A CENSUS OF WILDLIFE POPULATIONS IN MOLE NATIONAL PARK USING A STRIP CENSUS TECHNIQUE, 1970-72. (Revised in January 2008).


(Elephants along the Samole River, circa 1995, a rare site in 1970.)

By:

Bob Jamieson
Former Assistant Game Warden
Wildlife Resource Survey Team
Department of Game and Wildlife
Box 8, Damongo, N. R.
Ghana.

TERMS OF REFERENCE

Probably the most significant finding in wildlife management in Africa over the last several decades has been the realization that many habitats in Africa support very high numbers of wild ungulates. This is led to extensive work in east Africa that has indicated that these high numbers are supported with minimal damage to the habitat while much lower numbers of cattle sheep and goats can cause severe damage. Biological characteristics of the African antelopes, such as weight gain per day, rate of maturation, calving interval and carcass composition; gives these species great potential for meat production. It has also been demonstrated that the potential net revenue is such that profitable ranching operations can be carried out with these species.

Some of the problems facing the advocates of game ranching and wildlife cropping in East Africa are the legal aspects of bush meat marketing and animal health problems. In West Africa as a whole and Ghana in particular, such seemingly large problems do not exist. The Wildlife Department's work has already indicated that a ready market exists in Ghana for the products of a game ranch. The laws of Ghana concerning animal health problems favorite game ranching. However the move to attempt game ranching has been discouraged by the fact that there is no relevant information on the problem of comparable value to that which obtains to East Africa. There is little relevant information available on the number of ungulates supported by wildlife habitats in West Africa and Ghana. This survey reports in part gave us an opportunity to collect some preliminary figures on this problem. Therefore as part of the dry season survey carried out in 1971 the wildlife resource survey unit was also asked to utilize the transect techniques to provide density data from various parts of the Park and an assessment of the various methods for analyzing the data, especially in relation to the restricted visibility found in the Guinea would land savanna. This will provide preliminary population estimates and estimates of the biomass, that is the pounds of animals per unit area; that could be compared to data from East Africa. In the light of this work it is expected that Departmental policy in respect to game ranching can be reviewed.

Signed

Chief Game and Wildlife Officer
E. A. O. Asibey

ABSTRACT

An area of 125 mi.^{2} of Guinea woodland savanna in mole national Park was surveyed using line transects. The major concerns of the survey were to identify the best areas for developing game viewing roads and trails, deriving preliminary population estimates for the park and testing the effectiveness of the survey techniques used. Various means of defining the width of the strip censused in a woodland situation are discussed, as are the problems arising from animals moving away from the observer. It was found that the normal distribution model suggested by Hemingway, 1971, was effective for most species. A chi square "goodness of fit" test was used to test the effectiveness of this model and the negative exponential model proposed by Gates in 1968. The negative exponential model gave estimates significantly higher than those from the normal distribution model for smaller ungulates such as duikers and bushbuck.

Data from a permanent line transect near Samole, using the normal distribution model, indicated populations of 80 animals/mi^2 in drier areas and 120 animals/mi^2 in areas closer to water. Data from the larger survey area (Samole to Lovi) indicated the total population in 125 mi.^{2} of 8,900 animals. This was made up of 31.4 large ungulates/mi^2, 15.0 small ungulates/mi^2 and 24.9/mi^2 primates, totaling 71.6 animals/mi^2. Biomass was estimated of 14,390 pounds per square mile. Aerial census work in the 2002-2006 era suggest that large ungulate numbers at Mole National Park in the early 1970's were of the same order of magnitude as those found in well managed wildlife areas in Burkina Faso in the 2000-2006 era; but that present numbers in the park are much reduced from levels found in the park in the 1970's.

We concluded that the line transect method can be used effectively for the census of small ungulates in the Guinea woodland savanna, and with further work, for large ungulates. Aerial surveys can provide good counts of buffalo and elephant, which cannot be surveyed effectively using line transects. Using both approaches in the same area would provide good estimates for small ungulates, two different estimates for large ungulates and good estimates of buffalo and elephant numbers.

The preliminary estimates provided here have important economic implications, since they indicate that with proper management, wildlife can provide high quality wildlife viewing in Mole National Park and, in areas outside national parks, could become a major source of protein in northern Ghana with well-managed wildlife cropping.

TABLE OF CONTENTS

LIST OF FIGURES

List of Tables

List of Photos

Staff List

A CENSUS OF WILDLIFE POPULATIONS IN MOLE NATIONAL PARK USING A STRIP CENSUS TECHNIQUE, 1970-72. (Revised in January 2008).

INTRODUCTION

The Ghana Wildlife Department manages several national parks in northern Ghana and some Game Reserves where the utilization of wildlife as a source of protein. Studies related to management problems in Mole National Park and data collected for planning the development of game viewing roads provided an opportunity for determining the carrying capacity for wildlife, of the Guinea woodland savanna of northern Ghana. The study also provided an opportunity for developing census techniques useable in the Guinea woodland savanna across Ghana, techniques which will be useful in more detailed work in the future.

Photo 1. West African Buffalo, in Guinea woodland savannah, 1972.

STUDY AREA

The study was carried out in Mole National Park in northern Ghana (Figure 1). An area of 125 mi.^{2} (324 km^2) of woodland savanna in Mole National Park was surveyed using line transects. The topography was relatively simple, with the land rising gently from east to west, broken by north and south trending scarps dropping 50-100 m. During the dry season, December to May, water is available in standing pools along watercourses throughout much of the area. Guinea woodland savanna is a relatively uniform habitat with trees 5-10 m in height, spaced 2-5 m apart and underlain by a dense grass and shrub community. During the study period, December to May 1971-72, the ground floor was minimal due to annual burning carried out in early December. Four major plant communities occur, as described by Hall and Janik 1968 and Lawson et al. 1968. Jamieson 1971, a report on a survey of the same area during the 1970 wet season, provides details on landforms, plant communities and the diversity of wildlife and fisheries species found in the study area.

There were effectively two study areas. The Samole study area was located adjacent to the Park Headquarters, below the Samole scarp (substrata X in Figure 2). This is one of the core areas for wildlife viewing in the park. The larger "Mole" study area included all of the south-east portion of the park, (Figure 2), extending north the Lovi River and Lovi Camp in the extreme north-west corner of the survey area.

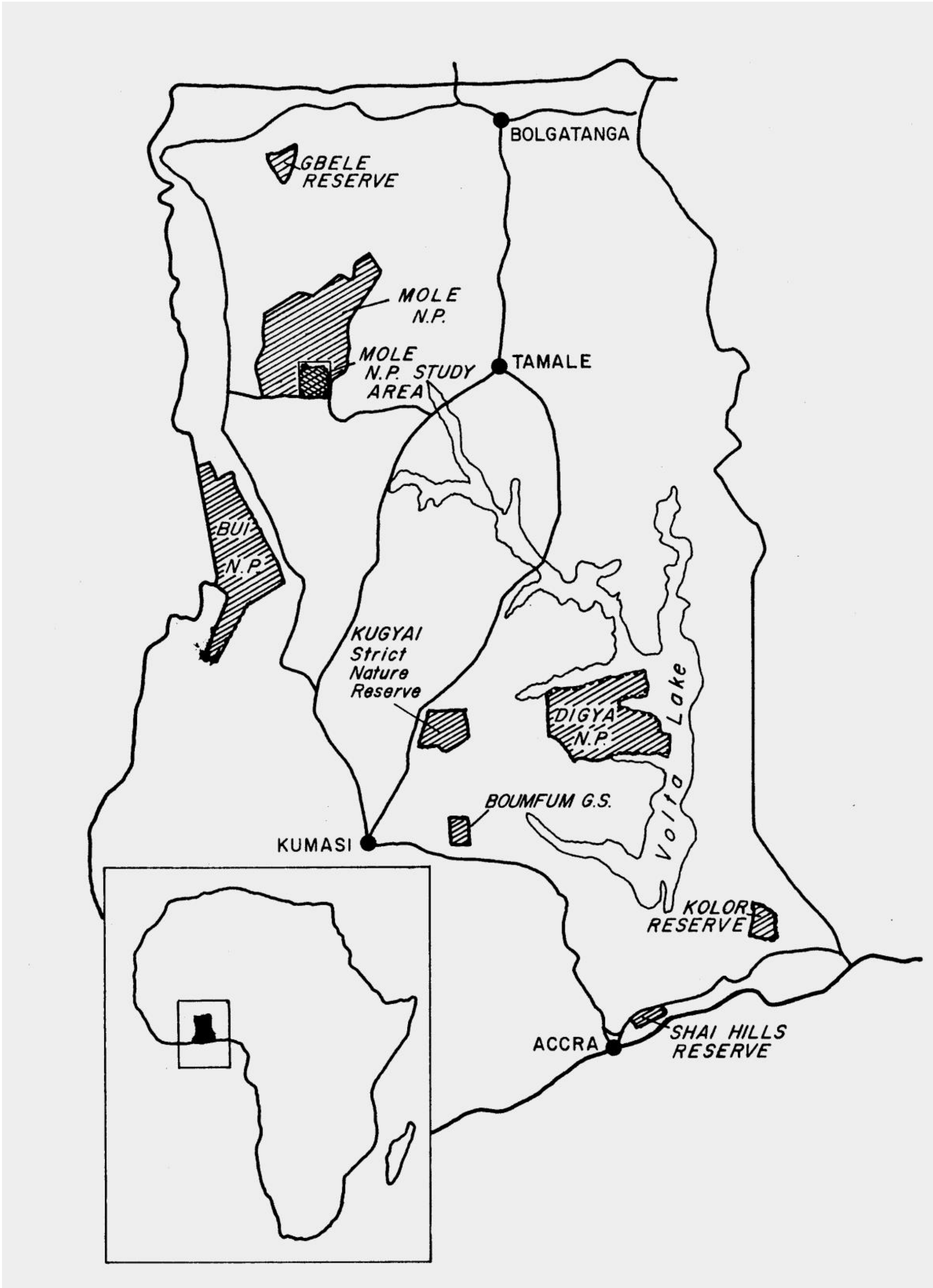

Figure 1. Location of the study area.

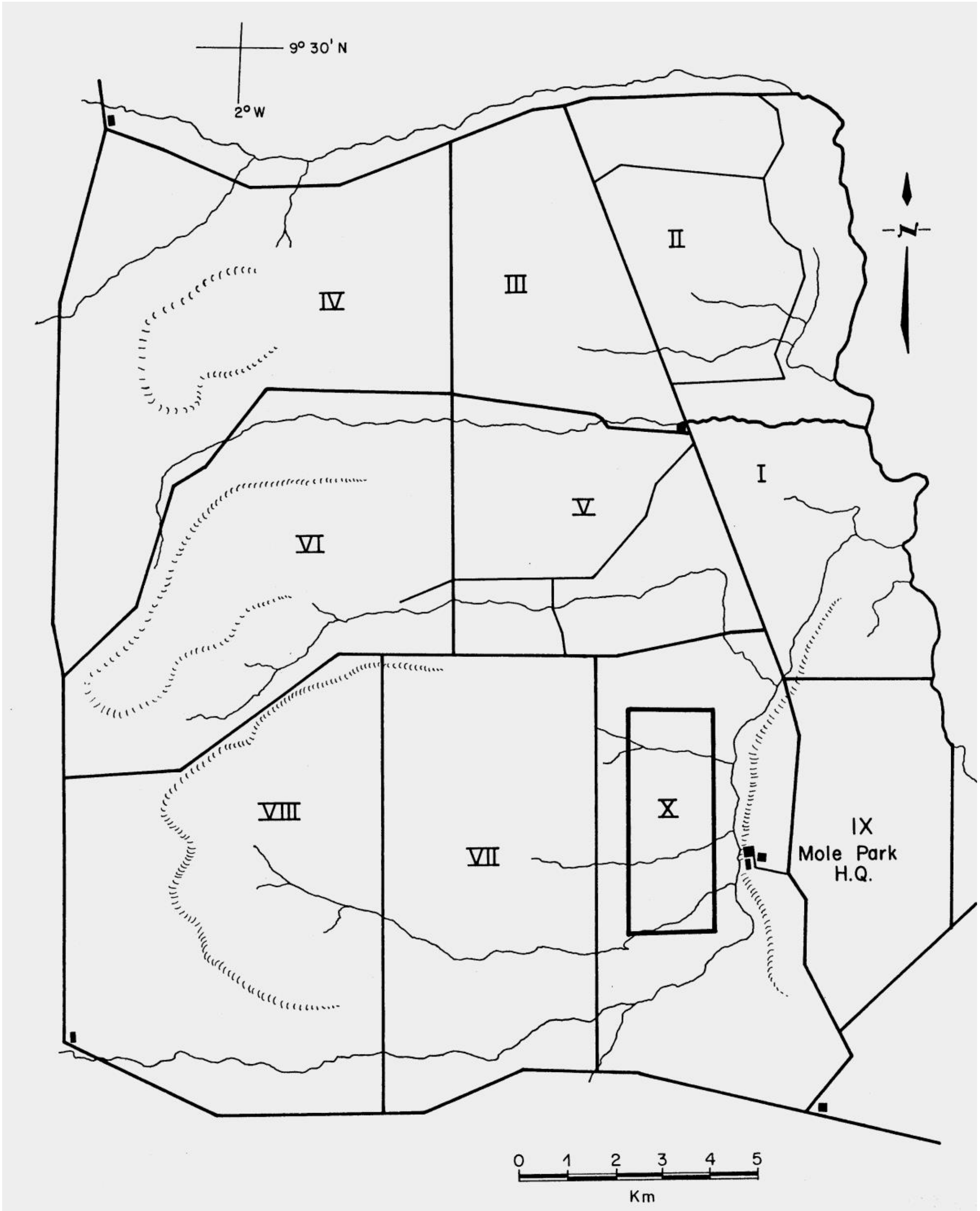

Figure 2. The study area and sub-strata.

Photo 2. Guinea woodland savannah, from the Samole motel scarp.

Photo 3. Typical viewing conditions in the Guinea woodland savannah, mid to late dry season.

METHODS

Aerial census using the small aircraft is the accepted procedure for the census in wildlife in Africa. However in dense woodland habitat this technique is not effective. Pinenaar 1966 found that aerial census in South African woodland was effective only for large, dark animals such as elephant in buffalo. Vehicle based strip census is used in many areas, however in northern Ghana there are few roads and it is difficult to travel by vehicle through the bush. Therefore walking transects were run, using a kilometer grid, as suggested by Hemingway in 1970, with pairs of observers walking compass lines 1 km apart through the survey area.

A variety of environmental factors were recorded at the beginning of each transect, including location on a 1:50,000 map and time at which the transect was initiated. While traveling along the transect line, times were recorded at landmarks. Each time an animal was sighted, information was collected on:

1. Time of sighting. This made it possible to locate sightings by extrapolating from times from known landmarks.

2. Activity of the animal when sighted. This generally documented if the animal was unaware of the observer, had sighted the observer, or was running away when first observed. One observation of note was the following: *"LION. Roaring loudly and advancing in a menacing manner. This report is being written from a tree…".*

3. Sex, age class and group number for each species of animal observed.

All measurements and calculations were made in metric units, then converted to English units.

4. Each of the measurements indicated below was taken.

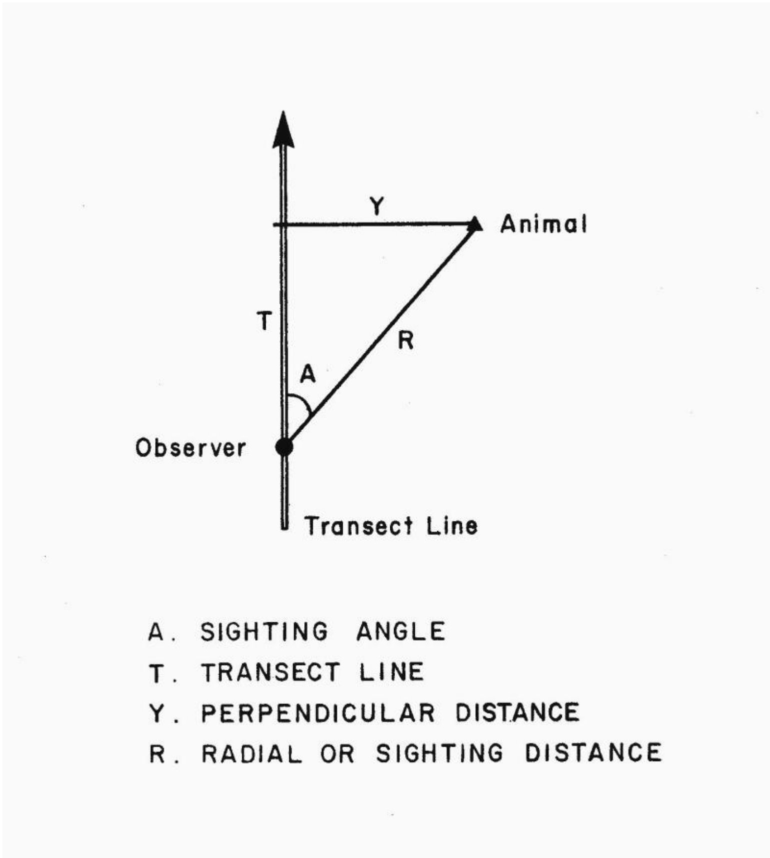

Figure 3. Transect Parameters

PRECISION OF MEASUREMENTS

Sighting angle was estimated using a compass bearing relative to the direction of the transect. Distances were measured using pacing. One of the observers paced to the location at which the animal was observed, then paced back to the transect line on a line perpendicular to the transect line. Pacing proved to be a surprisingly precise technique, when tested against measured distances of 500 m. Variability between observers was not significant. Only one observer at the 12 members of the team had a pace significantly different from the mean for the group of .8 m per pace. Weather conditions were stable throughout the study period (dry season 1971-72). Wind was almost nonexistent during the study period, and the weather was clear and hot throughout.

Significant differences in the ability of different observers to see animals did occur. Luivie Kanton, Lutie Kanton and Bayon Vegila, game scouts, had spent their entire lives in the Guinea savannah, first as hunters and later as employees of the Department. They were significantly quicker in seeing animals before they moved than were the other observers, especially in the 1970 wet season survey. The other observers were Game Rangers who were younger and had spent less time in the bush, we relatively poor observers at first, but improved quickly. By 1971-72, the entire team was at more or less the same level of proficiency. (We kept an unofficial tally of who saw the most animals each day and the tail end Charlie had to buy the *pito* (beer) at the end of the day. (The guy with the white skin and hairy legs bought a lot of beer…).

A negative bias, resulting in lower final population estimates, could have resulted from overestimating the perpendicular distance (Y) and by misjudging what constitutes a line meeting the transit line at 90°. However this was checked using the radial distance (R), the sighting angle (A) and the transect distance (T). The bias found amounted to .62 m, an amount that was insignificant at the level of precision of this survey.

Double counting due to the movement of animals from one line to the next was also found to be insignificant, only three or four incidents per hundred observations. They usually involve the larger and more mobile ungulates, therefore group size and sex composition of the group could be used to identify the groups counted twice. In the few cases in which this did occur, one group was deleted from the data.

SAMPLING APPROACH

The transects were run in a systematic grid rather than a random pattern. Though theoretically less valid, the grid pattern was required since the data was also used to map seasonal species distributions. Also, as Bergerund 1968 points out, for species with clumped distributions (i.e. caribou in his example), systematic transacts sampling gives greater precision than random sampling blocks. The larger species in the survey, which are the major components of the population, have clumped distributions.

Transects were run in pairs in most locations as indicated below in Figure 4. This was found to be an effective means of simplifying the pickup of observers and did not introduce any important bias. The one km distance between transect lines was paced out. Observers generally arrived at the road within 200 m of the proposed pickup point.

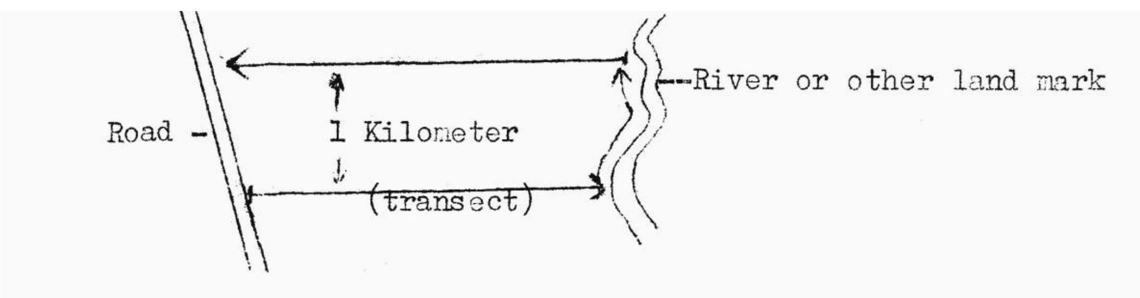

Figure 4. Transect layout.

As indicated in Figure 2, the survey area was divided into nine sub strata, sampled using a grid system, and one strata sampled using a permanent line transect. The permanent line transect, referred to as the Samole survey, was repeated 61 times and provided 854 km of transect. In the larger survey area, referred to as the Mole survey, sampling varied from one to three replications per transect, as indicated below.

Number of replicates

Unit Ia	= 3 replicates
Unit Ib	= 3 replicates
Units IIa	= 3 replicates
Unit IIb	= 1 replicate
Unit IIIa	= 2 replicates
Unit IIIb	= 1 replicate
Units IVa	= 3 replicates
Unit IVb	= 2 replicates
Units V	= 3 replicates

We completed 149 transects and approximately 1043 km of transect in the larger survey area.

CONCEPTUAL MODELS FOR STRIP CENSUS.

The first attempt to census wildlife using strip census was carried out by King, as reported by Leopold in 1933. He assumed that the average radial distance (R) at which an animal was observed was a good estimator of the effective stripwidth. Webb 1942 used a similar method on snowshoe hare. Both of these methods were based on the assumption that animals observed at greater distances compensated for those present close to the observer that were not seen or flushed. Haynes 1949 improved results from the King's census method by stratifying the population into flushing distance classes. Robinette et al. (1954 and 1956) discussed the problems associated with sighting angle, while comparing King's, Webb's and Hayne's methods for estimating the number of winter lost dear in Utah. Skellum 1958 looked at the problems associated with the high mobility of birds in relation to line transects.

It became apparent early on that there were two fundamentally different situations that ecologists were concerned with when using strip census. For deer carcasses, duck nests and game birds that generally flush or are observed only when the observer is very close to the animal, the probability of observing an animal dropped off very fast from the line which the observer is walking. Gates et al. 1968 proposed that the probability function of flushing an animal that increased with perpendicular distance could be described by a negative exponential curve (Figure 5). He found good correlation between the distribution of observed perpendicular distances for flushing grouse and those expected from the formula he derived. He then used computer simulation studies to look at the theoretical precision of his own and all other estimators proposed up to that time.

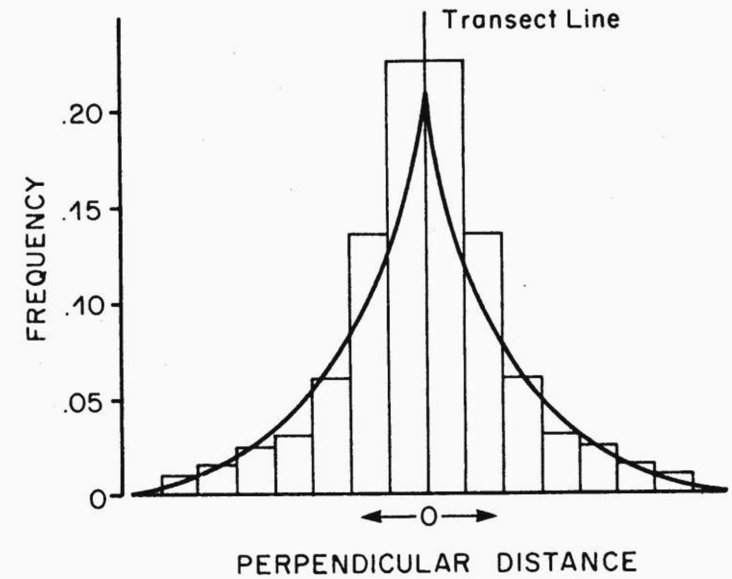

Figure 5. The Negative Exponential Model for strip census.

With large ungulates in woodland it was found that the situation was one of observing rather than flushing animals and the probability of observing an animal was defined by the visibility in the habitat, rather than the behavior of the flushing animal. Beginning with Kelker in 1945, it was found that the number of observations made per unit of perpendicular distance was constant for some distance away from the transit line, then dropped off quickly to zero, as indicated in Figure 6. This approach has been used in more open wildlife habitats, as in found in parts of East Africa and in the Sahel savannah zone further north in West Africa. The obvious solution in these habitats was to truncate the data at the point at which the observations per unit of perpendicular distance began to drop off. Keller et al. 1965 used this approach. Observations beyond this distance were ignored in computing the data, as indicated in Figure 6.

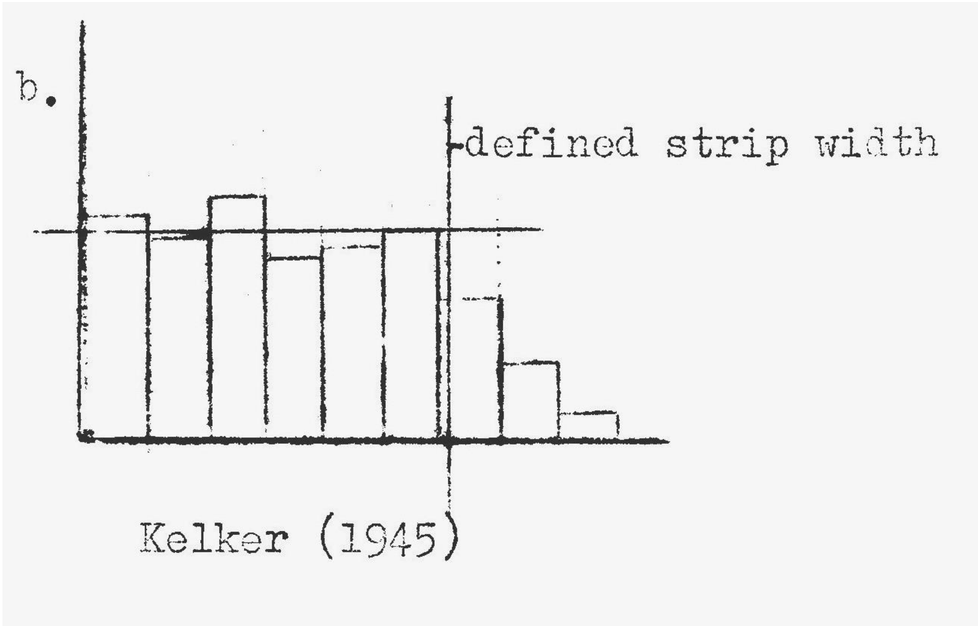

Figure 6. Belt transect model.

Hirst 1969 proposed a similar model, as indicated in Figure 7. Hirst's approach is effective because the areas indicated as "a" and "b" in Figure 7 are approximately equal. Hirst 1969 tested and compared the belt transect method to the mean visibility or mean disappearing distance method. He found that the mean visibility or mean disappearing distance approaches provided a better approximation to the known population and had lower variance.

Other workers attempted to estimate the area censused by measuring the visibility of the habitat. Hahn 1949 and Terr et al. 1965 used the meaning of the distances at which animals disappeared as they moved away from the observer, as half the effective strip distance. Lamprey 1964 used the visibility profile defined by the point at which a man dressed in karki disappeared as he walked away from the transit line. More recently, Hirst 1969 and Henshaw (pers. comm.) have used wooden models of animals to compute the disappearing distance of their study animals.

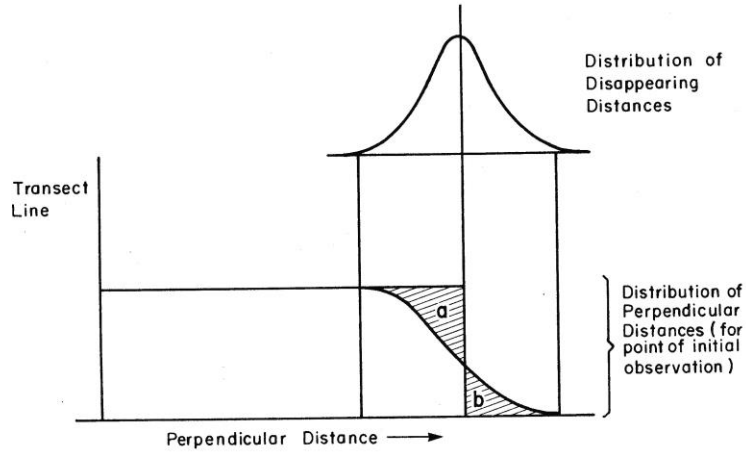

Figure 7. Mean visibility model.

This approach assumes that a person or cutout of an animal would be seen out to the same distance as an animal. It also assume that the visibility of moving animals is the same as that of a stationary person or a animal cutout. This approach however, appeared to be effective. Hirst's 1969 population estimates, based on this approach, were 95% and 92% of the actual values, (based on a known population) and the true values are well within the 95% confidence limits of the estimate.

However, in situations where visibility is restricted at distances very close to the transit line, then a much greater proportion of the total sample is involved in the "a" = "b" assumption. For dealing with situations such as this, several authors have developed mathematical models to describe the rate at which the number of animals observed drops off with perpendicular distance. Eberhardt 1968 suggested that the best approximation to the true probability distribution is a sigmoid curve (Figure 8). He felt however that the derivation of the sigmoid curve would be too complicated and suggested a set of simple curves based on the probability $x=1-x^a$. This provided a good theoretical basis which Anderson and Pospahala 1970 used for waterfowl nesting data. They use numerical integration to find the formula describing the curve indicated in Figure 8. They then multiplied the original estimate by a factor to add the shaded portion, representing the missed nests, to their final estimate.

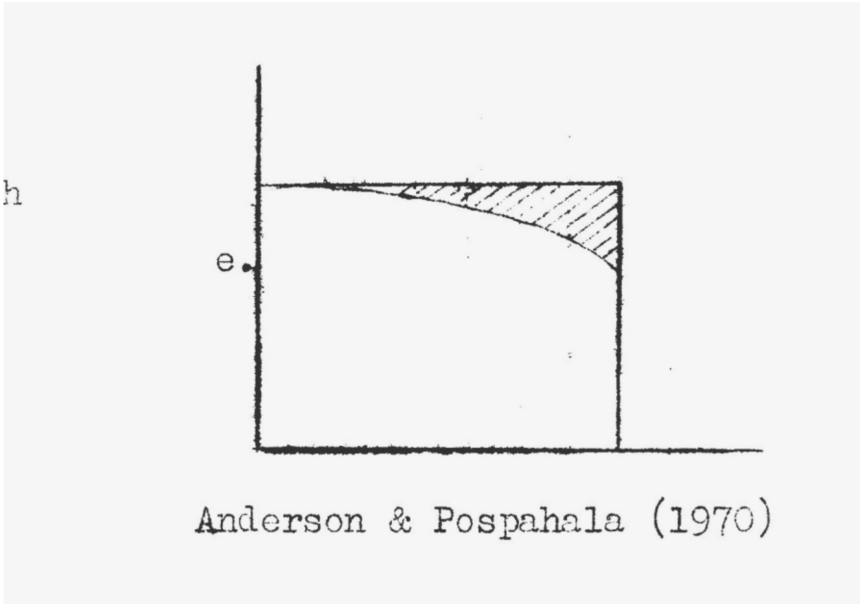

Figure 8. Sigmoid curve model.

Sokal and Rahlf 1969 used a similar and very simple approach. They drafted the frequency of observations on graph paper and drew a straight line that best described the data. This approach however does not allow for the estimation of variance.

Hemingway 1971 found that the visibility of ungulates in Miombo woodland in Tanzania approximated a normal distribution curve (Figure 9). He derived a formula based on the normal distribution curve to describe the decline in visibility over perpendicular distance.

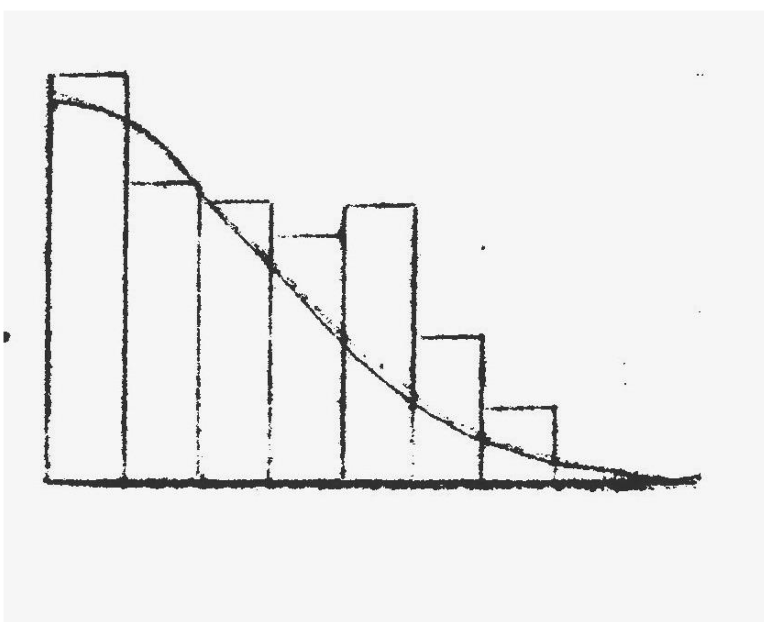

Figure 9. The normal distribution curve model.

This approach is flexible since distributions around a mean can vary substantially, as indicated in Figure 10. Normal distributions calculation used by Hemingway could account for these different forms of distribution.

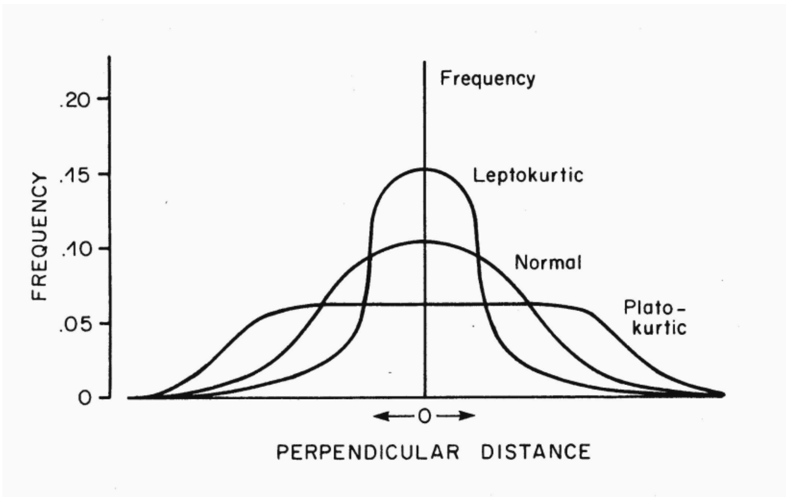

Figure 10. Forms of distributions around a mean.

Listed below are the various methods of estimating population density and strip width used in this survey.

Where:

D = The density in animals per square mile or per square km.
N = The number of animals observed on the transact.
L = The length of the transect.
W = The width of the strip census strip.

And Density D = N/L*W.

The estimators of strip width used in this survey are:

1. The King's Method where W = 2 * R where R =mean radial distance.
2. The Gates et al. 1969 Method where W = 2*(N* Y)/n-1, where Y is the mean perpendicular distance
3. The Hemingway 1970 Method where W = 2* (2Pie) * (square root of Y^2)/N-1)

RESULTS AND DISCUSSION

THE DISTRIBUTION OF SIGHTINGS RELATIVE TO THE TRANSECT LINE.

The distribution of sightings in each class of perpendicular distance are presented in Figures 11 to 16 for each study area and for all species for which more than 20 observations were made. Most species in each study area had a sample of > 50 observations. Elephant were present but in much lower numbers than occur now (Boule 2006); perhaps 25-40 in the Mole study area. Buffalo were more common but traveled in large groups and were observed only a few times, though we regularly found their spoor. Only a few groups of Roan Antelope were observed.

Small Ungulates
Most of the smaller antelope species (duikers and bushbuck) approximated a normal distribution model or the negative exponential model (Figure 11) and appear to be expressing a typical "flushing" response when the observer is at very close range.

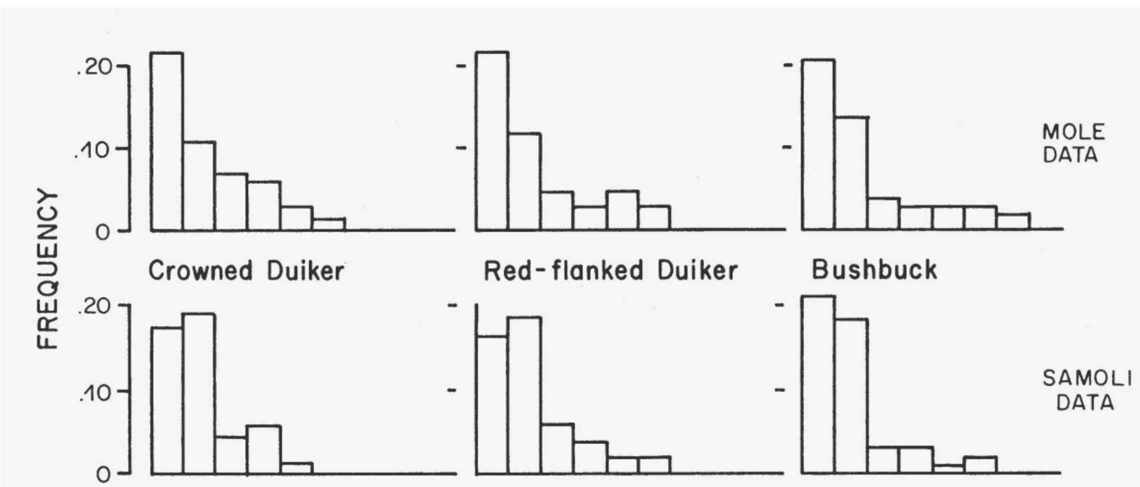

Figure 11. The perpendicular distance of observations of small ungulates. (8 m data sets, with the two sides of the transect folded into one data set).

Figure 12 below shows these same data fitted to the normal distribution model.

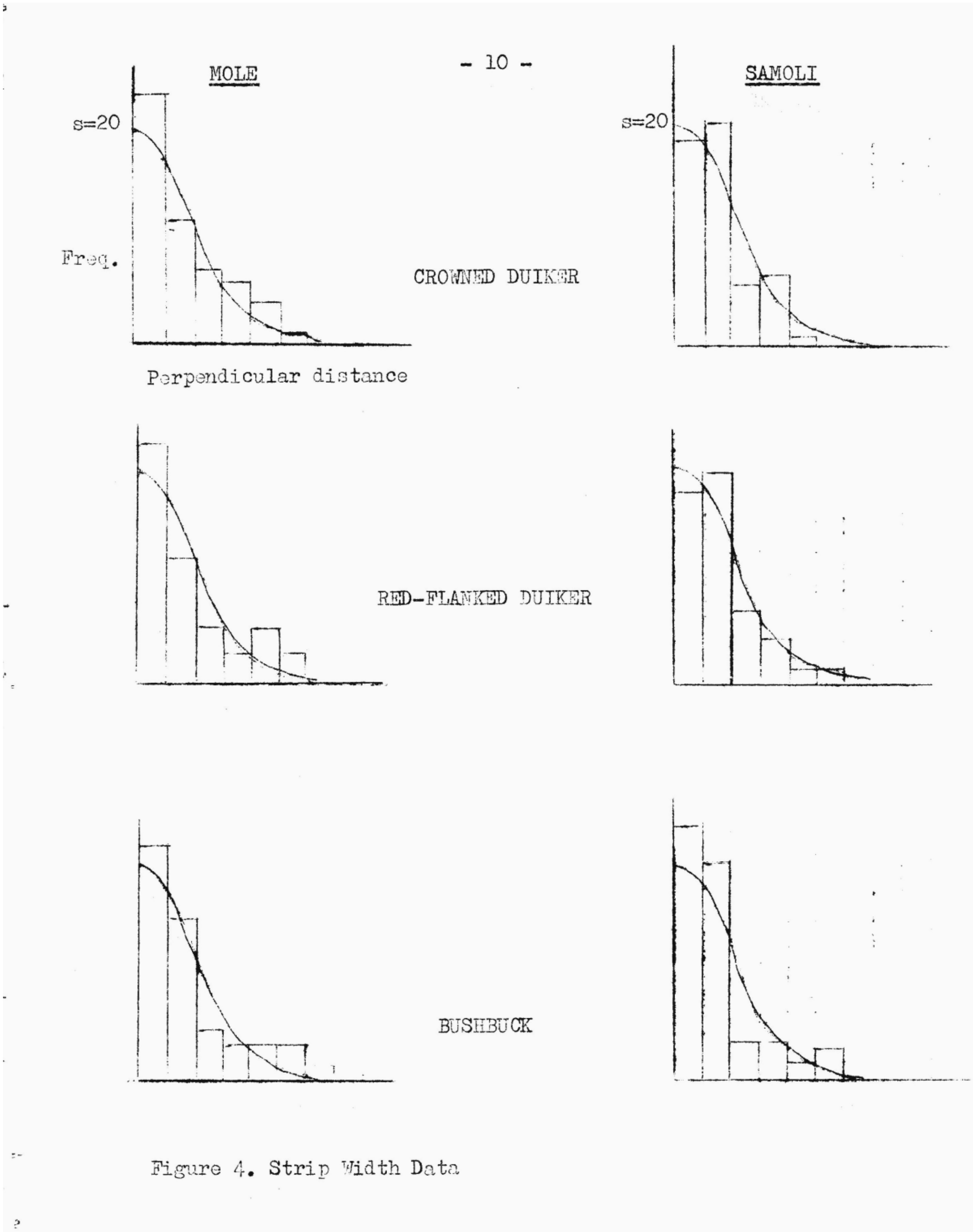

Figure 12. Perpendicular distance of observations of small ungulates. (8 m data sets).

Small Mammals
We classed baboon, warthog and oribias "small mammals" to differentiate them from the "small ungulates" which had smaller strip widths. The data for these species approximated a "flatter" normal distribution model (Figure 13) with some animals being observed at some distance from the transect line.

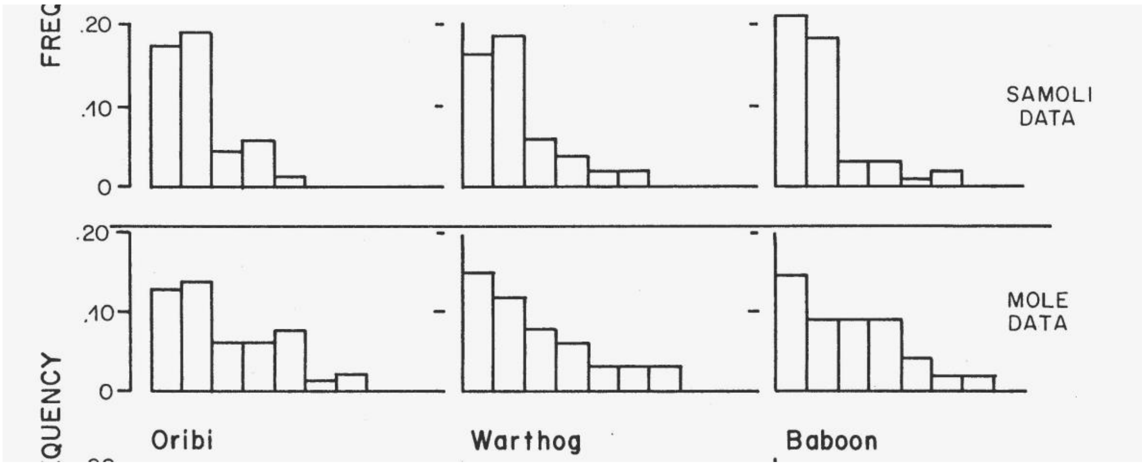

Figure 13. Perpendicular distance of observations of small mammals.

Figure 14 below shows these same data fitted to the normal distribution model.

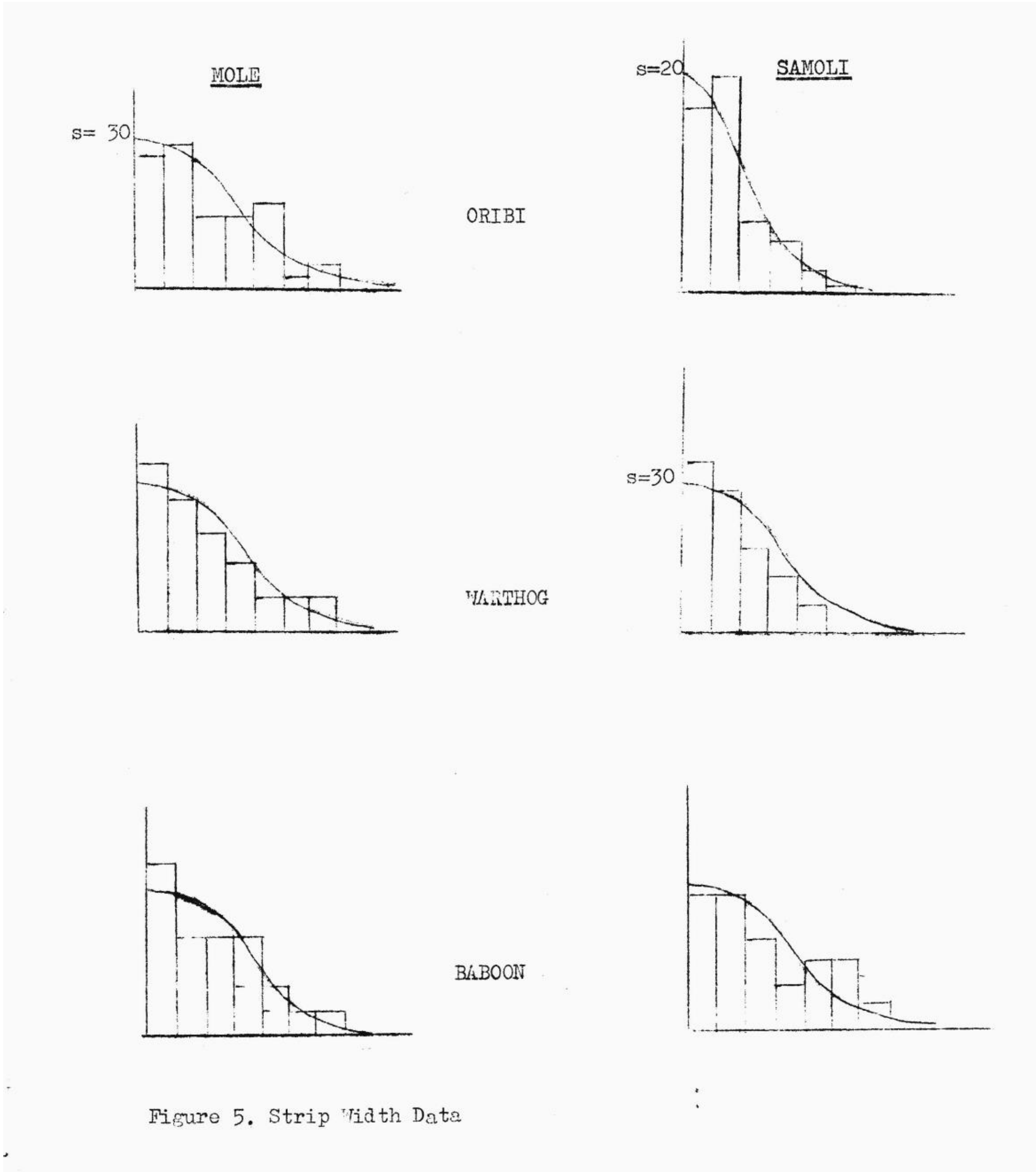

Figure 14. Perpendicular distance of observations of small mammals.

Large Ungulates

Hartebeest, kob and waterbuck were not only observed at some distance from the transect line, they were also observed in greatest numbers at some distance from the transect line (Figure 15), providing what could be described as a bimodal distribution of perpendicular distances.

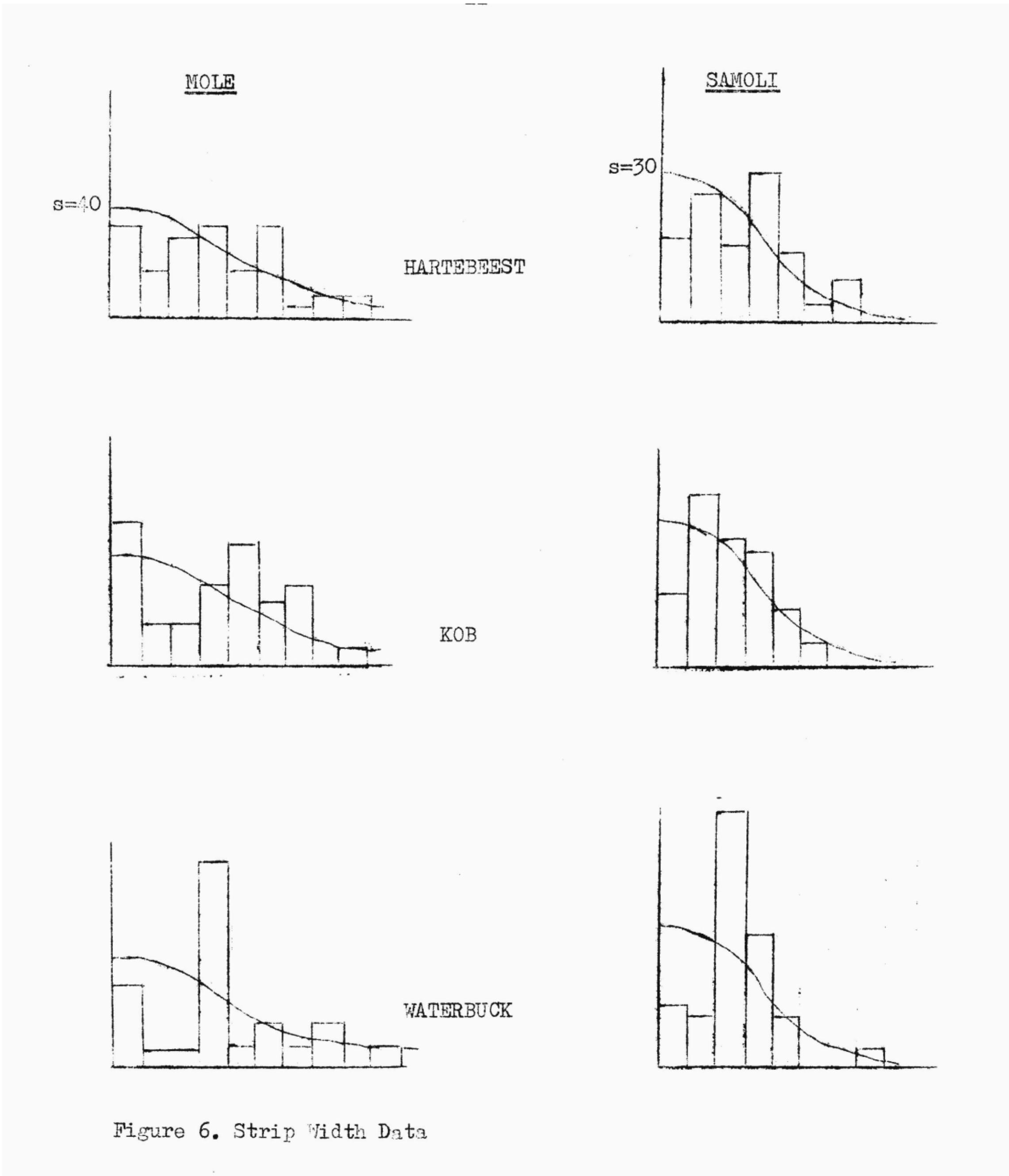

Figure 15. Perpendicular distance of observations of large ungulates.

We took this same data and lumped it into 16m classes, as indicated in Figure 16, since the observations of these species, which travel in larger groups, often spanned more than one 8m perpendicular distance class. Lumping the data in this way results in distribution curves that more closely approach the normal distribution model, but with this small number of distance classes, goodness of fit tests could not be applied. Therefore, all further assessments were based on the 8m data classes.

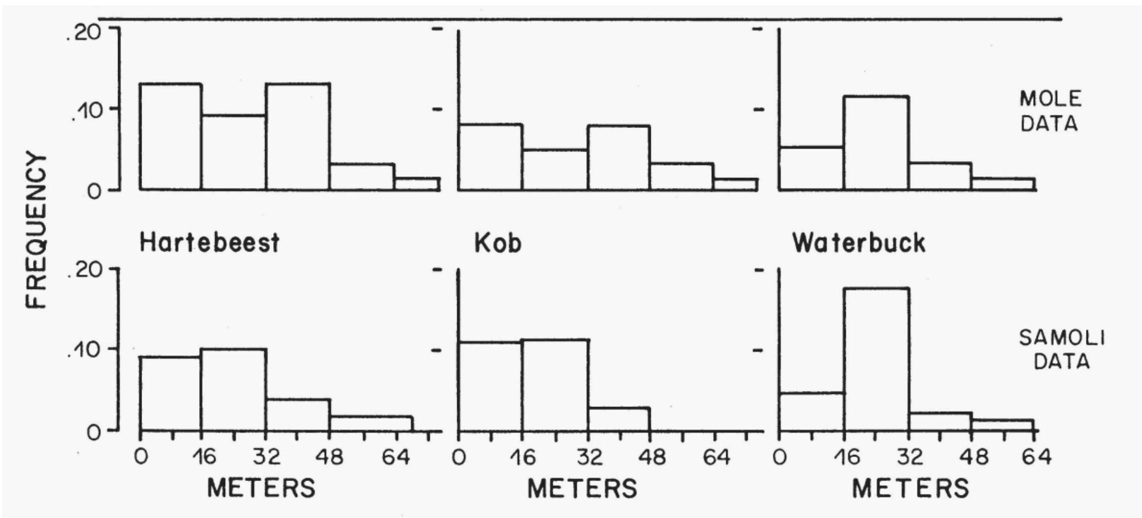

Figure 16. Perpendicular distance of observations of large ungulates, lumped in 16m distance classes.

It was obvious that for these species, other factors were coming to play. On the permanent line transit in this study, habitat features such as a preferred meadow or a salt lick could have resulted in the data curves presented for the larger ungulates. However, the data from the Mole study, based on a grid of transects, exhibits the same kind of perpendicular distance data distribution.

INTERACTIONS BETWEEN THE OBSERVER AND THE ANIMAL OBSERVED.

Small Ungulates

Most of the data for these species approximate a normal distribution model rather than the negative exponential model. Some animals may have been moving before being observed, but not such that the data departs from the normal distribution model.

Small Mammals

Data for these species also seemed to fit with the normal distribution, but with more animals being seen further from the transect line. There is some indication of movement by oribi, from the 0-8m to the 8-16m data class.

Large Ungulates

The larger species, such as Hartebeest, Roan Antelope, Waterbuck and Kob were observed at greater distances from the transect line and were apparently fleeing away from the transect line before being observed. This phenomena seems to have shifted observations from low perpendicular distances to mid range perpendicular distance.
It would appear that this shift occurs because the animals see the observer first and begins to move away without being seen. This seems likely since most of the time the observer is moving while the animal is stationary. In addition, the senses of animals are much more sensitive than that of those of a human observer and may allow them to sense the observer before they are seem by the observer. However, this situation is more complex than appears at first blush, as indicated by the data in Figures 16.

Theoretically one would assume, absent any movement by the animals generated by the observer, that one would expect to see animals, on average, at about the same distance at any angle from the observer. As can be seen, the expected values suggest that large ungulates were first seen at much smaller distances (30-40 m) in those perpendicular distance classes closest to the observer (0-32m) than at distance classes further from the observer and the transect line.

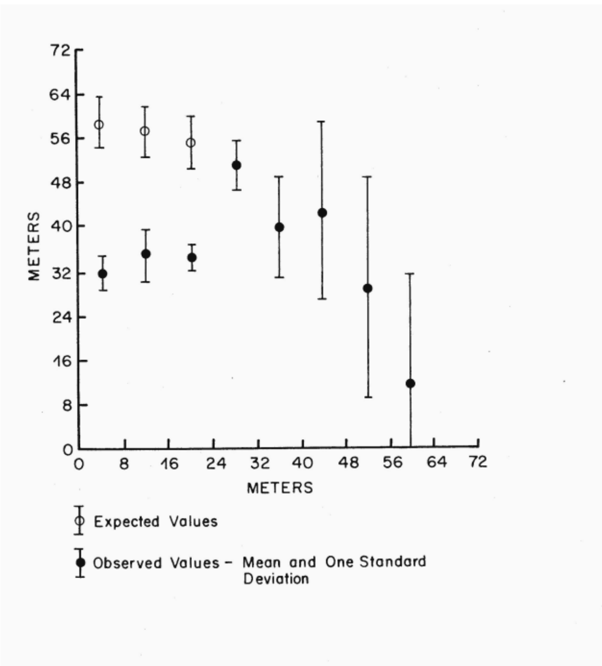

Figure 16. Observed and expected values for the distance from the observer to the animal sighted (large ungulates, Samole data).

The data on observation location was also plotted showing the relative position of the observer and the animal observed (Figure 17) at the time at which the observation was made. These data suggests a counter-intuitive situation where animals are first being observed at very close distances (15-20m), when they are located close to the transect line, and at much higher distances when they are observed at larger perpendicular distances (30-60m).

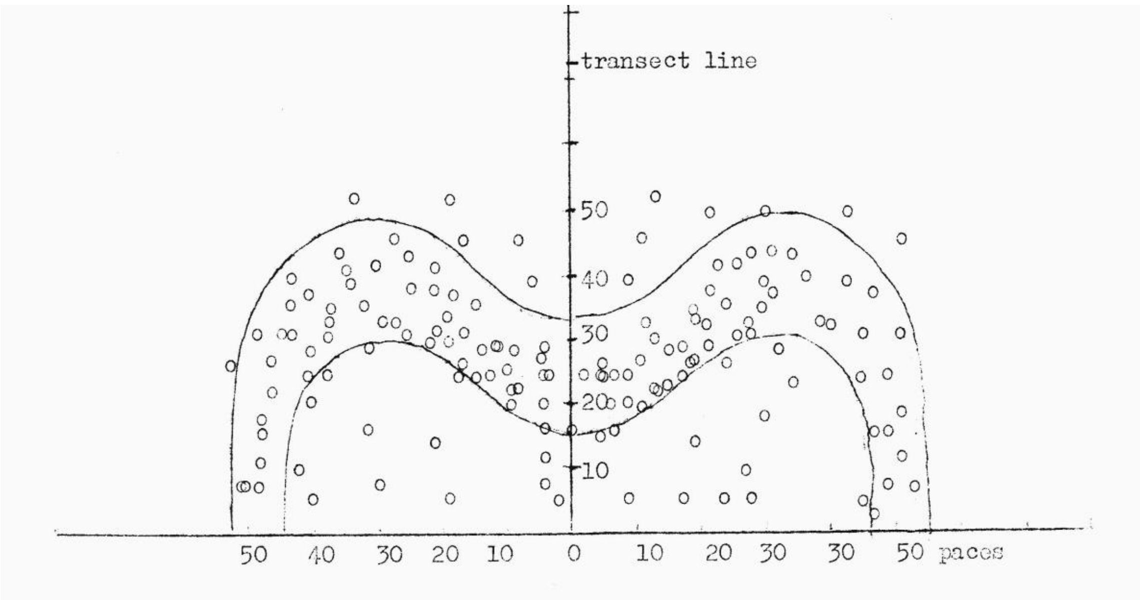

Figure 17. The location of sightings relative to the observer (large ungulates, Samole data).

Robinette et al. 1956 found a similar problem. He found an average sighting angle of 45 to 50°, rather than the 32 to 45° expected from theoretical calculations. He attributed this to the observer looking to the sides rather than ahead and does not seen the animals as soon as they came into sight when they were directly and ahead of the observer. In this study the mean sighting angle was actually quite close to the expected value for most species, suggesting that in this study that the situation is better explained in other terms.

The vegetation through which the transacts were run is made up of trees 5-10m (15 to 30 feet) tall with trunks from 10- 40 cm (4 to 16 inches) in diameter, along with various shrubs and old, unburned patches of grass up to 2m (6 feet) tall. These forms of vegetation act as blocks to visibility. As the observer moves trough this vegetation, these trees and shrubs and grass move through his field of view, and it is through this matrix of vegetation that the animals must be observed. **In the area immediately ahead of the observer, from 0º to 20° on either side of the transect line, the trees remained**

stationary in relation to the observer as he moves forward. As a result, the areas behind these visibility blocks are blocked from his view for long periods of time as the observer moves forward. In other words, the area behind the tree trunk or shrub remains hidden as he moves toward it. Conversely, at 45 to 90° the trees move by each other in relation to the observer in his field of view, alternative revealing and hiding any particular point or animal. This phenomena would appear to decrease the visibility distance significantly from 0° to 20° from the transect line for both the observer and the animal.

Photo 4 demonstrates the situation in which animals were observed. One can see that the tree trucks and clumps of shrubs in the photo would constitute blind spots before the observer as he moves forward. If this photo was taken along the direction of transect, the hartebeest would be observed as some distance ahead of the observation team, as in this picture. However, if there was an animal in this area, located behind the big, dark tree truck in center left in the picture, that animal would not be observed until the observation team has proceeded to a point very close to the tree and the animal. Note the two tree trucks that mask most of the 4th hartebeest in the picture, in the extreme left portion of the photo.

Photo 4. Hartebeest and vision blocks in Guinea woodland savannah.

This is an important point. If animals directly in the path of the transect line are not reacting to the observer until the observer team is very close, then when they move it is very unlikely that they will move out of sight without being seen by the observer team. In effect, the animals that were present close to the transect line move to perpendicular distance classes that are further from the transect line before being observed. They are unlikely to be able to escape notice by the observer when he is relatively close before disturbing the animals. This would suggest that the data in the perpendicular distance curves in Figure 15 represent all of the animals present in the lower perpendicular distance classes. However, this phenomenon still presents two problems.

1. It is impossible to know from this data if the normal distribution model or the belt transect approach best approximates the actual effective strip width for large ungulates.
2. If in fact, all animals are seen out to mid range (32-64m) data classes, as suggested by the belt transect approach, there is no effective way to identify the distance at which one should truncate the data.
3. If the actual data, absent observer induced movement, approximates the normal distribution model, it is impossible to tell how "flat" the normal distribution model should be.

These problems introduces major variance into any estimate made using this data, using either the normal distribution model or the belt transect approach. The problem is most difficult in the case of kob and waterbuck and occurs in both the Samole and Mole data. Differences in average group size for the three species may explain some of this phenomena. Waterbuck and kob tend to occur in singles and small groups more than Hartebeest, making it easier for them to "hide" behind barriers to the observer's view as one move along the line.

Though an understanding of this phenomena is of value, but does not resolve the issue of trying to decide which of these two models is best suited for developing estimates of large ungulate density in Guinea woodland savannah. Intuitively, it would seem that the normal distribution model would be the better choice for large ungulates, however, there is no effective way to differentiate between the approaches, given the data sets presented here.

DERIVATION OF STRIP WIDTH ESTIMATES

We tested the closeness of fit of the data on perpendicular distances to the normal distribution model for all species and the negative exponential model for small ungulates, as indicated in Table 1.

Small Ungulates

Reasonable goodness of fit was found with both models for small ungulates. (The Samole data for crowned duiker appeared to fit the normal distribution model, but did not meet the goodness of fit test. Sample size for this species was small (20 and 30 observations)). However, the strip widths that result from each model are very different. Strip widths using the negative exponential model are in the 20-27m range, while strip widths in the 40-50m range are found with the normal distribution model.

Small Mammals

There is good fit for the normal distribution model for oribi, waterhog and baboon, as one would expect, given the data in Figure 10.

Table 1. Strip width estimates using two models.

Species	Survey Area	Strip Width based on exponential model (Gates et al. 1969)	Strip Width based on normal distribution model (Hemingway 1970)
Crowned Duiker	Mole	25.4*	43.2*
	Samole	20.6	41.8
Red-flanked Duiker	Mole	26.8*	42.8*
	Samole	26.8*	40.2*
Bushbuck	Mole	25.0*	49.0
	Samole	23.4*	41.4
Oribi	Mole		60.0*
	Samole		44.1*
Warthog	Mole		56.8*
	Samole		44.0*
Baboon	Mole		60.2*
	Samole		58.8*
Hartebeest	Mole		82.3*
	Samole		68.5*
Kob	Mole		82.8
	Samole		59.0
Waterbuck	Mole		87.6
	Samole		61.2

* - Data fits the model at the 95% level using the Chi Square Goodness of Fit Test. Goodness of fit was based on n-3 degrees of freedom where n =7, the 95% value is 9.48.

Large Ungulates

For the large ungulates, only the data for hartebeest approximates the normal distribution model and only marginally so.

There were differences in strip width between the Samole and Mole data. These differences are minor with the negative exponential model for the small ungulates, but are significant with the normal distribution model, as indicated below in Table 2.

Table 2. Average strip width estimates for the Samole and Mole study areas.

Species Group	Samole Study Area	Mole Study Area	Difference
Small Ungulates	41.1m	45.0	3.1
Small Mammals	49.0	59.0	10.0
Large Ungulates	62.9	84.2	21.2

The average strip width was significantly higher in the Mole study area for all classes and the difference between the two areas increased with the size of the animals. This may be due in part to the larger proportion of riverine areas in the Samole study area and the presence of old farming areas with thick vegetation along one portion of the permanent line transect in that study area.

Comparison of different strip census models

Small Ungulates

For small ungulates, the normal distribution model gives a much wider strip width and thus lower population estimates. The negative exponential model assumes that some animals would be missed even very close to the transect line, as would occur with grouse. It is hard to visualize duikers and bushbuck not flushing when the observer is at close range (0-8m) during dry season conditions. The normal distribution model therefore is probably the better approach for these species, howver the data for these three species was calculated using the formulas provided by Gates et al. 1969, using the negative exponential model. Population estimates from this model were a factor of 1.5 to 1.87 higher than those derived using the normal distribution model. (If the negative exponential model was more correct, then the totals for small ungulates in Table 5 below would be increased from 26.2 animals/km^2 to 34.7 animals/km^2 in riverine habitats and from 18.3 animals/km^2 to 31.6 animals/km^2 in savannah habitats in the Samole study area).

Small Mammals

For small mammals, the normal distribution model seemed to fit the data well; the negative exponential model was not tested.

Large Ungulates
Given the assumption that animals were moving away from the transect line before being observed, the normal distribution model likely provides the best theoretical model for describing the visibility of large ungulates in Guinea Woodland Savannah. However, simply looking at the distribution of perpendicular distances (Figures 16) would suggest the use of the belt transect method. Based on the data in Figure 16, and estimating strip width for large ungulates by looking at the point at which observations dropped off substantially, would result in effective strip widths that were much larger than those calculated using the normal distribution model, as indicated in Table 3. Using this approach would likely provide population estimates that were very much lower than those provided by the normal distribution model, however, the belt transect method was not tested and the data is no longer available to test this model.

Table 3. Strip width with various models

Species Group	Belt transect Method	Normal Dist. Model	Negative Exponential Model
small ungulates	Not applicable	40	25
small mammals	64-96 m	41.1-60.2	Not applicable
large ungulates – Samole data	96-160	59.0-68.5	Not applicable
large ungulates – Mole data	80	82.3-87.8	Not applicable

Based on these data sets, the best options for modeling the visibility of various large mammals in the guinea woodland savannah are:

- the normal distribution model for small ungulates, though the negative exponential model may be credible alternative.
- the normal distribution model for oribi, warthog and baboon.
- the normal distribution model for hartebeest, kob and waterbuck, although the belt transect method is potentially applicable, or some sort of binomial distribution model for kob and waterbuck.

In general, these normal distribution model would seem to work best in the Mole National Park situation, and in the Guinea woodland savannah, as indicated in Table 4. We did not have sufficient observations to develop credible estimates of effective strip width for roan antelope, buffalo and elephant (estimates based on the available data are provided in Table 5). As noted, buffalo and elephant are best monitored using aerial transects.

The ultimate choice for inventory work will depend on more data to refine our understanding of animal behavior of each species relative to the disturbance generated by the presence of the observer and simple more data to refine the distribution of perpendicular distance data sets.

Table 4. Population estimates with various models.

Species Group	Belt transect Method	Normal Distribution Model	Negative Exponential Model	Aerial survey
small ungulates	Very low	**Best**	**Good**	Very poor
Medium sized mammals	Very low	**Best**	Poor	Very poor
large ungulates	Low	**Fair to Poor**	Very poor	**Fair**
Buffalo	Poor	Poor	Very poor	**Best**
Elephant	Very poor	Very poor	Very poor	**Best**

DERIVATION OF POPULATION ESTIMATES

The variance inherent in estimates developed using any of these approaches suggests that any estimate based on these models will provide an **order of magnitude estimate** of population density only. However, an order of magnitude estimate of wildlife populations was made, since no such information was available at that point in time (1970). The normal distribution model was used for all species, for consistency, with the provisions identified above.

Samole study area

Table 5 provides population estimates from the Samole survey, based on the normal distribution model. The data were separated into two habitat types: Riverain Habitat, defined as all areas within 1 km (6/10 of a mile) of water and dry savanna covering all the remaining areas.

Table 5. Population density estimates (animals/km^2) for the Samole area.

Species	Savanna Habitat density	Stan. Dev.	Riverine Habitat Density	Stan. Dev.
Elephant	Trace			
Buffalo	0.3	0.1*	0.1	-
Roan Antelope	1.8	0.8	0.3	0.2
Hartebeest	8.1	1.8	5.1	0.9
Waterbuck	0.7	0.2	13.0	2.5
Kob	Trace	0.2	4.5	2.1
Reedbuck			trace	
Large Ungulates	**10.9**	**1.6**	**23.0**	**3.0**
Oribi	3.7	0.4	0.1	-
Bushbuck	0.8	.01	4.9	1.1
Warthog	3.0	0.7	0.3	0.3
Common Duiker	2.6	0.3	1.0	0.3
Red-flanked Duiker	0.3	0.1	2.1	0.3
Small Ungulates	**10.4**	**1.1**	**8.4**	**1.4**
(and warthog)				
Baboon	6.7	1.9	7.5	0.2
Red Patas Monkey	2.3	1.2	1.1	0.7
Green Monkey	0.6	0.5	8.6	1.2
Primates	**9.6**	**1.9**	**17.2**	**2.6**
Total Large Mammals	**30.9**	**3.0**	**48.6**	**4.4**

* The standard deviation for the normal distribution model was that used by Hemingway, 1970.

Mole study area

The data from the Mole survey was computed in a similar manner, but the data was not segregated by habitat types. Calculations were also made using the normal distribution model. Data from the six substrata are presented in Table 6. These data indicate the range of population density estimates found in various parts of the study area. Figure 18 shows the number of animals observed per km^2 and shows the overall distribution of large mammals in the study area. Highest densities were found generally in areas close to water. Unit V has very low estimates compared to the other areas, we found no obvious reasons for the low density estimates for this area. From the Samole data it is obvious that significantly higher populations are found in the riverain habitat type. The sub-strata in the mole studies supporting the highest numbers were those containing the most riverine habitat.

Table 6. Population Estimates by sub-strata (animals/km2)

Sub-strata	Large Ungulates	Small Ungulates	Primates	Total
I (Samole road east)	18.5	1.7	24.6	44.8
II (Asibey pools)	22.5	4.9	4.7	32.1
III (Brugbani road west)	25.0	4.3	6.4	35.7
IV (Lovi south)	8.2	1.8	33.7	43.7
V (Brugbani south)	.2	1.8	3.6	5.6
VI (Brugbani uplands)	15.2	10.3	11.6	37.1
VII (Kananto uplands)	7.2	6.3	5.2	18.7
VIII (Kananto midlands)	7.6	6.6	0	14.2
IX (Samole)	15.2	4.1	5.2	24.5
X (Samole east)	16.9	9.4	13.4	39.7

Population estimates for the entire study area, including the Samole study area, as a sub-strata, are provided in Table 7. These are order of magnitude estimates only, given the problems discussed previously.

Table 7. Overall Population Estimates for the study area. (animals/km2)

Species	Density /km2	Density/mi2	Study Area Population
Elephant	trace		
Buffalo	0.8	2.3	260
Roan Antelope	1.8	4.6	580
Hartebeest	6.0	15.3	1,910
Waterbuck	1.3	3.4	420
Kob	2.0	5.1	640
Reedbuck	Tr?	1.1	100
Large Ungulates	**11.9**	**31.8**	**3,910**
Small Ungulates	**5.7**	**14.8**	**1,840**
Primates	**9.7**	**25.0**	**3,100**
Total Large Mammals	**27.3**	**71.6**	**8,850**

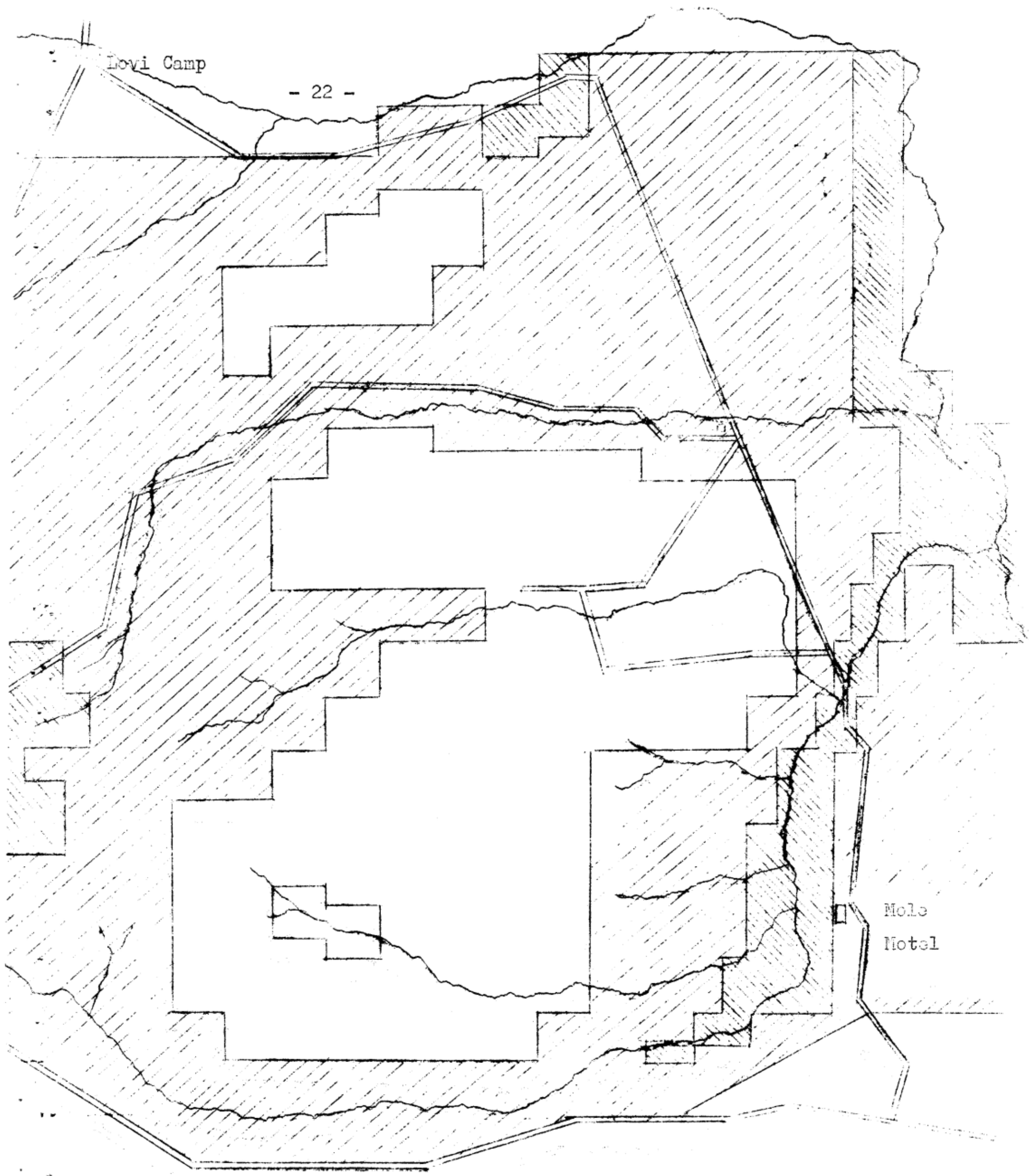

Figure 10. Wildlife Numbers

-High Density -Medium Density -Low Density

Figure 18. Wildlife densities in the Mole study area (observations/km).

COMPARISON TO OTHER STUDIES IN SIMILAR HABITATS

There's little data is directly comparable to that presented here for ungulates in Guinea woodland savanna. Geerling and Bakdan 1971 studied Kob in Komoe national Park in northern Ivory Coast, but the data is not directly comparable. Henshaw (pers. comm.) did census work in northern Nigeria, but worked in an area where densities are very much lower than those found in Mole National Park. The data that is most comparable is that from Miombo woodland in Selous Game Reserve in southern Tanzania, as described by Rodgers 1970. His data on hartebeest for the Miombo woodland using the normal distribution model indicated densities of 17.9/mi^2 which compares well with figures from this study (15.4/mi^2). Dowsett 1965 studied hartebeest in Zambia and calculated the area of territories occupied by family and bachelor herds. This data, when converted to a density estimate, gives an estimate of 7.3/mi^2, lower than that found here for the Mole area, or the Selous study area (15-17/mi^2). Field 1970 indicates that Waterbuck numbers in prime habitat in Queen Elizabeth national Park are 35.1 animals per square mile. These are much higher values than was found for riverine habitat in this study at 13.0/mi^2. However Hank et al. 1970 found lower values of 18.1/mi^2 for Waterbuck in a study of riverine habitat in Zambia. These figures seem to confirm that the estimates provided here have at least order of magnitude precision. Buffalo numbers and densities in Mole Park are lower than those found in most other areas. Roan Antelope occurs at higher densities than found here in the Nazinga area. No comparable studies of the small ungulates were found. Primate numbers were quite high; Bohol 1965 from similar densities for baboons in Uganda.

Biomass Estimates

The estimates provided here indicate that populations in excess of 120 animals per square mile occur in many riverine areas in Mole national Park and the study area supported overall population densities of over 70 animals/mi^2. Biomass estimates (Table 8) however, are found to be low relative to densities in many parts of East Africa. The census of many smaller species, usually ignored in other census work, increases the density estimates for this area but does not contribute substantially to the biomass figure.

Table 8. Biomass Estimates for the study area.

Species Group	Kg/km2	Lbs/mi2
Large Ungulates	2110	12,210
Small Ungulates	200	1,140
Primates	170	1,010
Total Large Mammals	**2,480**	**14,360**

These estimates are of the same order of magnitude of those found in the Nazinga area (Lungren 1975) in southern Burkina Faso, some 300 km north, of 19,000 lbs/mi^2. This estimate would appear to include the biomass represented by 250-300 elephants, about 2.5 to 3.0 elephants /mi^2. Elephant were not included in the estimates provided here. They occurred in relatively low numbers in the 1970's era. (Perhaps 25-40 in the Mole study area). Using the negative exponential model would increase estimates of small ungulates but would alter the estimate of total biomass by very little since most of the biomass is provided by the larger animals.

Wildlife populations in Mole national Park are still increasing. Little evidence of heavy grazing was found, and the young to female ratios are high for most species, indicating an expanding population. Populations here have had proper protection for slightly more than 10 years. Future population increases should be expected. The Mole study area is perhaps slightly better watered than the Guinea savanna zone in general, but the overall biomass of this zone should still be a minimum of 15,000 pounds per square mile.

DISCUSSION AND RECOMMENDATIONS

USING THIS DATA AS AN INDEX OF LARGE MAMMAL PRESENCE

A simple estimate of the number of animals observed per unit of transect length can be used as a rough index of wildlife presence in an area, over time (Jamieson 1971, Brashares 2003). It is a rough estimate however, since changes in habitat type along a transect line and changes in visibility in the habitat over time may alter visibility and therefore the value of this approach.

In this study a major concern was that of developing an index of large mammal abundance over time. If we made even rudimentary estimates of population density, this would provide an index that is more sensitive to changes in visibility between habitat types and over time. We therefore developed population density estimates for two uses.

1. To provide an order of magnitude estimate of population density.
2. To provide an index of population status that is sensitive to changes in visibility.

From the data on effective strip width in Table 2, it is obvious that visibility is more restricted in the Samole area, though this is not obvious to an observer on the ground. This sensitivity to differences in habitat suggests that this approach may be very useful in documenting habitat change in differentiating that from actual population change as indicated. With the normal distribution model, changes in visibility would be reflected in the shape of the curve and the effective strip with, allowing one to separate these changes from changes in the actual animal populations. Fire management regimes, timing of surveys across the dry season, differences between dry seasons, long term changes in visibility due to long term drought in recent decades, catastrophic bush fires in some areas and changes due to elephant impacts on savannah landscapes; can all act to affect visibility.

We attempted to apply this strategy in work done by the Faunal Survey Team in other parts of Ghana (Jamieson 1971, 1971a and 1972). The team carried out surveys in Digya National Park (224 mi of transect), the Tumu area (now Gbele Game Reserve) (134 mi of transect) and the Gambaga Scarp area (no record exists of the miles of transect covered). We did not have sufficient data to create visibility curves for these areas, so we estimated effective strip width as below (Table 9).

TABLE 9. CENSUS STRIP WIDTHS IN THE MOLE AND TUMU AREAS.

Study Area	Large Ungulates	Medium Ungulates	Small Ungulates*	Primates
Mole N.P.	60-87 m	44-60m	40-49m	60m
Digya N.P.	80 m	60m	40m	60m
Tumu study	200m	150m	50m	150m
Gambaga study	Data lost	Data lost	Data lost	Data lost

Table 10 provides a comparison of wildlife density estimates for the three areas. This data indicates that these areas, with heavy hunting activity, wildlife populations had declined to a level about an order of magnitude below those found in Mole National Park.

Table 10. Wildlife Population densities (animal/mi^2) in four areas of Ghana. (from Jamieson, 1972a).

Species Group	Mole National Park	Dwija Arm, Digya N. Park	Gbele Game Res.	Gambaga Scarp/Red Volta area
Large Ungulates	**31.7**	**4.7**	**.4**	**.5**
Small Ungulates	**15.0**	**4.0**	**4.0**	**1.3**
Primates	**24.9**	**8.0**	**9.6**	**11.0**
TOTAL	**71.6**	**16.8**	**14.0**	**12.8**

This provides a demonstration of the utility of this approach in documenting order of magnitude differences in wildlife populations due to excessive hunting or other causes. Surveys of these same areas in the present day, with sufficient data to develop good estimates of effective strip width, would allow one to document present day populations, even if visibility in these areas had been altered over the intervening years by fire, elephant activity or other habitat changes.

RECOMMENDATIONS FOR FUTURE CENSUS WORK

The data presented here serves to indicate that it should be possible in the future to carry out effective census in woodland savannah, with precautions. The major problems are listed below.

Estimating Variance

With a larger sample, the variability found in this data should be reduced to a point where the normal distribution model can be used to provide population estimates with acceptable variance values. The major problem concerns the large ungulates. These are the most important species and it is therefore especially important that the data for these species is precise. Kob and Waterbuck provide major problems in developing credible estimates, given their reaction to the observers, as discussed. More data points should provide a better basis for deciding if the normal distribution model or the belt transect approach is most applicable in the Guinea woodland savannah situation.

Sampling Intensity

The very limited visibility found in this habitat type creates a special problem in sampling. The best solution to this problem is increasing the number of transects carried out. Testing using portions of the data from the permanent line transact indicate that variance values of 20%, at 95% percent confidence limits can be obtained for most species with from 15 to 25 replicates. Sampling by vegetation type carried out on a portion of the data from a larger study i.e. the Mole study, reduced variance by almost half.

Alternative approaches to strip census

Alternative approaches to carrying out these surveys should be considered. During this study the two observers walked together on each transect. It should be possible to separate the two observers by 50 m, and thereby increasing the sampling area substantially. Maintaining the 50 m distance between observers should be possible using a makeshift rangefinder, i.e. a pencil held at arms length and marked to indicate a man's height at a measured 50 m distance, or a modern range finder. This should give the required precision. This technique would also be valuable in studying the movements away from the line as found with kob and waterbuck. It would provide a 50 m sample area in which we could be quite sure of seeing all large ungulates. There would be some safety issues and two parties of two observers each, with one rifle in each group, may be required.

Combining walking transects and aerial census

Elephant and buffalo travel in large groups that are hard to detect using this approach. They are amenable to detection using aerial inventory. Aerial inventory (Bouche 2006) however, is poor at detecting small mammals, so some combination of the two strategies would appear to be the best approach. An approach that combined annual surveys using walking transects and aerial surveys and a decadal basis would provide good information over time on changes in populations over time for the range of large mammals found in the Guinea woodland savannah.

Tools for data analysis
A program for analyzing data from strip census is now available. It is called Distance 5.0 and and is available at http://www.ruwpa.st-and.ac.uk/distance/.

Survey Costs
Unfortunately we did not document the costs of doing these foot based surveys. However, with low labor costs, this technique can be applied at very low cost. This strategy has the added value of keeping money in country and providing jobs and experience in the bush for Department staff. Again, some combination of foot and aerial surveys is probably the most cost effective strategy.

CONCLUSIONS

The line transect method can be used effectively for the census of small ungulates in the Guinea woodland savanna, and with caution, for large ungulates. Aerial surveys provide good counts of buffalo and elephant, which cannot be surveyed effectively using line transects. Using both approaches in the same area would provide good estimates for small ungulates, two estimates for large ungulates and good estimates of buffalo and elephant numbers. Over the last 35 years various approaches to strip census have been tested around the planet. The work completed here was a relatively simplistic approach to a complex problem, however it does provide first-order estimates the population density and the approach can be used as a simple index of population numbers over time.

These population estimates are of the same order of magnitude as those found in other parts of Africa in that era and with recent work for larger ungulates in other parts of West Africa. Aerial census work in the 2002-2006 era suggest that large ungulate numbers at Mole National Park in the early 70's were of the same order of magnitude as those found in well managed wildlife areas in Burkina Faso in 2000-2006, but are much reduced from those levels in 2006 (Appendix I.).

The census and biomass figures presented here have important implications for future management of the wildlife resource in Ghana. Assuming a biomass of 15,000 pounds/mi^2 and a annual harvest of 10%, the Guinea woodland savannah, with proper management, could generate a potential production of 1500 pounds of fresh meat per annum. This is similar to the harvest of 1440 pounds per square mile described in Desmond's 1964 study of game cropping in Rhodesia, now Zimbabwe. In that study he found that the biomass of wild ungulates on sub-optimal land was significantly higher than that of domestic cattle better range. Further, he was able to show that for the 103 mi.^{2} ranch there, that the profits from the game cropping operation were roughly six times that possible from the cattle operation. The factors that make the situation possible are also present in Ghana. As indicated in the Terms of Reference for the work, provided by Dr. E. Asibey, with effective wildlife management, such operations could provide a significant source of protein for the people of northern Ghana; and do so in the context of the present infrastructure and culture around bushmeat as a traditional and important part of the Ghanian diet.

LITERATURE CITED

Old and recent
include
Gbele report
Digya report
Bouche
Bia tawya
Team report
Nazinga report
Brasheres

Appendix I. Comparison of 1970's data to more recent survey data.

Bouche 2006 provides recent data from aerial surveys in 2006 and earlier aerial surveys in Mole National Park and other areas in Burkina Faso. Though variance is high on all of these estimates, there is a suggestion, and a suggestion only, that populations of buffalo, hartebeest, roan antelope and waterbuck at Mole NP have declined substantially over the intervening years, as indicated in Table 1 below. While elephant numbers at Mole have increased substantially, the other large mammals appear to have declined substantially. It also appears that numbers for these four species at Mole NP in 1972 approximated the densities found in relatively well managed wildlife populations at Nazinga and Konkombouri in Burkina Faso (Boule 2006). In both cases one must assumes that these comparisons of numbers generated using different survey techniques are credible, which is a poor assumption. It also compares data in 1972 for the south-east corner of the park, to data for the entire park in 2006. The Samole-Lovi area is generally better habitat, and better protected than the remainder of the park. It may be possible to use Bouche's data to look only at the aerial flight data for the Samole to Lovi area and make a direct comparison that would give a much better understanding of the population changes over the intervening 34 years.

Table 1- Large mammal densities (/km^2) in wildlife areas in Ghana and Burkina Faso.

Species	1971-72 ground census Mole NP	2006 aerial survey Mole NP	2003-5- Nazinga	2005 Konkombouri
Buffalo	0.80	0.14	0.30	0.87
Roan Antelope	1.80	0.40	3.12	4.99
Hartebeest	6.00	0.76	3.80	5.25
Waterbuck	1.30	0.22	1.70	0.29
TOTAL	**9.90**	**1.72**	**8.90**	**11.4**