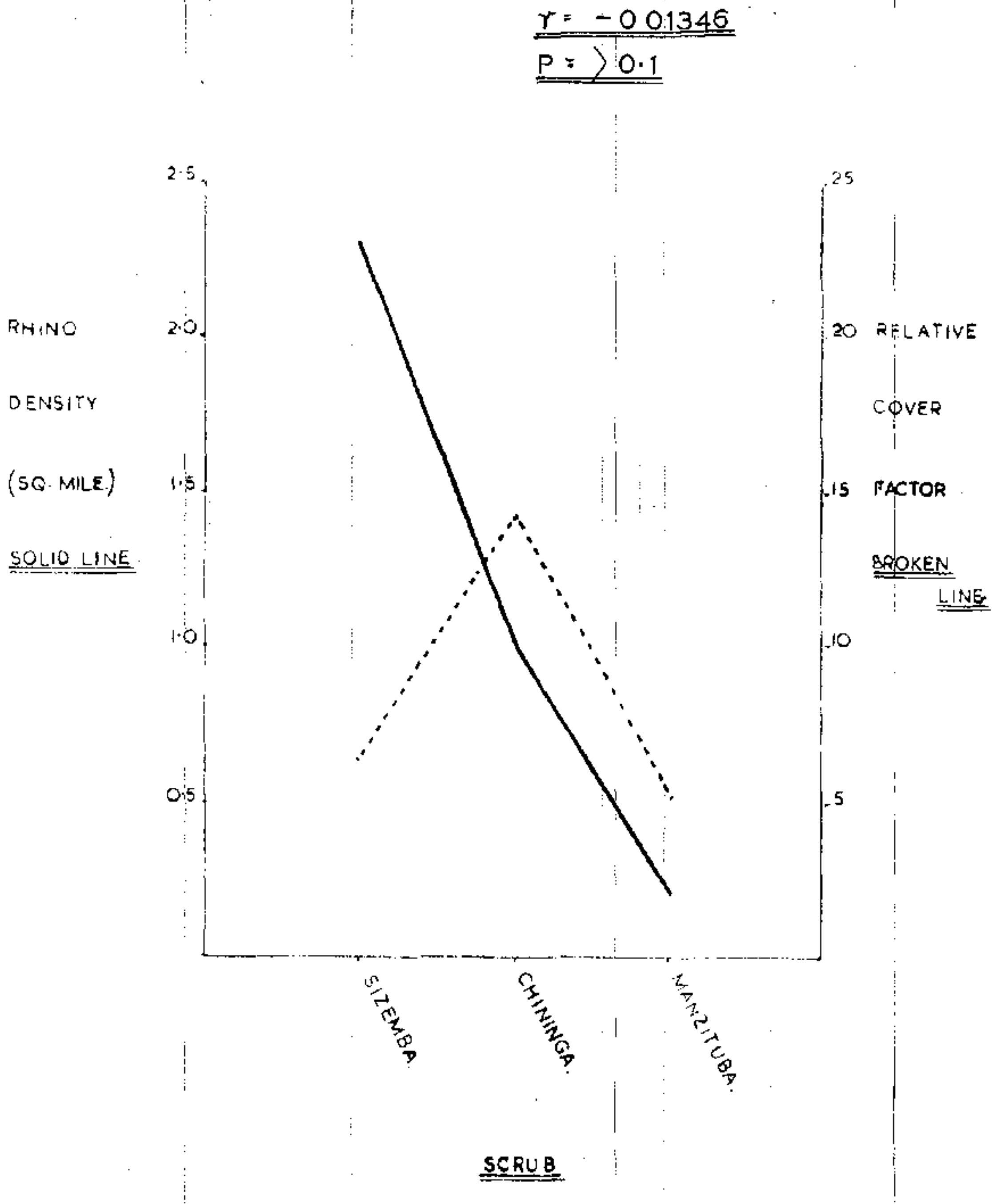
FIG. 8(a).



THICKET

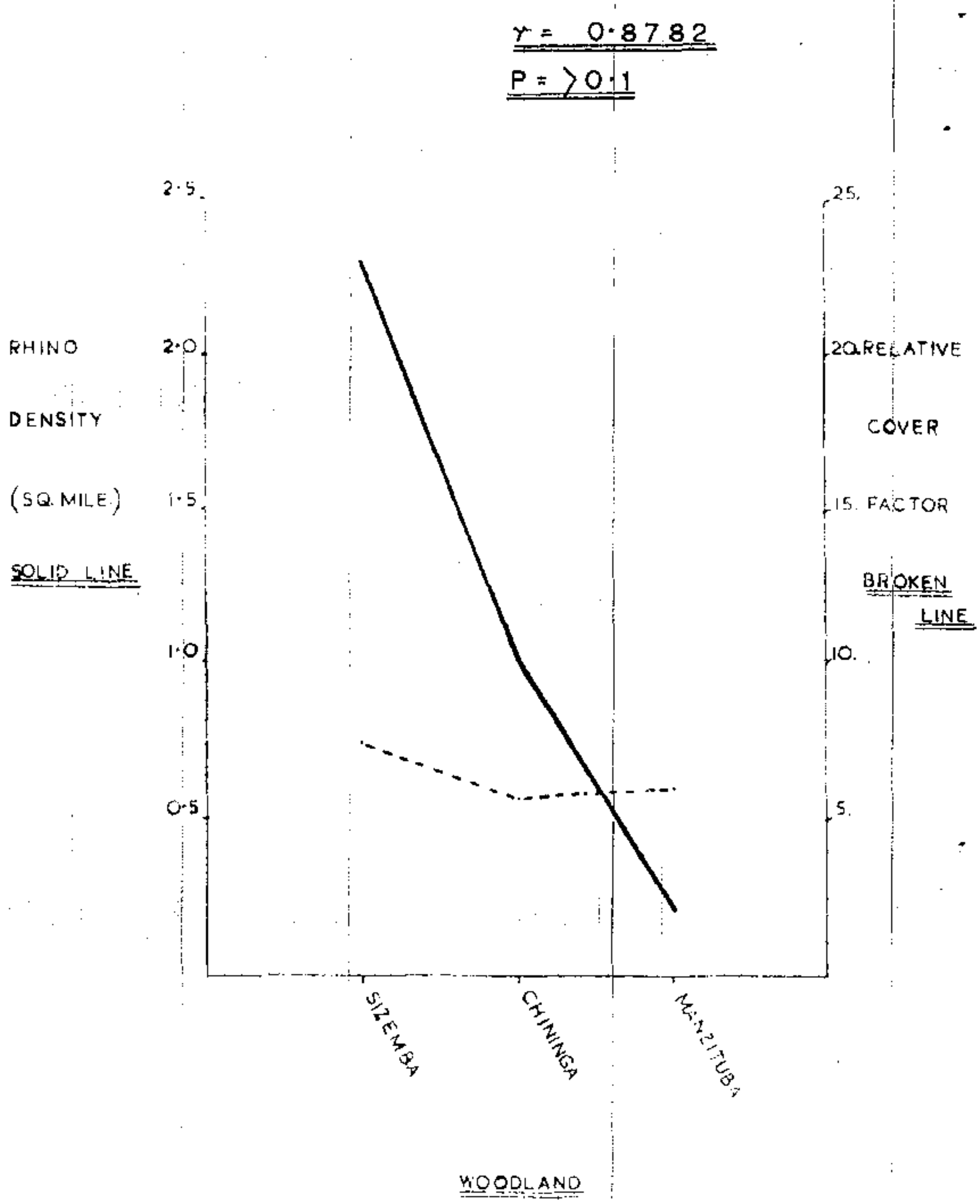
CORRELATION RESULT BETWEEN RHINO POPULATION DENSITIES AND RELATIVE COVER FACTORS IN THE THICKET PARTS OF THE STUDY AREAS.

FIG 8(b).



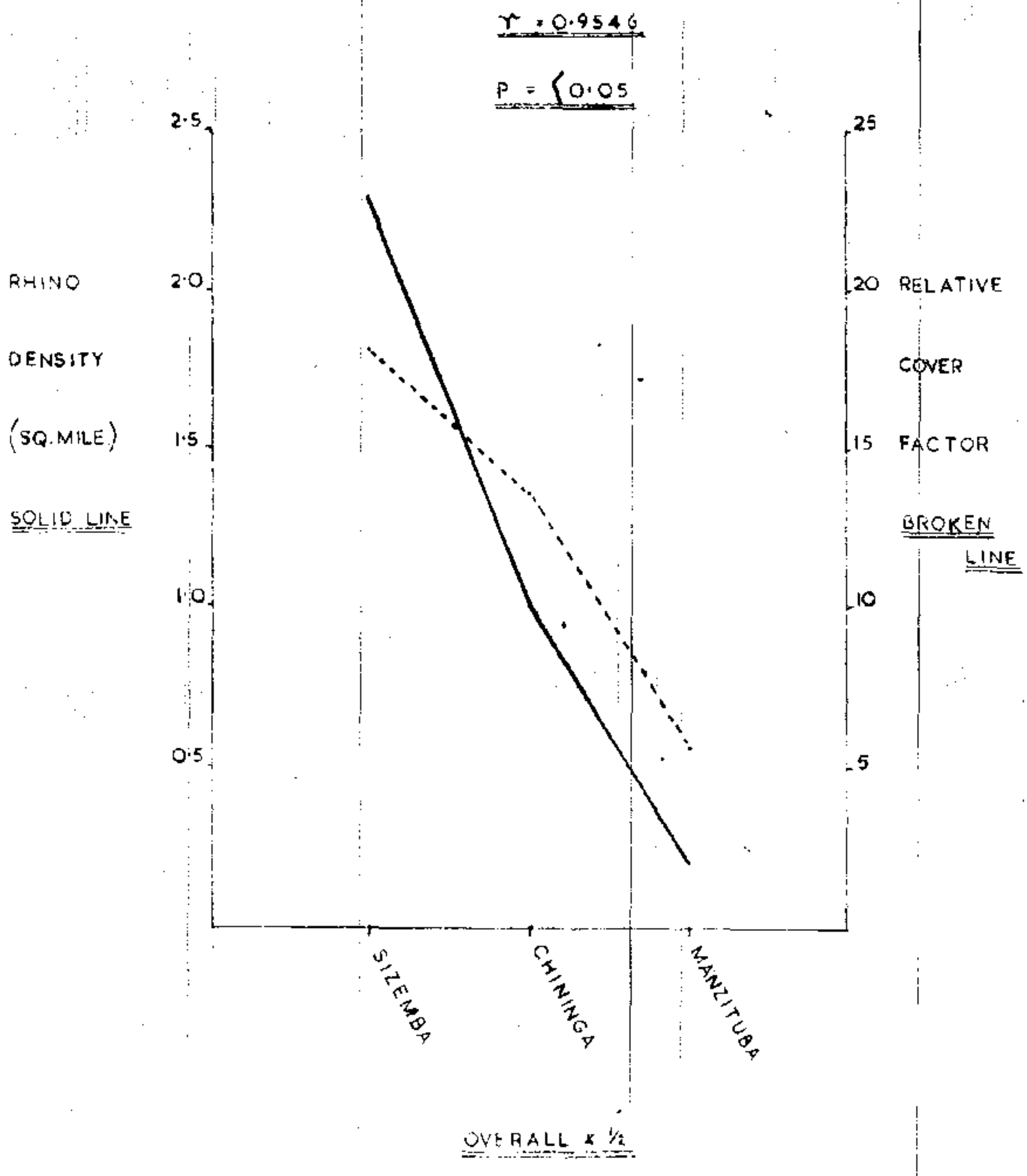
CORRELATION RESULT BETWEEN RHINO POPULATION DENSITIES AND RELATIVE COVER FACTORS IN THE SCRUB PARTS OF THE STUDY AREAS.

FIG. 8(c).



CORRELATION RESULT BETWEEN RHINO POPULATION DENSITIES AND RELATIVE COVER FACTORS IN THE WOODLAND PARTS OF THE STUDY AREAS.

FIG. 8(d).



CORRELATION RESULT BETWEEN RHINO POPULATION DENSITIES AND THE OVERALL RELATIVE COVER FACTORS OF THE STUDY AREAS.

available to each rhino in the respective habitats; for this calculation, as a result of the population density at Manzituba being so low, the more accurate density figure of 0.16 rhino/sq.mile, as opposed to the 0.2 rhino/sq.mile given elsewhere in the paper, was applied. The R.C.F./Rhino for each habitat is contained in column (f)., of Table 2 .. The correlation resulted in a coefficient of - 0.9881 with a probability for a perfect negative correlation greater than 98% (See Fig 9 .). The significance of the inverse relationship between these two variates will be explained later.

(4). <u>Difference in Habitat Utilization by the Sexes at Sizemba.</u>

During the 1964 capture operation at Sizemba, it became apparent that the animals in the population occupied their habitat in a definite pattern. Bulls were confined entirely to thicket during the day and sometimes solitary adult cows, or cows with large calves, were found in the same type of cover. Heavily pregnant cows and those with small calves, however, were found in the open part of the habitat where they spent the heat of the day in the shade of baobabs (<u>Adansonia digitata</u>) or other large trees. See Fig 10.(Details extracted from 1964/65 Diaries, Fothergill & Thomson.).

This behaviour is completely contrary to that of the cows and calves at Hluhluwe (Natal). Hitchins (pers.comm.) states " It appears that females with very small calves are almost entirely confined to thicket for approximately the first four months after the calf is born ". I believe that, because

FIG. 9.

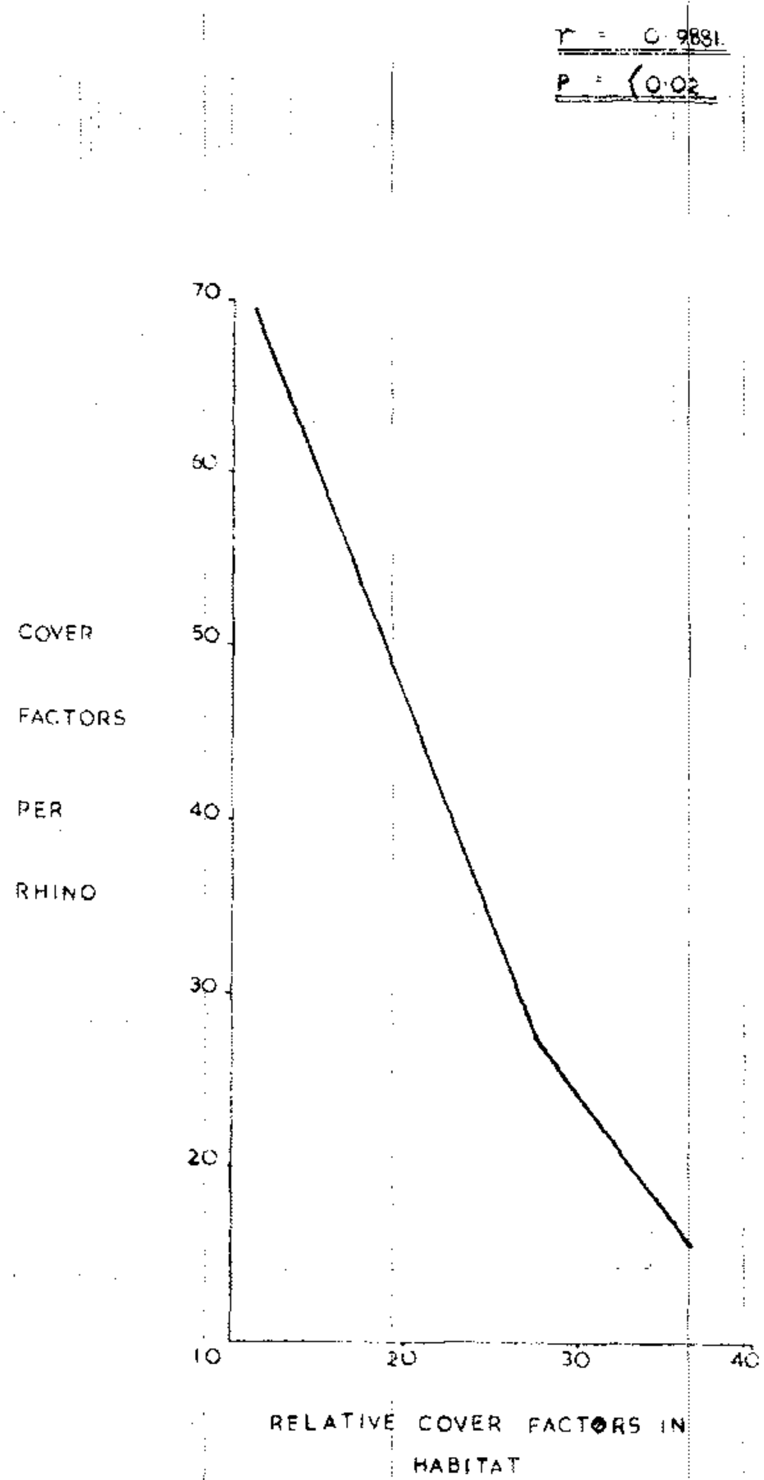
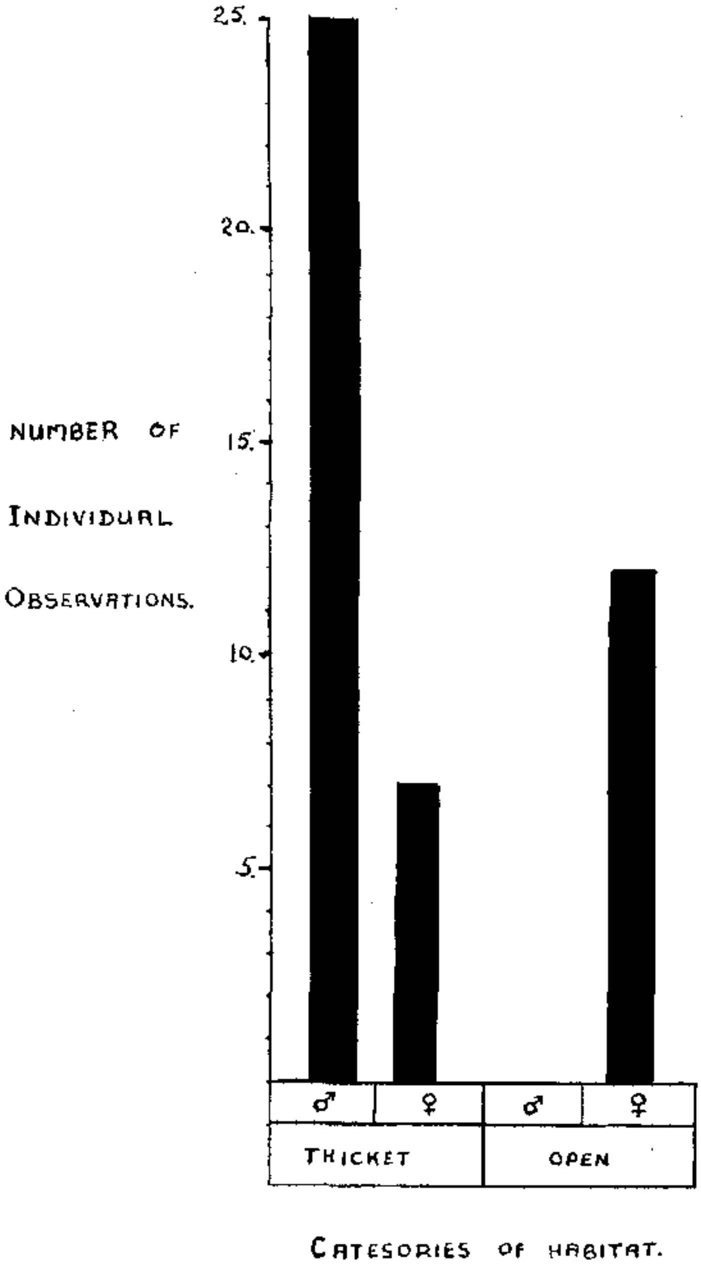

r = 0·9881
P = (0·02
COVER
FACTORS
PER
RHINO
70
60
50
40
30
20
10
20
30
40
RELATIVE COVER FACTORS IN
HABITAT

FIG. 10.

DIURNAL UTILIZATION OF THE THICKET AND OPEN PARTS OF THE HABITAT BY THE DIFFERENT SEXES IN THE SIZEMBA RHINO POPULATION IN 1964.



of the importance attached to the rhino's requirement for thicket, Hitchin's observations are probably more likely to be the norm so why should the Sizemba population be so completely different?

Upon examination of the environmental factors in the two habitat areas, there appear to be two main differences; the presence of White Rhino (Ceratotherium simum.) and the absence of elephant (Loxodonta africana.) at Hluhluwe and the opposite at Sizemba. See Table 6 .. Hitchins (pers.comm.) confirms that there is little or no interspecific competition between the black and white rhino whilst at Sizemba there was evidence to suggest a degree of competition for diurnal retreats between the rhino and the elephant. A state of tolerance was, however, achieved between the rhino bulls and the elephant in most cases.

A binomial Chi-square test, based on the data in Fig 10., showed a highly significant difference in the dispersion of the sexes in the habitat, which suggests, in view of Hitchin's observations, that a reason must exist for this distribution. (The Ch-square test calculation can be found in Appendix 3 .).

Although Hluhluwe is subjected to certain tourist pressures and Sizemba is not, the fact that cows at Sizemba were reluctant to move back into the thicket except under extreme hunting pressure, suggests that man's presence was not involved. There was also no evidence to suggest inter-sexual competition for diurnal resting sites which, in any case were not in short supply. Elephant were seen to disturb rhino bulls on several occasions, however, and its is probable

Table 6.

Environmental Factors likely to affect the Dispersion of Black Rhino in the Habitats of Hluhluwe Game Reserve, Natal and Sizemba, Rhodesia.

FACTOR	SIZEMBA	HLUHLUWE	REMARKS
Habitat			
Thicket	Extensive	Extensive	
Open Country	Extensive	Extensive	
Other Species			
Elephant	Numerous	Nil	10/sq.mile (approx.)
White Rhino	Nil	Numerous	5/sq.mile
Buffalo	Numerous	Numerous	
Lion	Present*	Present+	* 0.3/sq.mile + 0.8/sq.mile
Hyena	Numerous*	Numerous+	* 2/sq.mile (approx.) + "Extremely numerous"
General Game	Plentiful	Plentiful	

that the high elephant population, resulting in over-numerous and disturbing contacts with rhino cows and their small calves, induced them to seek resting sites not normally frequented by elephant. As the elephant were always in the thicket during the heat of each day, this would have forced the rhino cows to seek sanctuary in more open situations.

(5). The Feeding Habits of Rhino at Mfurudzi and Ruya with Comparative Observations from other areas in Rhodesia.

Observations on the feeding habits of rhino in Rhodesia indicate that the species has a wide range of feeding preferences. A quantitative assessment of the feeding habits of the two populations captured at Mfurudzi and Ruya, obtained over a period of 22 days when 22 adult rhino were tracked for from 6 to 10 hours each day and their food intake recorded, is contained in Table 7., and shows that Diplorhynchus condylocarpon is by far the most favoured feed in both these areas; this species is also eaten in a " toasted " state after veld-fires have burnt out an area. At Mfurudzi this preference was followed by Grewia spp., Dalbergia melanoxylon and then Bauhinia petersiana whilst on the Ruya the second preference was Ficus capreaefolia; D. melanoxylon and B.petersiana did not feature in the rhinos diet at all on the Ruya, probably the result of their less frequent occurrence there. On the other hand, the Ruya record of F.capreaefolia related to part of a single rhino's feed during one night and it does not necessarily reflect a true preference.

Some pertinent facts emerge when this information

Table 7.

A complete record of feeding observations at Mfurudzi and on the Ruya in the north-east of Rhodesia. June - August 1970.

	M F U R U D Z I.			R U Y A.		
	F.O.	O.C.	P.R.	F.O.	O.C.	P.R.
Acacia gerrardii.	12	2	6	47	1	47
Acacia macrothursa.	-	1	0	5	3	2
Acacia schweinfurthii.	36	1	36	-	1	0
Albizia amara.	8	2	4	-	1	0
Alternanthera nodiflora.	20	1	20	-	-	0
Bauhinia petersiana.	155	3	52	-	1	0
Brachystegia boehmii.	1	5	1	-	-	0
Cassia singueana.	61	2	31	-	-	0
Colophospermum mopane.	-	2	0	25	5	5
Combretum elaeagnoides.	20	2	10	10	3	3
Combretum apiculatum.	10	2	5	33	3	11
Combretum fragrans.	66	2	33	-	1	0
Combretum hereroensi.	-	1	0	5	2	3
Combretum imberbe.	14	2	7	18	2	9
Combretum mossambicense.	65	2	33	4	3	1
Crossopteryx febrifuga.	-	-	0	2	1	2
Dalbergia melanoxylon.	112	2	56	-	1	0
Dictrostachys cinerea.	11	1	11	-	2	0
Diospyros quiloensis.	53	1	53	-	1	0
Diplorhynchus condylocarpon.	623	3	208	1001	3	334
Disperma crenatum	111	3	37	43	2	22
Euphorbia cooperi.	15	1	15	-	2	0
Euphorbia ingens.	16	1	16	-	1	0
Euphorbia sp..	32	1	32	-	-	0
Eminia antennulifera.	20	1	20	10	1	10
Ficus capreaefolia.	-	-	0	250	1	250
Flacourtia indica.	10	2	5	-	-	0
Gardenia jovis-tonantis.	3	1	3	-	-	0
Gardenia resiniflua.	-	1	0	8	1	8
Grewia spp..	115	2	58	51	2	26
Julbernardia globiflora.	31	5	6	-	5	0
Lonchocarpus capassa.	15	1	15	-	1	0
Phyllathus reticulatus.	-	-	0	15	1	15
Pterocarpus rotundifolius.	5	3	2	-	4	0
Popowia obovata.	24	2	12	-	2	0
Rhus quartiniana.	10	1	10	24	1	24
Ricinus communis.	-	-	0	12	1	12
Securidaca longipendunculata.	-	1	0	16	1	16
Securinega virosa.	-	-	0	23	1	23
Solanum incanum.	23	2	12	-	1	0
Steganotaenia araliacea.	35	1	35	8	1	8
Strychnos madagascariensis.	27	3	9	-	2	0
Strychnos stuhlmannii.	2	1	2	-	-	0

F.O. = Number of actual feeding observation records.

O.C. = Occurrence rating of the species in the habitat area.

P.R. = Feeding preference rating. This was obtained by dividing the actual number of feeding observation records (F.O.) by the occurrence rating of the species in the habitat area (O.C.).

is compared with observations from other localities, e.g., D.condylocarpon does not occur in the Sizemba habitat at all, only sporadically at Chininga but is fairly common at Manzituba; Brachystegia boehmii and Julbernardia globiflora are dominants ant Manzituba and have an equivalent occurrence rating at Mfurudzi, but in the latter area they reflect only a very small portion of the rhino's diet whilst at Manzituba they are highly favoured. This discrepency is difficult to explain; rhino populations in both areas were light so force of numbers in one area could not have biased the findings; Manzituba,however, has a much higher water table than Mfurudzi, with sponges and springs a common occurrence (which is not the case at Mfurudzi) so perhaps the vegetation at Manzituba has a higher general water content which might influence palatability.

Certain species, e.g., Diplorhynchus condylocarpon, Diospyros quiloensis, Euphorbia cooperi and Euphorbia ingens generally show a high preference rating (3 +) wherever they occur in rhino habitats; all these are highly succulent. In this context it should be pointed out that all feeding data were collected during the dry season and when feeding preferences are subjectively compared with the other vegetation occurring in a habitat, it is generally found that they are amongst the most succulent available in the habitat; it may be found that feeding preferences become broader during the rains when succulence in most plants is high. It has been observed, however, that the annual weed Disperma crenatum is also eaten during the dry season when it is completely dessicated and dead.

Samples of the 18 principal food species were collected at Mfurudzi and Ruya in 1970 and despatched to the Department of Research and Specialist Services for analysis. The samples were first wind-dried in the field and then oven-dried in the laboratory before being tested for % Ash; % Crude Protein; % Ether Extract(Fat); % Crude Fibre; % Carbohydrate; % Calcium; and % Phosphorus. No correlation could be made between the results and feeding preferences which brings to our attention the only other major factor which was not analysed, % Moisture; this again indicates that it is this which is the probable important factor influencing feeding preference.

Inconsistencies were noted in feeding habits of rhino in different areas. Colophospermum mopane is by far the most common and widespread vegetation species in the Sizemba, Chininga, Tende and Pohwe habitats and it is well represented in all the other habitats in which feeding observations were made and yet I only once recorded a single stick being eaten by any rhino living in these areas, at Sizemba in 1965. However, records from Dindi in the Mrewa District show that this species was fed upon heavily in preference to D. condylocarpon (Coetsee and Peek - pers. comm. 1970.), and observations from the Gona-re-Zhou show that C.mopane was one of the first species to be fed upon by rhino released into the area and now twelve months and more after release, these same rhino continue to feed on C.mopane.

Other interesting observations illustrating the rhino's range of food species come from Binga where two animals were observed feeding heavily on the water-lily, Nymphaea calliantha, in a pan in the Chizarira Game Reserve(P.Thomson - pers.comm.); I also recorded rhino at Sizemba feeding on the Kariba Weed, Salvinia auriculata, on several occasions. To obtain both these sources of food the rhino waded into the water until it reached their chest whereupon they moved about amongst the plants eating them with apparent relish.

Grass rarely features in a rhino's diet but observations at Tended in 1969 showed that a regenerating Hyparrhenia sp., emerging from tussocks after a complete burn earlier in the season, was much favoured by an individual on several occasions. In 1967 I observed a rhino on Manzituba feeding heavily on the sedge, Cyperus digitatus, about a month after the first rains when the sedge-bed was some 9 inches tall and regenerating after a complete burn; this animal consumed vast quantities of this species spending several hours moving through the vlei. When I visited Pretoria Zoo in 1970, I saw a rhino eating, with apparent relish, the grass Cynodon dactylon, which was growing in its enclosure and whilst this observation is from completely unnatural conditions, it nevertheless demonstrates versatility in the rhino's feeding habits.

All observations from throughout Rhodesia indicate that during the hot-dry season, rhino are principally nocturnal feeders; a certain amount of feeding is done in the early mornings and late afternoons but during the day it is neglible. The period 8 a.m. to 4 p.m. is normally taken up with resting although frequent rest periods also occur during the night. During the hot-wet and cold-dry seasons, when temperatures are not too great, feeding may occur right throughout the day and night with regular short rest periods interspersed throughout the 24 hours; these details were obtained as a result of tracking interpretations made during the different seasons. Observations on captured rhino in the pens indicate that their feeding and resting periods alter little in captivity and, as in the field, vary according to the temperature and the weather.

Wherever rhino live in association with thicket, feeding is often carried out on the ecotones within the thicket, i.e., on and around termite mounds, along streams (if they occur) and along the thicket edge, but the bulk of the rhino's feeding occurs at night, often in the most open part of the adjacent woodland or hillside, and often several miles from their diurnal retreats. Although the principal component species of the thicket are often eaten, it is pertinent to record that the main feeding period, 4 p.m. to 8 a.m., is normally spent in nearby open country and consequently I believe that in Rhodesia, the deciduous Commiphora-Combretum thickets, with which the rhino is generally associated, are not necessarily important to the animal as feeding areas.

On a visit to the Addo National Park (Cape Province) in late 1969, I observed four of the eight resident rhino feeding in the open at 5 p.m.. I learnt that if one wanted to see these anaimals the best time is in the early morning or late afternoon " when the rhino are out of the extremely dense thicket and feeding in the open " (Le Roux - pers. comm.). Schenkel (1969) records a similar feeding habit in East Africa, but in Hluhluwe Game Reserve (Natal) the situation is apparently completely different. In this latter area one of the major thicket components, Acacia karoo, is a highly preferred food species and the bulk of the feeding occurs within the thicket complex (Hitchins - pers. comm.). The period during which the rhino feed and the variation in feeding times with the season, however, appear to vary little in Hluhluwe from those noticed in Rhodesia.

Schenkel (1969) has listed the species of plants which are eaten by rhino in the Tsavo National Park (Kenya) and it is of interest to note that of the 70 species listed, only three, Acacia tortillis, Solanum incanum and Grewia villosa, have been recorded in the Rhodesian rhinos diet. However, species of the same genera, Bauhinia spp., Commiphora spp., Grewia spp., Disperma spp., Euphorbia spp., Strychnos spp. and Xeromphis spp. are fed upon in both East Africa and in Rhodesia. Of the ten species listed by Schenkel as preferred foods in East Africa, none at all appear in the Rhodesian rhinos diet and only one, Bauhinia taitensis, falls within the same genus of plants recorded as being fed upon by rhino in this country.

Rhino are obviously very adaptable to a variety of diets and emphasis on known food species occurrence is probably of minor importance when assessing rhino habitats.

(6). <u>The Water Requirements of Rhino related to Diurnal Ambient Temperatures and other Pertinent Observations.</u>

Schenkel (1969) observes that during the dry season, the occurrence of surface water will contribute towards the determination of a rhino's home-range but that when living in a feeding area far from water, a rhino cannot drink every evening because of its other activities, i.e., feeding, resting, wallowing, sleeping etc., and must, therefore, be able to remain without water for several days. He accepts that a rhino will go without water for periods of " 4 to 5 and perhaps even 6 days " but unfortunately he makes no mention of ambient temperatures when describing this activity.

My hunting programme, as a member of the Rhodesian rhino capture team (1964 - 70.), was normally orientated about existing waterholes in the habitat and before dawn each day, tracker teams were despatched to check all waterholes in the area and rhinos which had made use of such water supplies were tracked from their place of watering as soon as the trackers had reported back; at distant waterholes, trackers actually camped nearby and either returned to base each morning, or radioed back their reports when a radio was available. This constant supply of reports provided a unique opportunity for study into the rhino's daily rythm and especially their programme to and from water. Consequently, although my observations are only subjective, I believe a different interpretation can be placed upon the rhino's daily rythm in this regard, than that offered by Schenkel.

In all areas where I have encountered ~~rhin~~ rhino in Rhodesia, they remain without water for periods up to 5 days at a stretch, only during the cool winter months but, as warmer weather progresses, the interval between their visits to water becomes shorter until, by mid-August, they are normally watering daily and only on those infequent days when the weather is cooler do they alter this daily activity. In September and October, when shade temperatures in most rhino habitats are well over 100°F. and often above 110°F., the rhino become distressed if they do not obtain water daily and on several occasions, when the animals were disturbed by the presence of a night-capture team at the waterhole, they were found the next morning to have proceeded directly to another waterhole right at the other end of the habitat. However, if similarly disturbed during the winter months, up to about mid-August, when temperatures are not high, they did not seem unduly concerned and merely missed that night's drink and returned the following night (unsuccessful night-hunts were normally followed up by a conventional day-hunt.). There were no observations to confirm that rhino, either willingly or unwillingly, went without daily water during the peak of the hot-dry season.

Schenkel suggests that the rhino's movement to and from water is determined by its programme of other daily activities, however, he later states that climatic conditions such as temperature, irradiation, wind and humidity also play an important role in determining the length of the period away from water.

Rhino sweat profusely, particularly under stress, and if flushed continuously during the day will turn quite black from the moisture as a result. When under the influence of immobilising drugs, if the chase has been strenuous and ambient temperatures high, the sweat literally pours off their bodies. The rhino's sweat glands, therefore, are very active and the animal undoubtedly loses large quantities of body fluid during normal daily activities in the hot-dry season. In contradiction of Schenkel's observations, therefore, all my observations indicate that the Rhodesian rhino's daily programme is modefied to comply with it's water requirements.

An interesting observation came from Chipangayi where the laso of the two surviving cows of that population was captured in November, 1969. This animal had taken up residence on the slopes and peaks of the Chipinga escarpment and observations suggested that she was able to go for extraordinary period without recourse to water. She had a heavy feeding preference for *Euphorbia cooperi* and *E. ingens*, which were prolific on the slopes of her mountain habitat,and it is believed that the xylem of these species was sufficiently succulent to maintain her body water balance during most seasons. Unfortunately full records of her watering cycle during the hot-dry season are not available although it is known that she did frequently visit waterholes during this period. However, there is a possibility that *this* rhino may have been able to extend the interval between visits to water, even at the hottest time of the year, as a result of her diet.

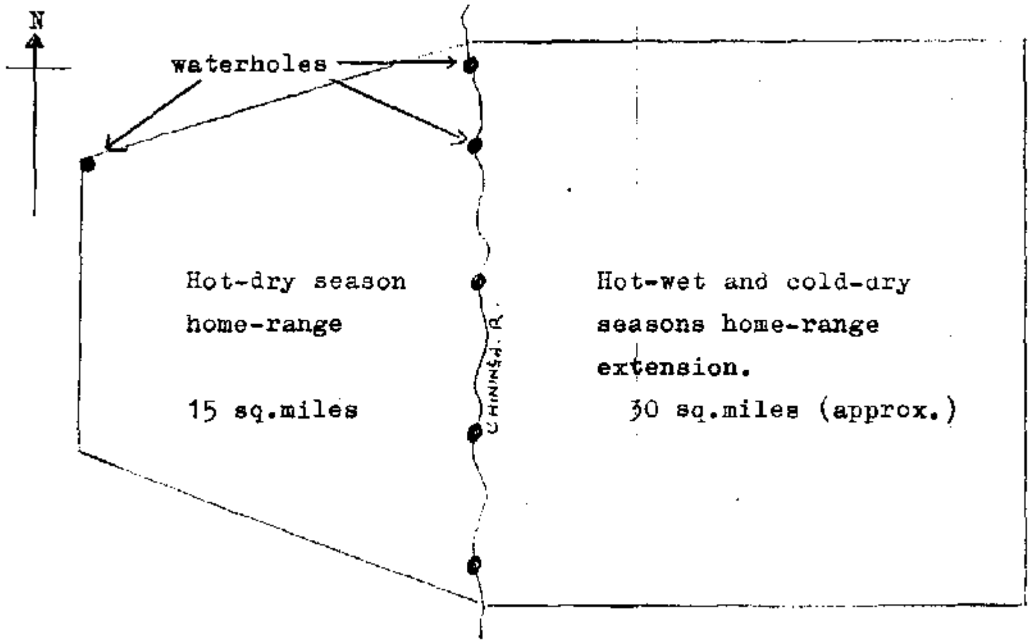
During the winter months rhino have been tracked for distances of 20 - 25 Kilometers from their places of watering. However, during the hot-dry season they usually remain within 5 kms. of the waterholes but occasionally they have been known to extend this to 10 kms.. This change in their habits is probably as a result of the rhinos greater dependence on water during the hotter months.

At Chininga, permanent pools in the river provided the main source of water for the rhino population and during the winter months the home-range extended east and west of the river over an area of approximately 45 square miles. However, during the hot-dry season, this was reduced to 15 sq.miles, only to the west of the river, and as the principal waterholes were located in the riverbed, this bias for only one side of the river suggests that water is not the only criterion in determination of home-range. The most obvious difference between the country on either side of the river is the lack of cover on the east side, particularly noticeable during the hot-dry season, which suggests that this factor also plays an important role in the determination of home-range. (See Fig11.).

On five or six occasions rhino have been recorded digging in the sands of river-beds for water and on two occasions an individual from the Chininga population reached a depth of approximately 3 feet before reaching water, when a small pool of water existed only 100 meters downstream. The

Fig. 11 .

Hot-Dry season home-range of the Chininga Black Rhino population and extension during the hot-wet and cold-dry seasons.



Comparative environmental differences between the two areas during the Hot-dry season.

Hot-dry season home-range.

1. Trees leafless (exceptions).
2. Good shade available.
3. Distance from water = 0 - 5 Kilometers.
4. Food abundant.
5. Poaching minimal.
6. Cover factors per sq.mile:-

a.	Thicket	7.4
b.	Rock Scrub	14.2
c.	Mopani Woodland	5.7
d.	Overall	27.3

Home-range extension.

1. Trees leafless (exceptions).
2. Good shade available.
3. Distance from water = 0 - 10 Kilometers.
4. Food abundant.
5. Poaching minimal.
6. Cover factors per sq.mile:-

a.	Thicket	0.0
b.	Rock Scrub	0.0
c.	Mopani Woodland	13.1
d.	Overall	13.1

The Colophospermum mopane woodland was not measured east of the Chininga river but it is similar in character to that on the west, which was measured by photographic technique. This latter measurement has been used to calculate the cover factors in the home-range extension area.

reasons for this animal's activity are difficult to understand, but in other instances the digging occurred because there was no surface water.

Examination of the excavated waterholes indicated that the rhino used their front feet only; there was no evidence to suggest that their horns are used is this activity, in fact one would expect horns to be an encumberance in the confines of such waterholes. The tracks and disposition of displaced sand indicated that the rhino begin their excavations with one front foot, throwing the sand backwards on that side of the body; they then use the other front foot in a like manner. The animal remains in one position, that is, it does not rotate about the hole, and when (or if) the two piles of sand on either side of its body run together and touch its belly, it disperses the sand backwards with its front feet before resuming digging.

(7). Behaviour.

(i). Population Grouping.

All my observations in Rhodesia have indicated that undxr natural conditions rhino populations occur as sedentary groups with little or no overlap with adjacent populations. Individuals within the group may have exclusive areas visited only by themselves but the greater part of their home-range overlaps those of the other individuals in the population group.

Subjective observations indicate that black rhino are predominantly solitary animals with adult bulls and adult cows, without calves, preferring to live as individuals; adult cows, however, are normally accompanied by their last calf with which they have a close-bonded relationship. Temporary groups of a bull, a cow and perhaps her calf, are formed when mating takes place but these are of short duration.

Aggregations of rhino occur from time to time, apparently as a matter of chance, and these have been known to include 5 or 6 animals. Such aggregations, however, have only been recorded during the mid-day rest period when the animals remain within sight or sound of each other, rarely do such groups actually rest as a herd, and they break up when the animals disperse to feed in the late afternoon.

One apparently permanent association between two cows was noted at Sizemba in 1965, when the two animals were seen together on five or six occasions and their spoor was observed together in the same area, over a period of about six weeks. It is possible, however, that the older cow was the mother of the younger one and that they had maintained their relationship due, perhaps, to the mothers inability to produce another calf or to successive calf losses.

In the same area and under much the same type of circumstance, two permanent bonds were noted between two young bulls in different parts of the habitat. In each of these associations the animals fed, rested and visited water together and were rarely out of vocal communication,remaining normally within each others sight. As they were young bulls, it is reasonable to assume that these bonds were established upon their achieving independence and that they persisted into young adulthood. How long this would have continued had the animals not been captured and thereby forceably separated is not known, but no bond of this nature has been noticed with fully mature bulls.

The Rhino at Mfurudzi and on the Ruya were disturbed populations and therefore they cannot be considered completely normal, however, during the capture of these populations the solitary disposition of individuals, unit grouping of the populations and aggregations of individuals is recorded as being similar to those found at Sizemba, Chininga and Manzituba in the Binga District.

At Chininga, where the population unit grouping was most closely studied, there appeared to be a set plan of escape in the event of danger. Some of the animals, especially mature bulls, had favourite resting sites which they always vacated, when disturbed, in one or another direction and on a definite route; these observations were made on several known animals during multiple unsuccessful hunts. It was also noted that certain thickets within the habitat were used as retreats during flight and the same routes between these thickets were used by many different animals in the population indicating that they were tested and well-tried escape routes for the population as a whole. This population, therefore, was not haphazardly dispersed but had some form of group organisation.

(ii). <u>The Rhino's Attitude in Repose in Relation to the Direction of the Wind.</u>

Twenty-eight records supporting the observation that rhino lie down facing directly away from the wind were obtained at Mfurudzi and Ruya during 1970 and none were obtained to contradict this. Unfortunately, due to the vicissitudes of the hunting and the dense nature of the vegetation, a larger sample was not possible. However, I have made several hundred subjective and unmeasured observations to support this record and, in seven years of close association with rhino, I have never found an animal lying in any position other than facing directly away from the wind.

Hitchins (pers. comm.) states, " Your observations on the resting attitude of rhino confirms my observations. I have found that 99% of all observations indicate that while at rest a black rhino will always orientate itself with its hind-quarters into the wind (this applies to open and closed habitat types). If while at rest there is a wind direction change, the animal gets up, reorientates itself and then lies down again.".

This habit of orientating its position according to wind direction before lying down, is so precise that it must have a high degree of significance in the animals survival. This will be discussed later when it will be shown that the rhinos special adaptations to life in thicket habitats is directly related to this behaviour pattern.

(iii). Observations on the Rhino's Hearing, Eyesight and Sense of Smell.

Observers such as Selous (1908), Schenkel (1969), Goddard (1967) and others, all support my own observations that the rhino's hearing and sense of smell are extremely acute. It is difficult to know how to measure these faculties but I can state with confidence that an alert rhino will follow the direction of a man's progress with its head and ears, at ranges of up to 100 meters, irrespective of how careful he may be to avoid making a noise; and a rhino will bolt at ranges of up to one kilometer if a man's scent is carried towards it on the wind.

When crossing the tracks of a human or another rhino, a rhino will immediately drop int's head to ground level and proceed to sample the scent with loud inward-outward sniffing sounds which can be heard at a considerable distance. They have also often been observed with their noses to the ground, tracing the spoor of another rhino which had recently passed that way and,in times of danger, have been known to back-track their own spoor (This will be explained later.).

The middens, or faecal scrapes, made by rhino have often been attributed to territorial behaviour. Dillon Ripley (1958) suggests that such middens demarcate a territory and I have often heard from several Rhodesian game officers that middens occur as the result of visual stimulus but without attributing any functional aspect thereto.

Goddard (1967) suggests that rhino have some method of identifying other individuals in the population by the scent trails they leave behind, resultant from dung deposits on their hind feet. Schenkel (1969) agrees with this interpretation although he also states that the function of scraping, combined with normal defecation has not yet been defined.

Middens occur as a result of repetitive defecation by the same, or other rhinos in the population, of both sexes, in one place. Several such middens may occur along short sections of a route, becoming progressively more numerous as waterholes are approached. Prior to defecation the rhino will maneouvre itself into position over the midden and give up to ten vigorous scrapes with its hind feet before depositing its dung on the heap. This is followed by equally vigorous scraping of the hind feet which scatters the fresh dung and thereby deposits a fresh scent on the rhinos back feet. (Records of this habit are too numerous to define accurately but they probably number over 200 hundred.)

It is therefore reasonable to assume that the rhino's habit of creating middens and scattering their dung with the hind feet, should be associated with their sense of smell. In this context it is pertinent to point out that although rhinos do not always use middens for defecation, they rarely defecate without scattering their dung with their hind feet.

I conducted experiments at Sizemba in 1964 to test an alerted rhinos eyesight. This was only carried out on those animals which were too alert to allow an approach to within the very short darting range of our (then) inferior weapons and only on about three occasions, but observations over the past seven years support my earlier findings. The test was carried out by simply waving a handkerchief in front of an alerted rhino at ranges above and below 30 meters; It was found that although the animal became agitated with the increased warnings from its attendant oxpeckers (Buphagus spp.), it was unable to detect the movement of the handkerchief above the 30 meter range, but below this range the movement was detected.

If oxpeckers are present on the rhino, they will give alarmed " churring " noises at each movement a hunter makes (this applied also to the waving handkerchief) and the animal will respond by appearing restive and moving its head from side to side in an effort to locate the source of trouble. The rhino must obtain some sort of directional guidance from the birds because they always seem to face in the general direction from which danger threatens. Such is the notice the rhino takes of these birds warning that they may be induced to instant flight upon their first warning call.

When assessing the eyesight of rhino, it was necessary to ensure that no noise whatsoever was made because their hearing is so acute that they quickly zero onto any noise made by an observer, with both ears extended forwards, which action is often incorrectly attributed to the animal's sight.

Alerted rhinos will hear a man moving, even although he does so with the utmost caution and determination to make no noise, at ranges up to 100 meters. A man walking normally through the habitat will be detected at ranges well in excess of this distance, provided the rhino is alert. However, an unalert rhino will respond to a man walking without caution, by raising its head or rising to its feet, when the man is 50 - 75 meters distant, under normal circumstances.

The rhino's three senses work together as detectors of phenomena in their environment and contribute towards the animal's security. Their sense of smell is the most acute, but this operates only in one direction, that dictated by the wind; their effective eye-sight only extends up to 25 - 30 meters; and beyond this distance the presences of an enemy is detected and its progress followed by the rhinos acute sense of hearing.

(iv). Aggression and Intraspecific Competition.

I have been charged many times by rhino, under a variety of circumstances, during capture operations and I have had detailed discussions with those of my colleagues who have been gored by rhino (Fothergill - 1965 and Coetsee - 1970.). However, I believe that Rhodesian rhino are generally not aggressive although repeated contact with man may promote a charge. Reported " charges " are often no more than demonstrative puffing noises issued by the rhino when alarmed and put to flight; such " charges " need rarely be taken seriously. If continuously pestered by man, however, the rhino is quite capable of making a determined attack but this will more often occur in heavy cover than in open situations. That attacks of this nature are predetermined and completely in earnest is not in doubt because the animal will stand perfectly still, following the man's progress by the sound he makes, and the more determined the rhino the longer will it hold its position before erupting into a full charge. If it misses its target in the first rush a determined rhino will often spin round and renew its attack.

If an aggressive rhino is approached by two hunters from different directions and it detects both areas of danger, it may, under these circumstances, be induced to flight. It may also, however, make a short, noisy and demanstrative rush, not necessarily towards an area of danger, which often induces one of the hunters to run for a tree. Once this has happened, the rhino will accurately locate the source of the noise and proceed with a determined charge in that direction, ignoring the second hunter.

Another method of attack has been observed on 10 - 15 occasions. When a rhino has been persistently tracked all day, it appears to realise that its pursuers are following its spoor and on about 10 occasions it was noticed that the animal has run over rocks and trampled grass rather than take a more direct and easier route where their spoor would have been more obvious, which suggests that the animal may have been trying to hide its tracks. If, during a pursuit of this nature, a contact is made in heavy thicket, a genuine charge has often originated from over 100 meters range and when the tracks have been examined later, it has been found that the rhino had run back along its own, often tortuous spoor, towards the trackers. These charges are always characterised by the rhino galloping at full speed, with its head close to the ground, which has led me to believe that the animal is back-tracking its own spoor by scent. Such charges are not as determined or dangerous as the previous one described and they are thought to be the result of frustration and panic by the rhino at failure to lose the tracking team; they are usually easily avoided by simply moving sideways off the tracks and away from the direct line of attack. Under these circumstances I have never found rhino to turn round and renew the attack, rather they appear content to have scattered their pursuers and made good their escape.

Mortality as a result of intra-specific contest is rare and determined encounters between rhino, involving grievous bodily harm, are uncommon. Only one rhino captured at Sizemba, in 1964, showed signs of having been involved in a fight and this animal displayed unusual pugnacity in the pens which might suggest that it was its particular disposition which caused the fight (conversely, its intractable nature may have been caused by the fight!). Another animal which had apparently been seriously injured in a fight, was found in the Chewore Game Reserve in 1970 (Coetsee - pers. comm.). The only definite record of a fatal encounter between two rhino was made at Mfurudzi in 1970, when two mature bulls had a fight which resulted in the death of one of them. The dead animal had severe lacerations in the region of the throat and lower neck and had three deep punctures along its spine which appeared to have been inflicted when the victim was lying on its side. The other bull was subsequently captured and showed signs of the fight only in superficial wounds on its forehead, which nevertheless burst open when it began to struggle during transportation from the field to the pens.

Despite the lack of evidence that many intra-specific encounters prove fatal, sparring or less serious encounters appear to be quite common amongst the adult bulls. Of all the animals captured, there was not a single adult bull which did not display scars on the forehead and, indeed, the lack of such scars may indicate subadult status in young bulls. Cows rarely display such scars which indicates that they avoid or have no inclination towards, intraspecific sparring encounters.

The Chininga population comprised 6 adult bulls, 4 adult cows, 2 subadult cows and three calves, which all appeared to live amicably together in the same composite home-range and there was no evidence at all to suggest that any serious conflicts occurred even between the bulls.

Hitchins (pers. comm.) has obtained information from his studies at Hluhluwe which involves the radio-telemetric tracking of rhino, suggesting that lesser bulls apparently give way to a dominant bull as it moves into a specific area within the common habitat. I have only one observation which suggests that a ranking structure might exist in the rhino populations of Rhodesia. On one occasion at Chininga, in 1968, two young bulls were sparring lightly near a waterhole when a third animal came down to drink. It was observed that the two earlier arrivals moved away from the water whilst the newcomer went to the water unchallenged. This latter animal was darted at the waterhole and successfully transported to the pens the following day; it subsequently proved to be the biggest rhino bull in the population.

(v). Interspecific Relationships.

On five or six occasions, when seriously harassed by hunters, rhino have sought out a herd of buffalo , by following the buffalo's spoor, and have taken up a position in the centre of the herd. On one occasion the rhino actively roused a recumbent herd of buffalo with loud demonstrative " puffing " noises and then ran off in the stampeding herd until they reached stoney ground whereupon the rhino moved away from the herd on its own; this was all observed visually and not merely from interpretation of the tracks left behind: on this occasion it was believed that the rhino had not only used the buffalo to gain protection from their more acute vision, but had also tried to hide its spoor in that of the herd and only left the herd when tracking conditions deteriorated. On the other occasions, the rhino had quietly taken up a position either in the centre or on the upwind side of the herd.

Adult rhino were often found feeding on the fringe of elephant herds at Sizemba, but cows with calves actively avoided such a close association. On several occasions adult bulls were observed being chased from their diurnal resting sites by elephant and at other times were seen to get to their feet and follow the progress of an elephant herd as it passed nearby and only resumed their rest when the elephant had passed. At Sizemba it is believed that only a state of tolerance was achieved between these two species, rather than amicable co-existence.

There was no evidence to support a positive relationship between the rhino and any other animal species.

(vi). Symbiotic Relationships.

The Red- and Yellow-billed Oxpeckers (*Buphagus erythrorhynchus* and *B.africanus*.) are the only species associating so closely with the rhino that their relationship can be considered symbiotic. These birds use the rhino as a feeding platform, investigating the ears, nostrils, the anal regions, the folds in their skins and their chest erosions, from which they obtain their food supply; chest erosions are ulcerative cutaneous lesions containing the filarial parasites *Stephanofilaria spp*.(Hitchins 1970) and which only occur in the lower throat or chest regions in Rhodesian rhino. In return the oxpecker provides the rhino with an effective alarm system. It is on very rare occasions that in a seriously disturbed rhino population, the animals do not take instant notice of of the birds alarm call; on several occasions the first alarm has resulted in the rhino erupting from a supine position into instant flight. A lack of oxpeckers in an insecure or very open habitat, would seriously detract from the rhinos chances of survival.

Associations with Cattle Egrets (Bubulcus ibis.) and Fork-tailed Drongos (Dicrurus adsimilis.) were found to be of a very temporary nature and appeared to afford the rhino little protection.

(8). Reproduction.

(i). Breeding Seasons.

Records of rhino calves caught and observed on capture operations indicate that there are two peaks in mating in Rhodesia, June and November, with corresponding peaks in parturition in September and February. See Table 8 and Fig 12.. The peak mating period, November, coincides with the end of the hot-dry season and the start of the rains, i.e., when relief from the period of stress during the hot-dry season is experienced. A second mating peak starts with the cold-dry season, reaching a peak in mid-winter, June, and declining again as the hot-dry season approaches; motivation for this mating period may be connected with depressed temperatures.

Parturition periods do not appear to coincide with environmental conditions best suited to the calves. One would expect a peak in December/January, declining in February/March, because at this time of the year cover is at a maximum; water

Table 8.

Months of Rhino Mating and Birth.

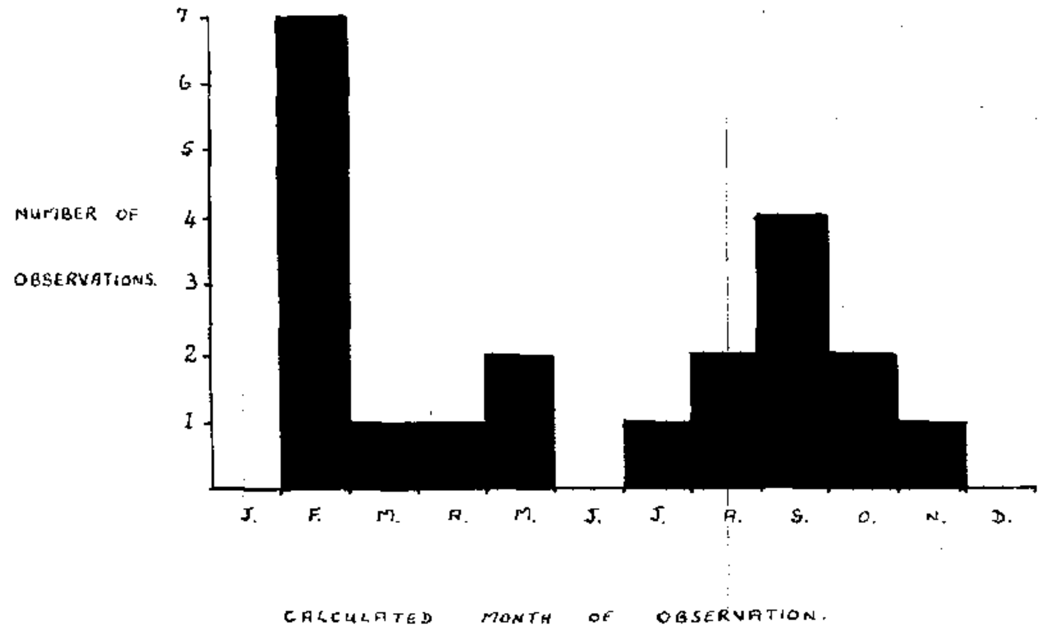
Age calculated from Data in Fig. 13; mating dates from accepted gestation of 15 months (Brand - pers.comm.)

Area	Sex	Date of Observation	Shoulder Height in inches	Age in Months	Birth Month	Mating Month
Sizemba	M	24. 7. 64	52	21	Oct.	Jul.
Sizemba	F	20. 8. 64	41	9	Nov.	Aug.
Sizemba	F	17. 9. 64	33	4	May	Feb.
Sizemba	F	15. 7. 65	49	17	Feb.	Nov.
Sizemba	F	18. 7. 65	25	½	Jul.	Apr.
Sizemba	F	4. 9. 65	45	11	Oct.	Jul.
Chininga	M	12.9. 67	*	½	Sep.	Jun.
Chininga	F	12. 9. 67	*	½	Sep.	Jun.
Chininga	F	8. 9. 68	48	16	May	Feb.
Mfurudzi	F	4. 6. 70	48	16	Feb.	Nov.
Mfurudzi	M	7. 6. 70	48	16	Feb.	Nov.
Mfurudzi	M	3. 7. 70	35	5	Feb.	Nov.
Mfurudzi	F	5. 7. 70	53	23	Aug.	May
Ruya	F	8. 8. 70	53	23	Sep.	Jun.
Ruya	F	9. 8. 70	43	11	Sep.	Jun.
Ruya	M	13. 8. 70	35	5	Mar.	Dec.
Ruya	F	14. 8. 70	37	6	Feb.	Nov.
Ruya	F	17. 8. 70	32	4	Apr.	Jan.
Ruya	F	21. 8. 70	28	½	Aug.	May
Ruya	M	22. 8. 70	50	18	Feb.	Nov.
Ruya	M	25. 8. 70	56	30	Feb.	Nov.

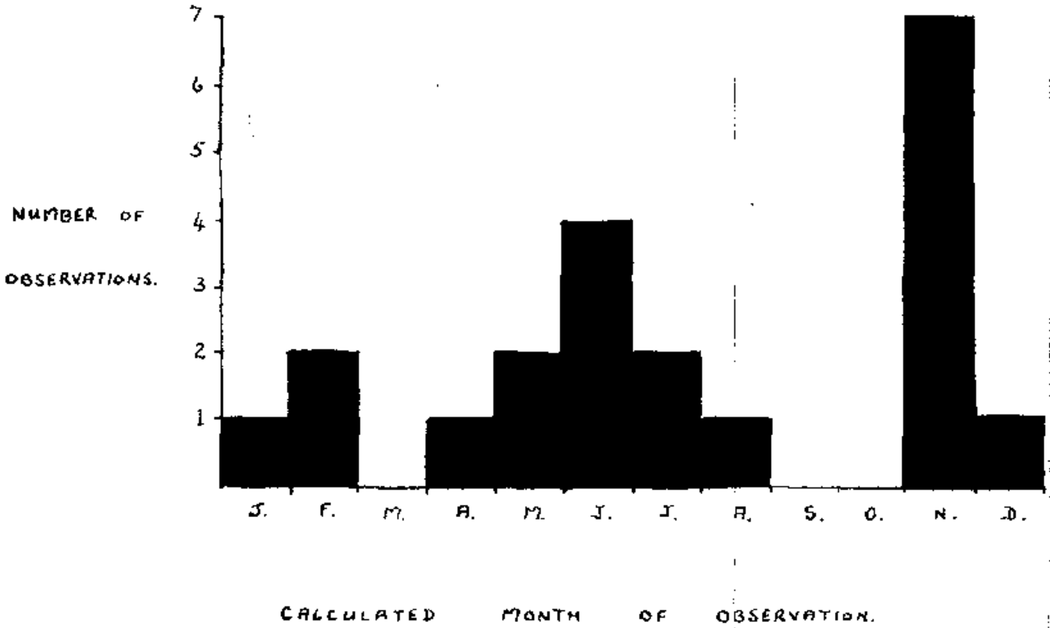
* Field Observations

Fig. 12.

(1). Calculated Months of Parturition.



(2). Calculated Months of Matings.



is abundant; vegetation is succulent, palatable and nutritious, thereby ensuring good lactation in the cows and reducing the possibility of malnutrition and disease in the calves; predators are scattered and predation is not severe (even from man); and the calf will have time to become strong and experienced enough to endure the rigours of the cold and hot-dry seasons. This, however, is not the case. The calves born from February to May have the benefit of some of the advantages listed above, but those born from July to November have to live through the harshest period of the year for their first few critical months.

Schenkel (1969) records one mating peak in East Africa in March/April which also corresponds with the beginning of a wet season (Choate - pers. comm.).

Breeding, therefore, appears to be controlled by the period providing environmental conditions conducive to mating and not by the period best suited to the calves.

(ii). Breeding.

(a). Sexual Maturity.

A Black Rhino heifer of a known age of 3 - 3½ years, was moved from Wankie National Park to the Matopos National Park, in 1964; upon release in the Matopos this rhino showed signs of being in oestrus (Cantle - pers. comm.). This agrees closely with Schenkel's estimate of sexual maturity at 3½ - 4 years which he based on the record of a Great Indian Rhino (Rhinoceros unicornis.) which mated for the first time at 3¼ years of age and gave birth when it was 4½ years old.

Schenkel also records that a Black Rhino cow in Frankfurt Zoo appeared almost fully grown at 4½ - 5 years of age. Full dentition, however, is not achieved until the animal reaches the age of 7 - 8 years (Anderson - 1966.) and measurements recorded during capture operations in Rhodesia indicate that rhino cows continue to grow after their first parturition.

(b). <u>Gestation Period.</u>

Brand (pers. comm.) records that the gestation period of a Rhodesia rhino cow in Pretoria Zoo was 457 days, which agrees with his record of 458 days from Chamarajenda Zoo in Mysore (India.). Goddard (1967) quotes estimates of 450-545 days; 450-480 days; 470 and 462 days; 469 days; 446 and 478 days; the average of which, excluding his exceptional record of 545 days (which I would suggest is subject to some doubt), closely agrees with Brand's known period of 457 days. It is this figure, therefore, which has been accepted for the purpose of calculation in this study.

(c). <u>Calving Intervals.</u>

Hitchins (pers. comm.) records intervals between calves in Hluhluwe of 5, 4, 3½, 3 and 2 years; he does not, however, record the possibility of calf mortality between the parturition intervals in those cows with extended interval records. Ripley (1958) records the interval between calves in the Rio de Janeiro Zoo as 22 months and Goddard (1967) records intervals of 25, 28, 29 and 36 months in East Africa and 24 months from the Kobe Oji Zoo in Japan.

In the Chizarira Game Reserve in 1968, I recorded an interval of 27 months between the calves of a well-known rhino cow and in the same year calculated a possible 20 - 22 month interval from a heavily pregnant cow (the foetus was visibly very active inside her) and her large attendant calf which were captured at Chininga.

Records from capture operations, field observations and calculations made from the estimated calf-age in relation to the pregnant state of their mothers, would indicate that normal calving intervals in Rhodesia are between 24 and 33 months. This agrees with Goddards estimate of every 27 months, on average.

Calves continue to suckle from their mothers up to the age of about 20 months and it is therefore normal for cows to continue lactating well into their next pregnancy.

(d). Reproductive Capacity.

Ripley (1952) states that a pair of Great Indian Rhino (*R. unicornis.*) was known to have lived in captivity for 45 years and as these animals are of a similar size to the Black Rhino, I believe this record can serve as a useful parameter. Bigalke (1945) records the age of a Black Rhino cow at the time of her death in Pretoria Zoo, as 29 - 29½ years. It seems reasonable in the absence of more definite material, therefore, to accept Schenkel's (1969) assumption that Black Rhino reach the end of their reproductive life at 30 - 35 years of age.

From the data available (See Table 9 . - Ages defined and not yet explained will be examined in the next sub-section.) it would appear that the reproductive capacity of the Rhodesian rhino cow is between 9 and 15 calves. In these calculations no account has beentaken of a possible increase in parturition intervals as the cow increases in age since there is no evidence to support this assumption; there is also no evidence to indicate that sexually mature cows should not be without a calf at foot throughout their reproductive lives. Cows without calves may be accounted for by predation of young calves; natural mortality in new calves after the mother-calf bond with the previous calf has been broken; young cows in their first pregnancy; senility or disease.

There is every indication that normal healthy cows will replace their calves continuously throughout their reproductive lives, rejecting their previous calf when the new one arrives (See next sub-section.). If there is a long parturition interval, the mother-calf bond appears to persist, certainly until the calf itself reaches sexual maturity. A rhino population with a preponderance of adult cows without calves may be an indication of heavy predation on the calves, or that some other factor in the environment has affected the population adversely.

(iii). Mother/Calf Relationships.

(a). Mother and New Calf.

Cows with new-born calves (10 + observations.) have been found to be very shy but, in the face of danger, extremely

TABLE 9.

Reproductive Capacity of Black Rhino in Rhodesia

Age at Independence	2 - 2¾ years *
Age at Sexual Maturity	3½ - 4 years
Age at First Parturition	4¾ - 5¼ years
End of Reproductive Life	30 - 35 years
Reproductive Years during Life	26 - 31½ years **
Interval Between Parturitions	2 - 2¾ years
Calculated Calving Potentials	9 - 15 calves ***

* A good working average would be about 30 months.

** (a) Lowest reproductive age limit, less, highest age at sexual maturity, i.e. 30 - 4 = 26.

(b) Highest reproductive age limit, less, lowest age at sexual maturity, i.e. 35 - 3.5 = 31.5.

*** (a) $\frac{\text{Lowest number of reproductive years}}{\text{Highest interval between parturitions}} = \frac{26}{2.75} = 9.5$

(b) $\frac{\text{Highest number of reproductive years}}{\text{Lowest interval between parturitions}} = \frac{31.5}{2} = 15.7$

aggressive. On human contact, noisy demonstration is often followed by a determined charge, or flight, whereupon the calf runs after the mother, sometimes trailing as much as 50 meters behind her. On such occasions the mother, when out of immediate danger, makes regular stops to enable her calf to catch up with her and once well away from danger, will reduce her speed to a pace which the calf can maintain. If the danger is continuous, as in the case of a persistent tracking team following their tracks, the cow may prolong her flight indefinitely and may exhaust her calf to the point of death; certainly to a state where lurking predators would find a kill an easy matter.

New-born and very young rhino calves are particularly helpless in the face of danger but the mothers appear to recognise this and give great attention to their offspring.

Cows have been known to leave their new calves for several hours each night whilst they go to water (Obs. 4 & 6, Appendix 2. and a further confirmatory observation Gona-re-Zhou in June, 1971.) and to further confirm this, in habitats where cows have been seen with very small calves, careful scrutiny of all the waterholes has revealed no spoor of baby calves. During the hot-dry season, in particular, predators such as lions and hyenas, often obtain their food at, or near waterholes and for a rhino cow to bring her new calf to water every night would seriously detract from its chances of survival. It is believed that this habit of leaving the calf in hiding whilst the mother goes to water each night, is a general one and, whilst this practice has its dangers since the calf is particularly vulnerable when left alone at night, it is felt that the hazard of regular visits to waterholes may be greater.

Cows with small calves have no set routine, no regular feeding or drinking places and may wander up to 25 kilometers during the 24 hour period, when the calf is strong enough to endure prolonged treks (number of observations too numerous to record accurately; c. 50 +.); the smaller the calf the more irregular the habits.

(b) Mother and Maturing Calf.

During the calf's first year and well into its second one, the mother and calf move continuously throughout the habitat area and are often found in locations not normally visited by other animals because of lack of water or the rugged nature of the terrain. Calves of about two months of age appear to be fully capable of the arduous wanderings imposed upon them by their mothers and are by this time, over the very helpless stage and thus less vulnerable to predators.

During the initial period, the calf follows on its mothers heels, but when they are at rest it often becomes restless and may move about her feeding. However, when the mother becomes heavily pregnant, i.e., when the calf is 20 - 30 months old, the younger animal often takes the initiative and will lead its mother away from danger. This reversal of the lead role probably occurs because the gravid state of the cow makes her loathe to move, especially during the heat of the day, unless it is absolutely necessary but it no doubt conditions the calf for independence which begins when the new calf is born.

(c). Age at Independence.

Schenkel (1969) suggests that the mother rejects her subadult calf when she is near to parturition but my Rhodesian records, which are supported by Goddard (1967) in East Africa, show that the mother-calf bond is not weakened until after the new calf is born and is only finally broken with forceful demonstration by the mother. How long the cow takes to accomplish this break is not known, but it is known that the demonstrations last, intermittently, for at least ten days, with the larger calf following its mother at a distance, or moving away to return to her during the day; and that the break is not accepted easily by the older calf.

The age at which a calf becomes independent, therefore, is determined by the interval between its birth and the birth of its mothers next offspring; in Rhodesia this is normally when the young rhino is between 24 and 30 months old. At this stage the animal is 50 - 56 inches at the shoulder with an anterior horn length of 14 -15 inches (See Obs. 4 & 7., Appendix 2.).

Several observations of groups of a cow, her young calf and a subadult have been made, but these are perhaps the result of a chance meeting which immediately break up upon their being disturbed. In these observations, it was assumed that the subadult was the mothers previous calf but the only positive confirmation of this has been recorded on the Chizarira when three known animals were often seen together. It is probable, however, that any recently independence subadult rhino will form a liaison with any other rhino prepared to accept its presence.

(d). First Stages of Independence.

Young rhino recently forced into independence appear restless and often move well beyond the limits of the group area to which they have become accustomed. They also display a degree of impatience in normal daily activities not normally associated with this species. Despite an increased alertness, caution is often lacking in their approach to waterholes at night and they regularly move along paths leading to water at a pace in excess of that noted in the more experienced animals. At this age the young rhino once again enters a new period of vulnerability and mortality may be high. (See Appendix 2., obs. 9.).

Goddard (1967) suggests that the nomadism of the subadults may serve an evolutionary function by assuring population dispersal thus preventing inbreeding. My subjective observations from Rhodesia support this. As well as maintaining gene-flow between sedentary breeding units by moving out of their natal group home-range and establishing themselves in the home-ranges of other populations, there is little doubt that young rhino in this age group are also responsible for pioneering new habitats.

(iv). Growth of Calves.

Goddard (1967), Roth and Child (1968) and Schenkel (1969) classify rhino calves according to size or weight, but no attempt is made to relate these classifications to chronological age. Hitchins (1970), illustrates the growth-rate of rhino calves in Hluhluwe with photographs, which closely agrees with my own observations in Rhodesia.

During capture operations all captured animals were carefully measured and sometimes, in the case of calves, their ages were known or could be estimated from previous observations. My data is recorded in Table 10. and illustrated in Fig 13 .. From this detail it can be seen that accurate assessment of a rhino calf's age, in the field, is not easy nor is it much more simple with the calf in captivity. The most accurate estimation of calf ages, however, will be found in the younger animals because it is in this group that growth is most rapid and difference in size, greatest.

There is a probable individual variation in the growth-rate of calves resultant from relative abundance and/or quality of food in the different years and seasons of birth, and in different environments. This may be difficult to substantiate scientifically but measurements from rhino calves caught on recent operations show a definite and marked inconsistency in horn length sizes (up to 35 %), particularly, and in other measurements, between animals of the same shoulder height; Hitchins (1970) observations on calf-size relative

Table 10.

Growth of Calves

Name	Sex	Date	Age	Height
Julie *	F	20.8.70	10 days (Known)	28"
Twana	F	18.7.65	14 days (Estimated)	25"
Mbira **	F	17.9.64	3 months (Estimated)	33"
Sengwa ***	F	5.9.65	11 months (Known)	45"
Chimangimangi +	F	8.9.68	15-17 months (Estimated)	48"
Ian ++	M	25.9.70	27-33 months (Estimated)	56"
Gwetera +++	F	24.6.70	4½-5 years (Estimated)	59"

* See observation 4, Appendix 2.

** See observation 1, Appendix 2. The animal was captured three months later.

*** See observation 11, Appendix 2.

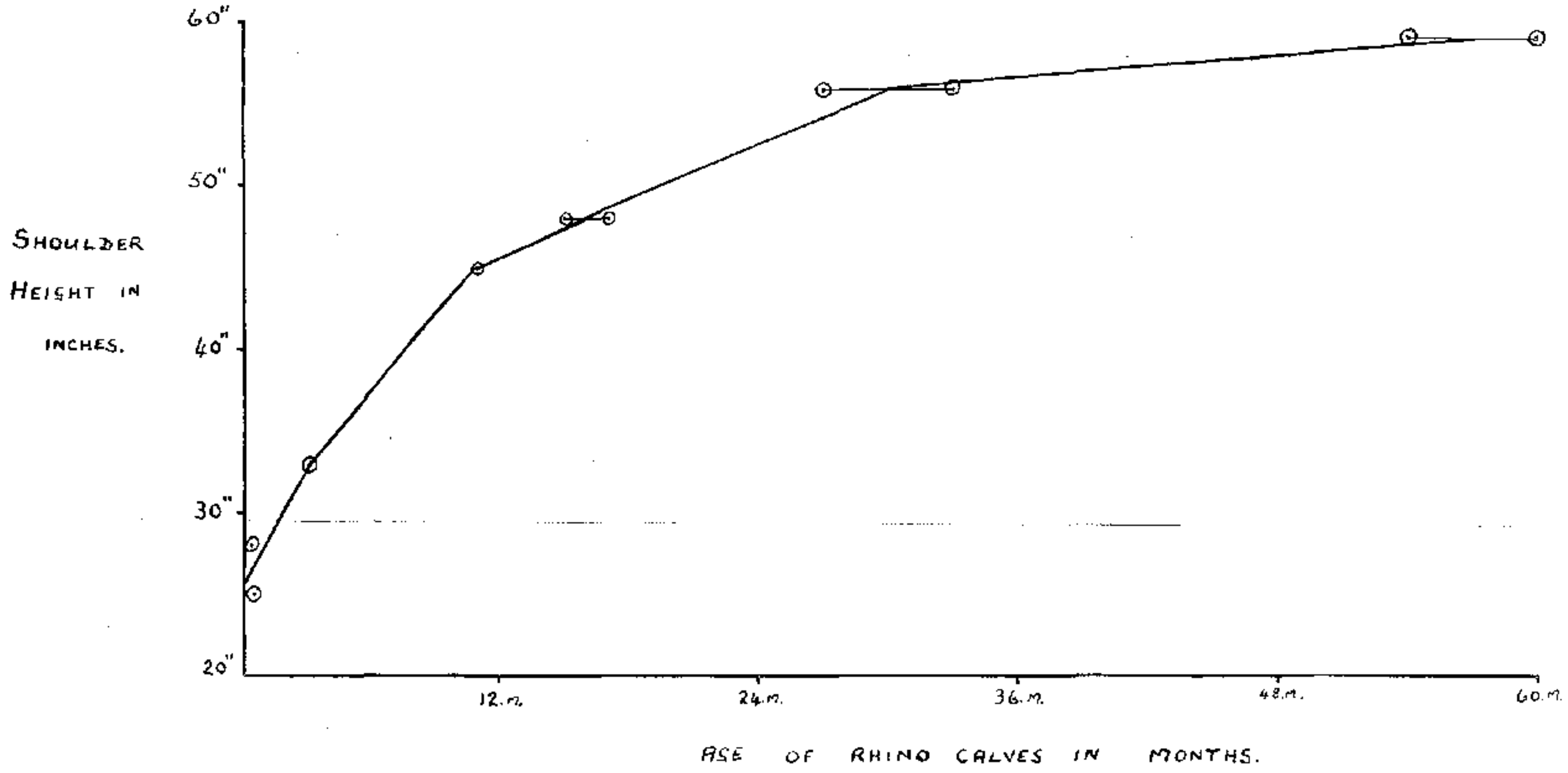
\+ See observation 7, Appendix 2.

++ See observation 4, Appendix 2.

+++ This animal was a young cow in her first prgnancy; she showed no sign of previous suckling. Her age has been based on the data in Table 9.

GROWTH OF BLACK RHINO CALVES.

(DETAILS IN TABLE 10)



SOLID LINE BETWEEN PLOTTED POINTS REPRESENTS ACCEPTED VARIABLE OF ESTIMATED AGE OF A RHINO CALF.

FIG. 13.

to their age shows a slight difference when compared with my own; this assumption is therefore, reasonable. Relative size difference between cows and their calves resultant from the individual differences in the size of adult cows make field criteria for ageing rhino calves even more difficult to define; this is also acknowledged by Hitchins (1970). However, notwithstanding the problems of ageing rhino calves, all observers and observations confirm that rhino calves have a very rapid rate of growth (See Fig 14 .).

(9). Survival and Predation.

(i). Calves.

Roth and Child (1967) estimated that two-thirds of the rhino calf-crop in the Kariba basin, died before maturity.

Lions predate on rhino calves but the main predator is the hyena (Obs. 8., Appendix 2.) and the wandering disposition of cows with small calves is attributed to the known predation of calves by these animals.

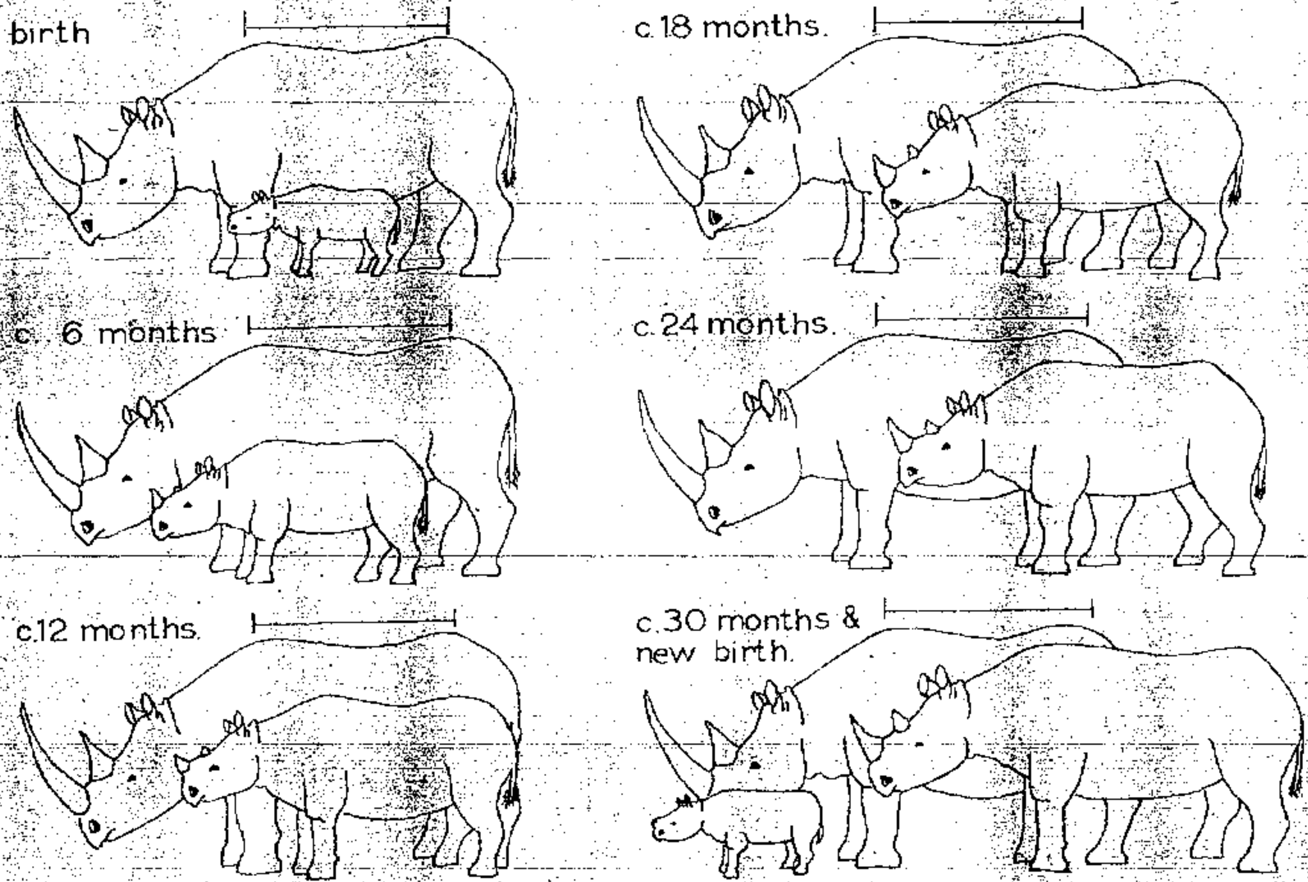
The period during which calves are born can have an advantage bias. Calves born during the rains have a more favourable chance of survival than those born during the hot-dry season, when water restrictions bring the predators and the rhino into closer contact.

(ii) General.

As rhino grow older, African poachers with steel-cable snares, muzzle-loaders and rifles, become the principal predators (See Obs. 9, Appendix 2.). Although adult animals show an uncanny ability to detect and avoid snares, they are

FIG. 14.

GROWTH RATE OF BLACK RHINO CALVES.



Adult cows are between 60 inches (illustrated) and 64 inches (indicated by line) in height at the shoulder: growth-rate of calves is probably individually variable resultant from relative abundance and/or quality of food in different seasons and years of birth and in different environments. There is therefore a probable inconsistency in age-class and cow/calf size differences.

frequently caught, whilst subadults appear unsettled and rash in their behaviour which renders them extremely vulnerable to African poaching methods. Mortality in this latter group, mainly from poaching pressures, is likely to be high and is probably surpassed only by that of the young calves.

Two observations from Wankie National Park (Fothergill and Rushworth - pers. comm.) show that lions will attack adult rhino and I have one record of a subadult rhino from Sizemba (1964) which had been severely mauled by a lion (Obs. 5., Appendix 2.). Attwell (pers. comm.) records an adult rhino being killed by lions in the Luangwa Game Reserve in Zambia but despite these observations, records of rhino being killed by lions are relatively few and it is doubtful if these predators affect rhino populations to any great extent.

The five populations studied in Rhodesia showed that the cows outnumbered the bulls in a ratio of 1.23 : 1.. In two areas, Mfurudzi and Ruya, the ratio agrees exactly with Schenkel's figure of 1.3 : 1. which he obtained from the Tsavo National Park in East Africa. (See Tables 11. and 12 .).

Cows are generally more alert than bulls; are less sedentary and therefore less likely to be preyed upon by man; do not participate in fighting; and are generally inclined to be more cautious than bulls, all of which probably make the cows less vulnerable. It would also appear likely that there is a natural preponderance of females as of the 21 calves in the study, there are 15 females and 6 males, a ratio of 2.5 : 1..

(See TABLE 11 .)

TABLE 11 .

Rhino populations in the Sizemba, Chininga, Manzituba Mfurudzi and Ruya areas in Rhodesia.

AREA	CAPTURED						NOT CAPTURED						TOTAL
	Adults		Subads		Calves		Adults		Subads		Calves		
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
Sizemba	16	14	2	1	-	5	1	2	-	1	-	-	42
Chininga	5	4	-	2	1*	1	1	-	-	-	-	1	15
Manzituba	-	-	-	-	-	-	2	1	-	1	1^{o}	-	4
Mfurudzi	5	8	-	1	3	3	2	1	-	-	1^{o}	-	23
Ruya	5	8	3	-	2	5	-	-	-	-	-	-	23
TOTAL	31	34	5	4	6	14	6	4	0	2	0^{o}	1	107

* Found dead (Observation 6, Appendix 2).

o Calves of unknown sex excluded from calculations.

TABLE 12 .

SEX RATIOS

AREA	SEX - RATIO		
	Cows	Bulls	Ratio - Cows:Bulls
Sizemba	23	19	1.21 : 1
Chininga	8	7	1.14 : 1
Manzituba	2	2	1.00 : 1
Mfurudzi	13	10	1.30 : 1
Ruya	13	10	1.30 : 1
OVERALL	59	48	1.23 : 1

7. DISCUSSION.

Previous studies deal mainly with the rhino's behaviour, population dynamics and general ecology but I have been unable to locate any literature which convincingly defines " rhino habitat " or connects varying population densities with contrasting environments. In applied ecology the determination of what consititutes an animal's habitat is the most important consideration and without this knowledge it is difficult to see how allied information can assist in the proper management of the species.

The problem in studying the habitat requirements of rhino in Rhodesia today, is the difficulty in locating undisturbed populations from which accurate and unbiased home-range and population density measurements can be made, in habitats sufficiently diverse in character to be worthy of comparison. Most of the country's rhino inhabit the Zambesi valley system below 3,000 feet, where they occur in largely similar habitats associated with Commiphora-Combretum thickets; groups living at higher altitudes and in different vegetation associations, are usually disturbed or relic populations which cannot be used for comparative purposes. Sizemba, Chininga and Manzituba have all the necessary conditions, and the two primary prerequisites of the study, home-range and population density, were accurately known for all three areas; it was for this reason that these three areas were chosen as the main study areas.

I have tried to bring pertinent factors into perspective by demonstrating correlations between cover and carrying capacity in different habitats and by relating behaviour and the rhino's natural faculties to its habitat requirements and chances for survival.

Records show that rhino have a wide range of environmental tolerance and once occurred over the greater part of Rhodesia in widely differing habitats. Although their present range is restricted, they still occupy a variety of environments and any extensive area of land which has woody vegetation and a permanent water supply may confidently be described as a habitat suitable for rhino. However, in order to effectively manage the species in the sanctuaries to which they will be ultimately confined, it is necessary to know more about the population density limitations of the different habitats.

The study has shown two significant and important correlations from which we can make the following observations.

(a). Rhino population densities are determined, within limits, by the degree of <u>thicket</u> cover available in the habitat, i.e., the greater the thicket cover, the greater the population density and vice versa (See Fig 8(a).). This does not mean that without thicket, rhino cannot exist, rather that in areas where there is little or no thicket, the population density will be low.

(b). There is also an inverse relationship between the rhino's requirement for cover and available cover in different habitats, i.e., as cover increases between habitats, so the rhino's need for cover decreases and vice versa (See columns (d) & (f)., in Table 2. - and Fig. 9.). To explain this in terms of the carrying capacities of different habitats, the following hypothetical models have been constructed.

(i). If, in Habitat A., there are 10 R.C.F.s per square mile and each rhino is known to require 10 cover factors in that habitat, the population density will be :-

$$\frac{10 \text{ c.f./sq.mile}}{10 \text{ c.f./rhino}} = 1.0 \text{ Rhino / square mile.}$$

(ii) If, in Habitat B., there are only 5 R.C.F.s per square mile, each rhino will require $>$ 10 cover factors (because there is less cover available). In this case the population density will be :-

$$\frac{5 \text{ c.f./sq.mile}}{> 10 \text{ c.f./rhino}} = < \frac{5}{10} = < 0.5 \text{ Rhino / sq.mile}$$

(iii) If, however, in Habitat C., there are 20 R.C.F.s per square mile, each rhino will require $<$ 10 cover factors (because there is more cover available). In this case the population density will be :-

$$\frac{20 \text{ c.f./sq.mile}}{< 10 \text{ c.f./rhino}} = > \frac{20}{10} = > 2.0 \text{ Rhino / sq.mile}$$

In practice, this will be demonstrated by extensive home-ranges in rhino populations occupying open habitats and smaller, mpre compact home-ranges in those populations living in more heavily vegetated areas. Subjective observations from all areas visited during and before the period of this study, indicate that there is an increase in the distances travelled by individual rhino with a corresponding decrease in their habitat cover and vice versa; this supports the change in home-range size suggested above.

There are probable variables to this trend which may render further definition of habitat carrying capacities impractical, e.g. density dependent factors, water restrictions or abundance and unsuitable food species all of which may restrict numbers irrespective of suitable cover being available. My observations indicate, however, that cover factor criteria are operative throughout Rhodesia and that wherever rhino populations occur in this country, available cover is likely to affect carrying capacities in the habitats.

The two correlations described and explained above reflect probable indeces for the determination of carrying capacities in different habitats. The correlation between thicket R.C.F. and population density is the most obvious and important whilst the second correlation may explain the reason why. It has already been explained that thicket is unimportant as a feeding area for rhino and therefore it can be assumed that it serves the purpose of providing security for the species; when thicket cover decreases so will the rhino's security and as a result the animals will have to substitute extra <u>space</u> for the loss in cover, whereupon cover itself becomes of secondary importance. This may explain the increased home-ranges observed in rhino living in open-type habitats as well as the decreased population densities. In this context, the rhino does not really <u>require</u> any more cover at all but it does require more security when cover factors decrease; cover, therefore, can be used as an index for security.

There may also be an upper limit to the security afforded by cover and once this optimum level is reached the density of rhino populations may be more finitely regulated by density dependent factors, whereupon cover will again become of secondary importance. Cover factors, however, will probably remain a useful index for carrying capacities in different habitats.

The correlations made in this paper must be taken as demonstrating the intensity of the relationship between cover and rhino population densities, only. Future studies should be directed towards more quantitative work which can best be achieved by detailed regressions based upon the determination of the individual animal's home-range as distinct from that of a breeding unit; this would only be possible using biotelemetric techniques. Determination of the cover factor allocation per rhino in this case will give a greater value than that derived in this text, so a new set of values, based upon the means of individual home-range sizes, will have to be evolved if the greater accuracy required is to be achieved.

A functional relationship between the variates, cover-factors-per-square-mile and cover-factors-per-rhino, in different habitats could be determined by regression. A scatter diagram would probably result from the plots of these variates, from which a regression line could be determined; this would represent a more accurate assessment of the data contained in Fig. 9. If this data could be collected from a sufficient number of different habitats, the resultant regression line could be used to determine the probable optimum carrying capacity of any rhino habitat, provided cover remains the principal factor governing population density as the Binga data correlations suggest.

The effective carrying capacity of any habitat, however, can only be assessed in an area of land which is contained within the comfortable daily scope of the rhino's movement from permanent water during the hot-dry season; this distance appears to be c.5 kilometers in Rhodesia, but is likely to vary according to the degree of succulence in food supplies and temperature variations at different altitudes. It has been shown that the rhino's independence from permanent water during the hot-wet and cold-dry seasons, combined with additional cover and a better food resource at this time of the year, makes possible an increase in the size of their home-range but the carrying capacity of an area should be assessed at the time of the year when resources are at a minimum, i.e. the peak of the hot-dry season.

An unmeasured component of the three study area habitats is the availability of shade and whilst this was abundant in all three study areas, the rhino's need for shade is such that lack of it during the hot-dry season may seriously affect the carrying capacity of a habitat which might otherwise be well-suited to the species.

A second unmeasured characteristic is the variation in topography. However, I have noticed that relatively broken country tends to reduce distances covered by individual animals which is an indication that this factor may influence the size of the home-ranges. The extent to which broken terrain can substitute for cover in the determination of home-range size is not known but I believe it is of sufficient importance to be worthy of inclusion in future studies.

There are several behaviour patterns and other characteristics which indicate that rhino are better adapted to life in the thickets than in open habitats:-

(a) The rhino's poor eyesight has little survival value in open country where predators, including man, will be able to locate the animal long before he is able to see them. In thicket, however, visibility is rarely in excess of the rhino's effective range of vision and animals living in such habitats will be able to use this faculty to the maximum of its efficiency.

(b) The rhino's specific behaviour of lying down facing into the lee of the wind brings into most beneficial use its two principle receptors for detecting danger, hearing and sense of smell. In this position the presence of an animal behind the rhino will be disclosed through its acute olfactory senses and to its front and sides by its acute hearing. In thicket country this will allow the rhino a radius of detection well beyond the range of visibility and it also means that predators locating the rhino by scent and moving towards it upwind will be confronted with their quarry head-on, which has considerable survival value.

(c) In their method of retaliatory attack the rhino use sound and scent to locate their target and their eyesight only comes into use in the final stages. This form of defence is particularly well-suited to thicket conditions but, where visibility is good, the lack of good vision is a definite survival deficiency.

(d) Plains animals generally have good vision and their means of identification and communication are either vocal, visual or both. The rhino's adaptation of voice and scent as a principal means of communication is, I believe, yet another indication that the species is better adapted to closed than open habitat.

The symbiotic relationship between the rhino and oxpeckers (Buphagus spp.) has considerable survival importance for the rhino and has its greatest significance in open habitat where the birds' keen eyesight substitutes for the rhino's own deficient vision and provides them with adequate protection in vulnerable quarters. This bond is perhaps one of the reasons for the rhino's ability to inhabit many open habitats which would otherwise be inimical to them.

Schenkel (1969) describes the rhino as "one of the species living in the transitional habitat between grassland and forest" and he states the belief that elephant benefit the rhino by reducing climax forest to a seral stage. I would agree that subclimax vegetation is of more use to the rhino and they benefit from regeneration following elephant damage but the rhino's own ability to modify its environment should not be underestimated for it is capable of pushing down quite large trees with its neck or chin. Against the benefits accrued from the presence of elephant in rhino habitats must be weighed the possible adverse effects on rhino behaviour as suggested at Sizemba. A considerable amount of investigation into the interspecific relationship is needed before any meaningful conclusions can be reached.

Rhino feed on a large number of woody vegetation species throughout the year and on forbs, sedges and, occasionally, grasses when these are most palatable. They have no dependence on specific vegetation types but they tend to have different preferences which appear to coincide with the succulence-rating of the food species in the different habitats. More detailed research into the succulence-rating and nutritional values of the rhino's diet is necessary before dependable conclusions can be reached but it is no doubt partly due to the versatility in feeding that the species was so widely distributed in Africa and in Rhodesia, in particular.

A high degree of insight is shown in many ways. The rhino's ability to track, using their highly developed olfactory senses, apparently enables them to recognise the persistence of a hunter with a similar tracking ability and results in their apparent attempts to hide their spoor. Insight is also shown in their use of the buffalo's keen eyesight when they associate with herds of this species to avoid danger and in the fact that, when under pressure from night capture teams, adult rhino will often stand away from a waterhole until other game animals have visited the water and come away unscathed, before approaching the water themselves. It is highly probable that this insight has a high survival value.

Rhino are solitary animals but they establish sedentary breeding units with home-ranges which increase during the rains and winter months, and observations indicate that these units are retained even during this period. Geneflow between breeding units appears to be maintained principally through the nomadism of the subadults.

There is no specific breeding season but peaks in breeding do occur, apparently controlled more by periods conducive to mating than by those most likely to benefit the calves. The breeding capacity of rhino is high and calves have a rapid rate of growth but calf mortality can also be great. Further significant mortality is possible amongst subadults following their independence, but mortality appears largely due to predation and will vary between populations in accordance with predatory pressures. I believe the longevity of this species, together with a high breeding capacity and the rapid growth of calves, is, perhaps, the main reason for its survival since prehistoric times.

Hyenas are the principal predators of rhino calves but lion may also contribute towards calf and subadult mortality. Man, however, is the greatest predator on the species and is the most important reason for the rhino's past and continued decline in Rhodesia. Although predation, in all its forms, is the principal reason for mortality, density-dependent controls on both mortality and natality may be equally important and should not be overlooked.

This study shows that rhino are adapted to and, in many ways, dependent upon thicket but that they can do without it. It is quite clear, therefore, that in our management of the species, we should promote the occupation of habitats containing extensive thickets as long as there is also permanent water available. At this juncture it is pertinent to point out that of the 40 rhino released into Wankie National Park, the majority scattered throughout the game reserve and we have knowledge of some having subsequently left the area; the only established population is centred between the Lukosi and Deka rivers near Sinamatella (Rushworth - pers.comm.) which coincides with the only substantial occurrence of Commiphora - Combretum thicket in the entire area.

Indications are that thicket is the rhino's original habitat, not a retreat in the face of increased human occupation, and the wide distribution and dispersal of the species can be attributed to versatility and adaptation to open habitat.

The present official awareness of the decline of this species in Rhodesia, the translocation exercises being carried out to re-establish the rhino in sanctuary areas within its known former range and an increasing understanding of the species' overall ecology, augers well for the future of the Black Rhinoceros in this country. However, there is still much we do not know and there is a need for further intensive study of this species in all aspects of its ecology.

8. ACKNOWLEDGEMENTS.

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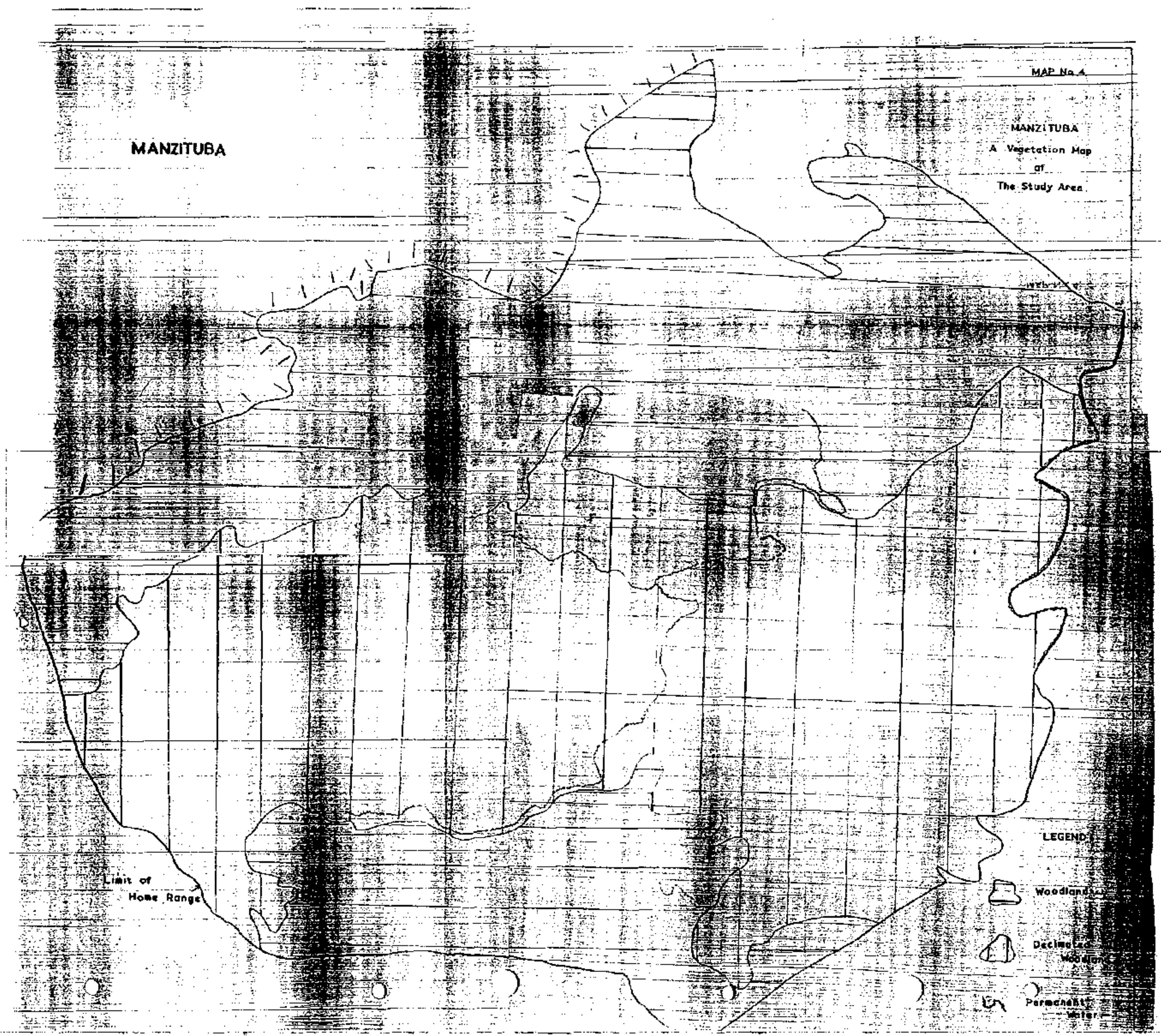
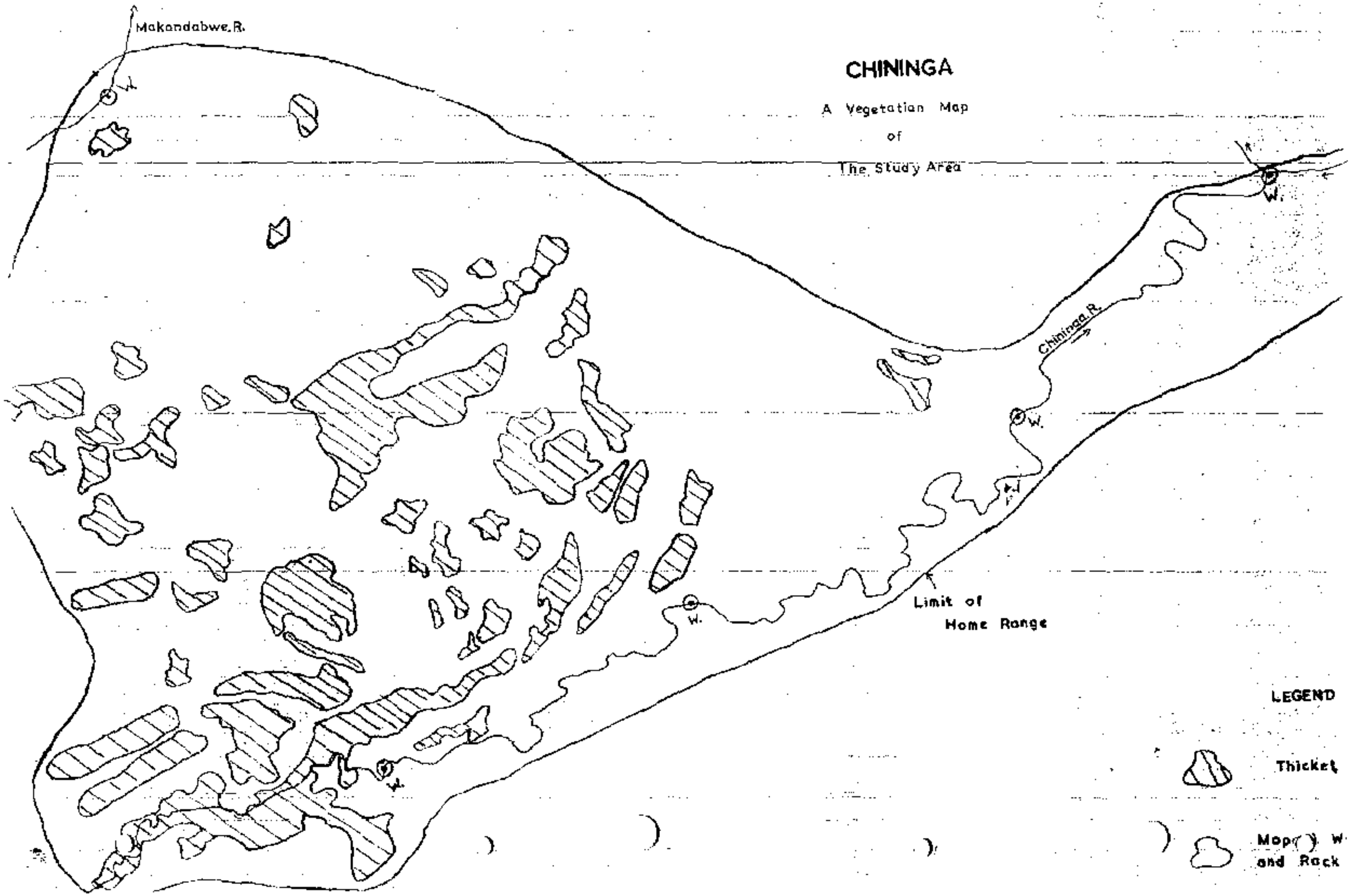
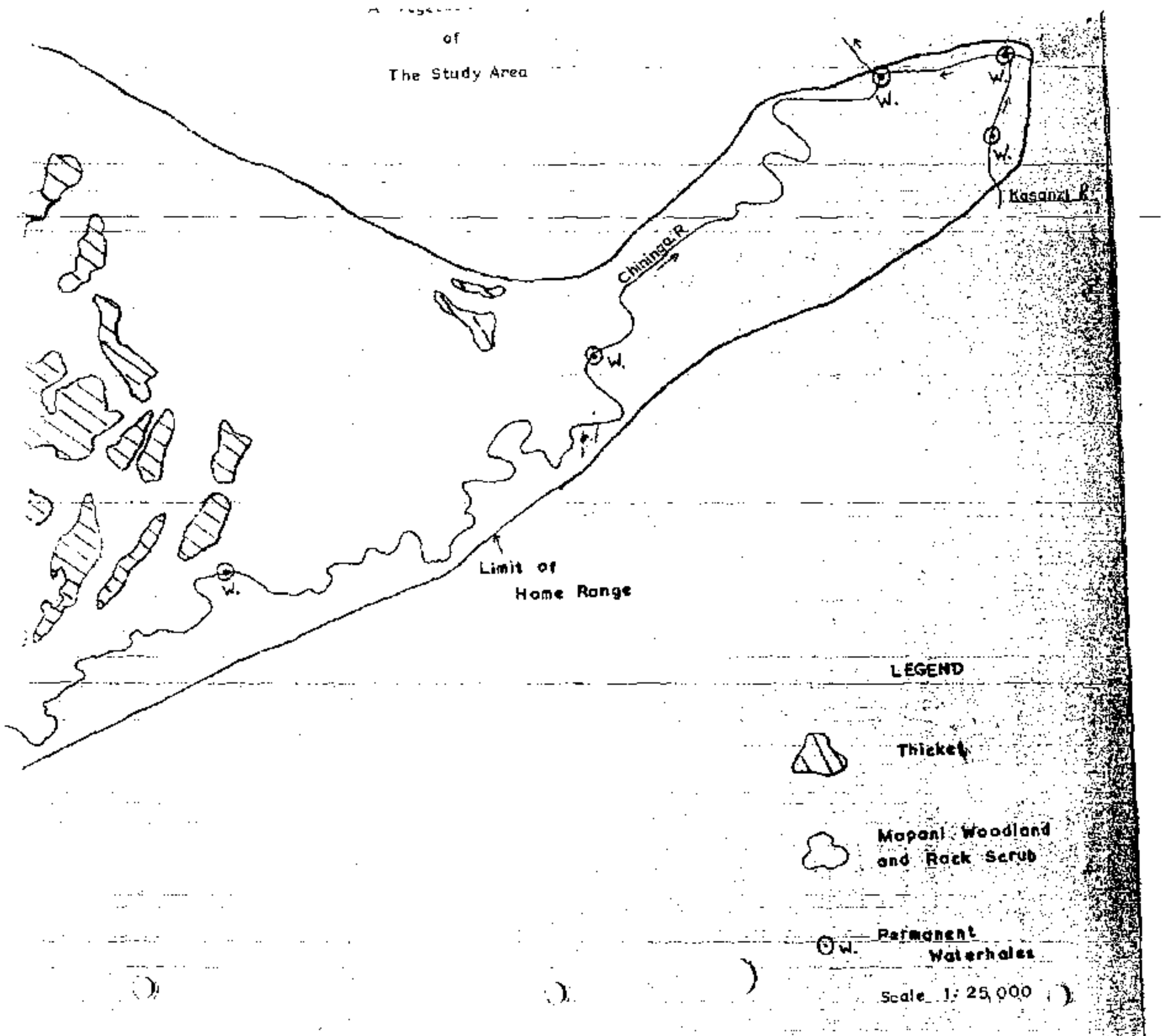
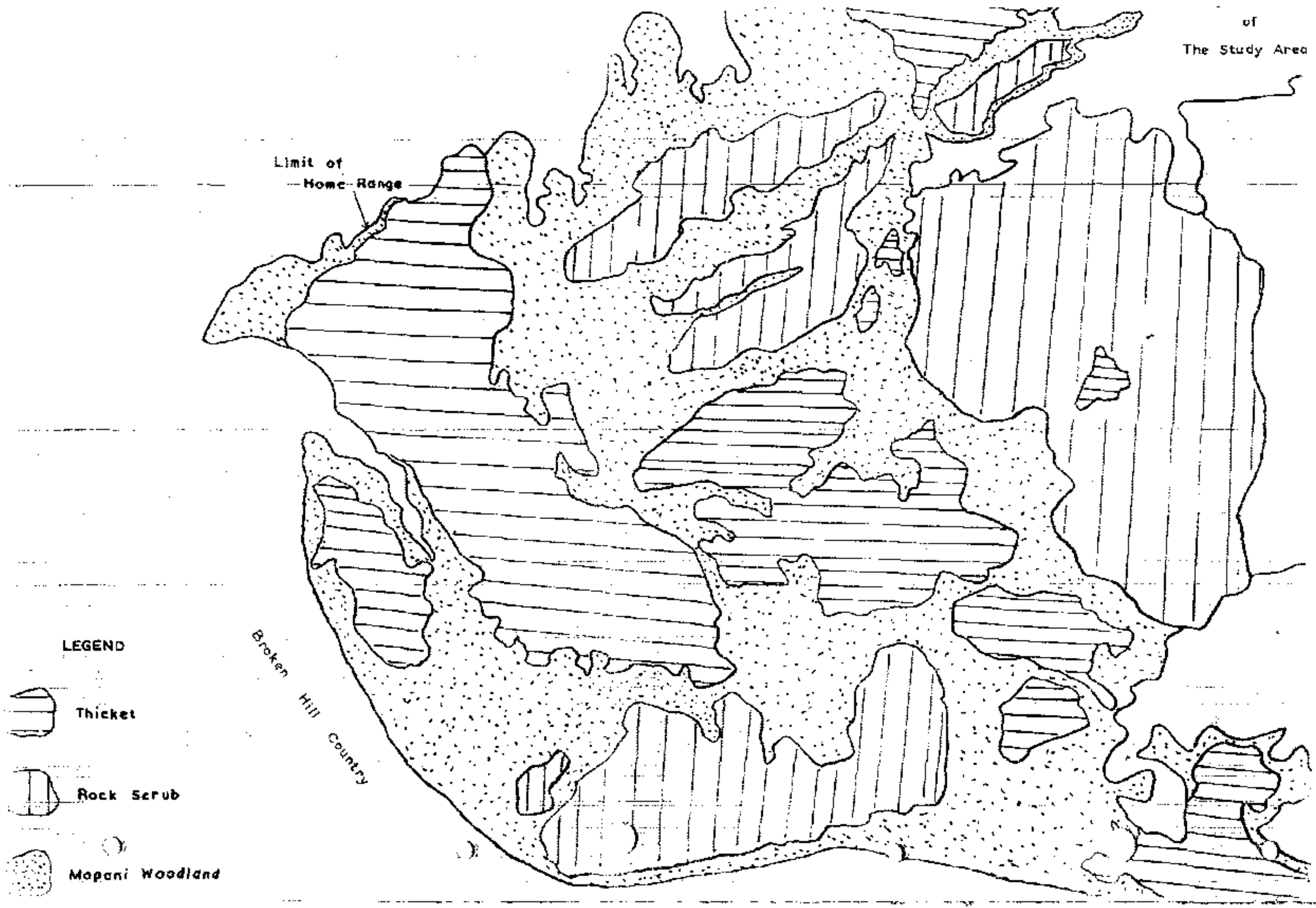
RUSHWORTH,D. Wankie National Park.
THOMSON,P. Chizarira Game Reserve.
WILLIAMS,D. Chizarira Game Reserve.
WOOD,A. Head Office.
WRIGHT,P. Mushandike National Park.


MANZITUBA
MAP No 4
MANZITUBA
A Vegetation Map
of
The Study Area
LEGEND
Woodland
Decimated Woodland
Permanent Water
Limit of
Home Range

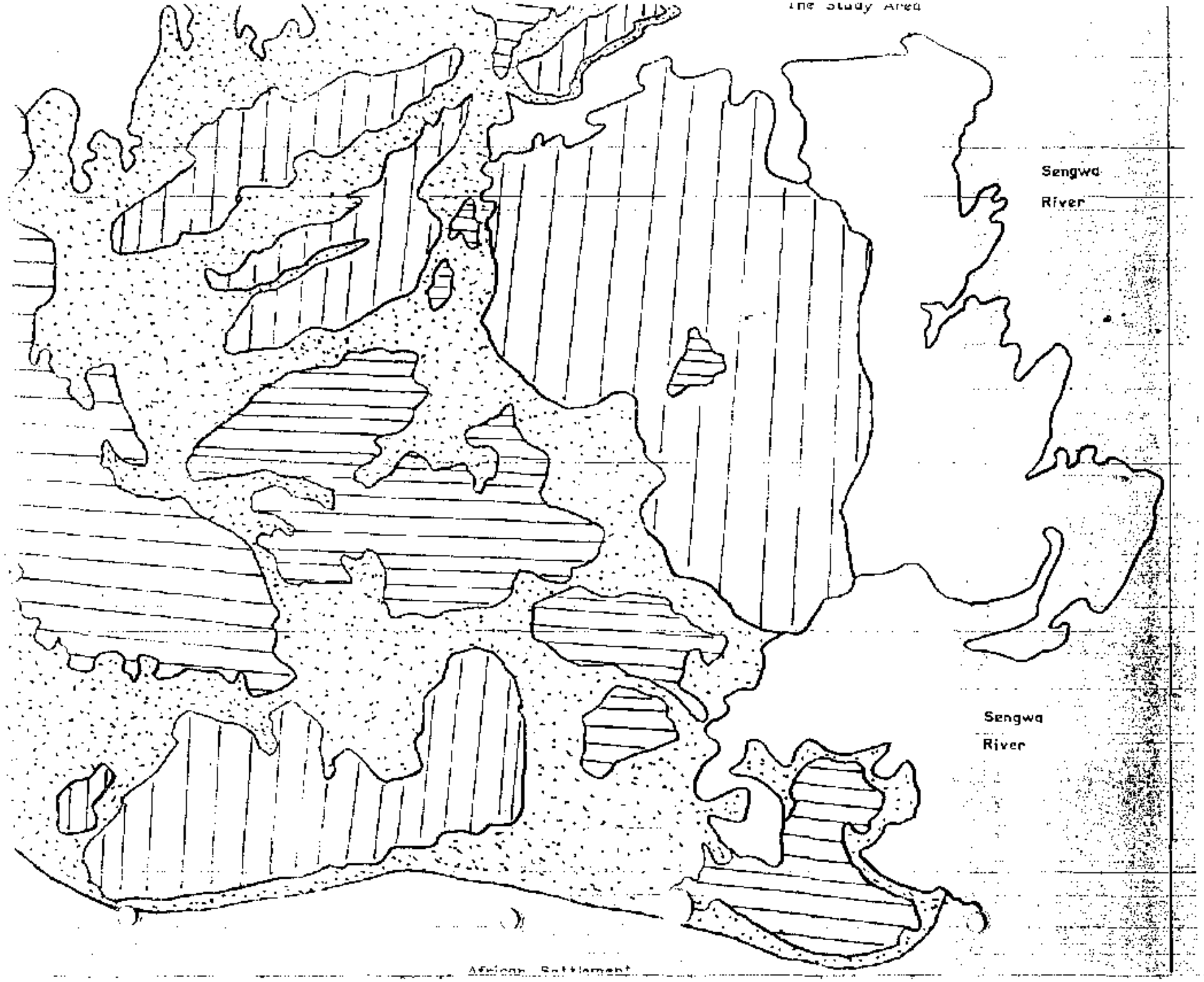


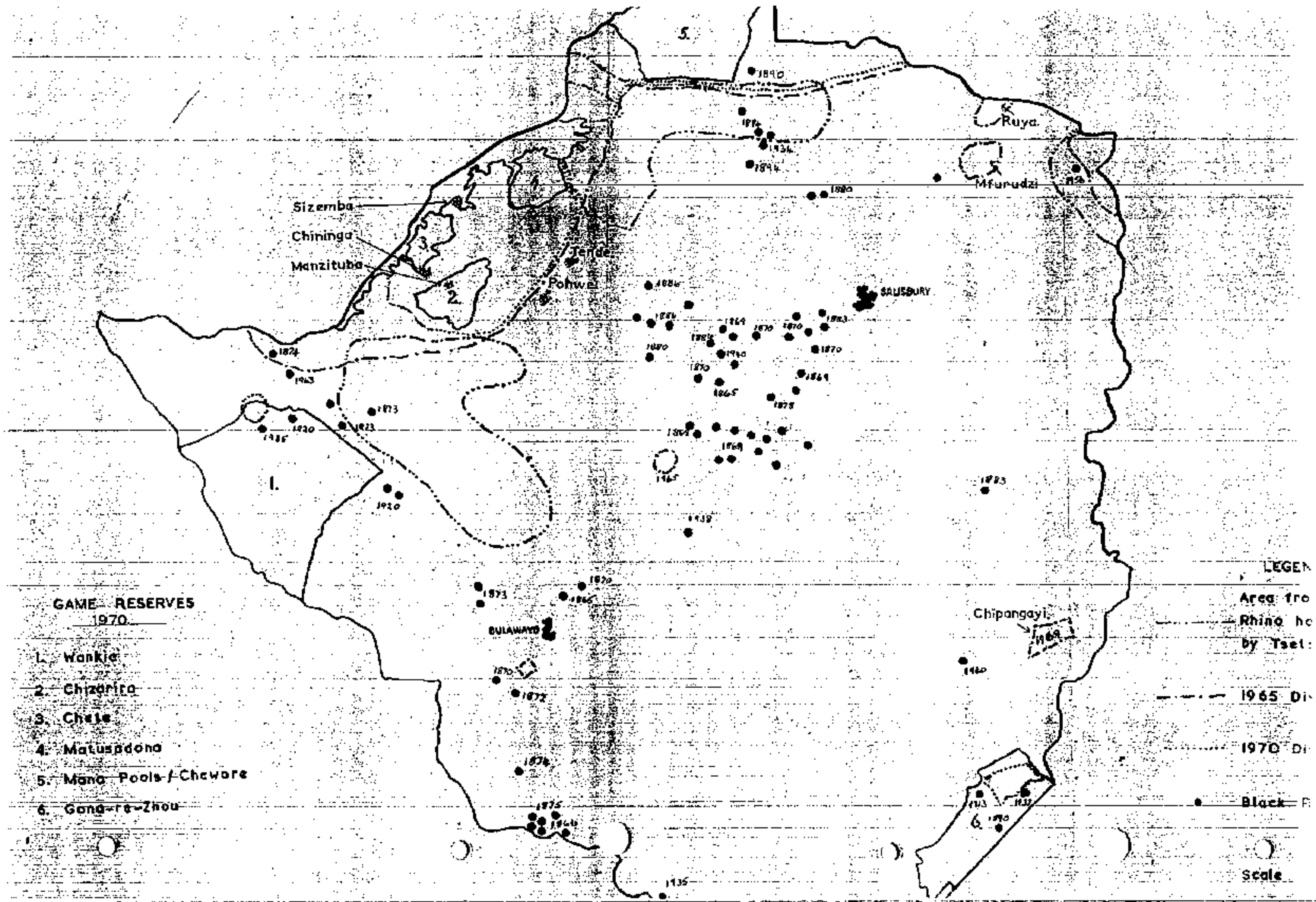
Makandabwe.R.
CHININGA
A Vegetation Map
of
The Study Area
Chininga R.
Limit of
Home Range
W.
LEGEND
Thicket
and Rock


of
The Study Area
Chiringe R.
Kasanzi R.
W.
W.
W.
W.
W.
Limit of
Home Range
LEGEND
Thicket
Mopani Woodland
and Rock Scrub
W. Permanent
Waterholes
Scale 1: 25,000

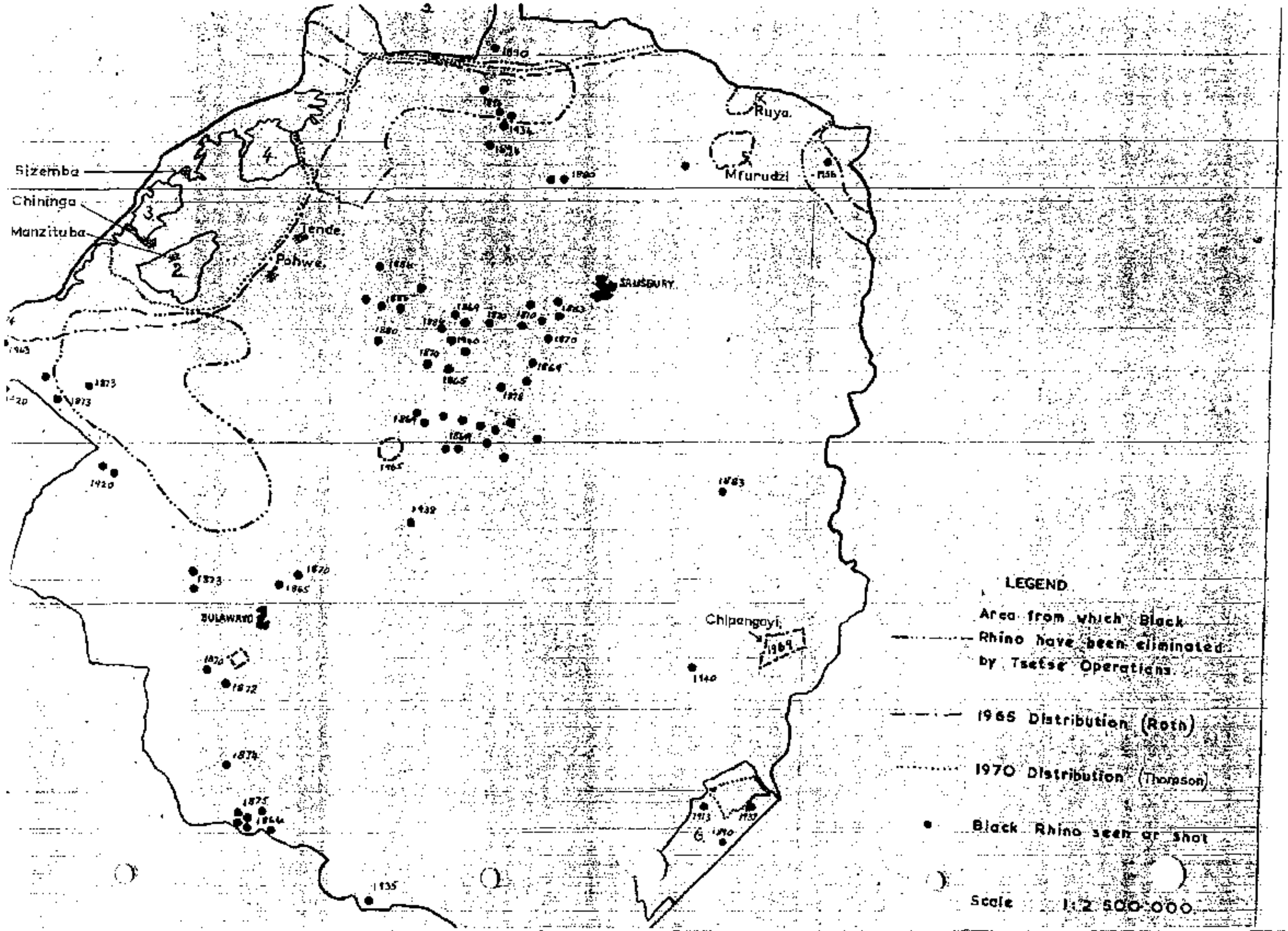


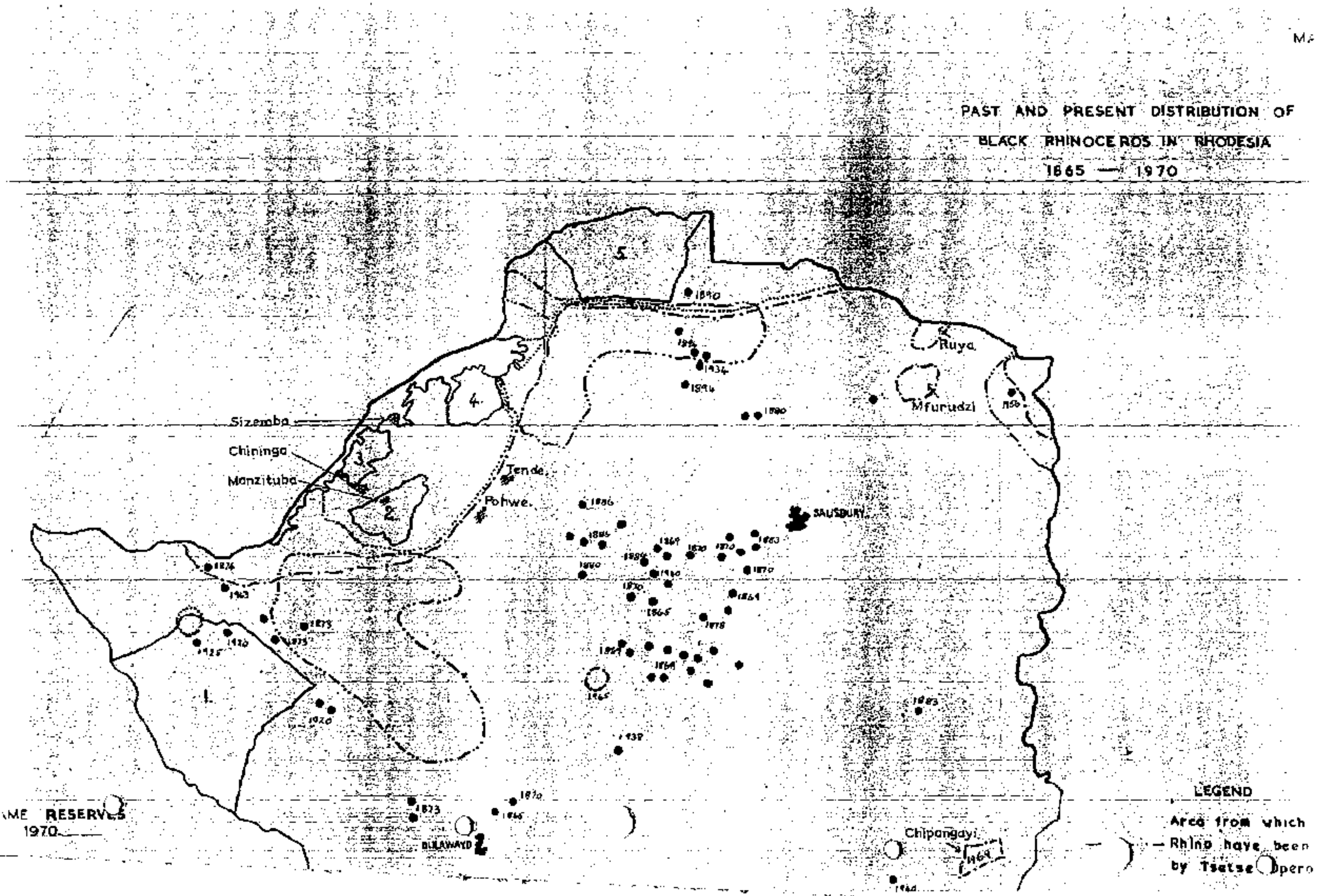
of
The Study Area
Limit of
Home Range
Broken Hill Country
LEGEND
Thicket
Rock Scrub
Mopani Woodland


The Study Area
Sengwa
River
Sengwa
River
African Settlement



Ruya
Mfurudzi
Sizemba
Chininga
Manzituba
Tende
Pohwe
SALISBURY
BULAWAYO
Chipangayi
GAME RESERVES
1970
1. Wankie
2. Chizarira
3. Chete
4. Matusadona
5. Mana Pools / Chewore
6. Gona-re-Zhou
LEGEN
Area fro
Rhino ho
by Tset
1965 Di
1970 Di
Black R
Scale


Sizemba
Chininga
Manzituba
Tende.
Pohwe.
Ruya.
Mfurudzi
SALISBURY
BULAWAYO
Chipangayi.
LEGEND
Area from which Black Rhino have been eliminated by Tsetse Operations.
1965 Distribution (Roth)
1970 Distribution (Thomson)
Black Rhino seen or shot
Scale 1:2 500 000



PAST AND PRESENT DISTRIBUTION OF
BLACK RHINOCEROS IN RHODESIA
1865 — 1970
Sizemba
Chininga
Manzituba
Tende
Pohwe
SALISBURY
Ruya
Mfurudzi
Chipangayi
BULAWAYO
RESERVES
1970
LEGEND
Area from which
Rhino have been
by Tsetse

Observation No.1.

A cow with a new-born calf was observed at Sizemba in 1964. Her previous calf (estimated age 30 months) stood some 20 yards away and when disturbed the three animals ran off together.

Observation No.2.

At Chininga in 1967, a cow with a new calf was tracked onto a small hill where she was found, with her calf, lying in the shade of a small tree. I approached the cow with the intention of darting her and then noticed another rhino lying next to a small bush some 5 yards ahead of me. None of the rhino noticed me but on my retreat I disturbed the oxpeckers which were on the cow and they immediately began their alarm call. The cow immediately became alert and the animal nearest to me rose to its feet and I noticed that it was a young animal some 30 months old.

This latter animal walked slowly towards the cow and calf, 'meowing' plaintively, and it became apparent that this was the cow's previous calf. When it got about 15 yards from the cow she rushed at the younger animal with head lowered to the ground and issuing loud demonstrative 'puffing' noises and with the small calf, approx. two weeks old, copying her actions, whereupon the young rhino rushed off, turning to face its mother when it got some 50 yards away. The cow had come forwards only 10 yards and then stood erect facing the younger animal holding this position for about a minute before returning to lie down in the shade.

The younger rhino stood still for a while, still 'meowing' from time to time, then it moved to within 35 yards of the mother and lay down . Every now and again it would lift its head and look towards the mother repeating its plaintive call and then, half an hour later, attempted another approach only to be chased off again.

Observation No. 3.

A well-known cow at Manzituba was observed with both a new-born calf and her previous calf in attendance (J.Bunce - Pers.comm.). Three weeks later I saw the cow and her calf in the same area and, on the same day, saw her previous calf about two miles away in the same home-range.

Observation No. 4.

On 9th.August, 1970, a heavily pregnant cow and a large bull calf were seen together on the Ruya (N.Payne Snr. - Pers.comm.). They appeared to have a close-bonded relationship and their individual characteristics were noted.

Three days later, game scouts began recording, daily, the spoor of two rhino which crossed a newly bulldozed road to get to water. The two sets of tracks were never more than 100 yards apart and were normally much closer.

On 21st. August, these tracks were followed into the hills where they became congested and confused with the spoor of a small calf. The congested spoor area showed only two large rhino entering the area, one leaving on its own and a cow and small calf leaving by another route. The cow and calf were both captured on the 21st. August and the large bull calf a few days later. The two large animals were positively identified as those which were seen on the 9th. and, as they were the last rhino in the area, there can be no possible confusion with any other animal.

Subsequent interpretation of the spoor indicated that the original two sets of tracks were those of the cow and large calf. The cow had had another calf and it was this latter animals spoor which was picked up in the hills. It was apparent that the cow had left her new calf in the hills when she went to water and was obviously followed by her previous calf. That she had tried to effect a break with this subadult was obvious from the spoor and there was every evidence to show that determined rushes had been directed towards the larger calf, by the mother, resulting in the subadult eventually moving off on its own.

Upon capture, all three animals were measured and their shoulder heights were:-

(a) Cow (Vickie No.2)	63"
(b) First calf (Male - Ian)	56"
(c) New calf (Female - Julie)	28"

As this indicates the older calf's size at independence it is important to record that his anterior horn, his means of defence, was 15" long.

Observation No.5

At Sizemba in July, 1964, a young rhino bull was captured and the dorsal part of his neck, both his shoulders and his spine showed claw and teeth marks which were undoubtedly caused by lions. The animal was not accompanied by a cow and appeared to be independent.

Shoulder height.	52"
Anterior horn length	14"

Observation No. 6

On the 28th. September, 1967, a rhino cow was darted as she came down to water during the night. The following day, when she was brought to the pens, she was found to be lactating heavily and had obviously had a calf which, we assumed at the time, had been taken by hyena.

Six days later, the carcase of a baby rhino was found about a mile from the site from which the rhino cow had been recovered and there was little doubt that this calf had belonged to the cow we had in t the pens. The calf was estimated at less than one month old as its front horn was just erupting and its umbilical scar was still pink. It had been dead about two days, when found, and the carcass was bloated but untouched by either hyenas or vultures and had obviously not died as a result of predator attack.

There was no small spoor at the scene of the cows darting and recovery and, in view of subsequent positive observations of cows leaving their calves at night whilst they go to water, it is now reasonable to assume that this is what occurred on this occasion, and that the calf had died of starvation.

Observation No.7

At Chininga in 1967, a large cow, with an easily recognisable set of horns, was observed with a calf some 36"-42" at the shoulder.

Both animals were captured twelve months later and the calf was then 48" at the shoulder (estimated age, 15-17 months). The cow was found to be very heavily pregnant, with her foetus showing constant signs of movement, and parturition would occur when her previous calf was only 20-22 months old.

Calf shoulder height	48"
Anterior horn length	7"

This parturition interval, however, is believed to be unusually short.

Observation No. 8

In 1964, five rhino calf carcasses were found in the Sizemba habitat area and a captured calf (Mbira) was found to have had its tail ripped off by predators. There were no claw marks to suggest a lion mauling and the wounds were consistent with those from a hyena attack.

The following year, in the same area, another calf was captured and found to have had half its tail bitten off by predators and an adult bull was also captured and found to have only half a tail. The adult animal had probably been attacked when still a calf and both cases were attributed to hyenas.

Hyenas were plentifult at Sizemba and an estimated 50 - 60 lived in the same area as the rhino. In 1968, when poisoned carcasses were placed in the area for man-eating lions, a total of 22 hyenas were found dead on the baits and others had taken the baits but were not found. The baits occupied only a small portion of the area and subsequent examination of the entire area supplied evidence to support the observation that hyena were still abundant.

A calf (Stompie) captured at Mfurudzi in 1970, had only half a tail and the remaining half was badly torn and displayed scars from a predator attack. The wounds were consistent with a hyena attack and, whilst lion were rare in the area, hyenas occurred in small numbers.

A mature bull was captured on the Mazoe in 1970 and showed two perfect rows of teeth-marks on each buttock which were the result of what must have been a severe wound resultant from a predator attack when the rhino was still a small calf. The rhino showed no signs of claw marks and this attack is again attributed to hyenas.

A further attack attributed to hyenas was upon a calf caught on the Ruya in 1970, which had half an ear ripped off and showed teeth-marks on the other ear but no claw marks at all.

Hitchins (pers.comm.) records two positive kills by hyenas at Hluhluwe and states that 'probably a lot more are killed than meets the eye'. However, he also records that there are no observations to confirm kills of white rhino (Ceratotherium simum) calves, despite a heavy population of both white rhino and hyena in the same area. The fact that white rhino calves precede their mothers when moving may contribute to their defence against hyenas. In contrast, black rhino calves follow their mothers, even in flight, and consequently are more vulnerable from behind.

There seems little doubt that hyenas contribute greatly to rhino calf mortality.

<u>Observation No. 9</u>

During the period February 1964 to September 1968, I personally recorded the poaching of 69 rhino in the Binga District alone. The poaching was done mostly with steel-cable snares and muzzle loaders although rifles were occasionally found to have been used. It is emphasised, however, that this figure represents only those brought to my attention and, without a doubt, the actual number killed far exceeds those recorded.

Subsequent to 1968, more rhino have been poached in this same area.

<u>Observation No. 10</u>

A fatal encounter between two adult bulls was recorded in the Mfurudzi population in 1970. The dead animal was found some 200 yards from the site of the encounter and displayed severe lacerations on the head, neck and throat and three large holes were found along its spine between the shoulders and hips.

It appeared that the fight had lasted some time and that once the victor had succeeded in knocking down its opponent, it had then administered the three spinal injuries whilst the victim was lying on its side. From the quantity of blood at the scene of the battle, it was evident that the injured animal had lain there for some time before getting up and moving off 200 yards before dying.

I subsequently captured the victor of this encounter and it proved to be a large bull which measured 57" at the shoulder. He had severe lacerations on the forehead, above the eyes, starting from the base of the posterior horn. These were healing well but burst open when the animal struggled during capture.

Observation No. 11

At Sizemba during 1964, we made several attempts to catch a heavily pregnant rhino cow without success. She was very easily recognisable because of a most peculiarly-shaped anterior horn and I saw her, for the last time that year, on 29th. September.

The following year, on the 5th. September, this same animal was captured together with her calf which was certainly no more than 11 months and 1 week old. Unfortunately no weight was recorded but the measurements were as follows.

Shoulder height	45"
Anterior horn length	6"
Total length	76"

CHI-SQUARE TEST

$$\text{(Binomial Proportions)} = \frac{N\,(ad - bc)^2}{(a+b)(c+d)(a+c)(b+d)}$$

	TRAIT X	TRAIT Y	
Sample A.	a	b	N(a) = a + b
Sample B.	c	d	N(b) = c + d
	a + c	b + d	N = N(a) + N(b) = a + b+ c + d

CALCULATION using data contained in Fig. 14.

	Open	Thicket	
Bulls	0	25	25
Cows	12	7	19
	12	32	44

Under the null hypothesis - that there is no difference between the choice of habitats in the sexes - χ^2 can be calculated as follows.

$$= \frac{44\,(0 \times 7 - 25 \times 12)^2}{25 \times 19 \times 12 \times 32}$$

$$= \frac{44\,(0 - 300)^2}{25 \times 19 \times 12 \times 32}$$

$$= \frac{44 \times 90{,}000}{182{,}400}$$

$$= \frac{3{,}960{,}000}{182{,}400}$$

$$= \underline{21.71}$$

For one degree of freedom, χ^2 of 21.7 indicates a probability of less than 0.005 that these two samples are estimates of the same population. Therefor one can conclude that there is a significant difference in the choice of habitat between the males and females in the population.

YATE'S CORRECTION.

Yate's correction for continuity for small samples is, in this case, calculated as follows.

$$\chi^2 = \frac{(ad - bc - \frac{N}{2})^2 N}{(a+b)\ (c+d)\ (a+c)\ (b+d)}$$

$$= \frac{(0 - 300 - 22)^2\ 44}{182,400}$$

$$= \frac{(-322)^2\ 44}{182,400}$$

$$= \underline{25.01}$$

For one degree of freedom, χ^2 of 25.01 still indicates a probability of less than 0.005 that the two samples are estimates of the same population.

CONCLUSION.

These tests show that the null hypothesis should be rejected as there appears to be only a $<$ 0.005 probability that it is correct, and that there is therefore a significant difference in the two sexes choice of diurnal resting sites.

CORRELATION COEFFICIENTS.

FORMULA : $r = \dfrac{\Sigma(x - \bar{x})(y - \bar{y})}{\sqrt{\Sigma(x - \bar{x})^2 \; \Sigma(y - \bar{y})^2}}$

CORRELATIONS :

(1). Rhino Population Density and Thicket R.C.F.. (Fig. 8(a)).

(2). Rhino Population Density and Scrub R.C.F.. (Fig. 8(b)).

(3). Rhino Population Density and Woodland R.C.F.. (Fig. 8(c)).

(4). Rhino Population Density and Overall R.C.F.. (Fig. 8(d)).

(5). R.C.F. per Rhino and R.C.F. in Habitat. (Fig. 9).

(1). Correlation :

Rhino Population Density and Thicket R.C.F.. (Fig. 8(a)).

Rhino Population Density				Thicket R.C.F.			
	x	$(x-\bar{x})$	$(x-\bar{x})^2$		y	$(y-\bar{y})$	$(y-\bar{y})^2$
	2.3	+ 1.1	1.21		22.5	+ 12.5	156.25
	1.0	- 0.2	0.04		7.4	- 2.6	6.76
	0.2	- 1.0	1.00		0.0	- 10.0	100.00
TOTAL	3.5			TOTAL	29.9		
$\bar{x}$	1.2			$\bar{y}$	10.0		

$\sum(x-\bar{x})^2 = 2.25$ $\sum(y-\bar{y})^2 = 263.01$

****

$\sum(x-\bar{x})(y-\bar{y})$

$(+1.1)(+12.5) = +13.75$

$(-0.2)(-2.6) = +0.52$

$(-1.0)(-10.0) = +10.00$

$\sum(x-\bar{x})(y-\bar{y}) = \underline{24.27}$

****

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$$

$$= \frac{24.27}{\sqrt{591.80}}$$

$$= \frac{24.27}{24.33}$$

$$= \underline{0.99753390}$$

With two degrees of freedom the significance probability for a correlation coefficient of 0.9975 is at the 99.% probability level.

P= <0·01

(2). **Correlation** :

Rhino Population Density and Scrub R.C.F. (Fig. 8(b)).

Rhino Population Density				Scrub R.C.F.			
	x	$(x-\bar{x})$	$(x-\bar{x})^2$		y	$(y-\bar{y})$	$(y-\bar{y})^2$
	2.3	+ 1.1	1.21		6.4	- 2.2	4.84
	1.0	- 0.2	0.04		14.2	+ 5.6	31.36
	0.2	- 1.0	1.00		5.2	- 3.4	11.56
TOTAL	3.5			TOTAL	25.8		
$\bar{x}$	1.2			$\bar{y}$	8.6		

$\sum(x-\bar{x})^2 = 2.25$ $\qquad$ $\sum(y-\bar{y})^2 = 47.76$

****

$\sum(x-\bar{x})(y-\bar{y})$

$(+1.1)(-2.2) = -2.42$

$(-0.2)(+5.6) = -1.12$

$(-1.0)(-3.4) = +3.40$

$= -0.14$

****

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$$

$$= \frac{-0.14}{\sqrt{107.46}}$$

$$= \frac{-0.14}{10.4}$$

$$= -0.01346$$

$P = > 0.1$

(3). **Correlation** :

Rhino Population Density and Woodland R.C.F.. (Fig. 8(c)).

Rhino Population Density — **Woodland R.C.F.**

	x	$(x-\bar{x})$	$(x-\bar{x})^2$		y	$(y-\bar{y})$	$(y-\bar{y})^2$
	2.3	+ 1.1	1.21		7.4	+ 1.1	1.21
	1.0	- 0.2	0.04		5.7	- 0.6	0.36
	0.2	- 1.0	1.00		5.9	- 0.4	0.16
TOTAL	3.5			TOTAL	19.0		
$\bar{x}$	1.2			$\bar{y}$	6.3		

$\sum(x-\bar{x})^2 = 2.25$ $\sum(y-\bar{y})^2 = 1.73$

****

$\sum(x-\bar{x})(y-\bar{y})$

$(+1.1)(+1.1) = +1.21$

$(-0.2)(-0.6) = +0.12$

$(-1.0)(-0.4) = +0.40$

$= 1.73$

****

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$$

$$= \frac{1.73}{\sqrt{3.8925}}$$

$$= \frac{1.73}{1.97}$$

$$= 0.87817258$$

$P = > 0.1$

(4). <u>Correlation</u> :

Rhino Population Density and Overall R.C.F.. (Fig. 8(d)).

Rhino Population Density	x	$(x-\bar{x})$	$(x-\bar{x})^2$	Overall R.C.F.	y	$(y-\bar{y})$	$(y-\bar{y})^2$
	2.3	+ 1.1	1.21		36.3	+ 11.4	129.96
	1.0	- 0.2	0.04		27.3	+ 2.4	5.76
	0.2	- 1.0	1.00		11.1	- 13.8	190.44
TOTAL	3.5			TOTAL	74.7		
$\bar{x}$	1.2			$\bar{y}$	24.9		

$\Sigma(x-\bar{x})^2 = 2.25$ $\Sigma(y-\bar{y})^2 = 326.16$

****

$\Sigma(x-\bar{x})(y-\bar{y})$

$(+1.1)(+11.4) = +12.54$

$(-0.2)(+2.4) = -0.48$

$(-1.0)(-13.8) = +13.80$

$= 25.86$

****

$$r = \frac{\Sigma(x-\bar{x})(y-\bar{y})}{\sqrt{\Sigma(x-\bar{x})^2 \; \Sigma(y-\bar{y})^2}}$$

$$= \frac{25.86}{\sqrt{733.9}}$$

$$= \frac{25.86}{27.09}$$

$$= 0.95459579$$

$P = < 0.05$

(5). **Correlation :**

R.C.F. per Rhino and R.C.F. in Habitat. (Fig. 9).

R.C.F. in Habitat	x	$(x-\bar{x})$	$(x-\bar{x})^2$	R.C.F. per Rhino	y	$(y-\bar{y})$	$(y-\bar{y})^2$
	36.3	+11.4	129.96		15.8	- 21.7	470.89
	27.3	+ 2.4	5.76		27.3	- 10.2	104.04
	11.1	-13.8	190.44		69.4	+ 31.9	1017.61
TOTAL	74.7			TOTAL	112.5		
$\bar{x}$	24.9			$\bar{y}$	37.5		

$\Sigma(x-\bar{x})^2 = 326.16$ $\Sigma(y-\bar{y})^2 = 1592.54$

****

$\Sigma(x-\bar{x})(y-\bar{y})$

$(+11.4)(-21.7) = -247.38$

$(+2.4)(-10.2) = -24.48$

$(-13.8)(+31.9) = -440.22$

$= -712.08$

****

$$r = \frac{\Sigma(x-\bar{x})(y-\bar{y})}{\sqrt{\Sigma(x-\bar{x})^2\ \Sigma(y-\bar{y})^2}}$$

$$= \frac{-712.08}{\sqrt{519{,}422.85}}$$

$$= \frac{-712.10}{+720.70}$$

$$= -0.98806715$$

$P = < 0.02$

RAW DATA

from

Photographic Measurements of Lateral Cover

at

Sizemba, Chininga and Manzituba.

In this appendix, Table A. gives the series identification letter for photographic transects made in the different vegetation categories in each of the three study areas. Each series comprises 15 photographs and a total of 330 photographs were taken to complete the overall measurement. Table B. Tabulates the actual percentage cover analysis for each photograph. Tables A. and B., therefore, should be considered jointly.

TABLE A.

		Thicket.	Scrub.	Woodland.
SIZEMBA.	1.	S	V	T
	2.	SR	X	U
	3.	W		
CHININGA.	1.	J	K	Q
	2.	L	M	R
	3.	P	N	
MANZITUBA.	1.		A	B
	2.		C	D
	3.		F	E
	4.			H

Appendix.

Table B.

	[illegible]	2.	3.	4.	[illegible]	6.	[illegible]	8.	[illegible]	[illegible]	11.	12.	13.	14.	15.
A.	[illegible]	[illegible]	9.8	5.8	[illegible]	24.3	[illegible]	36.3	2.7	[illegible]	13.8	2.0	12.7	[illegible]	5.5
B.	[illegible]	[illegible]	0.7	0.0	[illegible]	6.8	[illegible]	0.3	[illegible]	[illegible]	0.0	33.0	[illegible]	[illegible]	0.0
C.	[illegible]	[illegible]	2.3	38.7	[illegible]	5.8	[illegible]	4.7	[illegible]	[illegible]	0.0	0.0	[illegible]	[illegible]	87.2
D.	[illegible]	[illegible]	0.0	28.3	[illegible]	60.3	[illegible]	54.2	0.0	[illegible]	0.0	7.0	[illegible]	37.2	0.0
E.	[illegible]	0.0	0.0	0.0	[illegible]	8.7	0.0	30.3	55.2	0.0	0.0	0.0	0.0	63.7	4.8
F.	[illegible]	0.0	0.0	0.0	[illegible]	3.7	54.3	5.0	5.5	27.5	29.0	10.5	2.5	2.5	0.0
H.	[illegible]	0.0	0.0	0.0	0.0	15.5	12.5	0.0	0.0	8.9	0.0	0.0	31.3	34.7	0.0
J.	[illegible]	26.0	17.7	32.7	[illegible]	42.2	21.2	60.2	67.7	33.7	14.2	62.8	36.0	71.5	85.3
K.	[illegible]	79.2	48.7	19.2	[illegible]	15.8	[illegible]	24.8	81.5	81.8	0.0	0.0	0.0	0.0	11.2
L.	[illegible]	[illegible]	54.2	96.5	[illegible]	9.5	61.5	65.7	51.8	79.0	81.7	48.5	56.2	76.5	93.8
M.	[illegible]	[illegible]	0.0	44.7	[illegible]	58.8	[illegible]	25.9	[illegible]	[illegible]	[illegible]	0.0	64.8	[illegible]	32.7
N.	[illegible]	[illegible]	4.2	0.0	[illegible]	47.3	[illegible]	97.0	[illegible]	[illegible]	0.0	7.0	[illegible]	[illegible]	0.0
P.	[illegible]	[illegible]	56.1	62.9	[illegible]	41.8	[illegible]	[illegible]	[illegible]	[illegible]	87.7	88.0	[illegible]	[illegible]	[illegible]
Q.	[illegible]	[illegible]	0.0	32.2	[illegible]	0.0	[illegible]	7.7	[illegible]	[illegible]	[illegible]	0.0	[illegible]	[illegible]	0.0
R.	[illegible]	[illegible]	7.0	16.9	[illegible]	56.0	[illegible]	0.0	[illegible]	[illegible]	0.0	9.2	[illegible]	[illegible]	0.0
SR.	[illegible]	[illegible]	96.7	86.8	[illegible]	98.7	[illegible]	99.1	99.3	[illegible]	90.2	97.0	94.7	[illegible]	91.5
S.	[illegible]	[illegible]	48.3	38.0	[illegible]	99.9	88.9	65.8	95.7	50.8	89.5	69.8	100.0	80.2	41.5
T.	[illegible]	[illegible]	0.0	31.5	[illegible]	0.0	0.0	26.2	9.5	0.0	33.2	6.0	19.7	0.0	0.0
U.	[illegible]	0.0	15.0	49.7	[illegible]	74.8	17.5	32.3	0.0	0.0	0.0	14.1	25.0	0.0	42.3
V.	[illegible]	[illegible]	32.0	40.3	[illegible]	53.0	10.3	0.0	10.8	33.7	0.0	0.0	43.8	41.8	31.7
W.	[illegible]	[illegible]	89.2	97.8	[illegible]	80.8	100.0	0.0	73.7	59.3	73.5	98.2	87.7	79.5	94.5
X.	[illegible]	0.0	0.0	0.0	[illegible]	21.3	0.0	58.2	76.2	83.0	7.8	0.0	0.0	0.0	38.0