E. Afr. Wildl. J. 7: 105-114 (1969)

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AERIAL CENSUS OF BLACK RHINOCEROS USING STRATIFIED RANDOM SAMPLING

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SUMMARY

During 1967–1968 a census was conducted of the black rhinoceros (*Diceros bicornis* L.) population in part of the Tsavo ecological unit. The region concerned covers an area of approximately 23,300 km² (9,000 square miles). Large parts of the region were systematically covered in a light aircraft and all rhinoceros observed were recorded on a 1:250,000 map. Because of the visibility bias inherent in such censuses correction factors were placed on the raw aerial data and crude estimates obtained. These crude estimates were then checked by intensive work on the ground in several sectors, and adjustments made where necessary.

Using these crude estimates approximately two-thirds of the area under consideration were stratified into five density strata: very high, high, medium, low, and very low. Within this area 250 randomly located 2.59 km² (1 square mile) plots were intensively searched from the aircraft and all rhinoceros observed on these plots recorded. In the very high, high, and medium density strata these intensive searches resulted, at the 95% level of significance, in a population estimate of 4,200±25% of the mean or an estimate of between 3,150 and 5,255 rhinoceros within these strata. In the low stratum the statistical analysis resulted in a population estimate of 306±83% of the mean or an estimate of between 47 and 565 rhinoceros at the 90% level of significance. In the very low stratum the population estimate, at the 50% level of significance, was 266 ± 50% of the mean or an estimate of between 133 and 400 rhinoceros. A comparison of the crude estimates and the refined statistical estimates illustrates close agreement.

The remaining third of the area was covered systematically and correction factors were placed on the raw aerial data. Crude estimates suggest a population of 2,800—3,000 occupying this part of the area. Assuming that this crude estimate, together with the statistical estimates for the low and very low strata, are rough approximations of the actual populations, it is statistically probable that the true population of black rhinoceros in this region lies between 6,130 and 9,220.

INTRODUCTION

Tsavo National Park, in Kenya, covers an area of some 20,850 km² (8,050 square miles). For administrative purposes the park is divided into eastern and western sectors; the dividing line is the railroad from Nairobi to Mombasa. The region is traversed by two permanent rivers, the Athi-Galana and the Tsavo. There are several seasonal rivers, the most important of which are the Tiva in the north-east and the Voi in the south-east. A prominent feature of the area is the Yatta plateau, a phonolitic lava flow, which runs parallel and adjacent to the northern part of the Athi-Galana river. Up until about 1950, large areas of the park were covered with *Commiphora* woodland. Under large-scale destruction by elephant (*Loxodonta africana* Blumenbach) and fire the tree-bush complex has been destroyed and thinned in many areas, and has been replaced by bush-grassland and grassland. Annual rainfall varies from 15.2 to 76.2 cm (6–30 in) with a markedly seasonal pattern (Laws, 1967).

The total number of elephant using the entire ecological unit (an area of some 44,000 km² which includes the park and extends for a considerable distance beyond the park boundaries) has now been established at 30–40,000 (Laws, 1967; Laws, pers.comm.). The damage to the woodland ecosystem partially created by this population has been phenomenal. Thousands of trees and larger bushes have been knocked over and destroyed, and many of the larger trees such as the baobab (*Adansonia digitata* L.) have been ring-barked and have fallen to the ground. With the large amount of dead and decaying

woody material and debris present, hot ground fires have swept through and have changed the whole ecology of the region. As Sheldrick (pers.comm.) has observed and as Laws (1967) has noted, "there has been an improvement in the balance of diversity of the ecosystem, because there has been a marked increase in the vegetation and fauna characteristic of the grassland habitat. It is not known, however, how stable this grassland vegetation may be in an area which receives an erratic 15.2–76.2 cm of rain with a markedly seasonal pattern".

In addition to its very large elephant population, Tsavo is one of the last strongholds of the black rhinoceros. Considerable concern has been shown in recent years by the government of Kenya, other African governments and international zoological organizations who have speculated on the fate of this species throughout its entire range in Africa. Much concern has been voiced about the possible effect that the changing environment in Tsavo will have on this species (Napier Bax and Sheldrick, 1963; Glover and Sheldrick, 1964). The black rhinoceros is predominantly a browser, and grazes to a limited extent (Goddard, 1968). The Kenya National Parks authorities require to know: (1) the effect on the black rhinoceros if very large areas of Tsavo are converted to a predominantly grassland or bush-grassland ecosystem; (2) whether the species is capable of adapting to the changing environment when it is known to be essentially a browsing mammal; (3) the status of the species and whether there is any scientific evidence that the population is in a state of decline.

Some observers felt that the large-scale devastation and damage initiated by elephant and fire had been detrimental to the black rhinoceros: they believed that the rhinoceros were suffering severe competition from the elephant for the remaining food supplies, and that the animals were slowly dying of malnutrition (Napier-Bax and Sheldrick, 1963). This anxiety was heightened in the early part of this decade, when during a marked drought period at least 282 rhinoceros died along a 64 km section of the Athi river in the eastern sector of the park (Foster, 1965; Sheldrick, pers.comm.).

As a result of this problem it was clear that one of the first concerns of research on the species in Tsavo would be to provide valid statistical estimates of the populations in the park. As a result, a census was undertaken. The area covered in this census included the whole of the Tsavo National Park, part of the Mkomazi game reserve in Tanzania, and Hunting Block 29 of the Kenya Game Department (Figure 1). The methods and results of this census are presented in this paper.

METHOD

As Eberhardt (1968) has noted: "there are few, if any, really satisfactory methods of assessing the abundance of wild animals. Difficulties with current methods include both biases and substantial variability in time and space". Censusing black rhinoceros populations from the air involves these difficulties. Goddard (1967) has shown the variability that can be encountered in aerial censuses of black rhinoceros populations when a complete or total area census is undertaken. Evans *et al.* (1966) demonstrated very similar results when they compared total area aerial counts of moose (*Alces americana* L.) with aerial counts obtained by searching very small square quadrats, in two regions of Alaska.

Because of the vast area of Tsavo the only feasible and practical method of assessing the entire rhinoceros population is by means of aerial census, and this was the major method employed. As Evans *et al.* (1966) point out, the cardinal problem in any aerial census of a wild animal population is to eliminate or evaluate the visibility bias, that is the errors which affect the percentage of animals seen by the observers. Such bias can be considerable in censusing black rhinoceros populations. Thus the only solution was to confine a statistical census to very small randomly located areas, where searches could be so intensive and so concentrated that practically no rhinoceros would be missed. Except with such intensive searching, which is not practicable for most total area censuses, black rhinoceros are relatively difficult to detect from the air, even in open thorn-bush habitat. Not only are they essentially solitary animals but their habit of wallowing and resting in dust depressions provides them with excellent camouflage in their surroundings.

Estimates of crude densities

In order to provide a basis for a statistical census it was necessary to stratify the area

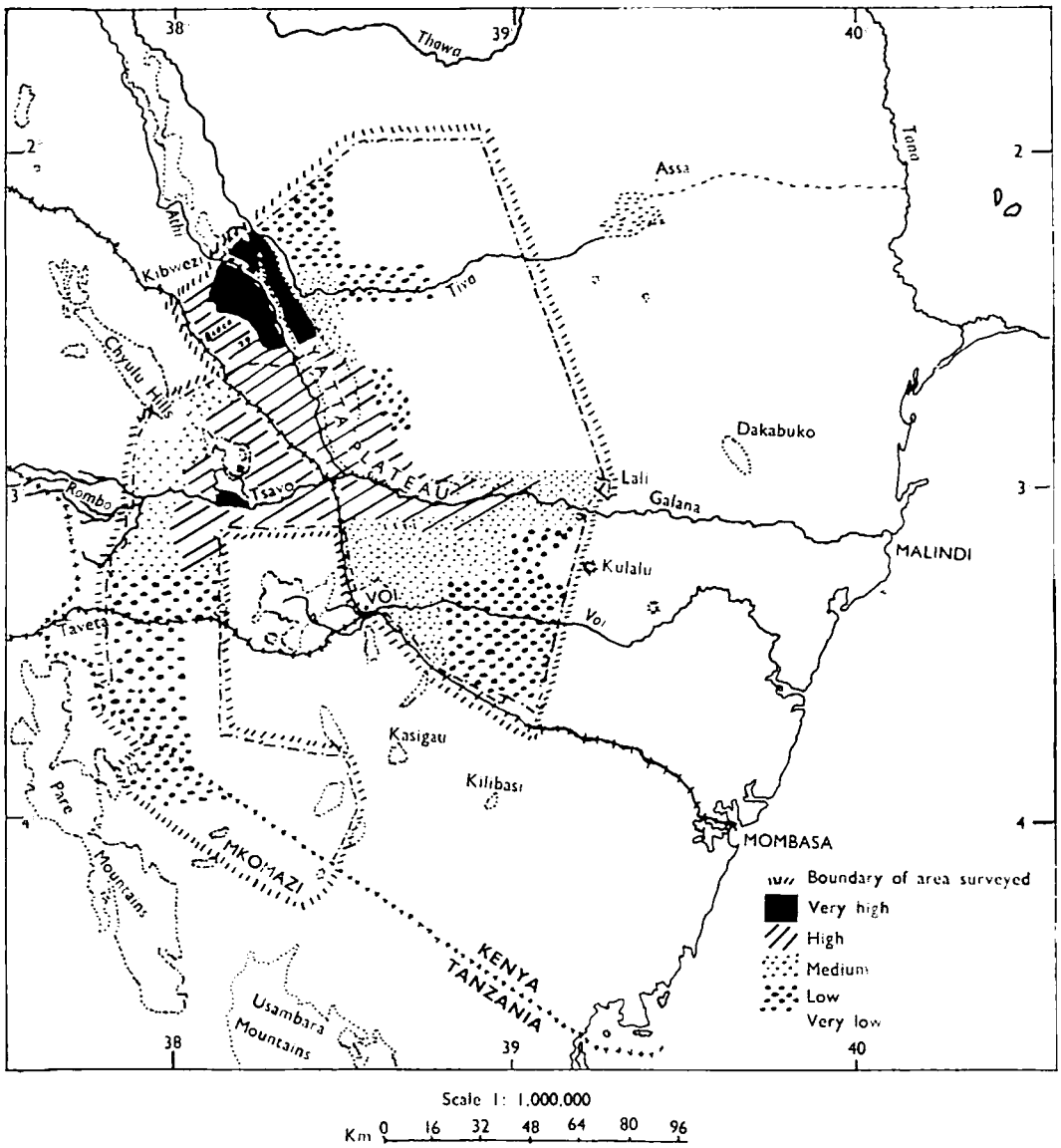

Figure 1

Density strata of black rhinoceros in part of the Tsavo ecological unit, based on a wet season distribution during 1967–68.

into different density media and this was accomplished in two ways. Firstly, large areas of Tsavo East, the whole of Tsavo West and Block 29, and part of the Mkomazi game reserve were systematically covered in a Piper Super-Cub and all rhinoceros seen were counted and recorded on a map. The Super-Cub is a high-wing monoplane giving an uninterrupted downward view. Animals seen were recorded as adults, immatures, females with calves, and females with young of the year. These systematic counts involved flying parallel linear transects of varying widths at low altitude (91.4 m (300 ft) or

below). Secondly, correction factors were placed on these counts, using the methods described below.

Because of the visibility bias, it was known that the systematic counts were only minimum appraisals of the populations actually present. The raw data collected from this census were plotted on maps with a scale of 1:250,000 and distribution and relative densities established. Correction factors were then placed on this raw data, mainly according to experience obtained at Olduvai (Goddard, 1967). The raw data obtained from the systematic counts was multiplied by factors varying from 2–7, depending on such criteria as the time of day the survey was conducted (cf. Plate 1a and 1b), nature of the vegetational cover and terrain (cf. Plate 2a and 2b), method of coverage, altitude etc. Crude estimates of mean densities were thus obtained.

These crude estimates were then checked by intensive work on the ground. Certain selected areas were covered on foot and all rhinoceros observed were catalogued using the identification procedure described by Goddard (1966). Because of the very sedentary habits of the black rhinoceros it is thus quite feasible to establish the number of animals which are inhabiting a certain area. In addition, randomly located 15.5 km^2 (6 square mile) plots were covered in a vehicle in the open grassland areas south of the Voi river in the eastern sector, and estimates (with confidence limits) of the population were determined. These ground counts of the populations were then checked against the crude estimates established from the corrected aerial data, and adjustments made to the latter where necessary.

The rhinoceros is ubiquitous in Tsavo, its density usually varying from approximately four animals per 2.59 km^2 (1 square mile) to as low as one animal per 26 km^2 (10 square miles) in the north-eastern sector of the park. In some localized areas densities can be considerably higher or lower than this, especially during the dry season.

Stratification

Using a map with a scale of 1:250,000 the whole of Tsavo East was then gridded into 210 km^2 (81 square mile) squares. These squares were then paired as described below giving a series of rectangular blocks 29 km (18 miles) long and 14.5 km (9 miles) wide. Each rectangular block thus contained 162 2.59 km^2 (1 square mile) units. From the distribution maps and the crude estimates established, each 210 km^2 square was assigned to a particular density stratum. Five density strata were used. These were very high, high, medium, low, and very low. Table 1 shows

TABLE 1

Crude density estimates of black rhinoceros populations in Tsavo East, derived from corrected systematic aerial counts, ground censuses and distribution maps. Stratification is based on a wet season distribution.

Stratum	Total area (km^2)	Estimated crude mean density per 2.59 km^2 (1sq. mile)
Very high	544	4
High	2,305	2.7
Medium	3,367	1.2
Low	2,642	0.4
Very low	6,268	0.1

the total areas occupied by each stratum of Tsavo East and the estimated mean crude densities within the stratum. In the stratification the administrative park boundaries were ignored and in a few areas part of the square lay outside the boundary. A 210 km^2 (81 square mile) square was a suitable and convenient size for defining significant changes in density according to a plotted wet season distribution. Each 210 km^2 square was then paired with another contiguous square of the same density stratum, resulting in a series of rectangular blocks within each density stratum. Pairing of squares facilitated the covering of the required plot size and the established plot width according to the method used, i.e. a longitudinal plot 29 km in length and c. 90 m in width (see below).

Intensity of census and shape of sample plots

In Tsavo East it was decided to conduct intensive searches on 250 randomly located 2.59 km^2 (1 square mile) areas (referred to as plots). In the largely featureless, very flat country of Tsavo with its extreme paucity of landmarks it is extremely difficult to pin-point randomly located 2.59 km^2 square quadrats accurately. It is even more difficult to define their boundaries and fly them systematically. Evans *et al.* (1966) used the square quadrat method successfully with moose populations in Alaska but were aided in these respects in many areas by the presence of numerous landmarks. Because of the paucity of landmarks in Tsavo it was decided to census

TABLE 2

Allocation of sampling effort to the five strata of Tsavo East

Stratum	a	b	c	d	e	f	g
Very high	210	0.037	840	31	0.034	8	23
High	890	0.152	2,403	365	0.400	100	100
Medium	1,300	0.223	1,560	348	0.381	95	80
Low	1,020	0.173	408	70	0.076	20	20
Very low	2,420	0.415	242	100	0.109	27	27

a = Total number of sampling units per stratum (number of 2.59 km^2 units)
b = Proportion of sampling units in each stratum
c = Estimated population in the stratum, i.e. estimated crude density × area of the respective stratum
d = Product of b and c
e = d as a proportion
f = Optimum allocation of sampling units for a sample of 250
g = Adjusted allocation of sampling units for a sample of 250

randomly located longitudinal 2.59 km^2 plots by flying along the long axes of each rectangular block, and starting from a known point at the corner of the block (see below).

Allocation and random location of plots

The number and allocation of plots to be covered in each stratum followed the method advocated by Cochran (1953) for optimum allocation; it was also used by Evans *et al.* (1966). Computations are shown in Table 2. Column (a) shows the total number of sampling units (number of 2.59 km^2 units) within each stratum of Tsavo East and column (c) shows the population estimate within each stratum derived from the crude estimates shown in Table 1. Using the method advocated by Cochran (1953), as shown in Table 2, this resulted in 8, 100, 95, 20, and 27 plots being assigned to the very high, high, medium, low, and very low strata respectively. The number of plots allocated to the very high stratum (8) was considered too low and 15 plots were deducted from the medium and placed in the very high stratum. This resulted in the adjusted allocation shown in column (g).

In almost every case each 210 km^2 square was contiguous with another square of the same density stratum. Those squares which were not were deleted from the random sampling. The pairing of squares resulted in 162 potential 2.59 km^2 plots within each rectangular block. Contiguous squares of the same density stratum were paired according to their position on the grid, so that some rectangular blocks were laid out in a north-south direction and others in an east-west direction. Pairing was accomplished partly by random combination, partly deliberately, and partly by possibly biased deletion. Pairing was done in this manner so as to sample the different vegetation types, topographic features and drainage patterns which were representative of the stratum. Potential plots within each stratum were numbered and the total number of plots allocated to the stratum were then chosen using a table of random numbers.

Plot characteristics

In order to conduct intensive searches it was necessary to decide on a suitable altitude and practicable plot width. After many experimental flights 76 m (250 ft) was selected as a suitable altitude at which to conduct the census. For the plot width, it was initially considered that 229 m (250 yd) on one side of the Super-Cub was an absolute maximum which could be covered by the observer. Markers were placed on the ground at measured distances of 229 m, 183 m (200 yd), 137 m (150 yd), 91 m (100 yd), and 46 m (50 yd) from a marked flight line. Further trials showed that a plot width of approximately 91 m on one side of the aircraft was the maximum which could be adequately scanned in the varying habitats of Tsavo East.

A type-writer ribbon 1.4 m (4.5 ft) in length was attached to the strut on one side of the aircraft in a position almost vertically below the eye of the observer in the rear of the aircraft. Another ribbon was attached at a distal point on the strut. By trial and error the position of the distal ribbon was adjusted on the strut so that at an altitude of 76 m the space between the ribbons delineated a plot 91 m wide on the ground.

As mentioned earlier each rectangular block was 29 km in length. In order to sample the length of each block and cover the 2.59 km² plot area this necessitated a plot width of c. 90 m and adjustments were made to the ribbons accordingly. The blocks were situated in north-south and east-west directions and the plots laid out in one or other of these directions accordingly. The aircraft compass was checked by flying along sections of roads which were laid out in exact north-south and east-west directions. These sections were carefully checked on the ground using two different compasses.

Method and time of coverage

By reference to a landmark on a large-scale map of the area a known starting point was established at the corner of each rectangular block. Plots were located by flying for predetermined time intervals from this point, based on a ground speed of 145 km/h (90 miles/h). Plots were then covered at the same speed at an altitude of 76 m for 12 min, with the plot width gauged at c. 90 m covering the 2.59 km² required. Slight adjustments were made where necessary for wind speed and direction. The boundaries of the rectangular blocks had been established on field maps prior to the survey and the latitudinal/longitudinal starting and finishing points of the plots approximately determined.

All plots in Tsavo East were covered during the period 6th March—3rd April, 1968. Black rhinoceros were more evenly distributed throughout their range during this period when the very heavy rains had filled the waterholes and wallows throughout their home ranges. In addition the majority of the systematic aerial counts completed in Tsavo East in 1967, from which the crude estimates were partially derived, were based on a wet season distribution. During this period of the long rains, in addition, the rhinoceros takes on the red colour of the Tsavo sand loam due to its wallowing habits, and it thus stands out in marked contrast to the green vegetation.

The great majority of plots were covered on very calm, clear mornings between dawn and 0930 h. This minimized the effect of drift and greatly facilitated keeping the aircraft on course and at the desired altitude by avoiding the thermals encountered later in the day. This is also the time when the majority of rhinoceros are active, thus assisting their detection (Plate 1b). In order to avoid possible effects of movement and dispersal of rhinoceros all plots located within each rectangular block were completed in less than 4 h, but in fact this effect is considered negligible because of the sedentary nature of the rhinoceros in Tsavo.

Nearly all observations on the plots were made by the author. Great care was taken to keep the eyes rivetted between the ribbons and to search with the same intensity in both the higher density strata and in the areas where very few rhinoceros were expected. The pilot rarely acted as an observer as he devoted most of his attention to keeping the aircraft in the required position. The pilot did contribute to the observations when he saw rhinoceros either running out of or into the plot. This was rare, however, since it is a tendency of black rhinoceros to flush either when the aircraft is over them, or has passed by them. Animals which ran into the plot from beneath the fuselage and those which were bisected by the distal ribbon were not included in the tally. Notes on habitats and vegetational types were recorded for each plot.

During May 1968 the entire area of Tsavo West and Block 29 were covered with systematic flight patterns and the area stratified by a wet season distribution into the same density media as used for Tsavo East. Part of the Mkomazi game reserve in Tanzania was covered in July 1968 in the same manner.

RESULTS

Tsavo East

Results of the statistical census in Tsavo East, together with population estimates and confidence limits, are shown in Table 3. Analysis of the very high, high, and medium density strata resulted, at the 95% level of significance, in a population estimate of 4.200 ± 25% of the mean, that is between 3,150–5,255 rhinoceros. Assuming that the mean estimates calculated for the low and very low densities are rough approximations of the true populations (at the 90% and 50% levels of significance respectively) it is probable that the rhinoceros population in Tsavo East is just under 5,000.

The number of rhinoceros seen on a plot varied from 0 to 12 and the largest number of animals seen in a group was six. Animals were classified as adults, immature and females

TABLE 3

Results of random sampling of the black rhinoceros population in Tsavo East

	Very high	High	Medium	Low	Very low	Total
2.59 km² units in stratum	210	890	1,300	1,020	2,420	5,840
Plots sampled	23	100	80	20	27	250
Plots with rhinoceros	20	74	40	4	2	140
Rhinoceros observed	79	236	85	6	3	409
Range (rhinoceros/plot)	0–8	0–12	0–7	0–2	0–2	—
Stratum means	3.44	2.36	1.06	0.30	0.11	—
Stratum variances	5.162	5.880	2.032	0.432	0.179	—
Population estimate	722	2,100	1,380	306	266	4,774
Probable population range at the 95% level of significance	517–928	1,673–2,527	960–1,800	47–* 565	133–** 400	see text

* At the 90% level of significance
**At the 50% level of significance

with calves. Calves born during 1967 were carefully noted. The activity of the animal was also recorded. Of the rhinoceros observed on the plots (n=409) 41% were running, 5% were trotting, 23% were walking, 13% were standing and 18% were lying down. 68% of the animals observed lying down rose to their feet as the aircraft passed over them. In the very high stratum 12.7% of the rhinoceros (n=79) possessed the black patches of dried blood on the dorsal areas of the body, described by Glover and Sheldrick (1964). In the medium, low, and very low density strata 34% of the animals (n=94) possessed these black patches.

Tsavo West

During the period 10–20th May, 1968 the entire area of Tsavo West was covered systematically in a Piper Super-Cub. Using methods identical with those used in Tsavo East, wet season distribution and crude estimates were established for Tsavo West. From the distribution maps and corrected aerial data (with ground checks made in some areas) these crude estimates were then compared with the crude estimates and refined statistical estimates for similar habitat types in Tsavo East. This comparison showed that most habitat types in Tsavo West supported very similar densities to corresponding types in Tsavo East. In a few areas densities in similar habitats in these two parts of the ecological unit were almost identical.

Unfortunately, time and man-power during the period of the wet season distribution did not permit a statistical census in Tsavo West. However, in view of the fact that similar habitat types in the two areas support similar densities it was considered permissible to use the statistical stratum means (see Table 3) established for Tsavo East as a basis for a crude estimate. Computations are shown in Table 4 and suggest a population of c. 2,350.

Adjustments were made in a few areas for factors which had adversely affected the population in past years. In the Rombo area, for example, heavy poaching has seriously depleted the rhinoceros population along the western borders of the park. Further into the park part of the Rombo area falls within the high density stratum. This habitat which presently supports a high population is identical with the habitat along the western border, but the latter area falls within the estimates of the low stratum. There appears to be little doubt that the main cause of the depletion is poaching. Jenkins (1966) records, for example: "Recently I spent two weeks in the Rombo-Magoine area. Only two rhinoceros were seen. In 1948-1949 12–15 were seen in one day and as many as 36 have been seen in one day in this area". Since the entire Rombo region obviously supported a high density in the past, and the habitats are very similar throughout, it is undoubtedly significant that the populations along the western area (adjacent to the park border) have been drastically reduced. Jenkins (pers. comm.) also records that many dead rhinoceros with their horns removed have been found in this area.

Block 29 and the Mkomazi game reserve

Both of these areas were systematically

TABLE 4

Crude density estimates of black rhinoceros populations in Tsavo West derived from corrected systematic aerial counts, ground censuses and distribution maps. Stratification is based on a wet season distribution.

Stratum	Total area (km^2)	Estimated mean density per 2.59 km^2 (1sq. mile)	Estimated crude population
Very high	210	3.4	280
High	1,259	2.4	1,150
Medium	1,468	1.1	600
Low	2,098	0.3	240
Very low	1,891	0.1	80
Total	6,926		2,350

covered in the aircraft and all data recorded as previously described. Correction factors were placed on the raw data, the area was stratified into the different density media and crude estimates were established. These estimates indicate 300–400 rhinoceros in Block 29 and 150–250 in the Mkomazi game reserve.

DISCUSSION

The crude mean density estimates for Tsavo East, established from the corrected systematic aerial counts and ground surveys, are shown in Table 1. Crude estimates of the total populations are shown in column (c) of Table 2. Comparison with the refined statistical means and population estimates shown in Table 3 illustrates close agreement. With the exception of the very low stratum the refined means are all slightly lower than the crude means. This is more apparent in the very high stratum and was not unexpected. Due to the extremely dense vegetation in parts of this stratum it was considered that some rhinoceros were undoubtedly missed, in spite of the very narrow plot width used. An example will illustrate this. On one plot the observer detected a very slight movement in a dense *Terminalia* thicket. The aircraft had passed over the area three seconds before and nothing was seen. A second later one rhinoceros backed out from underneath the thicket and trotted away. An instant later it was followed by three more rhinoceros. Unless this very slight movement had been detected these animals would have been missed. This illustrates the tendency of black rhinoceros to flush after the aircraft has passed over them.

In the other strata it is considered that a very high percentage of the rhinoceros on the plots was detected. On many plots all animals present were probably seen, but visibility bias is also inherent in the intensive search method. This undoubtedly accounts for the slightly lower results obtained using this method. Thus it is probable that the true populations lie nearer the higher confidence limits than the lower.

Many criticisms may be made of the longitudinal plot method. However, in view of the close agreement between the crude estimates and the refined statistical estimates, I consider that the results are realistic and that the method is valid. The intensive search method greatly reduces the effect of visibility bias. The square quadrat method, as used by Evans *et al.* (1966), is undoubtedly superior to the longitudinal plot but is not adaptable to the featureless country of Tsavo. The major problem with the method used here is keeping the aircraft at the correct altitude, because this affects the plot width. This is not, however, very difficult in the very flat country of Tsavo. The method used here makes no pretence of extreme accuracy but the plot areas actually covered were undoubtedly close to the 2.59 km^2 plot required.

From the systematic aerial counts used to determine relative densities and distribution it was calculated that two observers, one of whom, the pilot, is part-time, are attempting to scan approximately 4.45 ha (11 acres) per second. By the intensive search method as used here, one observer is scanning approximately 0.36 ha (0.9 acre) per second. Evans *et al.* (1966), using the quadrat method, were scanning on average 0.28 ha (0.7 acre) per second. These are far more realistic appraisals.

In the total area systematic counts the observers are scanning a vast area and the

human eye tends to rest longer in open places, e.g. wallows. Also, rhinoceros sleeping under acacia trees or resting behind termite hills some way from the flight line will not be seen unless they flush, and they may not always be detected even then (see Plate 2a). On one of the systematic counts a flight-line bisected an extensive area of acacia scrub and wild sisal (*Sansevieria ehrenbergii* Schweinf.). One area in the open sisal was scanned and the aircraft passed by it. Two seconds later a puff of dust attracted the attention of the observers. Two rhinoceros were immediately seen, running at full speed through the wild sisal about 300 m from the flight line. The animal in the lead had brushed its side against a termite hill, thus raising the dust. The observers had scanned the area seconds before and it was probable that the rhinoceros were trotting or running at the instant the aircraft passed by them. But for the dust, they would probably have remained undetected.

On several occasions during the systematic counts, objects resembling rhinoceros were spotted several hundred metres from the flight-line. A first pass over the area often resulted in the detection of one or two rhinoceros. More passes occasionally resulted in the detection of two, sometimes three additional animals, as they lumbered out from thick vegetation. Employing the intensive search method the observers' eyes are almost directly above the animals during the entire search.

It is interesting to consider these statistical estimates with other sources of documented information. Stewart and Stewart (1963) show that c. 1885 the black rhinoceros occupied approximately 90% of the land surface of Kenya. These authors also show that its present distribution (1963) occupies about 50% of Kenya. The publication "The Launching of a New Ark" (Scott, 1965) quotes the surviving world population of this species at 11,000–13,500. Guggisberg (1966) states: "In 1960 the number of black rhinoceros surviving in Kenya was estimated at 2.500". Guggisberg does not quote the source of this estimate, but it was probably obtained from Simon (1962). Guggisberg (1966) also mapped the distribution of the species in Africa c. 1850, at which time black rhinoceros occupied approximately one-third of the land area of Africa south of the Sahara. The present distribution (1966) shows that its range has been reduced considerably but that it still occupies a substantial part of its former range.

In view of the statistical estimates of the population in Tsavo East, the crude estimates of the population in Tsavo West, Block 29, and the Mkomazi game reserve, and the known present distribution of the species in Africa, it is concluded that the world population of black rhinoceros is very considerably higher than is currently believed.

ACKNOWLEDGMENTS

I should like to thank the East African Wild Life Society, the New York Zoological Society, the Kenya National Parks, the Canadian Federal Government and the Ontario Provincial Government for financial support of the rhinoceros research in Tsavo.

I should also like to express my sincere appreciation to the wardens of Tsavo, Messrs. D. L. W. Sheldrick, E. C. Goss and C. W. Marshall, and the warden of northern Tanzania, Mr. D. Anstey, for their splendid co-operation and enthusiasm during the aerial surveys.

A special word of thanks is extended to Dr. G. H. Freeman and Dr. R. M. Laws for statistical advice.

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(Received for publication July, 1968)

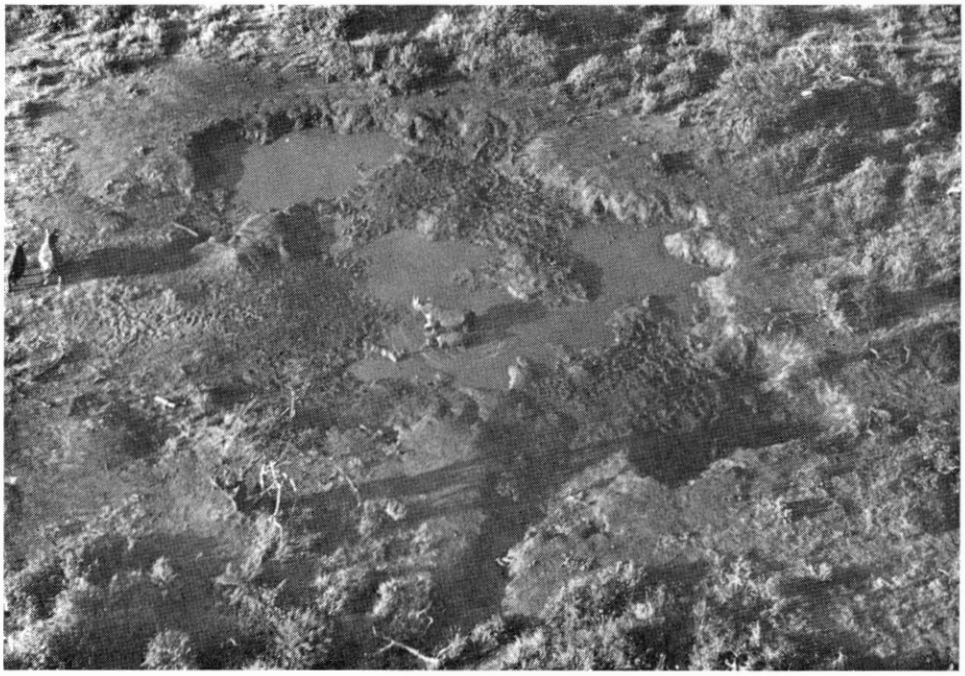

Plate 1a

14th May, 1968; 1745 hours. Four rhinoceros at a wallow in Tsavo West. At the original sighting seven were seen in the wallow. Some rhinoceros move to wallows in the late afternoon and hence are more easily detected.

Plate 1b

The combination of shadow and the sun on the side of the animal causes it to stand out from its background. The animal in the bottom left corner is an oryx (Oryx beisa *Ruppell*).

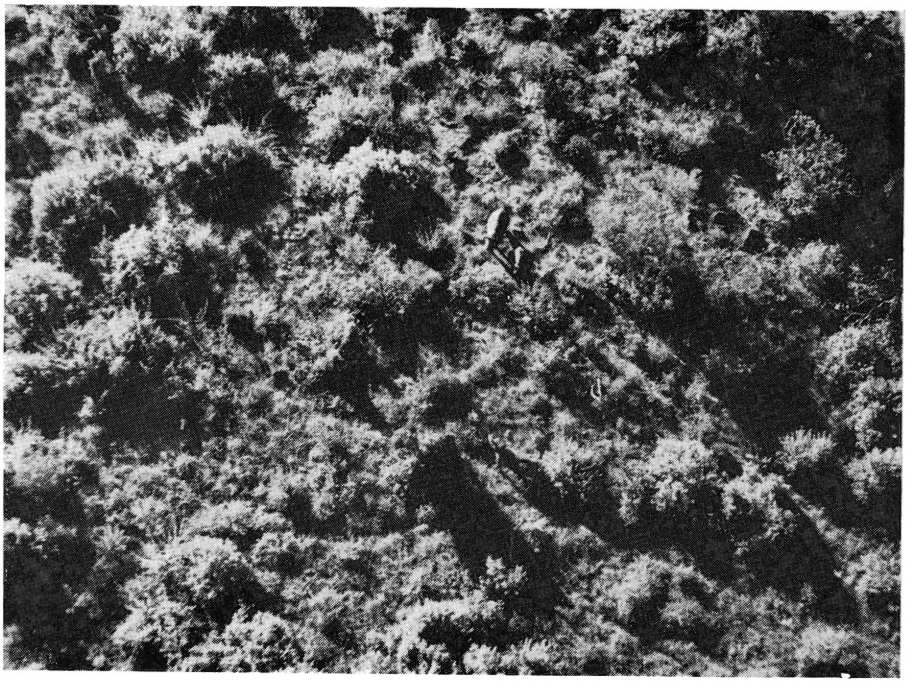

Plate 2a

20th May, 1968; 1715 hours. A female with a 1967 calf, and another adult, in Block 29. The adult (lower centre, facing directly into the sun) was not detected until after the photograph was developed.

Plate 2b

10th June 1968; 1545 hours. A female with a 1967 calf, and an adult (sex undetermined), running from a low-flying aircraft in Tsavo East.