RUFIJI BASIN DEVELOPMENT AUTHORITY

Results of three aerial surveys of wildlife within the immediate impact area of the Stiegler's Gorge Hydroelectric Dam

FINAL REPORT

Ecosystems Limited
P.O. Box 30239
NAIROBI
Kenya

February, 1980

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SECTION 1

TERMS OF REFERENCE AND OBJECTIVES

1.1 Terms of Reference

The terms of reference for the three aerial censuses of the immediate impact area of the proposed Stiegler's Gorge Hydroelectric Dam were as follows:-

> "For each of the three censuses (April, July and October), EcoSystems Limited will mobilise a Cessna 206 aircraft from its base in Nairobi, Kenya, to the Rufiji River, Tanzania via Dar es Salaam; census the 6200 km^2 census zone with one flight line every three kilometers; demobilise the aircraft to Nairobi, Kenya via Dar es Salaam; analyse each set of census data to give numbers and distribution maps of the wildlife and other variables recorded; and correlations between wildlife/vegetation/environmental variables as requested; preparing a brief preliminary report within four weeks of each census.
>
> "After the third census, EcoSystems will prepare and analyse all the data to show time series trends in distribution/habitat/environmental associations, and will present this assimilated Report within eight weeks of completing the third census".

1.2 Major Objectives

The major objectives of the three censuses were as follows:

(a) to obtain base line data on the numbers and distribution of wildlife within the immediate impact area of the proposed Stigo Dam.

(b) to obtain base line data on the present patterns of seasonal movements of wildlife with respect to the major rivers, the proposed reservoire, the 'Lake Tagalala Area' and habitat/environmental features of the immediate impact area, so that

(c) a preliminary assessment could be made of the likely ecological impacts of the hydroelectric dam on the wildlife in the Selous Game Reserve.

1.3 Scope of the Study

The study was conceived in terms of a joint venture between the Department of Zoology, University of Dar es Salaam and the Rufiji Basin Development Authority (RUBADA) on the one part, and EcoSystems Limited, on the other. EcoSystems Limited designed the censuses and provided the aircraft, pilot and equipment for implementing them and the expertise for processing and analysing the data. The Department of Zoology, University of Dar es Salaam, provided the three observers for each census, and will provide, based on the assimilated results presented in this Report and other information gathered elsewhere, a preliminary assessment of the ecological impacts of the proposed dam within the Selous Game Reserve.

1.4 Census Timing and Reporting

The three censuses were carried out as stated in the Terms of Reference.

Census *1	wet season	April 19-April 24, 1979
Census *2	early dry season	July 5-July 9, 1979
Census *3	late dry season	October 25-October 29, 1979.

Preliminary Reports on the first two censuses, dated 28 May 1979 and 13 September 1979, respectively, were presented to RUBADA and to the Department of Zoology, University of Dar es Salaam.

This third Report represents the assimilation of all the data collected on the three censuses. This Report replaces entirely all population estimates, distribution maps and analyses presented in the first two Reports.

1.5 The Study Team

The following personnel from the Department of Zoology, University of Dar es Salaam, took part in the three censuses:

Dr W A Rodgers	Senior Lecturer, consultant to RUBADA and team leader for this study
Dr K Bullstrode	Lecturer, observer
Mr B N Mbano	M.Bc. Student and Game division, obser

EcoSystems Limited provided the aircraft and pilot (Dr M Norton-Griffiths) and the facilities for data processing and analysis.

SECTION 2

METHODS OF DATA COLLECTION AND ANALYSIS

2.1 The Approach

A census zone of 6354 km^2 (Fig. 1) was chosen to incorporate the immediate impact area of the proposed Stiegler's Gorge Hydroelectric Dam in the Selous Game Reserve. Upstream of the dam site, the census zone effectively incorporated an area 20 km beyond the maximum extent of innundation by the reservoir. Downstream of the dam site, the census zone included the inland delta of the 'Lake Tagalala Area' and additional, lower lying areas south of the Rufiji River.

In view of the major objectives of the study, the three censuses were carried out in the wet (April 1979), early dry (July 1979) and late dry (October 1979) seasons. These timings were selected to show the minimum and maximum dependencies of wildlife on the main river systems and the inland delta system.

Since the analysis of the distribution of animals, and seasonal changes in their distribution was of equal, if not more, importance than the mere enumeration of their abundance, the census design utilised unstratified, systematic sampling. The advantage of this sampling method over alternative methods - such as stratified, random sampling - is discussed further in Section 2.2 (sampling technique) and 2.6 (data analysis).

Parallel flight lines were spaced systematically across the census zone at 3 km intervals to give a sampling intensity approaching 10%. The flight lines were orientated north-south to cut across the major ecological axis of the census zone (the major rivers) and to permit a more sensitive analysis of the dependence of wildlife on the major rivers and inland delta. The same flight lines were flown on each census.

The four seater, Cessna 206 aircraft contained a four-man crew with the following duties:

Pilot	Dr M Norton-Griffiths	Navigation, height and speed control
Front seat observer	Dr W A Rodgers	Recorded flight parameters, height above ground, and qualitative parameters
Rear Seat observers	Dr K Bullstrode Mr Mbano	Recorded quantitative data on the numbers of animals seen in the sampling strips.

A nominal flying height of 300 feet above ground level and a nominal ground speed of 180 kph (c. 110 mph) was selected for each census. The pilot maintained height control by reference to a radar altimeter and ground speed control by reference to elapsed times over known distances.

The pilot called out over the crew intercom the start of each successive minute along each flight line, and the three observers kept their observations separate within these successive, one minute intervals. At the Nominal ground speed 180 kph, each minute represented approximately 3 km. This formed the basis for plotting the distribution of wildlife and environmental parameters.

2.2 Sampling Technique

Systematic sampling is undoubtedly the most widely used method of data acquisition throughout the natural and physical sciences. To name just a few, the discipline of meteorology, oceanography, geomorphology, X-ray crystalography and astro-physics all rely primarily on data derived systematically through space and time.

These applications share in common the analysis of pattern, and the superiority of systematic sampling versus random sampling in the analysis of pattern is widely known and documented [3/]. This present study was primarily concerned with the analysis of distribution patterns through space and time and with the changing relationships between patterns through space and time. Systematic sampling was therefore the most appropriate method to use.

3/ See reference 3/ in Annex III - Bibliography

Stratifying before a census is only of real advantage when a restricted set of data is to be analysed. The most usual application for stratifying in advance is when the main objective of a census is to estimate the numbers of animals. In applications such as the present study, where a wide range of analyses are required, stratifying in advance is a definite hindrance. Indeed, many of the stratifications carried out on this data set are mutually incompatible; they could not have been carried out had the data been stratified before the census.

Stratifying in advance imposes a homogeneity on the data with the objective of reducing sampling error. This, as is stated above, is of advantage when the overriding objective of a census is to obtain estimates of animal numbers with as great a degree of precision as is practicable. However, by stratifying in advance, information is lost about the very object in which one is interested, namely the variation in time and space of the distribution of animals. In an unstratified census, this variation is used as a tool for studying the distribution, and it is studied by means of the analysis of variance (section 2.6.3).

"Sample error" as such is, therefore, of no account for the analysis of variance, as its name implies, decomposes the total variation into its various sources, and thus effectively filters out the influence of sample error.

Biological phenomena are studied through their variation in space and time. In contrast, physical phenomena are usually studied by means of their absolute values. When studying biological phenomena such as the patterns of distribution of animals within the STIGO impact area, we consider it quite inappropriate to utilise a method which is not well suited to the objectives of the study.

Stratified, random sampling and unstratified, systematic sampling represent two very different approaches to ecological study. Stratified, random sampling answers best the question "How many animals are there in an area?", and it does this very effectively and much more efficiently than unstratified sampling, random or systematic. In contrast, unstratified, systematic sampling answers best the questions "How are the distributions of animals related to each other and to their environment?", and "How do these relationships vary through space and time?"

2.3 Front Seat Observations

2.3.1 General

The front seat observer recorded flight parameters, such as take-off and landing times, transect start and finish times, etc, and once in each minute, the reading from the radar altimeter and from the two photospectrometer probes.

In addition, the front seat observer recorded once in each minute, a number of qualitative, environmental parameters about the area being overflown. Only those used in subsequent analyses are discussed below.

2.3.2 Topography (map 4)

Seven topographical categories were distinguished:

ridge: sub-units dominated by elevated plateau features and broad ridges in large scale, catenary associations

hills: sub-units dominated by distinct relief features with two directional slopes, not including the small scale relief associated with catenary associations

slope: sub-units dominated by a uni-directional, steep slope

valley: sub-units dominated by the presence of a major valley which has cut into the surrounding features

flood plain: non-incised valley features including the river beds, swamps and levees of the lower Rufiji river

flatland: sub-units with no relief or dissection, excluding flat plateaux tops and flood plain features

undulating: sub-units showing the typical, gentle relief of the catenary ridge-slope-valley topographical sequence.

2.3.3 Dissection (map 3)

The four categories of dissection give details about the scale of the overall topography:

flat: no significant dissection or relief

gentle: gentle relief, frequently catenary

medium: medium scale relief, including small hills, ridges and incised valleys

steep: steep relief, including major hill features and fault scarps

2.3.4 Vegetation (map 4)

The dominant vegetation in each successive minute was classified into one of nine vegetation types (section 3). Consistency between censuses was good, with 84% of the discrete categories e.g. grassland, bushland, etc, receiving the same classification on successive flights. The classification of catenary associations such as Miombo and Combretum was more variable, only 48% being classified in the same way. However, the most frequent reclassification was from "Miombo with some Combretum" to "Combretum with some Miombo" and vice versa. This reflects the small scale heterogeneity of the catenary associations.

Where a sub-unit received different classifications on successive flights, data from the surrounding units were used to select a single classification.

2.3.5 Tree cover

The percent canopy cover of the dominant vegetation was classified into 10% class intervals within each sub-unit.

2.3.6 Grass Greeness

Five subjective categories of grass colour, reflecting growth stage and forage value, were recognised. The seasonal relationships between grass colour categories and photospectrometer ratios are discussed in Annex 1.

green	young, growing grass, pre-flowering stage, including fresh, post burn flush
yellow green	the onset of flowering and increase in stem growth gives a yellow tinge to the grass. This class includes wilted, post burn flush
yellow	fully mature stage with insignificant proportion of green leaf. Mature stem inflorescence gives the yellow colour.
yellow brown	the onset of senescence and leaf fall, virtually no green leaf visible. A stage reach early in the year by annual grasses.
brown	senescent with stem and old dry leaf remaining, no green leaf.

2.3.7 Surface water

A subjective index of the availability of surface water within each sub-unit was obtained by scanning up to 500 meters from the aircraft. Four classes of availability were used:

0	no surface water seen
1	occasional small pools or pools in river beds
2	frequent pools and/or large water holes, pools in large rivers
3	abundant water, lakes, swamps or flooded areas

2.3.8 Photospectrometer

Readings were taken from the two photospectrometer probes once in each minute. These probes were mounted outboard near the wing tips, pointing vertically downwards. From 300 feet above ground level, the average flying height for the censuses, the probes scan an area of approximately 2000 meters square.

The photospectrometer probes measure the amount of light reflected from the canopy layer at 8000A and 6750A [14/]. The ratio of these readings bears a linear relationship to the standing crop of green plant biomass. In one study in the Serengeti, Tanzania, [7/] the equation

$$\text{green g/m}^2 = 109.8R - 83.8$$

derived from some 1500 plant biomass clippings explained 95.5% of the variation in green plant biomass (R is the ratio of reflectances measured by two probes). From the air, at 300 feet above ground level, the ratio was able to account for 85.6% of the variation in the standing crop of green plant biomass[8/].

The seasonal relationship between the ratio of the photospectrometer probe readings and the subjective index of grass colour is discussed in Annex 1.

2.4 Rear Seat Observations

Two fibreglass rods attached to the aircraft wing struts demarcated a strip within which the rear seat observers counted all the animals seen. The rods were set up, and the strip width calibrated, using standard techniques[11/].

Window marks were used in association with the rods to ensure that the observers maintained their heads in the correct position when counting.

All observations were recorded onto tapes and later transcribed onto data sheets.

2.5 Bias

2.5.1 General Considerations

Errors and bias in aerial censuses are two very different things. Errors, by definition, are random and their cumulative effects cancel out. Biases, in contrast, are errors in a consistent direction whose cumulative effects do not cancel out. For example, an aircraft flown by reference to a radar altimeter may on occasions be a little higher than the selected height and may on occasions be a little lower; but overall these variations in height will cancel out. If, however, the radar altimeter is overreading by 30 feet, then the aircraft will be consistently below the selected height, leading to a bias.

The many many sources of bias in aerial census are well known and well documented[9/10/1/], so too are the methods of dealing with them[2/9/6/]. Biases can arise through the design of the survey, from inaccurate maps, from observer performance and from the analysis of the data.

There are three aspects to the treatment of biases:

(i) design the entire census operation to minimise them (within the constraints of practicality),

(ii) maintain the biases constant both within and between censuses, and

(iii) identify the major sources of bias and, when practicable, correct them.

It may not be generally realised that it is quite impossible to identify, let alone eliminate, all sources of bias from an aerial census. This, however, is of no account so long as the bias is held constant.

2.5.2 Bias from aircraft operation

The mean flying heights, strip widths and ground speeds for the three censuses are given in Table 1A. These parameters are acceptably consistent. Table 1B lists the strip widths for each flight line.

Bias from navigation errors - drifting off course, flying in the wrong direction - can be considered negligible. There were occasions when deviations of around 500 meters from the selected flight lines became apparent, in which case the flight lines, or parts thereof, were repeated. Some slight problems were also encountered in the wet season flight when navigating over totally flooded areas, for most ground features were obscured. However, this was probably of little import since these areas were largely devoid of wildlife. In general, navigation errors were kept to within 100-200 meters from the selected flight lines.

Height control was maintained by reference to a radar altimeter whose readings were recorded by the front seat observer once in every minute interval. Any bias from inaccurate height control is normally eliminated by using the actual mean height along a flight line to calculate the actual strip width. This, however, presupposes that deviations from the selected height are consistent over all types of topography.

This was checked in each census by analysis of variance of flying height as a function of topography (Table 2). Significant differences between mean heights over different topographical areas were found only in the wet season flight - the first of the series.

Accordingly, for this flight the strip widths were calculated separately for each topographical area. In the second and third flights the strip widths are calculated for entire flight lines.

2.5.3 Observer bias

The consistency of observer performance was excellent, and Table 3 shows the number of each species count ed by the two observers in each census, adjusted for their actual strip width.

The difference between the numbers of buffalo, elephant and impala, all notoriously difficult to count, are of a magnitude to be expected from sampling error. This demonstrates consistency in counting bias throughout the three censuses, for these species are non-migratory.

There was, however, a significant change in numbers counted for some species. For hippo, the steady increase in numbers throughout the three censuses was undoubtedly an effect of lowered river levels making the animals more vi sible. With giraffe, wildebeest and zebra, emigation from the census zone was the most likely explanation (see section 4).

The performance of observers within counts was less consistent. Overall, the left observer tallied 58% of all the animals seen (adjusted for actual strip width).

Photography was not used on these censuses, with the exception of the hippo total count in the dry season, for neither observer was used to handling a camera in an aircraft. Bias correction factors have therefore been derived from data obtained elsewhere under conditions of similar vegetation, animal density and observer experience, and from sample counts carried out at similar heights and speeds, and with similar strip widths. The correction factors listed below were applied to the individual sightings of each observer.

buffalo:	factor x 1.49	derived from total counts of buffalo in the Serengeti woodlands
eland:	factor x 1.11	derived from sample counts of eland in the Serengeti woodlands
elephant:	factor x 1.11	derived from elephant counts in Ruaha National Park, Rungwa Game Reserve, Rukwa and Selous Game Reserves, and Serengeti woodlands
giraffe:	factor x 1.11	derived from sample counts in Serengeti woodlands
hippopotamus:	factor x 1.12	derived from total count in Selous Game Reserve (this study)
impala:	factor x 1.66	derived from sample counts in Serengeti woodlands and Ruaha National Park
kongoni:	factor x 1.07	derived from sample counts in Serengeti woodlands
waterbuck:	factor x 1.11	derived from sample counts in Serengeti
wildebeest:	factor x 1.16	derived from sample counts in Serengeti woodlands.
zebra	factor x 1.14	derived from sample counts in Serengeti woodlands

No correction factors were applied to the sightings of sable, greater kudu, rhinoceros, or carnivores since no data are available. Indeed, aerial census of these specier i's of quite dubious value.

2.6 Data Analysis

2.6.1 Data Processing

The transcribed tape records of the rear seat observers and the data sheets of the front seat observer were all checked for consistency in the field. Subsequently, the data were transferred to computer data files where they will remain available for further processing for a period of twelve months from the presentation of this report.

For mapping purposes, each minute along each flight line was assigned to a 3 x 3 km grid square. This was done by reference to position marks on the flight maps and by reference to the front seat observer records.

The numeric - rear seat observer - data were treated as follows: after checking for internal consistency, each sighting was multiplied by its correction factor. The left and right sightings for each minute interval were then summed, and the strip width for each flight line was calculated. Densities within each grid square were subsequently calculated from the mean strip widths, and these densities were mapped to show the distribution of each species. Densities were also summed over all three flights to show the annual, mean density within each grid square.

The analyses of these numerical data, see below, were based on segments of flight lines passing though various strata.
Accordingly, the strip width of each flight line segment was found from the radar altimeter readings along the segment.

2.6.2 Stratified population estimates

Each density distribution map for each species for each census was inspected and was divided up into strata of similar density. Population estimates were then calculated from these density stratifications.

The stratum boundaries were fed into the computer on a grid square basis as follows:

stratum 1	grid square	X-10 Y-05 to X-10 Y-28
		X-1 Y-04 to X-11 Y-20
		X-12 Y-04 to X-12 Y-22
stratum 2	grid square	X-10 Y-01 to X-10 Y-04
		X-11 Y-01 to X-11 Y-03
		X-12 Y-01 to X-12 Y-03
		etc
stratum 3	etc	

These grid squares were then related back to individual flight line segments. Thus, the squares X-10 Y-05 to X-10 Y-28 might be related, say, to Flight Line 10, minutes 12-31 inclusive.

The population estimates were then calculated from the flight line segments; not from the individual minutes or from the individual grid squares.

The ratio method - Jolly Method 2 - was used to calculate these stratified, population estimates[5/].

2.6.3 Relationship to environmental variables

The seasonal relationship between the various species and their environment[12/] has been approached through the Analysis of Variance, still one of the most powerful statistical tools available to ecologists. The analysis of variance provides insights into the nature of variation of natural events, in short, into Nature itself. It one can speak of beauty in a statistical method, analysis of variance possesses it more than any other.

Unstratified, systematic sampling lends itself directly to anovar techniques to explore the nature of the relationship between animals and tneir environment. Essentially, the approach is the same as with the density stratification described above, but with one major difference. The objective of the density stratification was to answer the question "how many animals are there" with an acceptable degree of precision. We are now asking the more interesting questions "how much of the variation in the density distribution of a species can be explained by the spatial distribution of a given environmental attribute" and, secondly, "how does this vary throughout the year?"

Let us take 'vegetation type' as an example. The census zone has been divided into eight major vegetation types (see section 3) on the basis of the front seat observer records. These types are treated as 'strata' in the same way as described above, and the grid squares within each vegetation type are related back to the individual flight line segments passing through them.

We want to ask three questions:

(i) Is there any overall effect of the distribution of the vegetation types on the distribution of the animals?

(ii) Which animals are particularly affected, and to what extent?

(iii) Which vegetation types are most important for them?

The first question is answered by a Model 1, 2-way anovar of the square root transformed data of all species in all vegetation types, the square root transform being used to increase the power of the anovar [4/13/]. Of particular interest here is the strength of any interaction and the proportion of the variance attributable to the vegetation types.

The second question is answered by decomposing in turn the sums of squares contributed by each species. The variance component is of particular interest here for it shows the degree to which each species' distribution is effected by the spatial distribution of the vegetation types.

The third question is answered by individual one-way anovars on the untransformed data between each species and the vegetation types. Our null hypothesis here is that the animals are distributed randomly with respect to the vegetation, in other words that the observed densities will be the same in each vegetation type. Analysing the anovar under the assumptions of Model 1 shows which vegetation types are being 'selected' and which 'avoided'. Analysing the anovar under the assumptions of Model 11 shows the proportion of the variation in distribution attributable to the vegetation types.

These answers are carried out independently on each set of census results. i.e. 'within' censuses. Analysis of the seasonal effects, in other words 'between' censuses, is made by comparing the 'within' census results. Three way anovar of seasons, vegetation and animals is theoretically possible, but we feel that the data do not quite meet the required assumptions.

A number of other points must be mentioned. Firstly, all statements about the 'importance' of environmental attributes on the distribution and movements of species are based ultimately on anovars of untransformed data. Secondly, the data are derived from densities within flight line segments passing through strata. Both of these increase the error sums of squares making it more difficult to disprove the null hypothesis. We are erring here on the side of conservatism.

Finally, all terminology and computational procedures follow those of Sokal and Rohlf[13/].

2.6.4 Computer printouts

The somewhat voluminous printouts accompanying this report presents in a number of forms, all the raw and processed data from the three censuses. The computer printouts serve three functions. First, they present the total

The printouts are organised into three sets:

Set A	-	maps
Set B	-	analysis
Set C	-	data files and tabulations

The underlying file structure is as follows:

STIGO*1 -	raw data from count 1 - April
STIGO*2 -	raw data from count 2 - July
STIGO*3 -	raw data from count 3 - October
STIGOALL-	merged data from all 3 counts

Each printout has the file name associated with it, as well as the descriptive labels, "wet season" (STIGO *1), "early dry season" (STIGO*2), "dry season" (STIGO *3), or "Annual data" (STIGOALL)

Set A Maps:

The titles of each of the 60 maps are followed by the maps themselves. The titles are self-explanatory, and the codes are to be found in Annex 2.

Set B Analysis:

sub-set B.1	analysis of annual distribution patterns
sub-set B.2	analysis of wet season distribution patterns
sub-set B.3	analysis of dry season distribution patterns

Within each sub-set, the analysis is structured as follows:
2-way analysis of variance on the square root transformed data
1-way analysis of variance on the untransformed data

Within each analysis of variance, the data are analysed stratification by stratification. A listing at the beginning of the Set B gives the titles of the 20 stratifications and of the strata within each.

Set C Data files and tabulations:

Listed first are the raw data files for STIGOALL, STIGO*1, STIGO*2 and STIGO*3. They show the corrected numbers of each species counted in each sub-unit of each flight line. Also shown is the mean flight line width.

After this comes a listing of the 2-way analysis of variance table for each stratification for each data file. Thus, in the order STIGOALL, STIGO*1, STIGO*2, and STIGO*3, the anovar tables (untransformed data) are listed for each stratification in turn.

Using the Data Base

Maps:

Restratification can be calculated directly from the mean distribution maps using the printed densities and the mean flying heights for each census. Alternatively, for more accuracy, the actual flying height for each flight line (Table 4) can be used. Alternatively, new stratifications can be based on the raw data files.

Analysis of variance:

Further anovars, 1-way, 2-way or higher order, can be based on the anovar listings. The columns and rows are labelled for each tabulation, as well as the cell frequencies, summation of x, summation of x^2 and summation of $(x)^2/n$. These are also calculated for the column and row totals, and for the grand totals.

SECTION 3

INVENTORY

3.1 Introduction

This section presents an inventory of the environment of the immediate impact area and of the plant and animal resources within it. Discussion of the seasonal dynamics of the area are left to Section 4.

The 1/250,000 map sheets (of Utete, Kipatimu and Mahenge) accompanying this report have the boundaries of the survey area marked on them as well as the 3 km grid system used for mapping purposes. Also shown are the start and end points of each flight line. In Fig. 1, the survey area alone is shown at a scale of 1/250,000.

3.2 Vegetation (FIG. 2)

The distribution of the seven major vegetation zones distinguished from the front seat observer records are shown in Map 1.

Miombo Woodland:
Characteristic of slopes and ridges to the south and west of the census zone, occurring on sandy, deep yellow and red soils. Deciduous, loosing most leaf in July and showing a late dry season flush in October-November. Canopy layer to 10-12 m, rarely more than 30% cover and then only on flat ridges. Dominated by <u>Brachystegia spiciformis</u> and <u>Julbernardia globifera</u> with frequent <u>Terminalia</u>, <u>Combretum</u> and <u>Pseudolachnostylis</u> in the under layers. A dense grass layer, up to 1.5 m, is present.

Miombo/<u>Combretum</u> Woodland (and <u>Combretum</u>/Miombo Woodland):

Much of the south and west of the census zone shows the typical topographic catenary pattern of ridge-slope-valley features on a small scale (< 1 km). Miombo is characteristic of the ridges and upper slopes while <u>Combretum</u>

communities characterise the lower slopes and valley bottoms. The *Combretum* areas typically have a more open appearance with lower canopy cover. Shrubs are inconspicuous and the grass layer can reach 2m. *Combretum molle*, *C. fragrans* and *C. ghasalense* with *Cassia auriculata*, *Sclerocarya* and *Dyospyros* are common elements. In the vegetation map (Map 1), areas dominated by Miombo and areas dominated by *Combretum* are distinguished by different map codes (Annex 2).

Combretum woodland:
In addition to the valley communities described above, broader areas are found of similar species composition which are associated with major river valleys and mbuga/swamp edges. *Combretum imbere* and *Combretum contrictum* are common. A more degraded type with *Combretum zeyheri*, *Terminalia sericea* and *Pteleopsis myrtifolia* in the canopy layer is also found.

Open woodland (wooded grassland):
Characterised by the dominance of *Terminalia spinosia* and *Spirostachys africana*, on hard, poorly drained alkaline soils. Grass cover is short and frequently sparse.

Bushland:
Characterised by the absence of a tree layer, and a shrub layer which reaches some 20% cover. Species composition is mixed, but stunted *Terminalia* and *Acacia* species are frequent.

Acacia woodland:
Restricted to the north of the census zone where clay loams and low ridges support a variable cover of *Acacia robusta*, *A. zanzibarica* and *Combretum hereoense*. *A. drepanolobium* is found on wetter sites.

Thicket:
Xerotypic climax vegetation for much of the Selous, it is now restricted to upland areas on red, sandy soils. In the census zone it occurs in two quite distinct localities. south of Shughuli Falls and on the slopes of Kidai and Tagalala hills. Thickets are semi-deciduous with a closed canopy of 7 m and occasional emergent trees. There is little overall species dominance, but Rubiaceae, Euphorbiaicae and Anonaceae are common families. Ground cover is minimal.

Grassland:
Characterised by the absence of tree or shrub cover, grasslands reach their greatest extent on the Mkigura mbuga in the north east of the census zone. Setaria, Hyparrhenia and Ischaemum spp are common, tall dominants.

Swamp:
Characterised by extensive areas of open water and much floating vegetation, with a tree cover of <10%. The swamp vegetation includes Borassus and Hyphaenae palm swamp, Combretum constrictum, C. mosambicensis and grassland areas.

3.3 Area and Cover Density of Vegetation Types

The area of each vegetation type, and the frequency distribution of cover density classes within each, are shown in Table 4. Mean cover density values for the woody vegetation have been calculated from the class intervals.

3.4 Watersheds (Map 2)

Four major watersheds have been defined, those of the lower Rufiji river below Stiegler's gorge, the upper Rufiji river above Stiegler's gorge (Ulanga river), the Ruaha river and the Kilombero / Luwegu rivers. The distance of each grid square from its nearest major river was measured to give a stratification of the census zone in terms of distance from permanent water sources. Table 5 shows the percentage breakdown of the census zone into distances from permanent water within each watershed.

3.5 Topography and Dissection (Maps 3 and 4):

Maps 3 and 4 show the distribution of the categories of dissection and topography recognised by the front seat observer. These categories have been used in defining the land regions and land systems (section 3.6 below).

3.6 Land Regions and Land Systems (Fig. 3 and Map 5):

The census zone is readily divided into two major Land Regions, the low lying alluvial plains and floodplains in the east of the impact area, below Stiegler's Gorge and east of the Tagalala fault line, and the upland Cretaceous/Karoo sandy soil areas to the west and south of the Tagalala fault. This second, larger, region could be further subdivided on the basis of the Karoo/Cretaceous geological boundary. However, since there are no major discontinuities in vegetation type, grass structure, etc, across this boundary such a further division would be of little value.

The low lying plains have been sub-divided into five main land systems:

(i) the mbugas of the Mkigura drainage system containing grasslands and grasslands/Combretum communities (Map code PM)

(ii) a tiny portion of the north Rufiji woodland terrace system (Map code PW).

(iii) the alkaline, clay sands of the outwash plain - interfluve system with open woodland, Acacia woodland and bushland (Map code PA)

(iv) the floodplain and associated landforms of the lower Rufiji valley with swamp, Combretum and grassland communities (Map code PR)

(v) the complex drainage system of the Mwama-Utunge area to the south of the Rufiji, with degraded Miombo-Combretum, Combretum and minor swamp/riverine features (Map code PD).

Each of these land systems are clearly definable in terms of topography, soil and vegetation and are mapped separately in Map 5.

The upland Cretaceous/Karoo region is more difficult to divide into land systems which have value in interpreting wildlife distribution patterns. In terms of topography and dissection, the following four land systems were recognised:

(i) hill features associated with the Tagalala - Hatambula fault (Map code UH).

(ii) the floodplain system of the Kilombero river (Map code UK)

(iii) the highly eroded Kidodi/Karoo sandstone to the north west and west of the Ulanga river system (Map code UE)

(iv) the less eroded, deep soil areas of the Cretaceous sandstones to the east and south of the Ulanda river system (Map code UM).

3.7 Areas Flooded by the Proposed Reservoir (Maps 58-60)

Upstream of the STIGO dam site, the 158 m, 171 m and 186 m contours were drawn in on the 1/20000 contour maps sheets (Norplan / Geosurvey 1976/77), to show the extent of flooding in the reservoir at mean low water, high water (Phase 1) and high water (Phase 2) respectively. The 3 km grid used in this study was superimposed on these contours, and a square was classified as 'flooded' if more than 50% of its area was within the relevant contour.

The reservoir at low water will cover an area of some 694 km^2 (11% of the census zone); at high water Phase 1 an area of some 792 km^2 (12% of the census zone); and at high water Phase 2 some 1242 km^2 (20% of the census zone).

3.8 Animal - Numbers

3.8.1 Procedures

Table 6 presents the population estimates, with their standard errors, for each census while Table 7 presents the merged population estimates over all three censuses.

The population estimates for each count were stratified on the basis of the observed density distribution of the animal concerned (section 2.6.2). A maximum of four density strata were permitted for each stratification. These were drawn in by eye on the density distribution maps and then entered into the computer. The stratified estimates were calculated using Jolly's method 2[5/].

Estimates for each species in each census were compared using a t-test. When estimates were merged, they were weighted inversely proportional to their variances[11/].

These procedures are all standard techniques[11/].

3.8.2 Buffalo

Count 1 = Count 2 = Count 3 : therefore the three estimates were merged.

3.8.3 Eland

Count 1 ≠ Count 2 : Count 1 = Count 3 : Count 2 ≠ Count 3: Count 2 was thus significantly lower than counts 1 or counts 3. Inspection of the seasonal distribution maps for eland, plus other information available about their distribution in the Selous, suggests that emigration did not occur and that the decrease in numbers was caused by a change in counting bias. Counts 1 and 3 only have therefore been merged together.

3.8.4 Elephant

Count 1 ≠ Count 2 : Count 2 = Count 3 : Count 1 = Count 3 : the three population estimates were therefore merged.

3.8.5 Giraffe

Count 1 ≠ Count 2 or count 3 : count 2 = count 3 : this shows a highly significant decrease in giraffe numbers between the wet and dry season censuses, and emigration is likely. Two estimates have therefore been calculated, one for the wet season and one for the dry season (counts 2 and 3 merged).

3.8.6 Hippopotamus

Count 1 $\neq$ Count 2 = count 3 : the increase in the number of hippopotamuses observed is, as has already been discussed, almost certainly due to lower dry season river levels making them more visible. The two dry season estimates (counts 2 and 3) have therefore been merged.

3.8.7 Impala

Count 1 = count 2 = count 3 : all three estimates have been merged.

3.8.8 Kongoni

Count 1 $\neq$ Count 2 : Count 1 = Count 3 : Count 2 $\neq$ Count 3 : as with eland, the early dry season estimate for kongoni is significantly lower than the wet or dry season estimates. Emigration followed by immigration can be ruled out, so a change in counting bi as must have occurred in the early dry season. Counts 1 and 3 have therefore been merged.

3.8.9 Rhinoceros

Any aerial survey of rhinoceros is bound to produce a somewhat dubious result. In this instance, count 1 $\neq$ count 2 = count 3 : fewer rhinos were seen in the dry season censuses than in the wet season one. The wet season figure alone has therefore been used. It should be treated strictly as a minimum estimate only.

3.8.10 Warthog

All three counts were merged.

3.8.11 Waterbuck

All three counts were merged.

3.8.13 Zebra

Count 2 = Count 3 : Count 1 ≠ Count 2 or Count 3 : the two dry season estimates are significantly lower than the wet season estimate, and emigration is almost certain. It is of interest that, as in other areas, the zebra moved before the wildebeest. Two estimates are therefore presented, one for the wet season (count 1) and one for the dry season (counts 2 and 3 merged).

3.8.14 Uncommon ungulates

The uncommon ungulates, sable, greater kudu, duikers (var), reedbuck, etc, have all been lumped together since so few of each species were seen. The three estimates have been merged together. With such cryptic and low density species, aerial estimates give a minimum value only.

Of these estimated 621 uncommon ungulates, 56% (348) were sable antelope and 36% (224) are greater kudu.

The grid squares in which sable and greater kudu were seen are given in Table 8.

3.9 Animals - Annual Distribution Patterns (Figs 4-12)

The annual distribution pattern for each species was found by averaging the observed numbers in each grid square and converting to density (animals per km^2). Maps 8 to 23 show these distributions. Marked differences in distribution pattern between species are apparent. The Lake Tagalala area also stands out as an area of high species density and diversity.

3.10 Animals - determinants of mean annual distribution

3.10.1 General

The basic philosophy of the analysis used in this report was set out in Section 2.6.3. The following discussion is based on Set B.1 of the computer printout. This sub-set concerns the mean annual distribution patterns. In Tables 9, 10 and 11, discussion is based on the columns headed 'overall'. These again refer to the analysis of the mean annual distribution patterns.

3.10.2 The Variance Components of each stratification

The mean annual distributions of all species have been stratified on a number of environmental parameters. In each stratification, a two-way analysis of variance was carried out. Each two way analysis of variance yields three F ratios; one for 'strata', one for 'animals' and one for 'interaction'. A significant 'animal' F ratio - and all of them are - merely confirms that the different species have different distribution patterns. It would be quite extraordinary to find a non-significant animal F ratio. A significant 'strata' F ratio indicates the stratification is influencing the distribution patterns of all animals; in other words that the physical distribution of the strata in space is related in some way to the physical distribution of the animals. A significant 'interaction' F ratio indicates interaction between the strata and the animals; not all animals are responding in the same way to the stratification. In general, the interaction terms are significant but are surprisingly weak.

Three variance components have also been calculated, for strata, for animals and for interaction. The important one in these analyses is the variance component for the strata. This shows the proportion of the variation in the distribution of all the animals that is accounted for by the strata.

Table 9 lists the variance components for the stratifications of mean annual distribution. Although these components appear low at first sight, they are explaining a significant proportion of the mean annual distribution patterns.

3.10.3 The variance components for each species

In Tables 10.1 to 10.13 the variance components for each species are listed against each stratification. While the overall variance components of Table 9 answer the question "to what extent does a stratification explain the distribution of all animals?", these more detailed analyses answer the question "how important is a stratification for a particular species?".

For example, Table 10.4 lists the variance components for each species within the stratification 'major vegetation zones'. It shows the proportion of the variation in annual distribution for each species that is attributable to the spatial distribution of the vegetating strata. Thus, the distributions of the major vegetation zones throughout the impact area is explaining a major proportion of the distribution of giraffe; giraffe are obviously responding to the characteristics of the vegetation. In contrast, the mean annual distribution of eland within the impact area is effectively random with respect to the vegetation. Whatever it is that is determining the distribution of eland, it is not the vegetation.

The significance (F ratios) of these variance component can be found in the appropriate computer printouts.

Tables 10.4 and 10.5 show, for example, that the major vegetation zones and the major land systems are determining a considerable proportion of each species annual distribution. In contrast, the overall distance from a major river (Table 10.6) is determining mainly the annual distribution of hippopotamus and waterbuck - a not surprising result.

These data have been retabulated in Tables 11.1 to 11.14 to show, for each species in turn, the variance components of the different stratifications. Thus the annual distribution of buffalo (Table 11.1) is most influenced by the major land systems. For elephant (11.3), the major land systems are equally important, although within the lower Rufiji watershed, distance from water is having a marked effect. In contrast, the mean annual distribution of eland remains stubbornly uninfluenced by anything (Table 11.2).

SECTION 4

SEASONAL PATTERNS

4.1 Introduction

This section of the Report considers the seasonal movements into and out of the immediate impact area and the seasonal relationships between the wildlife and their environment.

4.2 Seasonal Patterns of Immigration and Emigration

The results of the three population estimates indicate significant, and consistent, changes to the populations of giraffe, wildebeest and zebra throughout the year. The giraffe and zebra populations dropped by 50% between April and July, while the wildebeest population dropped by around 20% between July and October. Inspection of the seasonal distribution maps for these species suggests where they may have moved to.

For giraffe (Maps 34-36) there is a movement out of the low lying plains (Land Region 1) eastwards, probably into the Rufiji woodland terrace system, and a movement northwards across the railway line. For zebra (Maps 46-48), there is a major movement northwards out of the low lying plains, across the railway line and into the swamps of the upper Ruvu. This movement is also seen in the two Selous-wide counts carried out by Douglas-Hamilton in 1976 (*)

For wildebeest (Maps 43-45), the major movement is between July and October north from the low lying plains and across the railway line to the Ruvu.

Table 13 shows the seasonal densities of giraffe, zebra and wildebeest in the lower Rufiji watershed. The giraffe and zebra densities halve between April and October, while the wildebeest densities, if anything, show a slight increase. Between July and October, giraffe and zebra densities show no change while the wildebeest density decreases by some 25%.

(*) Douglas-Hamilton, I. 1976. Elephant Wildlife Survey, Selous, Tanzania. DANIDA/IUCN.

4.3 Seasonal Relationships with the Environment - general patterns

Table 9 indicates a seasonal shift in the environmental parameters determining the distribution of wildlife in the immediate impact area. Topography and dissection, never very important determinants, become less so as the seasons progress. So too does the influence of cover density.

Major changes are seen in the influences of the major vegetation zones and the major land systems. Both have much less influence in the dry season than in the wet and early dry seasons.

In contrast, there is a trend for those parameters involving water and grass greeness to become stronger.

This is shown in Table 14 in which a selection of stratifications have been ranked (in the order of their influence on the distributions of animals) for each of the three censuses. There is a clear change in that the influence of the major vegetation zones and the land systems becomes less whilst the influence of distance from water and grass greeness becomes stronger. In the dry season, distance from water and grass greeness are the major determinants of distribution.

4.4 Seasonal Relationships with the environment - detailed patterns

4.4.1 Topography (Table 10.1)

The influence of topography as a determinant of animal distribution decreases as the seasons progress. Table 10.1 shows that giraffe, hippopotamus, waterbuck and wildebeest are responding to topography.

Giraffe show a consistent selection for flatlands (from inspection of the 1-way anovars for counts 1, 2 and 3). This is a reflection of their vegetation type and land system associations.

Hippopotamus show strong selection for flatlands, slopes and valleys, all areas in which rivers and swamps are found. However, in the dry season a strong selection is shown as well for floodplains.

Waterbuck show a consistent avoidance all through the year of hilly areas, the undulating catenas and ridge top plateaux. In the wet season they are showing strong selection for slopes and valleys, while floodplains become important in the early dry and dry seasons.

In the wet season, wildebeest are selecting for flatlands and are strongly avoiding floodplains, valleys, hilly areas and the undulating catenary areas. Indeed, this avoidance of hills, catenas and valleys is consistent throughout the year. In the early dry season they show a selection for the floodplains and flatlands while in the dry season they show as well as strong selection for ridge top plateaux.

4.4.2 Dissection and woodland cover density (Tables 10.2 and 10.3)

The influence of dissection and of woodland cover density are not strong enough either between seasons or within seasons to warrant detailed discussion.

4.4.3 Major vegetation zones (Table 10.4)

The major vegetation zones are important determinants of the seasonal distribution of giraffe, hippopotamus, impala, waterbuck and wildebeest, while occasionally they are important determinants of the distribution of buffalo (early dry season) and zebra (wet season).

Buffalo (Table 15.1) are showing more avoidance than selection for vegetation zones, but in general the vegetation zones are not important determinants of their distribution.

Both eland and elephant are effectively showing a random distribution with respect to the vegetation, even though occasional instances of selection/avoidance can be found in the 1-way anovars.

Giraffe are strongly influenced by the vegetation (Table 15.2). In the wet season, they are strongly selecting acacia woodlands, open woodlands and grasslands. This changes in the early dry season when they are selecting for bushland, open woodland and grasslands, and avoiding the acacia woodland. In the dry season they maintain their selection for bushland and open woodland and once more are selecting for acacia woodland. Their avoidance of miombo, combretum swamp and thickets is consistently strong throughout the year.

Impala (Table 15.3) are consistently selecting for bushlands and open woodlands throughout the year, and are effectively avoiding the other vegetation zones.

Wildebeest (Table 15.4) show strong selection during the wet and early dry seasons for bushlands, open woodlands and acacia woodlands and avoidance of the miombo and combretum woodlands. In the dry season, however, there is a marked shift, and a strong selection for the grasslands and a slight selection for the swamp areas.

Zebra (Table 15.5) are only heavily influenced by the vegetation in the wet season, when they show strong selection for the acacia woodlands and weaker selections for the bushlands and open woodlands. Selection for vegetation zones is weaker during the early dry and dry seasons. However, zebra's avoidance of swamps and thickets is consistent throughout the year, as is their random association with the miombo and combretum woodlands.

4.4.4 Major land systems (Table 10.4)

Although the major land systems are important determinants of animal distribution, they often mask the details of seasonal environmental associations.

Buffalo(Table 15.6) show a clear change in selection for land systems as the seasons progress. In the wet and early dry seasons, the majority of the population (80%) is showing a random association with the eastern cretacious and Kidodi/Karoo systems. However, that portion of the population in the low lying plains Land Region shows a strong association with the alkaline plains system in the wet season and a marked shift to the Rufiji plains system in the early dry season. By the late dry season, almost 50% of the entire population is found in the Mwama/Utunge drainage land system. For buffalo, the land systems are the major determinants of their distribution throughout the year.

Elephants (Table 15.7) show little association with land systems throughout the year apart from a strong selection for the Rufiji floodplain in the dry season. Even so, only 12% of the population is associated with this land system.

Giraffe (Table 15.8) show very strong selections and avoidances for land systems. Throughout the year they show a consistently strong selection for the alkaline plains and the Mkigura mbuga systems. However, this analysis by land systems masks the details of their seasonal patterns of movements shown by the vegetation type analysis.

Hippopotamus(Table 15.9) show a consistently strong selection for the Rufiji and Kilombero floodplains. This selection for the Kilombero floodplain was not shown in the vegetation analysis. However, only 6% of the hippopotamus population is associated with these two land systems, so they are of somewhat underwhelming importance.

Impala (Table 15.10) are likewise showing a strong selection for the Kilombero floodplain land system throughout the year. This selection, like that for the hippo, was not shown in the vegetation analysis. However, like the hippopotamus, only 4% of impala are associated with this land system. The impala's selection for other land systems throughout the year gives less information than does the vegetation type analysis.

Kongoni (Table 15.11) show a strong selection throughout the year for the Mkigura Mbuga, and some 20% of the population is associated with this single land system. The most important land system for Kongoni is the eastern cretaceous system for which it shows a randon association. 60% of the population occurs in this land system.

Waterbuck (Table 15.12) show strong selection throughout the year for the floodplain systems, but again an insignificant proportion of the population is involved.

The associations shown by wildebeest (Table 15.13) for land systems gives less information about their seasonal movements than does the vegetation analysis.

The patterns of movement shown by Zebra between land systems (Table 15.14) are interesting. The strong association with the alkaline plains system in the wet season is significant since 35% of the population is found there. These animals then migrate out of the census zone leaving a residual thousand or so for the rest of the year. The associations throughout the rest of the year are of minor importance since only small segments of the total populations are involved.

4.4.5 Distance from permanent, major rivers (Tables 10.6–10.10)

Five stratifications were carried out to investigate the seasonal importance of the major rivers in determining the patterns of movement and distribution of wildlife in the immediate impact area. The stratifications were increasing distances from major rivers within the whole census zone and within the four major watersheds of the lower Rufiji, the upper Rufiji (Ulambo), the Ruaha and the Kilombero/Luwegu rivers.

Within the whole census zone (Table 10.6), the importance of these major rivers increased towards the dry season, at which time they were the major determinants of animal distribution. However, only waterbuck and hippopotamus were strongly influenced by them throughout the year. Giraffe, impala, warthog and wildebeest were only strongly influenced in the dry season.

Table 16 lists the proportions of each population found at different distances from the major, permanent rivers.

Within the individual watersheds, a clear difference is seen between the lower Rufiji (Table 10.7) and others (Tables 10.8–10.10).

SECTION 5

INTERPRETATION

5.1 Introduction

Up to this point, the analysis has proceded on inductive lines to sift out the major determinants of the seasonal distributions and movements of animals within the immediate impact area of the STIGO dam. This section discusses those determinants which will be of most use in predicting the impact of the proposed dam.

It is very clear that the ecology of the two main Land Regions is very different. The low lying plains (Land Region 1) are characterised by high species density and diversity (Table 18), with many species showing strong seasonal patterns of association with vegetation types and land systems as well as strong seasonal dependencies on water. In contrast, in the upland cretaceous/karoo Land Region (Land Region 2), species densities and diversity are less, and the animals are showing a much more homogeneous relationship with their environment and an almost random seasonal distribution with respect to the environmental determinants studied thus far.

These two Land Regions will therefore be stratified separately to provide an initial basis for evaluating the impact of the STIGO dam on their wildlife.

5.2 Land Region 1 - the low lying plains

The low lying plains are essentially an inland delta, and changes to the hydrology of the area may initiate marked vegetation changes. The Peace/ Athabasca delta in Canada (*) is an interesting comparison for STIGO. Here, control of annual flooding into the inland delta following the construction of a hydroelectric dam triggered off rapid successional changes in the vegetation culminating in new climax communities. The vegetational changes were highly detrimental

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(*)The Peace-Athabasca Delta Project. Technical Report. Prepared by the Peace-Athabasca Delta Project Group, Canada, Alberta. 176pp.

to the wildlife populations, and were only later reversed by exceedingly costly engineering works which returned a degree of annual flooding to the area.

Our analysis of the possible impact of the dam in this Land Region is therefore based upon an interpretation of the seasonal and annual utilisation of the different vegetation types. Land systems were not used because in general they were of less predictive value for wildlife movements and distributions. Furthermore, land systems as such do not change; only components within them change, so an analysis based on land systems would mask any intuitive interpretation of the underlying nature and extent of change.

Our objective here is to answer two questions:

(i) which species are most at risk from major changes in this Land Region, and

(ii) to what degree will they be effected.

Table 19 shows the proportion of the population of each wildlife species utilising the vegetation zones of the low lying plains Land Region on a seasonal basis and on a mean annual basis. The species at risk from changes within this Land Region are those which use the area proportionately more than would be expected on a null hypothesis of random distribution throughout the impact area. In order of magnitude of risk, the species concerned are giraffe (94% of the population utilises Land Region 1 on an annual basis), wildebeest (58%), buffalo (36%), zebra (27%), impala (30%), waterbuck (25%), elephant (23%).

Giraffe will be very adversely effected by any changes to the open woodlands or to the acacia woodlands. These two vegetation types provide their wet season habitat, while the open woodlands provide their dry season habitat. The giraffe's pattern of distribution does not suggest that there is any alternative wet season or dry season habitat available to them. The emigration of giraffe in the early dry season suggests that alternative dry season habitat is available to them outside the Land Region, so the impact of changes to these vegetation types will probably be in the form of a major, and permanent, shift in population distribution.

Buffalo are at risk to changes in the bushlands and the combretum woodlands of this Land Region. The bushlands provice wet season habitat, while the combretum woodlands provide dry season habitat. There are extensive areas of combretum available elsewhere for utilisation in the dry season, so local changes within the Land Region may not be that disruptive. However, the higher than average densities of buffalo in their dry season habitat, compared with the overall density in combretum woodlands, suggests that a very favourable wet season habitat is contributing towards this local, high population density. Changes to the bushlands might therefore trigger a decline in this local section of the buffalo population.

Impala are heavily dependent upon the open woodlands for wet season and dry season habitat. Impala have little flexibility in their patterns of vegetation type utilisation, and alternative habitat does not appear to exist.

Wildebeest are similarly heavily dependent upon the open woodland for wet and dry season habitat. Their emigration in the dry season suggests that alternative habitat is available elsewhere.

The waterbuck show marked seasonal utilisation of the swamp areas in the wet season, so are at risk to some extent to changes in the swamps. Open woodlands and combretum woodlands are also important on a seasonal basis, but to a lesser extent.

The open woodlands and combretum woodlands provide wet season and early dry season habitat for elephant, but a relatively small proportion of the total population is involved.

Zebra show a heavy utilisation of the open woodlands during the wet season, prior to their emigration from the Land Region. Changes to this vegetation type might therefore initiate a permanent shift in population distribution.

It appears, therefore, that any deleterious changes to the bushlands, open woodlands and acacia woodlands of the low lying plains Land Region will adversely effect the populations of giraffe, buffalo, impala, wildebeest and zebra. However, the converse is also true. If the changed hydrology resulting from dam closure leads to an increase in the area of these vegetation types then these populations will benefit. Densities will increase, and the seasonal patterns of emigration will decrease.

The swamps of the inland delta should also be mentioned here. They support very high densities and diversity of wildlife, and are of obvious aesthetic attraction. However, they are not important ecologically for any of these populations at risk.

5.3 Land Region 2 - upland cretaceous/karoo

The situation in this land region is very different. Densities and diversities are low, and the wildlife are showing quite homogeneous seasonal patterns of utilisation. The important consideration therefore is the proportion of the various populations that will be displaced by the flooding of the reservoir.

Table 20 shows the present seasonal patterns of utilisation of the areas that will be flooded at mean low water, at high water Phase 1 and at high water Phase 2.

Buffalo, giraffe, wildebeest and zebra all utilise these areas less than expected on a null hypothesis of random distribution. The local effect of displacing these small proportions of their populations is therefore likely to be minimal.

Elephant, kongoni, rhinoceros and warthog all show an effectively random distribution with respect to the areas that will be flooded. Increase in local population densities through displacement will therefore be of the same order as the percentage of the area that is flooded. Inspection of the

Eland, hippopotamus and waterbuck all utilise the areas that will be flooded more heavily than expected on the null hypothesis of random distribution. Disruptions to their populations must therefore be expected. With eland and waterbuck,.the degree of disruption will depend upon the extent to which their habitat is reduced or altered by the flooding levels. For hippopotamus, the extent of the disruption will depend upon the extent to which their grazing areas will be effected.

5.4 Conclusion

It is very clear that the effect of the reservoir on the wildlife within the immediate impact area will be much less than the possible downstrean effects within the inland delta of Land Region 1. The reservoir will displace small proportions of most species, and the capacity seems to be there to absorb these displacements without major disruptions. Only for hippopotamus, eland and waterbuck is there the possibility for major disruption.

In Land Region 1, the 'Lake Tagalala area', the situation is quite different. Significant proportions of the populations of giraffe, buffalo, impala, wildebeest, waterbuck and elephant are at risk for they show very strong, seasonal dependencies on four vegetation types which comprise a mere 14% of the total impact area. The degree of disruption will depend upon the influence of the changed hydrology on these vegetation types. If these vegetation types become less suitable as habitat for these species, then major disruption to densities and distributions are to be expected. If, on the other hand, increasing areas of suitable habitat arise, then these populations will benefit.

SECTION 6

SCOPE FOR FURTHER STUDIES

6.1 Land Region 1 – the low lying plains

In view of the analysis presented here, there is an urgent requirement for a detailed ecological study into the seasonal patterns of habitat utilisation of the wildlife, concentrating upon those species most at risk. The urgency stems from the possibility of major disruption to the populations following the altered hydrology of the area. If engineering measures are required to minimise any disruption, their scope must be known as soon as possible.

The study should address itself to answering, very specifically, the following questions:-

(i) what is governing the present patterns of habitat utilisation. Are the species selecting for certain habitat types or are they avoiding other habitat types.

(ii) to what extent are alternative habitats available to them on a seasonal basis both within and outside the immediate impact area.

(iii) to what extent will be predicted habitat changes following the altered hydrology effect the densities and distribution of the wildlife.

Such a study is best carried out through intensive, ground based field sampling. Additional aerial surveys would be of advantage to quantify further the larger scale patterns of seasonal movements and distributions. Since the objective of these aerial surveys will be the quantification of animal numbers within habitat types, stratified random sampling within habitat types will be the most appropriate methodology.

6.2 Land Region 2 - upland cretaceous/karoo

There is less urgency here for further ecological work. The existing habitat preferences of hippopotamus and waterbuck should certainly be studied at some convenient moment in time. So too should the habitat preferences of impala, for they have quite a strong dependency on the existing rivers in the dry season.

6.3 Monitoring of Animal Numbers and Distribution

It is important, even at this early stage, to consider the design of a programme to monitor the effects of dam construction and dam closure on the Selous Wildlife. The objectives of such monitoring will be to detect changes in animal numbers, changes in the seasonal patterns of distribution, movement and habitat selection, and changes to the major determinants of animal distribution.

We recommend that the methodology of unstratified, systematic sampling be utilised, with the same flight lines; although a strong case can be made for extending the census zone at least another twenty kilometers in all directions.

This monitoring need not be too intensive. We would suggest a series of three flights, with the same seasonal timing as the present series, at least once before construction commences, at least once during construction, and then more regularly during the initial flooding of the reservoir.

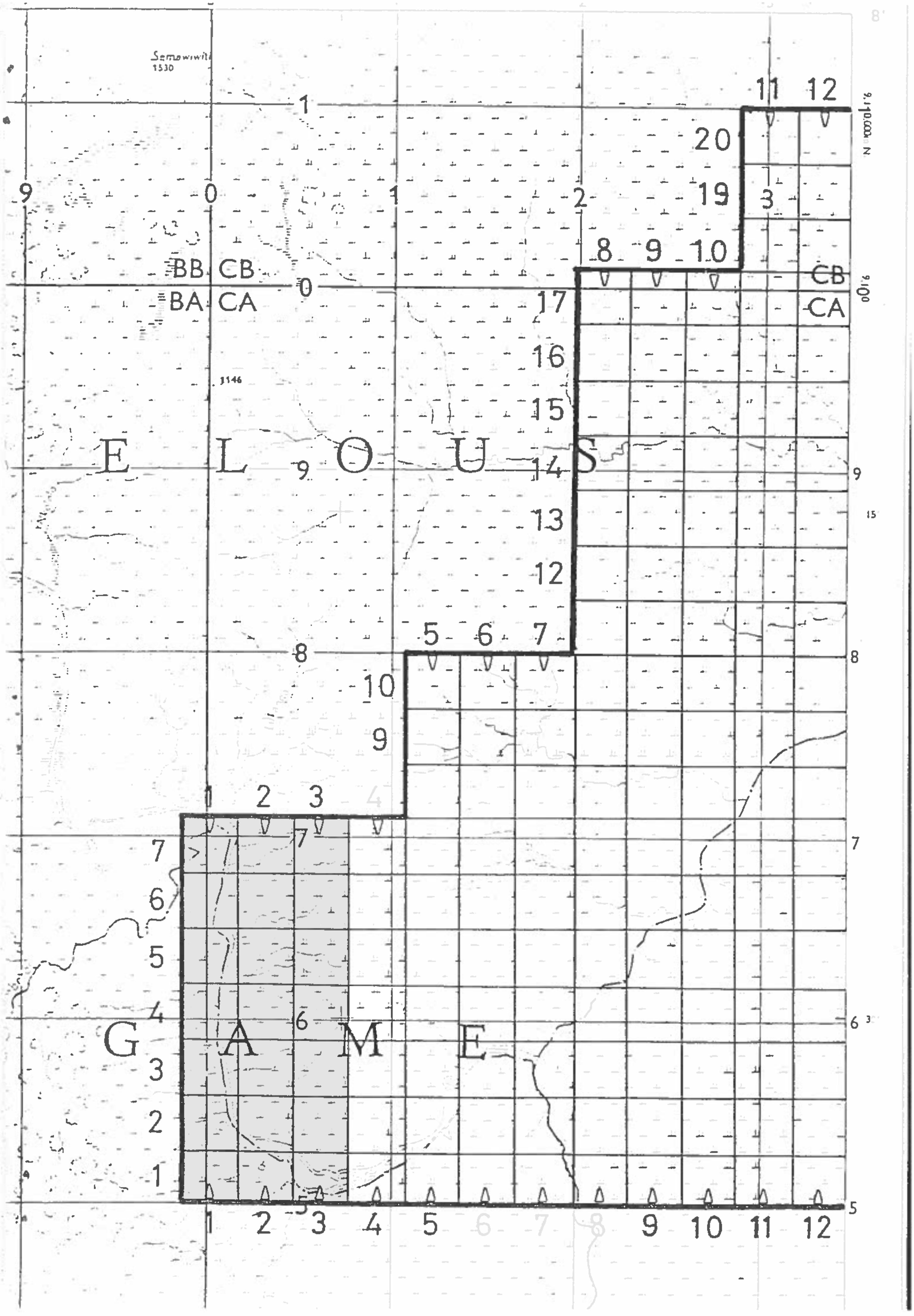
Serious consideration should be given by RUBADA to ensuring that the Game Division of Maliasili has the expertise to carry out these monitoring flights.

FIGURE 1 to FIGURE 12

Figure 1

1:250000 scale map of the census zone showing 3 x 3 km grid system (used for mapping purposes) and the start and end points of each flight line. The grid squares are numbered from the origin.

Also shown are the four segments of the rivers along which hippopotamus were total counted.



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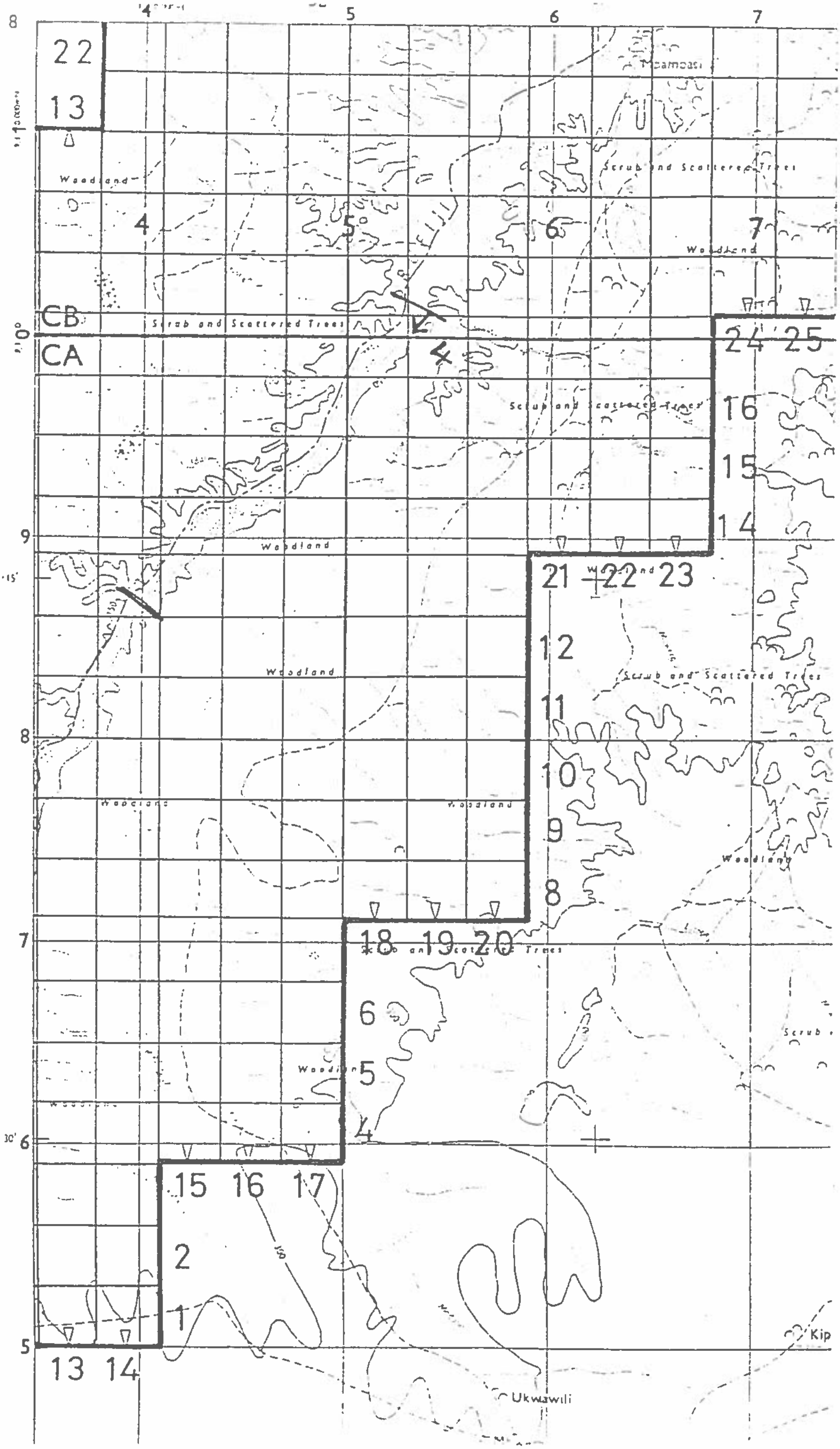

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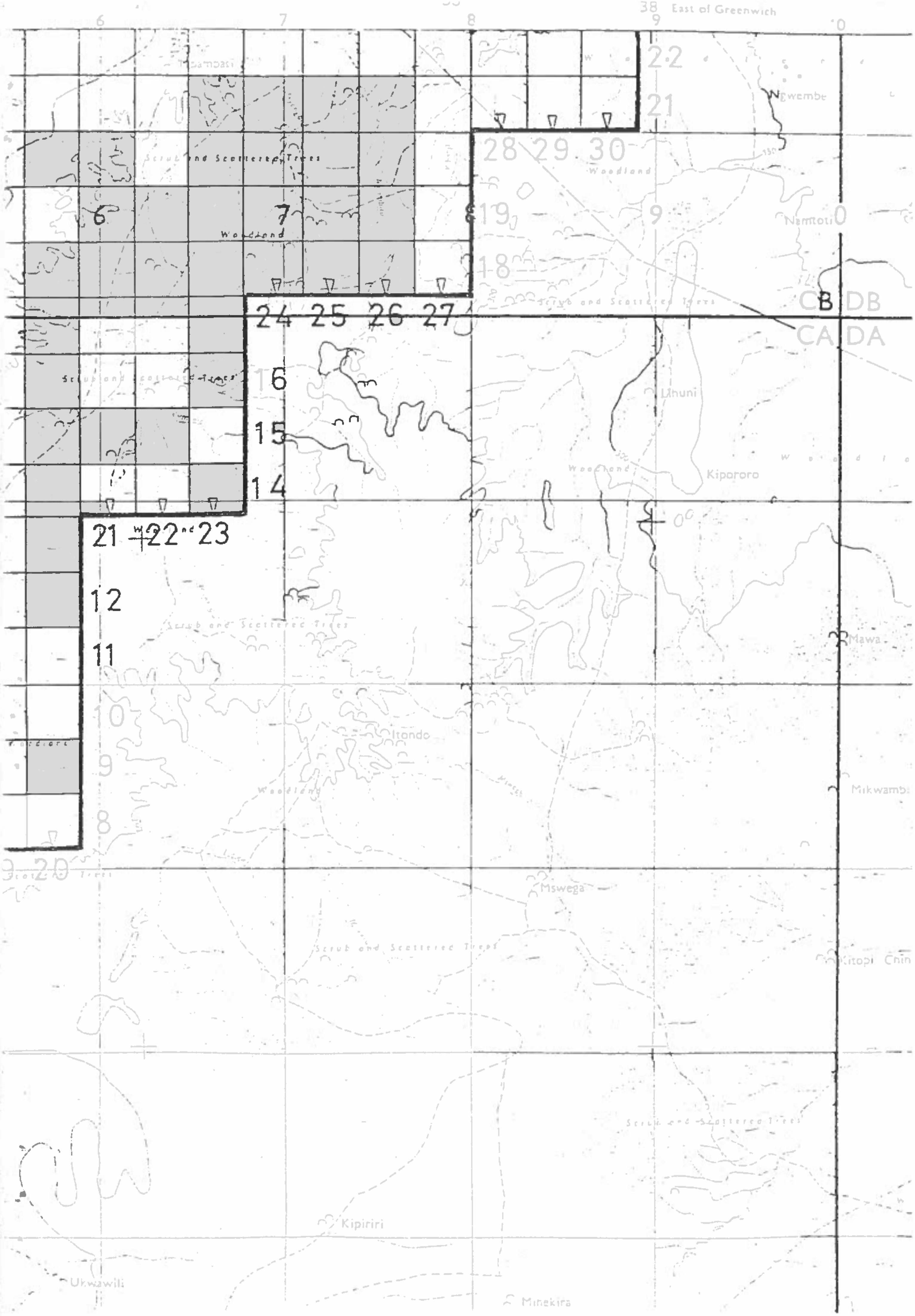
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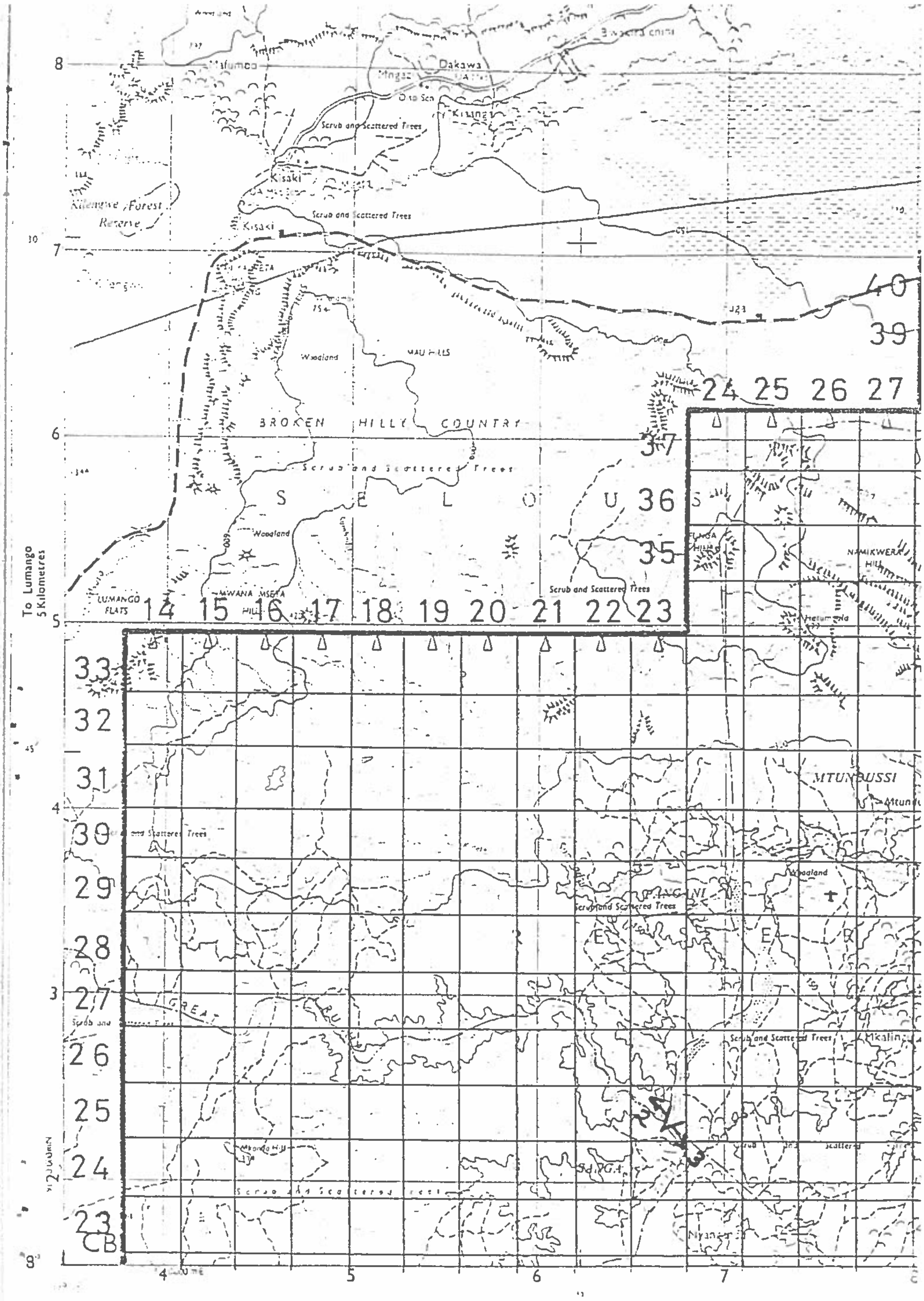
Mikwamba
Mswega
Kitopi Chin
Kipiriri
Ukwawili
Minekira



Dakawa
Kisaki
Kilengwe Forest Reserve
Scrub and Scattered Trees
Woodland
MAU HILLS
BROKEN HILLY COUNTRY
S E L O U S
To Lumango 5 Kilometres
LUMANGO FLATS
MWANA MSETA HILL
NAMIKWERA HILL
MTUNDUSSI
PANGANI
GREAT
R E S E R
14 15 16 17 18 19 20 21 22 23
24 25 26 27
40
39
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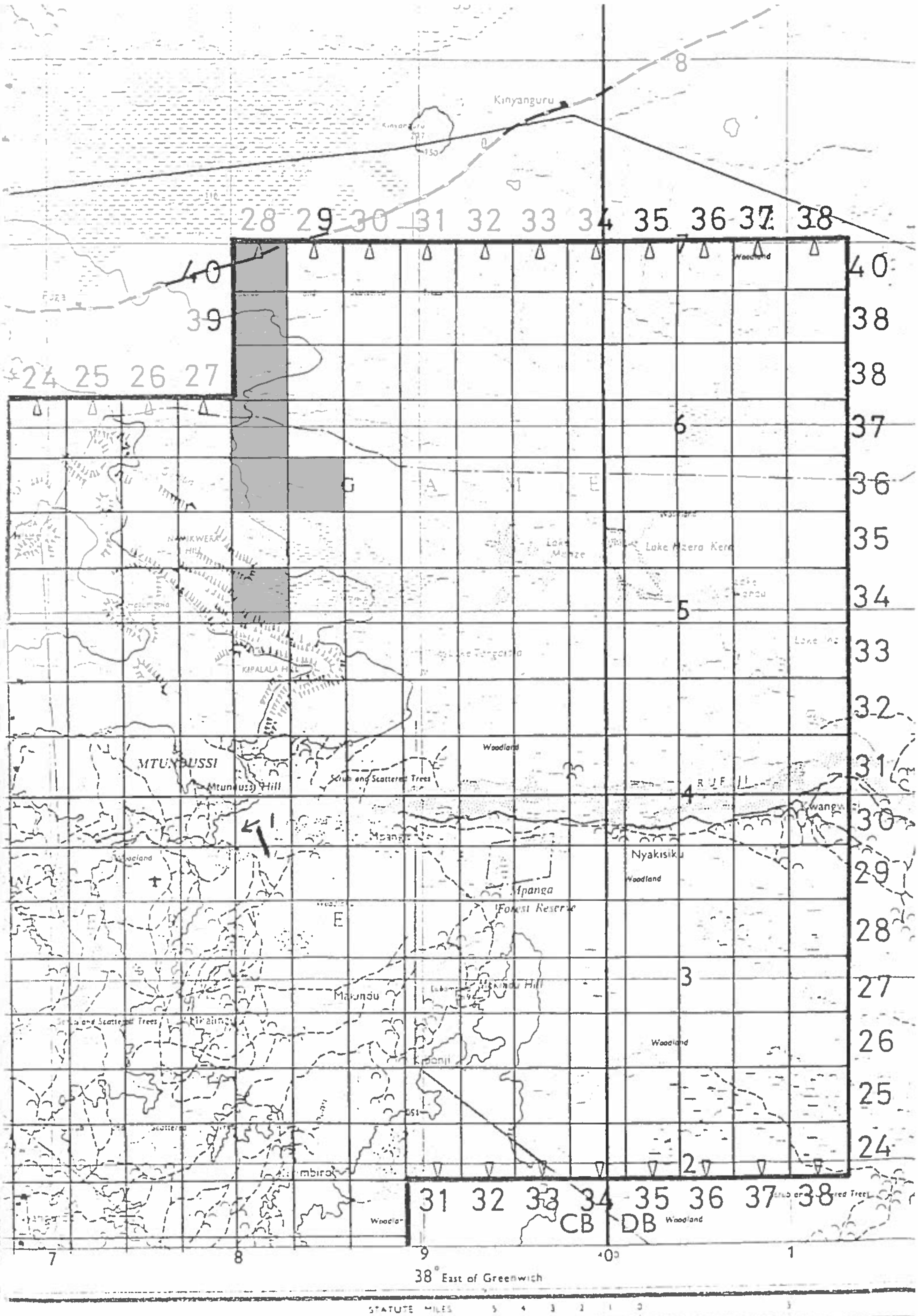
25
24
23
CB
4 5 6 7
8 7 6 5 4 3



Kinyanguru
28 29 30 31 32 33 34 35 36 37 38
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24 25 26 27
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30
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27
26
25
24
G A M E
NAMIKWERA HILL
KIPALALA HILL
Lake Manze
MTUNDUSSI
Mtundussi Hill
Scrub and Scattered Trees
Woodland
Nyakisiku
Mpanga
Forest Reserve
Matundu
E
31 32 33 34 35 36 37 38
CB DB
7 8 9 40 1
38° East of Greenwich
STATUTE MILES

FIGURE 2

MAJOR VEGETATION ZONES

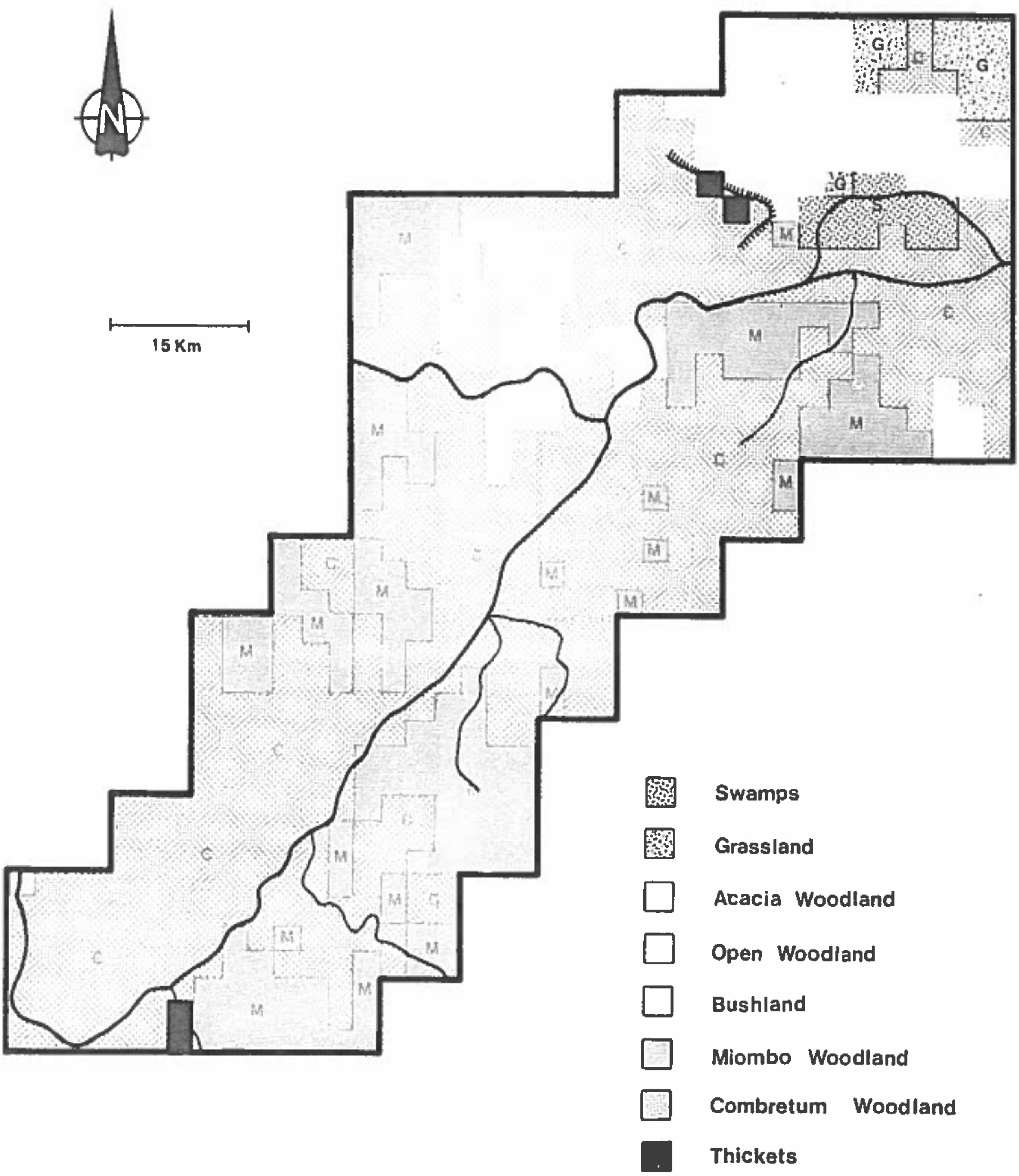

FIGURE 3

MAJOR LAND SYSTEMS

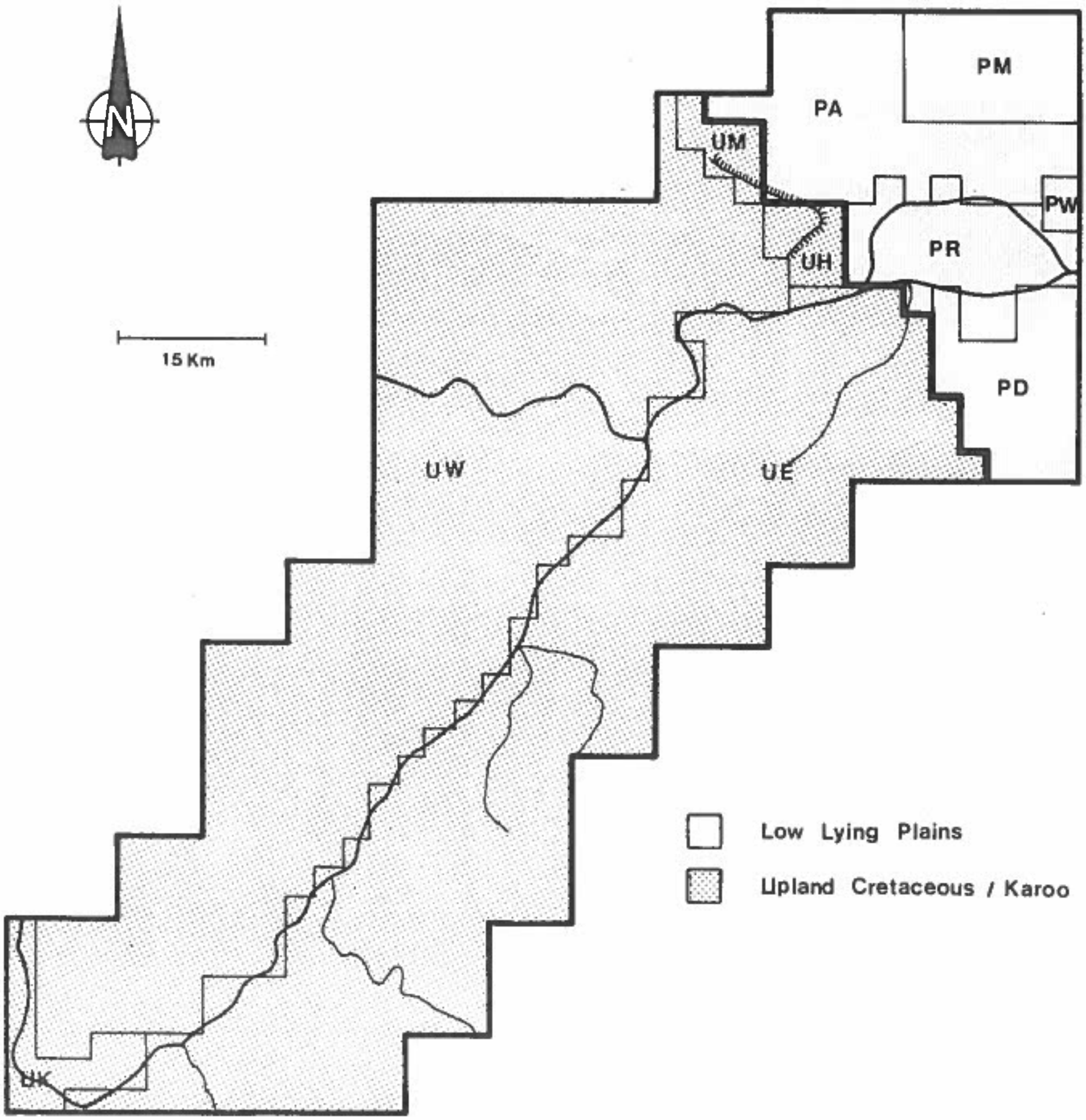

FIGURE 4

BUFFALO : Mean Annual Distribution

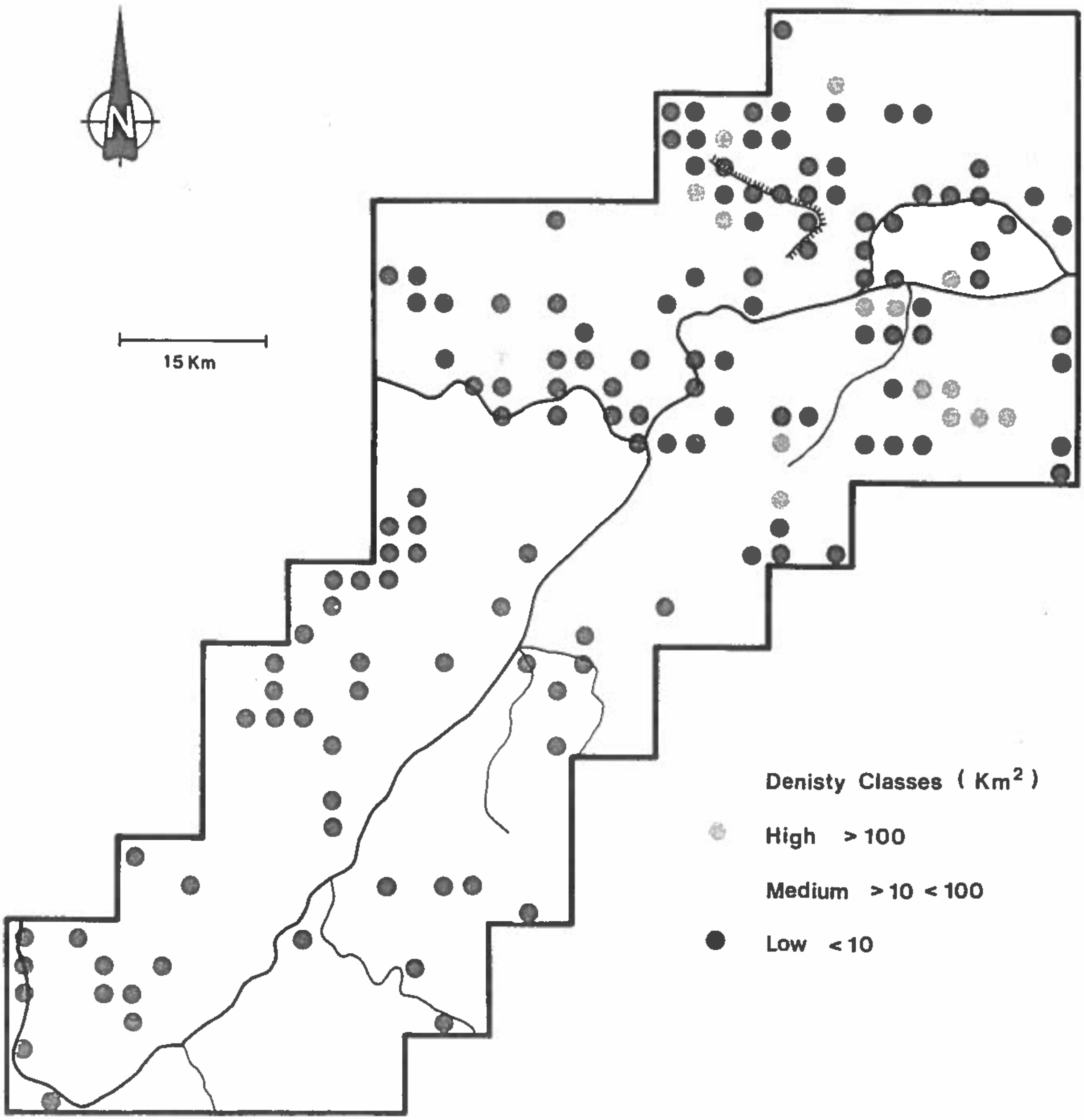

FIGURE 5

ELEPHANT : Mean Annual Distribution

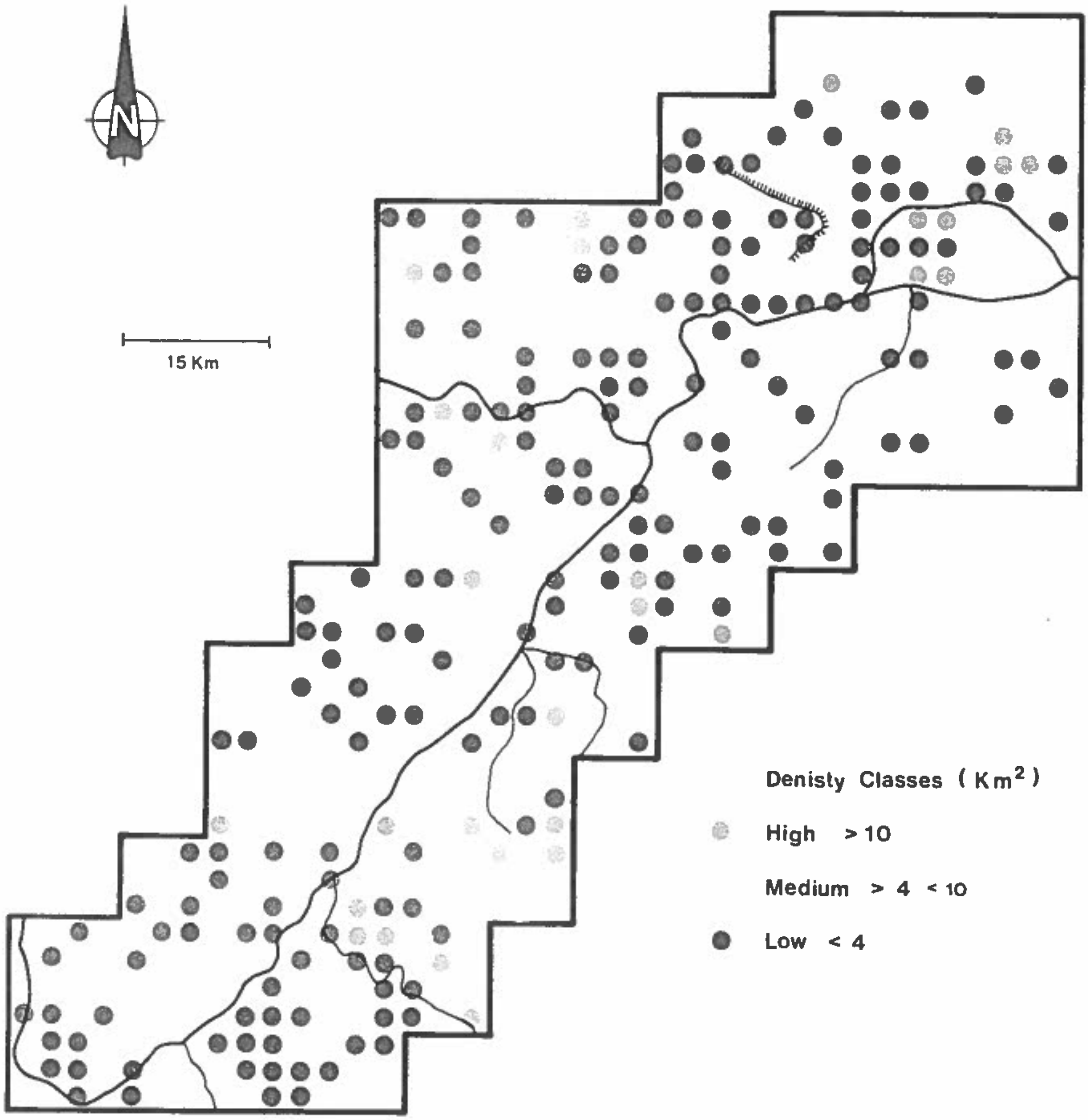

FIGURE 6

GIRAFFE : Mean Annual Distribution

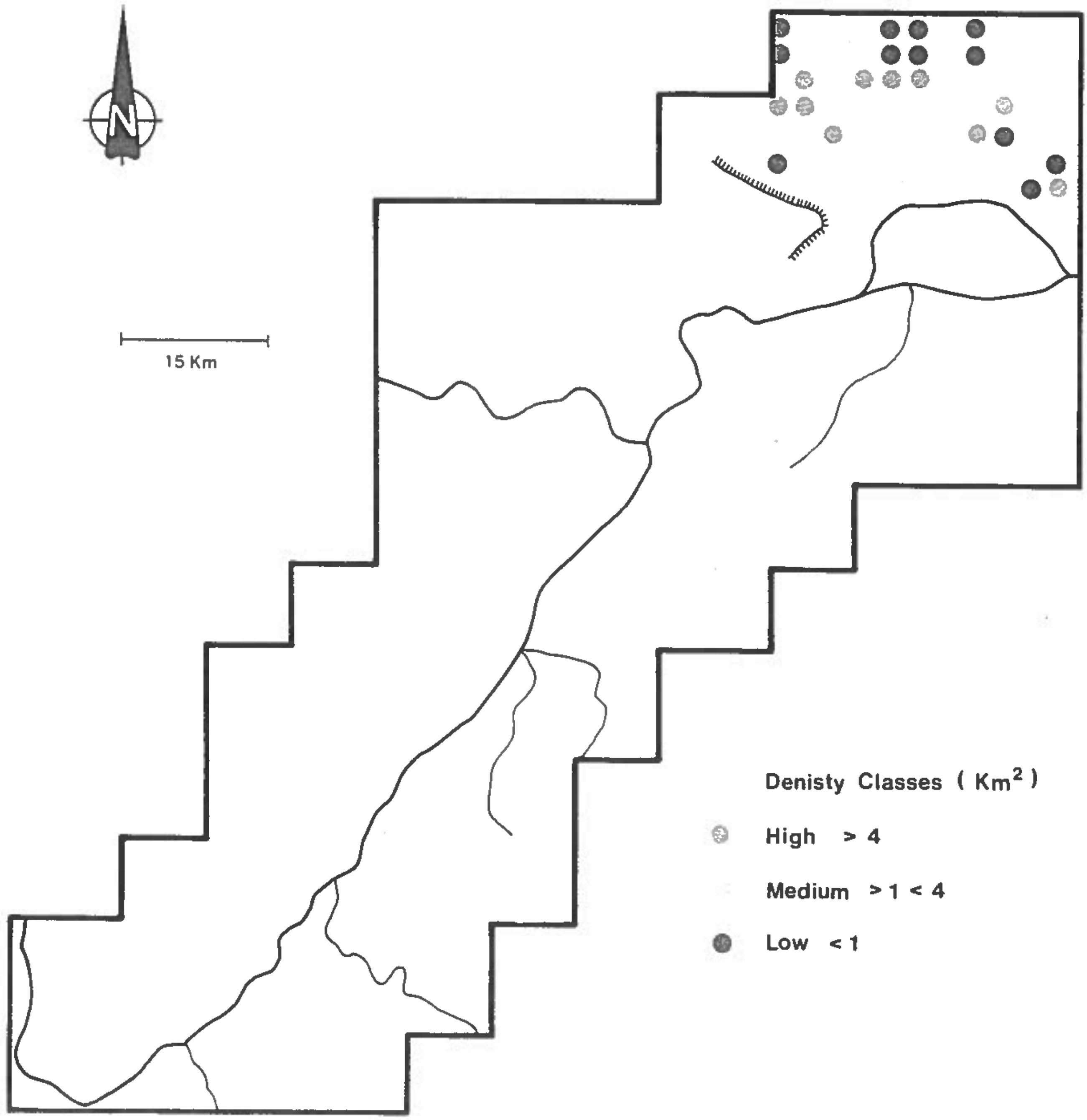

FIGURE 7

HIPPOPOTAMUS : Mean Annual Distribution

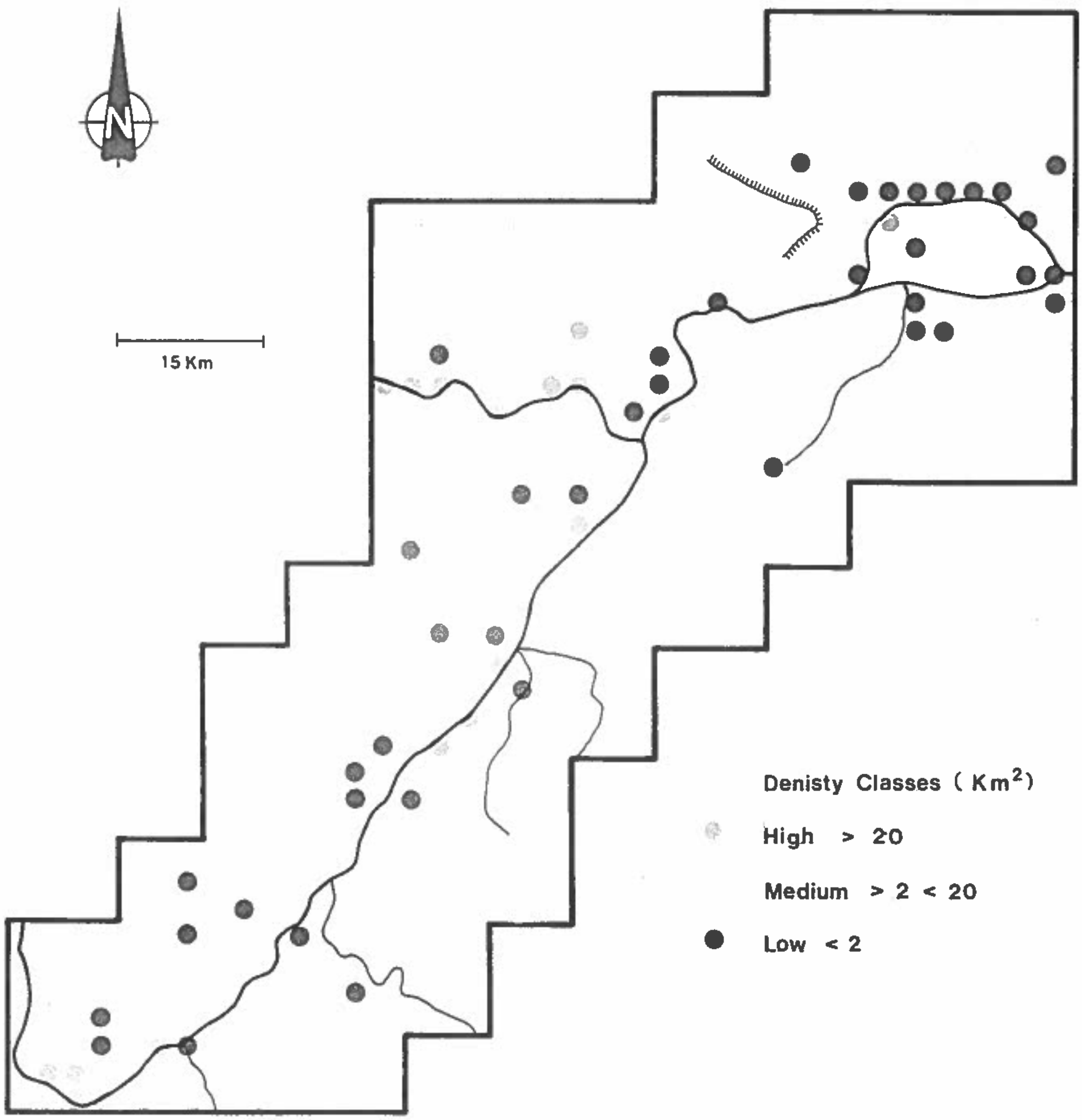

FIGURE 8

IMPALA : Mean Annual Distribution

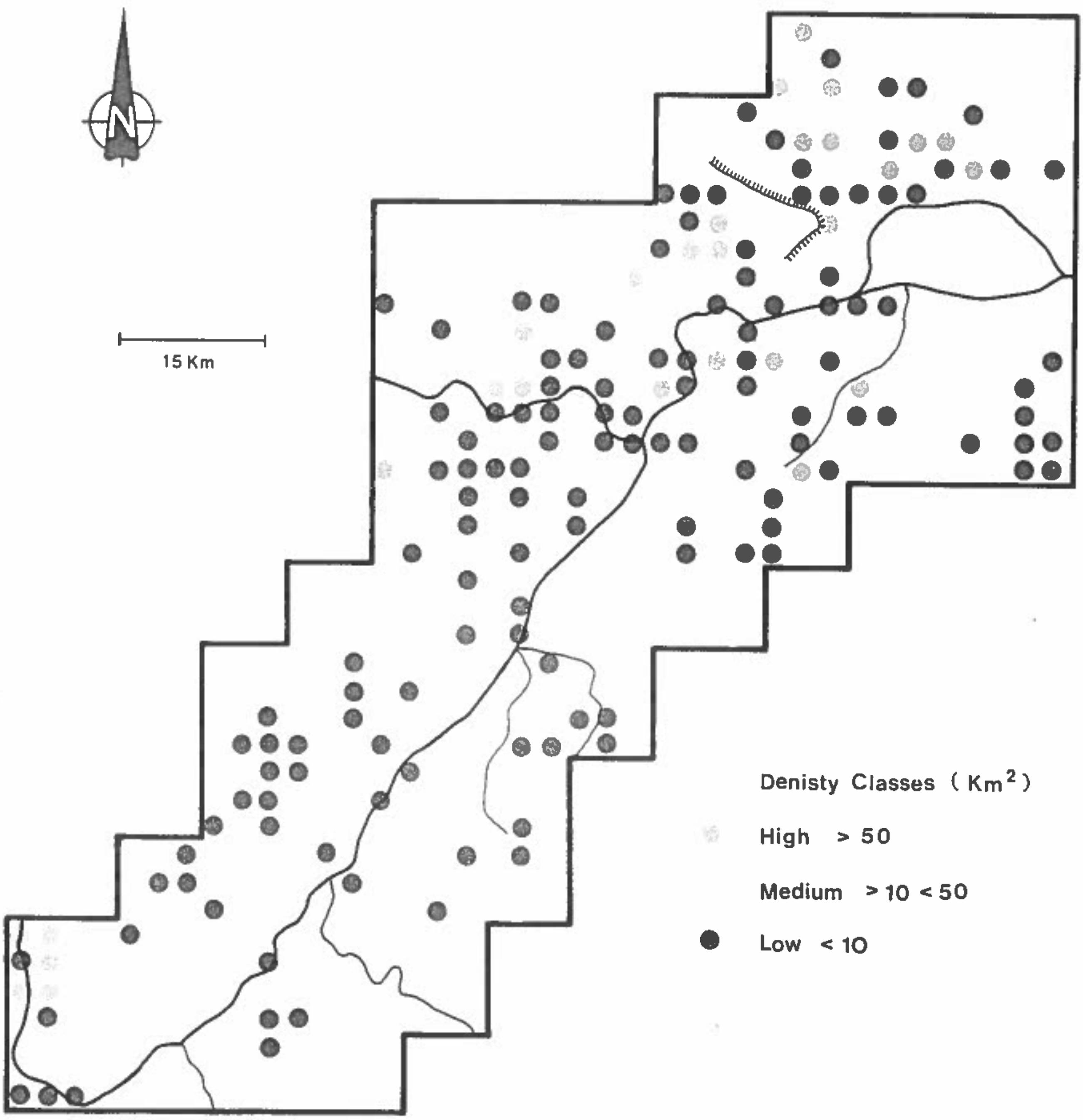

FIGURE 9

WILDEBEEST : Mean Annual Distribution

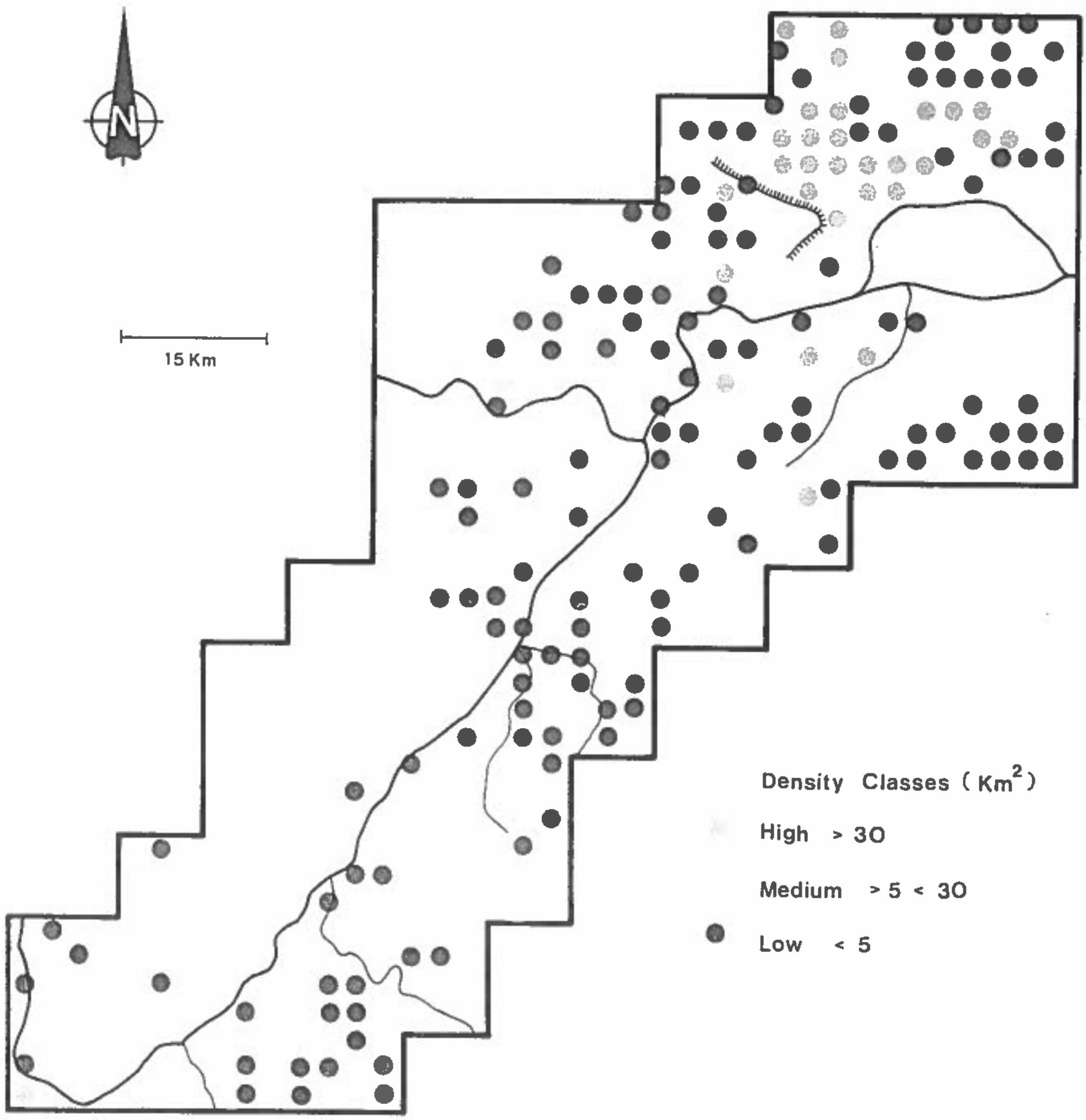

FIGURE 10

ZEBRA : Mean Annual Distribution

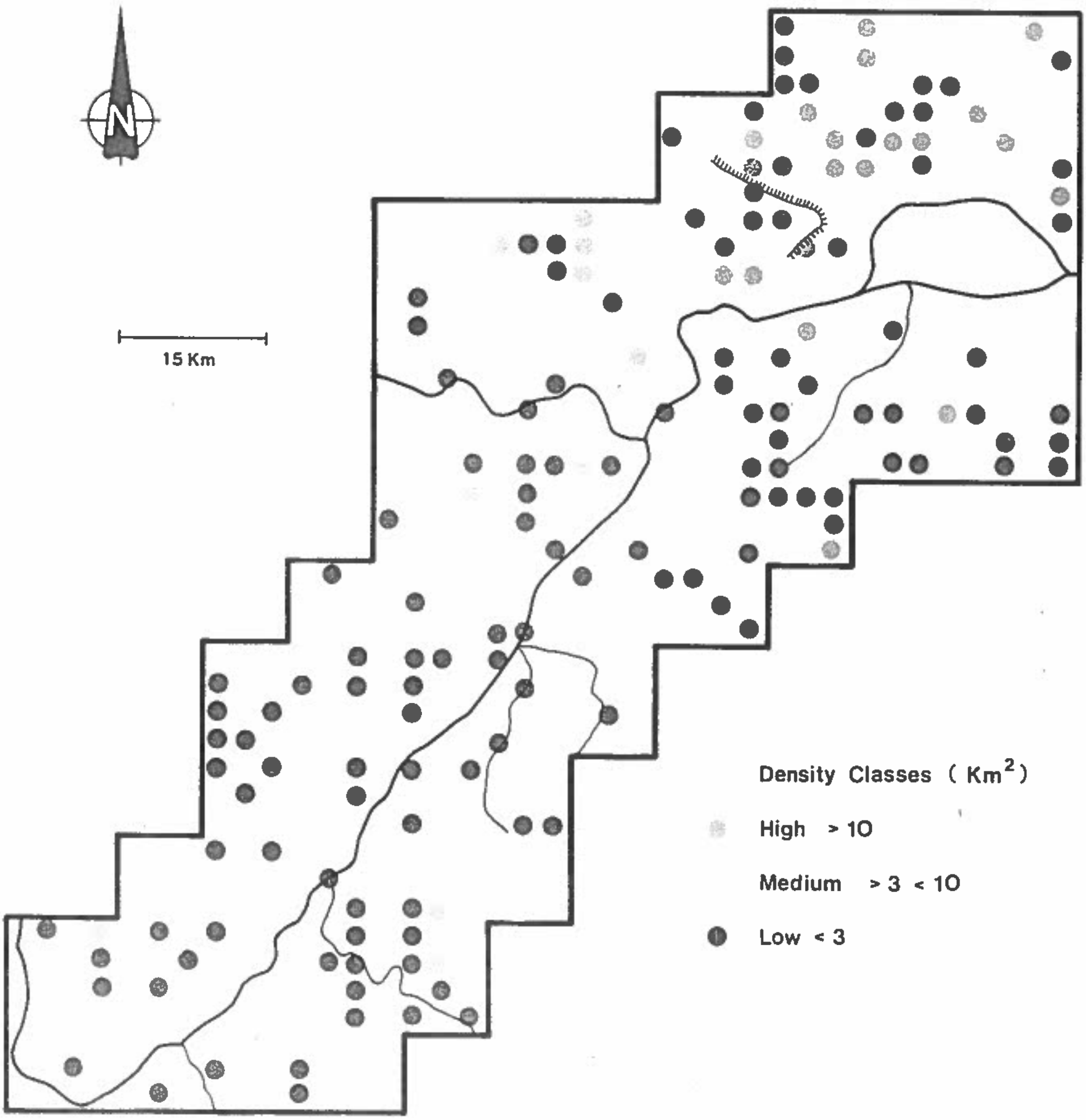

FIGURE 11

TOTAL WILDLIFE DISTRIBUTION

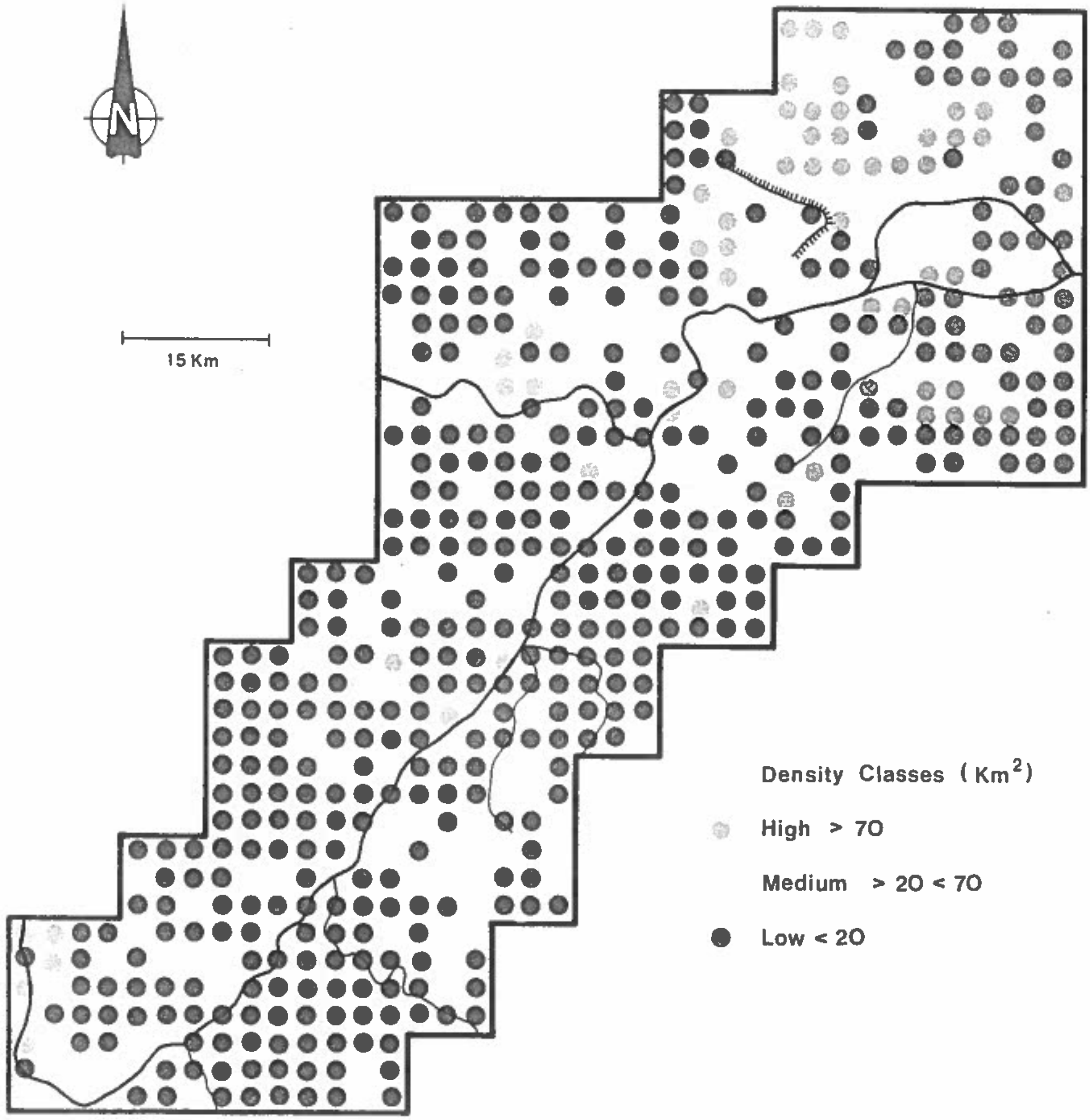

FIGURE 12

Wildlife Diversity : Annual

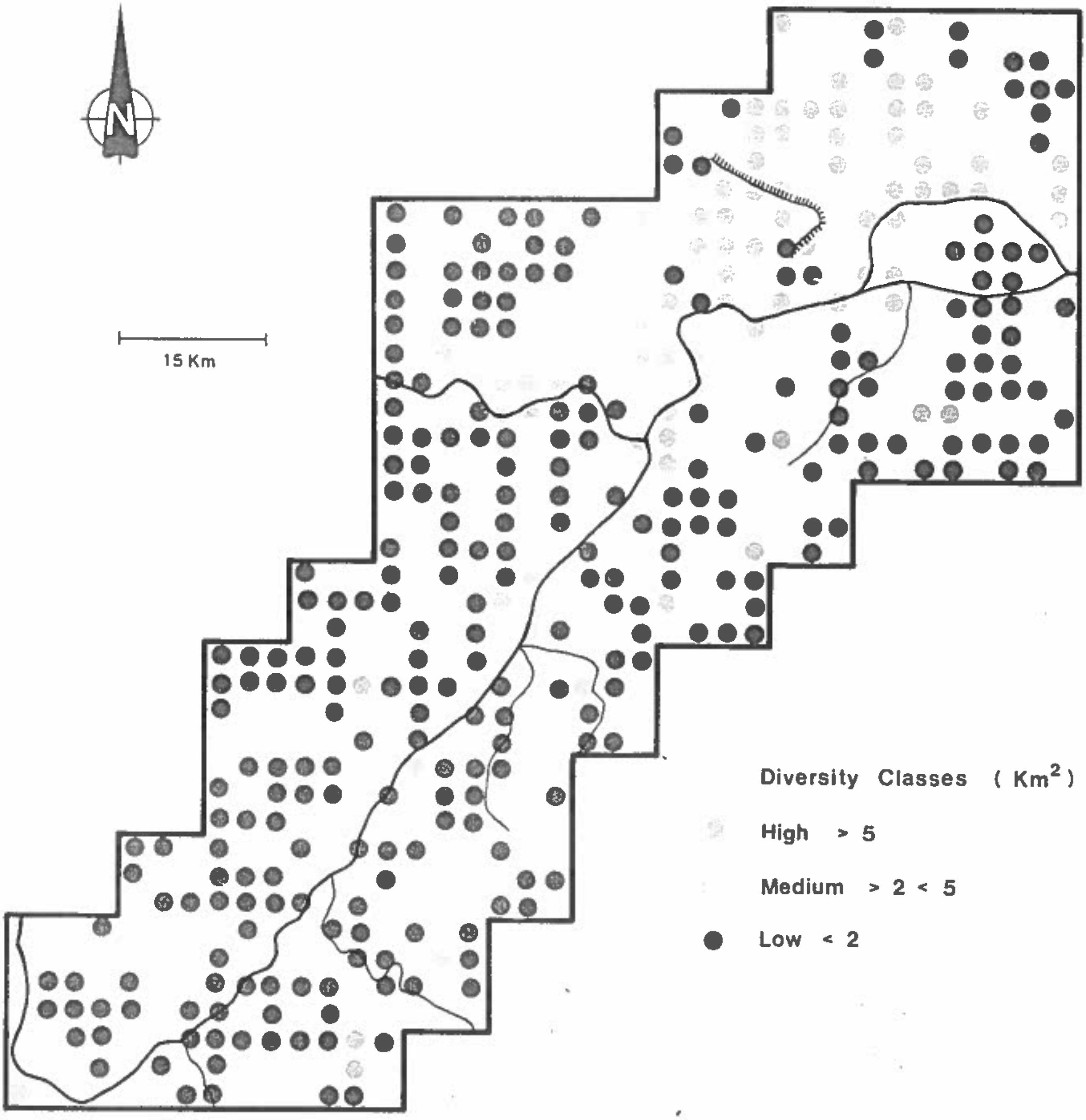

Table 1.A

<u>flight parameters for the three aerial censuses</u>

	wet season April 1979	early dry season July 1979	dry season October 1979
area of census zone (km^2)	6354	6354	6354
% sample	7.9%	9.9%	8.5%
mean flying height (feet)	306	300	300
mean ground speed (kph)	178	177	179
mean strip width (m)	237	297	254
number of flight lines	38	38	38

TABLE 1B

Mean flying heights and strip widths for each flight line in counts 1, 2 and 3

Flight Line	COUNT 1		COUNT 2		COUNT 3	
	Height (ft)	Strip Width (m)	Height (ft)	Strip Width (m)	Height	Strip Width (m)
1	297	236	306	320	291	248
2	288	231	305	319	300	256
3	295	235	302	316	284	243
4	306	241	313	327	299	255
5	299	237	307	322	291	248
6	301	238	316	330	318	271
7	299	237	311	325	288	246
8	300	238	306	321	294	251
9	290	232	294	308	313	267
10	304	240	302	316	302	258
11	318	248	320	334	307	262
12	298	237	305	319	293	250
13	296	236	316	330	296	252
14	309	243	303	133	306	261
15	304	240	299	313	308	263
16	310	243	291	304	297	253
17	301	238	295	309	314	268
18	309	243	315	329	299	255
19	289	231	285	298	297	254
20	298	237	297	311	298	254
21	295	235	283	297	302	258
22	308	242	312	327	302	258
23	296	236	292	307	295	252
24	307	241	303	318	300	256
25	290	232	303	318	294	251

. . . over

Table 1B : continued

Flight Line	COUNT 1 Height (ft)	COUNT 1 Strip Width (m)	COUNT 2 Height	COUNT 2 Strip Width (m)	COUNT 3 Height (ft)	COUNT 3 Strip Width (m)
26	302	239	294	308	292	249
27	302	239	301	316	287	245
28	306	241	306	321	301	257
29	304	240	295	310	292	249
30	287	231	301	316	305	260
31	306	241	311	327	298	254
32	304	240	297	312	292	249
33	299	237	301	316	299	255
34	299	237	300	315	287	245
35	298	236	307	322	306	261
36	301	239	298	313	291	248
37	294	234	304	319	303	258
38	302	239	299	314	292	249

Table 2

analysis of variance of flying height (feet above ground level) as a function of topography

		census 1		census 2	census 3	n
flatland & swamps	mean	295	(*)	301	300	53
	s	13		22	11	
undulating catena	mean	306		300	297	68
	s	29		17	12	
hills	mean	293	(*)	299	305	8
	s	26		11	20	
slopes	mean	325	(*)	300	303	22
	s	38		25	19	
ridge top plateaux	mean	299	(*)	305	299	28
	s	23		21	14	
valleys	mean	317	(*)	302	302	32
	s	33		15	16	
	Grand Mean	306		300	300	211
	s	27		35	22	
	F ratio	6.66		0.39	0.47	
	p =	<0.001		ns	ns	
	L.S.D.	4.77		na	na	

notes: (i) n refers to the number of flight line segments crossing each kind of topography. Mean altimeter readings were calculated along each flight line segment

(ii) for census 1, the significant F ratio ($p < 0.001$) disproves the negative hypothesis that all the mean heights are equal. The L.S.D. (least significant difference) is used to show which means are significantly above or below the grand mean (*).

Table 3

<u>numbers of animals counted by both observers (uncorrected counts) adjusted for strip widths</u>

species	uncorrected counts count No. 1	 count No. 2	 count No. 3
buffalo	6.23	5.73	6.38
eland	0.58	0.34	0.64
elephant	3.57	2.76	3.08
giraffe	0.31	0.18	0.17
hippopotamus	1.25	2.57	2.77
impala	7.40	6.89	7.20
kongoni	1.57	1.25	1.72
warthog	0.76	0.62	0.85
waterbuck	0.50	0.59	0.46
wildebeest	7.14	6.41	5.24
zebra	4.06	2.09	2.07

(population estimate = counted x actual strip width x correction factor x sample fraction -1)

Table 4

area and cover density of major vegetation types

vegetation type	area	cover density classes 0	1	2	3	4	5	6	mean
miombo woodland and miombo/combretum	22%	5	38	32	20	5			23%
combretum woodland and combretum/miombo	62%	28	52	13	4	3			15%
open woodland	7%	74	16	8	2				9%
bushland	4%	81	19						7%
acacia woodland	1%	13	50	37					18%
thicket	(<1%)					(25)	(25)	(50)	58%
grassland	2%	100							0%
swamp	2%	92	8						6%
overall		31	43	16	7	3			

% figures under 'area' refer to the whole census zone. Figures under cover density classes give the percentage break down of each vegetation type into each cover density class:

0=<9.9%; 1=10 - 19.9%; 2=20 - 29.9%; 3=30 - 39.9% etc.

Table 5

percentage breakdown of distances from permanent water sources within each watershed and within the whole census zone

	Watersheds				
distance km	Lower Rufiji	Rufiji	Ruaha	Kilombero and Luwegu	census zone
3	15	19	23	42	21
6	16	21	20	23	20
9	13	16	16	13	15
12	14	14	18	13	15
15	13	13	12	6	12
18	12	8	8	-	8
21	12	8	3	3	8
23	4	1	-	-	2
26	1	-	-	-	-
N	189	360	105	62	
% of census zone in each watershed	26%	50%	15%	9%	

Table 6

population estimates for the STIGO wildlife, stratified on the basis of their observed density distributions

		count 1 April	count 2 July	count 3 October
buffalo	$\hat{Y}$	27863	25391	28241
	SE($\hat{Y}$)	1137	1555	2882
eland	$\hat{Y}$	1939	1131	2104
	SE($\hat{Y}$)	109	81	172
elephant	$\hat{Y}$	11932	9115	10212
	SE($\hat{Y}$)	731	605	270
giraffe	$\hat{Y}$	1044	589	568
	SE($\hat{Y}$)	53	30	34
hippopotamus	$\hat{Y}$	4183	8537	9258
	SE($\hat{Y}$)	235	914	708
impala	$\hat{Y}$	36748	39945	35783
	SE($\hat{Y}$)	2062	4330	3469
kongoni	$\hat{Y}$	5035	3971	5507
	SE($\hat{Y}$)	308	182	309
rhinoceros	$\hat{Y}$	265	153	136
	SE($\hat{Y}$)	43	34	33
warthog	$\hat{Y}$	2294	1854	2538
	SE($\hat{Y}$)	140	114	194
waterbuck	$\hat{Y}$	1672	1930	1520
	SE($\hat{Y}$)	128	118	132
wildebeest	$\hat{Y}$	24839	22172	18157
	SE($\hat{Y}$)	1267	1471	1390
zebra	$\hat{Y}$	13989	7084	7039
	SE($\hat{Y}$)	785	506	539
uncommon ungulates	$\hat{Y}$	977	470	714
	SE($\hat{Y}$)	160	84	111

$\hat{Y}$ population estimates

SE($\hat{Y}$) standard error of $\hat{Y}$

Table 7

combined population estimates from the three censuses

		$\hat{Y}$	SE($\hat{Y}$)	95%CL	as % of $\hat{Y}$
buffalo	three counts	27116	875	1715	6.3%
eland	counts 1 & 3	1985	92	180	9%
elephant	three counts	10224	234	459	4.5%
giraffe	wet season (1)	1044	53	104	10%
	dry season (2)	580	23	45	7.8%
hippopotamus	dry season (2)	8988	560	1098	12.2%
impala	three counts	36130	1640	3214	8.9%
kongoni	counts 1 & 3	5270	218	428	8.1%
rhinoceros	wet season (1)	265	43	84	32%
warthog	three counts	2117	80	157	7.4%
waterbuck	three counts	1724	73	143	8.3%
wildebeest	wet season (2)	23703	960	1882	7.9%
	dry season (1)	18157	1390	2724	15%
zebra	wet season (1)	13989	785	1539	11%
	dry season (2)	7063	369	723	10.2%
uncommon ungulates	three counts	621	62	122	19.6%

$\hat{Y}$ population estimate

SE($\hat{Y}$) standard error

95%CL 95% confidence limits of $\hat{Y}$

Table 8

grid squares in which sable and/or greater kudu were observed

sable		greater kudu	
X	Y	X	Y
3	4	9	11
9	10	11	6, 15
11	6, 20	14	1, 2
12	6	15	32
13	2, 4, 5	16	18, 28
15	9, 26, 30	17	27
16	24	19	30
17	9	20	10, 11
18	22, 30	21	25, 30
22	18	24	34
23	29	27	35
24	18, 19	31	38
25	25	33	27, 28, 37
29	23	34	28, 37
		37	29
		38	27

Table 9

seasonal relationships between environmental stratifications and all species

		season			
		annual	wet	early dry	dry
1.	topography	4.0	6.5	4.0	3.7
2.	dissection	2.8	5.9	3.6	3.1
3.	% cover density	2.8	5.0	4.6	1.8
4.	major vegetation zones	10.2	17.2	11.3	4.3
5.	major land systems	4.0	11.2	6.7	1.4
6.	overall distance from water	2.7	0.6	4.1	8.7
7.	- Lower Rufiji watershed	4.7	0.0	10.1	14.9
8.	- Upper Rufiji watershed	3.6	4.0	3.9	3.9
9.	- Ruaha river watershed	10.5	11.0	12.3	9.7
10.	- Kilombero/Luwegu watershed	15.5	14.7	14.9	18.0
11.	grass greenness		3.6	2.9	7.3
12.	surface water		0.9	6.8	1.3
13.	photospectrometer ratios		1.1	6.0	3.6

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 10.1

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: topography

		seasons			
		overall	wet	early dry	dry
1.	buffalo	0	0	10	2
2.	eland	0	2	1	2
3.	elephant	6	6	4	9
4.	giraffe	21	18	17	13
5.	hippopotamus	45	20	27	42
6.	impala	6	7	5	1
7.	kongoni	15	5	12	9
8.	rhinoceros	2	1	2	5
9.	warthog	3	2	4	2
10.	waterbuck	27	13	16	4
11.	wildebeest	14	13	13	9
12.	zebra	7	7	3	1
13.	total wildlife density	8	6	3	6
14.	species number	8	8	5	6
15.	overall variance ratio	4.0	6.5	4.0	3.7

Table 10.2

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: dissection

			seasons		
		overall	wet	early dry	dry
1.	buffalo	9	4	10	3
2.	eland	2	0	1	1
3.	elephant	3	2	2	5
4.	giraffe	2	4	0	3
5.	hippopotamus	3	2	2	2
6.	impala	2	19	3	7
7.	kongoni	26	1	17	20
8.	rhinoceros	14	3	4	4
9.	warthog	5	1	0	3
10.	waterbuck	3	5	2	0
11.	wildebeest	5	4	2	1
12.	zebra	4	2	19	1
13.	total wildlife density	6	2	10	2
14.	species number	5	4	1	5
15.	overall variance ratio	2.8	5.9	3.6	3.1

Table 10.3

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: woodland cover density

		seasons			
		overall	wet	early dry	dry
1.	buffalo	1	1	3	2
2.	eland	0	2	1	2
3.	elephant	1	0	0	2
4.	giraffe	2	2	7	3
5.	hippopotamus	1	1	1	0
6.	impala	2	1	1	0
7.	kongoni	0	2	1	2
8.	rhinoceros	0	0	0	1
9.	warthog	1	0	0	1
10.	waterbuck	6	1	9	2
11.	wildebeest	3	7	3	1
12.	zebra	5	4	3	1
13.	total wildlife density	3	4	4	2
14.	species number	10	11	2	2
15.	overall variance ratio	2.8	5.3	4.6	1.8

Table 10.4

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: major vegetation zones

		seasons		
	overall	wet	early dry	dry
1. buffalo	4	2	12	2
2. eland	1	3	6	5
3. elephant	9	2	5	8
4. giraffe	50	63	12	27
5. hippopotamus	32	13	26	25
6. impala	29	27	18	15
7. kongoni	11	0	8	1
8. rhinoceros	4	2	1	3
9. warthog	9	12	8	5
10. waterbuck	32	13	19	14
11. wildebeest	38	42	46	16
12. zebra	11	15	4	0
13. total wildlife density	30	27	25	7
14. species number	20	21	21	8
15. overall variance ratio	10.2	17.2	11.3	4.3

Table 10.5

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: major land systems

			seasons		
		overall	wet	early dry	dry
1.	buffalo	11	3	12	26
2.	eland	1	3	3	3
3.	elephant	24	15	12	20
4.	giraffe	65	62	44	40
5.	hippopotamus	24	19	20	12
6.	impala	25	36	15	8
7.	kongoni	39	25	26	20
8.	rhinoceros	2	6	6	2
9.	warthog	7	0	20	4
10.	waterbuck	25	4	28	12
11.	wildebeest	40	34	34	17
12.	zebra	17	18	22	5
13.	total wildlife density	17	24	17	6
14.	species number	14	21	12	5
15.	overall variance ratio	4.0	11.2	6.7	1.4

Table 10.6

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: overall distance from major river

			seasons		
		overall	wet	early dry	dry
1.	buffalo	1	1	1	1
2.	eland	0	0	2	2
3.	elephant	2	1	1	0
4.	giraffe	6	1	4	13
5.	hippopotamus	53	18	34	67
6.	impala	10	5	4	13
7.	kongoni	3	0	1	2
8.	rhinoceros	0	0	1	1
9.	warthog	6	1	0	14
10.	waterbuck	31	10	22	15
11.	wildebeest	4	1	0	13
12.	zebra	0	0	3	0
13.	total wildlife density	4	1	3	9
14.	species number	2	0	3	4
15.	overall variance ratio	2.7	0.6	4.1	8.7

Table 10.7

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: Lower Rufiji watershed: distance from river

			seasons		
		overall	wet	early dry	dry
1.	buffalo	1	2	3	4
2.	eland	7	2	1	8
3.	elephant	11	8	5	15
4.	giraffe	3	1	1	14
5.	hippopotamus	51	20	25	72
6.	impala	16	11	19	19
7.	kongoni	10	5	4	0
8.	rhinoceros	30	32	0	0
9.	warthog	22	4	4	39
10.	waterbuck	34	7	24	28
11.	wildebeest	10	1	2	19
12.	zebra	3	0	9	2
13.	total wildlife density	10	4	16	17
14.	species number	0	3	2	15
15.	overall variance ratio	4.7	0.0	10.0	14.9

Table 10.8

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: Upper Rufiji watershed: distance from river

		seasons			
		overall	wet	early dry	dry
1.	buffalo	1	1	0	2
2.	eland	3	7	3	2
3.	elephant	3	1	2	2
4.	giraffe	5	1	0	2
5.	hippopotamus	59	17	43	69
6.	impala	6	6	2	6
7.	kongoni	2	1	3	1
8.	rhinoceros	0	1	2	1
9.	warthog	0	4	2	1
10.	waterbuck	24	10	29	14
11.	wildebeest	0	1	3	1
12.	zebra	2	1	3	2
13.	total wildlife density	2	1	0	2
14.	species number	4	1	3	2
15.	overall variance ratio	3.6	4.0	3.9	3.9

Table 10.9

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: Ruaha watershed: distance from river

			seasons		
		overall	wet	early dry	dry
1.	buffalo	1	0	2	2
2.	eland	7	2	9	4
3.	elephant	1	10	7	0
4.	giraffe	0	0	0	0
5.	hippopotamus	60	15	36	78
6.	impala	20	6	5	7
7.	kongoni	4	11	2	9
8.	rhinoceros	6	13	25	0
9.	warthog	9	16	4	8
10.	waterbuck	40	18	37	5
11.	wildebeest	6	7	8	17
12.	zebra	3	5	7	2
13.	total wildlife density	11	4	8	10
14.	species number	4	10	8	0
15.	overall variance ratio	10.5	11.0	12.3	9.7

Table 10.10

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: Kilombero/Luwegu watershed: distance from river

			seasons		
		overall	wet	early dry	dry
1.	buffalo	4	9	13	9
2.	eland	6	15	5	2
3.	elephant	14	14	7	12
4.	giraffe	0	0	0	0
5.	hippopotamus	50	44	36	46
6.	impala	23	22	14	9
7.	kongoni	29	2	3	39
8.	rhinoceros	7	7	0	0
9.	warthog	6	13	8	2
10.	waterbuck	7	5	2	4
11.	wildebeest	8	9	11	3
12.	zebra	13	10	23	12
13.	total wildlife density	33	21	16	16
14.	species number	18	29	8	17
15.	overall variance ratio	15.5	14.7	14.9	18.0

Table 10.11

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: grass greenness

			seasons		
		overall	wet	early dry	dry
1.	buffalo	na	1	1	1
2.	eland	na	1	0	1
3.	elephant	na	1	1	4
4.	giraffe	na	0	9	0
5.	hippopotamus	na	1	3	11
6.	impala	na	4	4	1
7.	kongoni	na	0	5	8
8.	rhinoceros	na	1	2	0
9.	warthog	na	0	0	3
10.	waterbuck	na	1	2	1
11.	wildebeest	na	2	18	9
12.	zebra	na	2	2	10
13.	total wildlife density	na	3	4	7
14.	species number	na	1	3	10
15.	overall variance ratio	na	3.6	2.9	7.3

Table 10.13

seasonal relationship between environmental stratifications and the various wildlife species in the census zone. Figures show the variance ratios and the proportion of each species distribution explained by the stratification

stratification: photospectrometer ratios

			seasons		
		overall	wet	early dry	dry
1.	buffalo	na	0	5	3
2.	eland	na	3	2	2
3.	elephant	na	2	2	2
4.	giraffe	na	0	13	1
5.	hippopotamus	na	9	7	12
6.	impala	na	1	2	4
7.	kongoni	na	1	2	2
8.	rhinoceros	na	1	1	3
9.	warthog	na	1	1	5
10.	waterbuck	na	4	3	4
11.	wildebeest	na	1	7	3
12.	zebra	na	2	0	1
13.	total wildlife density	na	0	6	0
14.	species number	na	1	9	0
15.	overall variance ratio	na	1.1	6.0	3.6

Table 11.1

seasonal relationships between environmental stratifications
and
buffalo

		season			
		annual	wet	early dry	dry
1.	topography	0	0	10	2
2.	dissection	9	4	10	3
3.	% cover density	1	1	3	2
4.	major vegetation zones	4	2	12	2
5.	major land systems	11	3	12	26
6.	overall distance from water	1	1	1	1
7.	- Lower Rufiji watershed	1	2	3	4
8.	- Upper Rufiji watershed	1	1	0	2
9.	- Ruaha river watershed	1	0	2	2
10.	- Kilombero/Luwegu watershed	4	9	13	9
11.	grass greenness		1	1	1
12.	surface water		2	3	1
13.	photospectrometer ratios		0	5	3

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.2

seasonal relationships between environmental stratifications
and
eland

		season			
		annual	wet	early dry	dry
1.	topography	0	2	1	2
2.	dissection	2	0	1	1
3.	% cover density	0	2	1	2
4.	major vegetation zones	1	3	6	5
5.	major land systems	1	3	3	3
6.	overall distance from water	0	0	2	2
7.	- Lower Rufiji watershed	7	2	1	8
8.	- Upper Rufiji watershed	3	7	3	2
9.	- Ruaha river watershed	7	2	9	4
10.	- Kilombero/Luwegu watershed	6	15	5	2
11.	grass greenness		1	0	1
12.	surface water		1	0	1
13.	photospectrometer ratios		3	2	2

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.3

seasonal relationships between environmental stratifications
and
elephant

		season			
		annual	wet	early dry	dry
1.	topography	6	6	4	9
2.	dissection	3	2	2	5
3.	% cover density	1	0	0	2
4.	major vegetation zones	9	2	5	8
5.	major land systems	24	15	12	20
6.	overall distance from water	2	1	1	0
7.	- Lower Rufiji watershed	11	8	5	15
8.	- Upper Rufiji watershed	3	1	2	2
9.	- Ruaha river watershed	1	10	7	0
10.	- Kilombero/Luwegu watershed	14	14	7	12
11.	grass greenness		1	1	4
12.	surface water		4	4	2
13.	photospectrometer ratios		2	2	2

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.4

seasonal relationships between environmental stratifications
and
giraffe

		season			
		annual	wet	early dry	dry
1.	topography	21	18	17	13
2.	dissection	2	4	0	3
3.	% cover density	2	2	7	3
4.	major vegetation zones	50	63	12	27
5.	major land systems	65	62	44	40
6.	overall distance from water	6	1	4	13
7.	- Lower Rufiji watershed	3	1	1	14
8.	- Upper Rufiji watershed	5	1	0	2
9.	- Ruaha river watershed	0	0	0	0
10.	- Kilombero/Luwegu watershed	0	0	0	0
11.	grass greenness		0	9	0
12.	surface water		0	0	1
13.	photospectrometer ratios		0	13	1

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.5

seasonal relationships between environmental stratifications
and
hippopotamus

		season			
		annual	wet	early dry	dry
1.	topography	45	20	27	42
2.	dissection	3	2	2	2
3.	% cover density	1	1	1	0
4.	major vegetation zones	32	13	26	25
5.	major land systems	24	19	20	12
6.	overall distance from water	53	18	34	67
7.	- Lower Rufiji watershed	51	20	25	72
8.	- Upper Rufiji watershed	59	17	43	69
9.	- Ruaha river watershed	60	15	36	78
10.	- Kilombero/Luwegu watershed	50	44	36	46
11.	grass greenness		1	3	11
12.	surface water		5	57	2
13.	photospectrometer ratios		9	7	12

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.6

seasonal relationships between environmental stratifications and impala

		season			
		annual	wet	early dry	dry
1.	topography	6	7	5	1
2.	dissection	2	19	3	7
3.	% cover density	2	2	1	0
4.	major vegetation zones	29	27	18	15
5.	major land systems	25	36	15	8
6.	overall distance from water	10	5	4	13
7.	- Lower Rufiji watershed	16	11	19	19
8.	- Upper Rufiji watershed	6	6	2	6
9.	- Ruaha river watershed	20	6	5	7
10.	- Kilombero/Luwegu watershed	23	22	14	9
11.	grass greenness		4	4	1
12.	surface water		2	8	0
13.	photospectrometer ratios		1	2	4

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.7

seasonal relationships between environmental stratifications
and
kongoni

		season			
		annual	wet	early dry	dry
1.	topography	15	5	12	9
2.	dissection	26	1	17	20
3.	% cover density	0	0	1	2
4.	major vegetation zones	11	0	8	1
5.	major land systems	39	25	26	20
6.	overall distance from water	3	0	1	2
7.	- Lower Rufiji watershed	10	5	4	0
8.	- Upper Rufiji watershed	2	1	3	1
9.	- Ruaha river watershed	4	11	2	9
10.	- Kilombero/Luwegu watershed	29	2	3	39
11.	grass greenness		0	5	8
12.	surface water		4	11	0
13.	photospectrometer ratios		1	2	2

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.8

seasonal relationships between environmental stratifications
and
rhinoceros

		season			
		annual	wet	early dry	dry
1.	topography	2	1	2	5
2.	dissection	14	3	4	4
3.	% cover density	0	0	0	1
4.	major vegetation zones	4	2	1	3
5.	major land systems	2	6	6	2
6.	overall distance from water	0	0	1	1
7.	- Lower Rufiji watershed	30	32	0	0
8.	- Upper Rufiji watershed	0	1	2	1
9.	- Ruaha river watershed	6	13	25	0
10.	- Kilombero/Luwegu watershed	7	7	0	0
11.	grass greenness		1	2	0
12.	surface water		4	0	0
13.	photospectrometer ratios		1	1	3

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.9

seasonal relationships between environmental stratifications
and
warthog

		season			
		annual	wet	early dry	dry
1.	topography	3	2	4	2
2.	dissection	5	1	0	3
3.	% cover density	1	0	0	1
4.	major vegetation zones	9	12	8	5
5.	major land systems	7	0	20	4
6.	overall distance from water	6	1	0	14
7.	- Lower Rufiji watershed	22	4	4	39
8.	- Upper Rufiji watershed	0	4	2	1
9.	- Ruaha river watershed	9	16	4	8
10.	- Kilombero/Luwegu watershed	6	13	8	2
11.	grass greenness		0	0	3
12.	surface water		1	13	2
13.	photospectrometer ratios		1	1	5

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.10

seasonal relationships between environmental stratifications
and
waterbuck

		season			
		annual	wet	early dry	dry
1.	topography	27	13	16	4
2.	dissection	3	5	2	0
3.	% cover density	6	1	9	2
4.	major vegetation zones	32	13	19	14
5.	major land systems	25	4	28	12
6.	overall distance from water	31	10	22	15
7.	- Lower Rufiji watershed	34	7	24	28
8.	- Upper Rufiji watershed	40	10	29	14
9.	- Ruaha river watershed	40	18	37	5
10.	- Kilombero/Luwegu watershed	7	5	2	4
11.	grass greenness		1	2	1
12.	surface water		4	11	1
13.	photospectrometer ratios		4	3	4

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.11

seasonal relationships between environmental stratifications and wildebeest

		season			
		annual	wet	early dry	dry
1.	topography	14	13	13	9
2.	dissection	5	4	2	1
3.	% cover density	3	7	3	1
4.	major vegetation zones	39	42	46	16
5.	major land systems	40	34	34	17
6.	overall distance from water	4	1	0	13
7.	- Lower Rufiji watershed	10	1	2	19
8.	- Upper Rufiji watershed	0	1	3	1
9.	- Ruaha river watershed	6	7	8	17
10.	- Kilombero/Luwegu watershed	8	9	11	3
11.	grass greenness		2	18	9
12.	surface water		1	3	1
13.	photospectrometer ratios		1	7	3

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.12

seasonal relationships between environmental stratifications
and
zebra

		season			
		annual	wet	early dry	dry
1.	topography	7	7	3	1
2.	dissection	4	2	19	1
3.	% cover density	5	4	3	1
4.	major vegetation zones	11	15	4	0
5.	major land systems	17	18	22	5
6.	overall distance from water	0	0	3	0
7.	- Lower Rufiji watershed	3	0	9	2
8.	- Upper Rufiji watershed	2	1	3	2
9.	- Ruaha river watershed	3	5	7	2
10.	- Kilombero/Luwegu watershed	13	10	23	12
11.	grass greenness		2	2	10
12.	surface water		2	6	1
13.	photospectrometer ratios		2	0	1

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.13

seasonal relationships between environmental stratifications
and
total wildlife density

		season			
		annual	wet	early dry	dry
1.	topography	8	6	3	6
2.	dissection	6	2	10	2
3.	% cover density	3	4	4	2
4.	major vegetation zones	30	27	25	7
5.	major land systems	17	24	17	6
6.	overall distance from water	4	1	3	9
7.	- Lower Rufiji watershed	10	4	16	17
8.	- Upper Rufiji watershed	2	1	0	2
9.	- Ruaha river watershed	11	4	8	10
10.	- Kilombero/Luwegu watershed	33	21	16	16
11.	grass greenness		3	4	7
12.	surface water		1	7	0
13.	photospectrometer ratios		0	6	0

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 11.14

seasonal relationships between environmental stratifications
and
species number

		season			
		annual	wet	early dry	dry
1.	topography	8	8	5	6
2.	dissection	5	4	1	5
3.	% cover density	10	11	2	2
4.	major vegetation zones	20	21	21	8
5.	major land systems	14	21	12	5
6.	overall distance from water	2	0	3	4
7.	- Lower Rufiji watershed	0	3	2	15
8.	- Upper Rufiji watershed	4	1	3	2
9.	- Ruaha river watershed	4	10	8	0
10.	- Kilombero/Luwegu watershed	18	29	8	17
11.	grass greenness		1	3	10
12.	surface water		2	11	0
13.	photospectrometer ratios		1	9	0

figures show the significant variance ratios from 2-way anovars and the percentage of the distribution explained by each stratification

Table 12

selection/avoidance shown for different
vegetation types by a number of species
with respect to their mean annual distribution

	vegetation type							
	MM	CC	BB	OP	AC	GR	SW	TH
buffalo								
eland								
elephant								
giraffe	--	--		++*	++*	-	--	--
hippopotamus							--	
impala	-	*	++	++		--		
kongoni	*	*				++	--	--
rhinoceros								
warthog								
waterbuck	--	*	++				++	++
wildebeest		-	++*	++*	++*	+		
zebra		*	+	+	++			
total density	-	*	++	++	+		+	
species number	-		+	+	+		+	

vegetation codes (MM, CC etc.) as in Annex II.

++ strong selection

-- strong avoidance

* most important vegetation type for a species

Table 13

seasonal densities of giraffe, wildebeest and zebra in the Lower Rufiji Watershed

		wet season April	early dry season July	dry season October
giraffe	d =	0.54	0.22	0.26
	s.e =	0.19	0.07	0.09
zebra	d =	3.60	1.20	1.43
	s.e =	0.93	0.28	0.38
wildebeest	d =	7.75	8.40	6.20
	s.e =	1.79	1.86	1.35

d = mean density

s.e = standard error

Table 14

<u>seasonal rankings of the influences of a number of environmental parameters in determining the distribution of wildlife in the immediate impact area of STIGO</u>

(data from Table 9)

stratifications	overall	season: wet	season: early dry	season: dry
major vegetation zones	1	1	1	3
major land systems	2	2	2	5
overall distance from water	3	6	5	1
grass greenness		3	6	2
surface water		5	3	6
photospectrometer ratios		4	4	4

TABLE 15.1

Seasonal determinants of distribution

Species: Buffalo
Stratification : Major vegetation zones

	Strata	Wet	Early Dry	Dry
1.	Miombo woodland	--	--	
2.	Combretum woodland			
3.	Bushland	++	--	-
4.	Open woodland	--	--	+
5.	Acacia woodland	++	--	--
6.	Grassland		--	--
7.	Swamp		++	
8.	Thicket	--	--	
	Variance component of stratification (%)	1%	6%	4%

++ strong selection
-- strong avoidance

TABLE 15.2

Seasonal determinants of distribution

Species: Giraffe

Stratification : Major vegetation zones

	Strata	Wet	Early Dry	Dry
1.	Miombo woodland	--	--	--
2.	Combretum woodland	--	--	--
3.	Bushland	--	++	++
4.	Open woodland	+	++	++
5.	Acacia woodland	++	--	+
6.	Grassland	+	+	
7.	Swamp	--	--	--
8.	Thicket	--	--	--
	Variance component of stratification (%)	66%	6%	27%

++ strong selection

-- strong avoidance

TABLE 15.3

Seasonal determinants of distribution

Species: Impala

Stratification : Major vegetation zones

	Strata	Wet	Early Dry	Dry
1.	Miombo woodland	--	-	-
2.	Combretum woodland	-		
3.	Bushland	++	+	+
4.	Open woodland	++	++	++
5.	Acacia woodland	+	--	
6.	Grassland	--	--	--
7.	Swamp	+	--	--
8.	Thicket	--	--	
	Variance component of stratification (%)	18%	13%	11%

++ strong selection

-- strong avoidance

TABLE 15.4

Seasonal determinants of distribution

Species: Wildebeest
Stratification : Major vegetation zones

	Strata	Wet	Early Dry	Dry
1.	Miombo woodland	--	--	
2.	Combretum woodland	--	--	--
3.	Bushland	++	++	
4.	Open woodland	++	++	+
5.	Acacia woodland	++	++	-
6.	Grassland		-	++
7.	Swamp	--	--	+
8.	Thicket		--	
	Variance component of stratification (%)	37%	44%	13%

++ strong selection
-- strong avoidance

TABLE 15.5

Seasonal determinants of distribution

Species: Zebra

Stratification : Major vegetation zones

	Strata	Wet	Early Dry	Dry
1.	Miombo woodland	-		
2.	Combretum woodland			
3.	Bushland	+	+	+
4.	Open woodland	+	+	+
5.	Acacia woodland	++	--	--
6.	Grassland	-	+	++
7.	Swamp	-	--	--
8.	Thicket	-	--	
	Variance component of stratification (%)	17%	1%	3%

++ strong selection

-- strong avoidance

TABLE 15.6

Seasonal Determinants of Distribution

Species: Buffalo

Stratification : Major Land Systems

	Strata	Wet	Early Dry	Dry
1.	Alkaline Plains	++		
2.	Rufiji Flood Plain	--	++	
3.	Mkigura Mbuga		--	
4.	Woodland terrace	--	--	+
5.	Mwamp/Utunge	--	--	++
6.	Eastern Cretaceous			
7.	Hatambula Scarp		++	
8.	Kidodi/Karoo			
9.	Kilombero Plain			
	Variance component of stratification (%)	3%	11%	28%

++ strong selection

-- strong avoidance

TABLE 15.7

Seasonal Determinants of Distribution

Species: Elephant

Stratification : Major Land Systems

	Strata	Wet	Early Dry	Dry
1.	Alkaline Plains	+	+	+
2.	Rufiji Flood Plain			++
3.	Mkigura Mbuga	–	–	––
4.	Woodland terrace	+		––
5.	Mwamp/Utunge			
6.	Eastern Cretaceous			
7.	Hatambula Scarp	+	–	–
8.	Kidodi/Karoo			
9.	Kilombero Plain		–	––
	Variance component of stratification (%)	5%	7%	18%

++ strong selection

–– strong avoidance

TABLE 15.8

Seasonal Determinants of Distribution

Species: Giraffe

Stratification : Major Land Systems

	Strata	Wet	Early Dry	Dry
1.	Alkaline Plains	+	++	++
2.	Rufiji Flood Plain	--	--	--
3.	Mkigura Mbuga	+	++	+
4.	Woodland terrace	++	--	+
5.	Mwamp/Utunge	--	--	--
6.	Eastern Cretaceous	--	--	--
7.	Hatambula Scarp	--	--	--
8.	Kidodi/Karoo	--	--	--
9.	Kilombero Plain	--	--	--
	Variance component of stratification (%)	72%	40%	34%

++ strong selection

-- strong avoidance

TABLE 15.9

Seasonal Determinants of Distribution

Species: Hippopotamus

Stratification : Major Land Systems

	Strata	Wet	Early Dry	Dry
1.	Alkaline Plains	+		
2.	Rufiji Flood Plain	++	++	++
3.	Mkigura Mbuga	--	--	--
4.	Woodland terrace	--	--	--
5.	Mwamp/Utunge		--	--
6.	Eastern Cretaceous			
7.	Hatambula Scarp	-	--	--
8.	Kidodi/Karoo			
9.	Kilombero Plain	++	++	++
	Variance component of stratification (%)	17%	15%	2%

++ strong selection

-- strong avoidance

TABLE 15.10

Seasonal Determinants of Distribution

Species: Impala
Stratification : Major Land Systems

	Strata	Wet	Early Dry	Dry
1.	Alkaline Plains	++		++
2.	Rufiji Flood Plain		--	--
3.	Mkigura Mbuga	--	-	
4.	Woodland terrace	--	++	
5.	Mwamp/Utunge	--	--	
6.	Eastern Cretaceous			
7.	Hatambula Scarp	+		
8.	Kidodi/Karoo			
9.	Kilombero Plain	++	++	++
	Variance component of stratification (%)	29%	22%	5%

++ strong selection
-- strong avoidance

TABLE 15.11

Seasonal Determinants of Distribution

Species: Kongoni
Stratification : Major Land Systems

	Strata	Wet	Early Dry	Dry
1.	Alkaline Plains	-	-	-
2.	Rufiji Flood Plain	--	--	--
3.	Mkigura Mbuga	++	++	++
4.	Woodland terrace	--	--	
5.	Mwamp/Utunge	-	--	
6.	Eastern Cretaceous			
7.	Hatambula Scarp	-	--	
8.	Kidodi/Karoo			
9.	Kilombero Plain	--		
	Variance component of stratification (%)	23%	25%	28%

++ strong selection
-- strong avoidance

TABLE 15.12

Seasonal Determinants of Distribution

Species: Waterbuck
Stratification : Major Land Systems

	Strata	Wet	Early Dry	Dry
1.	Alkaline Plains	+	-	
2.	Rufiji Flood Plain	+	+	+
3.	Mkigura Mbuga	-	+	--
4.	Woodland terrace	-	-	--
5.	Mwamp/Utunge			--
6.	Eastern Cretaceous			
7.	Hatambula Scarp		++	-
8.	Kidodi/Karoo			
9.	Kilombero Plain	++	++	++
	Variance component of stratification (%)	7%	29%	15%

++ strong selection
-- strong avoidance

TABLE 15.13

Seasonal Determinants of Distribution

Species: Wildebeest

Stratification : Major Land Systems

	Strata	Wet	Early Dry	Dry
1.	Alkaline Plains	++	++	++
2.	Rufiji Flood Plain		--	+
3.	Mkigura Mbuga		++	++
4.	Woodland terrace		(++)	(++)
5.	Mwamp/Utunge		--	
6.	Eastern Cretaceous			
7.	Hatambula Scarp		++	
8.	Kidodi/Karoo			-
9.	Kilombero Plain		++	-
	Variance component of stratification (%)	34%	28%	18%

++ strong selection

-- strong avoidance

TABLE 15.14

Seasonal Determinants of Distribution

Species: Zebra
Stratification : Major Land Systems

	Strata	Wet	Early Dry	Dry
1.	Alkaline Plains	++		
2.	Rufiji Flood Plain	-	--	--
3.	Mkigura Mbuga	+	--	+
4.	Woodland terrace	--	+	
5.	Mwamp/Utunge	--	-	
6.	Eastern Cretaceous	-		
7.	Hatambula Scarp	-	++	+
8.	Kidodi/Karoo			
9.	Kilombero Plain			-
	Variance component of stratification (%)	18%	37%	2%

++ strong selection
-- strong avoidance

Table 16

distribution of wildlife populations with respect to major, permanent rivers in the dry season, ranked by the fifty percentile

	proportion of the population			
	25%	50%	75%	100%
hippopotamus	3	3	3	6
waterbuck	3	3	3	12
rhinoceros	6	6	15	18
impala	3	9	12	27
elephant	6	9	15	27
warthog	6	9	15	27
wildebeest	6	12	18	27
zebra	9	12	18	27
eland	15	18	18	18
buffalo	15	18	21	21

numbers show the distance (km) from major rivers

Table 17

frequency of categories of surface water throughout the STIGO census zone during the three censuses

category	wet season	early dry season	dry season
		season	
0	1%	14%	44%
1	77%	76%	24%
2	16%	9%	25%
3	6%	1%	7%

surface water categories as in section 2.3.7.

TABLE 18

Wildlife densities in the two major land systems of the Stigo Impact Area

	lowlying plains	upland cretaceous/Karoo
Buffalo	8.53	3.33
Eland	0.14	0.41
Elephant	2.06	1.51
Giraffe	0.86	0.01
Hippopotamus	1.41	1.42
Impala	9.47	4.85
Kongoni	0.92	0.81
Rhinoceros	0.02	0.05
Warthog	0.37	0.33
Waterbuck	0.38	0.25
Wildebeest	12.02	1.91
Zebra	3.30	1.96
Total Density	39.48	16.84
Species Number	4.92	3.88

TABLE 19

Proportion of each wildlife population utilising the vegetation zones in Land Region I (low lying plains) of the STIGO impact area, on a seasonal and an annual basis

Vegetation code		CC	BB	OP	AC	GR	SW	totals LR.1	totals LR.2
Area		6%	1%	6%	1%	2%	2%	18%	82%
Buffalo	W	1	30	2	3	3	1	40	60
	ED	18	1	1	5	–	–	33	67
	D	32	1	12	–	–	1	46	54
	AN	18	8	5	1	1	3	36	64
Eland	W	1	5	4	–	1	–	11	89
	ED	1	–	5	5	3	–	15	85
	D	1	–	–	–	–	–	1	99
	AN	1	2	3	1	1	–	8	92
Elephant	W	4	7	5	2	1	2	21	79
	ED	5	–	13	–	–	4	22	78
	D	13	–	7	–	–	8	27	73
	AN	7	2	8	1	1	4	23	77
Giraffe	W	1	3	43	42	7	–	96	4
	ED	16	22	67	0	4	–	100	–
	D	4	15	60	3	3	–	85	15
	AN	6	9	55	19	5	–	94	6
Hippopotamus	W	13	–	8	–	1	8	30	70
	ED	7	–	2	–	–	9	18	82
	D	4	–	1	–	–	7	11	89
	AN	7	–	3	–	–	8	18	82
Impala	W	1	11	21	2	–	4	39	61
	ED	1	1	13	–	1	–	15	85
	D	3	4	27	1	1	–	35	65
	AN	2	5	20	1	1	1	30	70
Kongoni	W	4	–	6	1	6	–	17	83
	ED	5	–	2	1	10	–	18	82
	D	7	–	6	–	11	–	25	75
	AN	5	–	5	1	9	–	20	80
Rhinoceros	W	2	11	5	–	–	–	17	83
	ED	10	–	–	–	–	–	10	90
	D	–	–	–	–	–	–	–	–
	AN	4	4	2	–	–	–	8	92

..over/

Table 19 : continued

Vegetation code		CC	BB	OP	AC	GR	SW	totals LR.1	totals LR.2
Area		6%	1%	6%	1%	2%	2%	18%	82%
Warthog	W	2	2	8	1	-	-	13	87
	ED	1	1	13	-	1	-	16	84
	D	3	1	19	1	1	1	26	74
	AN	2	1	14	1	1	1	20	80
Waterbuck	W	6	-	11	1	3	13	33	67
	ED	12	-	6	-	-	9	26	74
	D	2	-	-	-	-	8	10	90
	AN	7	-	6	1	1	10	25	75
Wildebeest	W	4	16	30	11	2	-	63	37
	ED	1	10	46	6	1	1	65	35
	D	2	3	20	1	9	6	41	59
	AN	3	10	33	6	4	2	58	42
Zebra	W	1	6	26	7	1	-	41	59
	ED	3	-	11	-	1	-	14	86
	D	5	5	3	-	7	-	20	80
	AN	2	4	16	3	2	-	27	73
TOTAL DENSITY	AN	7	6	15	2	1	2	33	67
SPECIES NUMBER	AN	4	8	6	5	4	5		4

W = wet season　　ED = Early dry season
D = dry season　　AN = Annual

TABLE 20

Proportion of each wildlife population utilising the reservoir areas on a seasonal and an annual basis

		RESERVOIR FLOODING LEVELS		
		Mean low	High Phase 1	High Phase 2
Area of census zone		11%	12%	20%
Buffalo	W	1	1	2
	ED	1	6	6
	D	1	1	1
	AN	1	3	4
Eland	W	19	26	41
	ED	13	12	15
	D	0	1	1
	AN	13	16	24
Elephant	W	10	10	16
	ED	10	10	21
	D	3	6	9
	AN	10	11	20
Giraffe	W	0	0	0
	ED	0	0	0
	D	0	0	0
	AN	0	0	0
Hippopotamus	W	9	8	12
	ED	30	25	42
	D	39	47	57
	AN	31	37	48
Impala	W	12	13	15
	ED	13	18	23
	D	9	12	14
	AN	16	17	23
Kongoni	W	7	14	20
	ED	7	9	13
	D	4	2	12
	AN	8	11	19
Rhinoceros	W	0	0	9
	ED	15	15	26
	D	9	16	16
	AN	11	14	22

.... over

Table 20 : continued

		RESERVOIR FLOODING LEVELS		
		Mean low	High Phase 1	High Phase 2
Area of census		zone 11%	12%	20%
Warthog	W	11	13	15
	ED	6	9	11
	D	13	17	18
	AN	14	15	19
Waterbuck	W	28	29	33
	ED	52	52	57
	D	36	39	47
	AN	51	55	61
Wildebeest	W	5	7	9
	ED	2	2	3
	D	5	6	7
	AN	4	5	7
Zebra	W	4	7	13
	ED	17	19	24
	D	5	5	7
	AN	7	8	12

W = Wet season ED = Early dry season
D = Dry season AN = Annual

ANNEX 1 to ANNEX 4

ANNEX I: SEASONAL RELATIONSHIP BETWEEN CATEGORIES OF GRASS GREENESS AND PHOTOSPECTROMETER READINGS

AI.1 Introduction

Categories of grass greeness, equivalent to growth stage, and spectrophotometer readings, equivalent to green biomass standing crop, have been used as stratifications for studying the seasonal distribution of animals within the STIGO census zone. This Annex explores the relationship between these two measurements of forage quality in more general terms, with the objective of deciding whether they are complimentary measurements or whether one can replace the other.

AI.2 Seasonal patterns of grass greeness and photospectrometer ratios

Table A.1 shows the seasonal percentages of the different categories of grass greeness. As the year progresses, the proportion of the 'brown' and 'yellow/brown' categories increase, demonstrating the cycle of grass growth throughout the census zone (section 2.3.6).

Table A.2 gives the seasonal percentages of photospectrometer ratios throughout the census zone. A similar pattern is seen, with green biomass becoming less as the year progresses.

Table A.3 presents three, one-way anovars of the photospectrometer ratios as a function of grass greeness categories - a 2-way anovar being impossible because of the large proportion of nul records for certain grass greeness categories.

Within seasons, the grass greeness categories have significantly different mean photospectrometer ratios, while between season it is obvious that the mean ratios for each category is showing a significant decrease. In general, therefore, it appears that the grass greeness categories and the photospectrometer ratios are complimentary, in that the categories are describing the growth stage, and therefore the structure, of the sward while the ratios are indicating the green biomass present.

However, the effect of the woodland vegetation is so far unknown, for green biomass in the tree canopy and tree stems must be effecting the photospectrometer ratios. Table A.4 presents a two-way anovar of photospectrometer ratios as a function of cover density of the woodland vegetation and of grass greeness categories. This anovar was carried out on the early dry season data (July) only for this data set had the best spread of grass greeness categories and photospectrometer ratios. Even so, both the cover densities and the greeness categories had to be combined into three classes each and, furthermore, approximately one third of the data had to be discarded, at random, to make the cell frequencies roughly proportional.

Inspection of the means in Table A.4 reveals a strong influence of cover density on the photospectrometer ratios in addition to the effect of grass greeness. The two-way anovar confirms this, showing highly significant row and column effects explaining 23% and 20% of the variance respectively.

Quite surprisingly the interaction effect was not significant, but this may well be due to lumping of categories. However, inspection of the means shows that ratio of the highest to the lowest is quite similar in each grass greeness category (1.17, 1.33 and 1.25 respectively).

Table A.5 presents a two-way analysis of variance of photospectrometer ratios as a function of vegetation types in each season. Over all three season, the variance component of the vegetation is swamped by the seasonal effect of changed in the standing crop of green biomass, while the interaction effect is weak, though significant.

Within seasons, the variance component of the vegetation is considerably stronger in the wet and early dry seasons than in the late dry season. Nevertheless, significant differences between the mean photospectrometer ratios within vegetation types are apparent. Of interest are the extremely low photospect rometer ratios recorded over the swamp areas.

The mean cover density of each vegetation type is also shown in Table A.5 (data derived from Table 4). By inspection, the influence of cover density on the photospectrometer ratios appears to be stronger in the wet season than in the dry season.

Table A.6(i), A.6(ii) and A.6(iii) show the frequency distributions of categories of grass greeness within each vegetation type in each season. The seasonal growth cycle of the grasslands is clear, as are some consistent differences between vegetation types.

In Table A.7, each vegetation type has been ranked on cover density , on 'greeness' from the grass categories and on 'green biomass' from the photospectrometer ratios. Within each season, the rank correlations (Spearman) are erratic and non significant, as is to be expected from such few vegetation categories. However, the picture is more interesting between season. The rank correlation between the photospectrometer ratios and grass greeness categories is stronger than that between the photospectrometer ratios and cover density while the correlation between greeness categories and cover density is weak.

In general , then, the following picture emerges. The grass greeness categories and the photospectrometer ratios compliment each other in that they both show the same seasonal pattern over the whole area and within different vegetation types. The greeness categories are indicating changes in growth stage of the sward while the photospectrometer ratios are indicating changes in the standing crop of green biomass. The photospectrometer ratios, however, are heavily influenced by the cover density of the woody vegetation. This influence seems to be proportional to cover density, and it seems to be weaker in the dry season than in the wet season. The grass greeness categories appear uninfluenced by the cover density of the woody vegetation.

ANNEX II: MAP CODES

A complete map of 40 x 40 grid squares is split into 4 quadrants, labelled; (Map: 1), (Map 2), etc. on each sheet. The heavy border of hash marks indicates the boundary of the census zone. The astericks within the maps show the approximate location of the major rivers. The course of minor rivers are shown by 'r', (see map 6).

Map 1: major vegetation zones (section 2.3 and 3.2);

In each grid square the first two characters of the four character code indicates the dominant vegetation type. The second two characters repeat the first two in upper case if the square is homogeneous. If a second, sub-dominant, vegetation type is present , it is shown in lower case in the second two characters.

MM	miombo woodland
CC	combretum woodland
BB	bushland
OP	open woodland
TH	thicket
AC	acacia woodland
GR	grassland
SW	swamps

Map 2: distance from major rivers (section 3.4);

Five major watersheds have been defined, mapped with the following codes:-

LF	lower rufiji below STIGO
F	upper rufiji, above STIGO (Ulanga river)
R	Ruaha
K	Kilombero
L	Lualla

The distance between the centre of each grid square and the nearest of these major rivers is coded thus:-

1. within 3 kilometres
2. within 6 kilometres
3. within 9 kilometres
4. within 12 kilometres

etc.

Map 3: dissection (section 2.3);

----	flat land, no relief
UUU	gentle relief, frequently catenary
hhhh	medium scale relief, including small hills, ridges and incised valleys
^^^	steep relief, including major hill features and fault scarps

Map 4: topography (section 2.3);

ᗰᗰᗰ	ridge:	elevated plateau features and brood ridges
hhhh	hills:	distinct relief features
////	slope:	uni-directional, steep slope
VVV	valley:	major, incised valley
fhfh	flood plain:	non-incised valley features including the river beds, swamps and levees of the lower Rufiji river
----	flat land:	no relief or dissection
unun	undulating:	typical, gentle relief of the catenary ridge-slope-valley topographical sequence.

Map 5: major land systems (section 3);

The two major land regimes are coded as:-

P- low-lying plains
U- upland, cretaceous/Karoo

Within each land region, the land systems are coded as follows:-

	(	PM	Mbigura mbuga drainage system
	(	PA	Alkaline plains
Low-lying	(	PW	Woodland terraces
Plains	(	PR	Floodplains of Rufiji river
	(	PD	Mwama - Utunga drainage system
	(	UH	Hatambula - Tagdala scarp and fault
Upland	(	UK	Kilombero flood plain
Cretaceous/	(	UE	Eastern cretaceous sandstones
Karoo	(	UM	Kidodi/Karoo sandstones

Map 6: boundary of census zone, major and minor rivers

✲	boundary of census zone
*	major rivers
r	minor rivers

Map 7: woodland cover density

blank	<10%
1	10-19%
2	20-29%
33	30-39%
444	40-49%
555	50-59%
6666	60%

Maps 8 - 23: mean annual desity of wildlife species;

Numbers snow density per square kilometre.

Map 24: wildlife diversity;

Numbers show the number of different species recorded in each grid square.

Maps 25 - 48: wet season, early dry season and late dry season, density distribution maps for selected species.

Maps 49-51: green-ness of grass in the wet, early dry and late dry seasons;

BB	brown
YB	yellow/brown
YY	yellow
YG	yellow/green
GG	green

Map 52-54: photosprectrometre ratio classes in the wet, early dry and late dry seasons;

<1	ratio	<0.9
1		1-1.9
2		2-2.9
3		3-3.9
4		4-4.9
5		5-5.9
>6		>6

Maps 55-57: surface water in the wet, early dry and late dry seasons;

blank	no water
*	few isolated pools
**	frequent pools
***	abundant water, flooded

Maps 58-60: squares which will be more than 50% flooded at mean low water, high water phase 1 and high water phase 2.

****	flooded squares

ANNEX III: BIBLIOGRAPHY

1. Caughley, G. 1974 Bias in aerial survey. J. Wild. Manage 38(4),921-933

2. Caughley, G, Sinclair, R.G. & Scott-Kermis, D. 1976 Experiments in aerial survey. J. Wildl. Manage. 40 (2), 290-300

3. Cochran, W.G. 1963 Sampling Techniques 2nd ed. John Wiley: New

4. Huitson, A. 1966 The Analysis of Variance, Griffin's Statistical Monographs, No.18. Charles Griffin: London

5. Jolly, G.M. 1969 Sampling methods for aerial census of wildlife populations. E. Afr. agric. For J. 34, 46-49

6. Jolly, G.M. and Watson, R.M. 1979. Aerial sample survey methods in the quantitative assessment of ecological resources. in press.

7. McNaughton, S.J. 1976 Serengeti migratory wildebeest: facilitation of energy flow by grazing. Science 191, 92-94

8. McNaughton, S.J. 1979 Grassland Dynamics. Chapter 7 in Serengeti A study of Ecosystem Dynamics. Sinclair, A.R.E. and Norton-Griffiths, M., Ed. Chicago University Press: Chicago

9. Norton-Griffiths, M. 1974 Reducing counting bias in aerial survey by using photography. E.Afr.Wildl.J. 12 (3), 245-248

10. Norton-Griffiths, M. 1976 Further aspects of bias in aerial census of large mammals. J.Wildl. Manage. 40.(2), 368-370

11. Norton-Griffiths, M. 1978 Counting Animal. African Wildlife Leardership Foundation: Nairobi

12. Sinclair, A.R.E. and Norton-Griffiths, M. 1979 Serengeti - A study in EcoSystem Dynamics. Chicago University Press: Chicago

13. Somal,R.R. and Rohlf, F.J. 1969 Biometry. W.H. Freeman: San Francisco

14. Tucker C.J., Miller, L.D. & R.L. Pearson, 1973. in Proceedings 2nd. Annual Remote Sensing of Earth Resources Conference. F. Shahrohic, Ed. Univ. of Tenessee Press: Tullahoma

ANNEX 4

TOTAL COUNTS OF HIPPOPOTAMUS AND CROCODILE

4.1 General

At the end of the third census, a total count was to be carried out of crocodile and hippopotamus along the main rivers. This exercise was not particularly successful.

Total counting only works under certain circumstances[11/]. First, the animals must be highly visible and concentrated into well defined herds. Second, very good maps are required so that the flight path of the aircraft and every group of animals can be located accurately. Accurate mapping is the only way to ensure that the whole area has been searched, that no part has been searched twice and that no groups of animals have been missed or double counted.

The areas downstream of the dam site, especially the lakes and the swamps, were thus quite unsuitable for total counting. The animals concerned were dispersed into small ill-defined groups and maps of all the new channels were unavailable.

It was therefore decided to restrict the total counting solely to the well defined river lines upstream of Stiegler's Gorge. Four sections of the rivers were counted (Fig. 1), totalling some 121 kilometers. Section 1 ran from just below Stigo to the junction of the Ruaha and Rufiji rivers. Section 2 ran from this junction along the Ruaha and sections 3 and 4 ran upstream from this junction.

The aircraft was flown at 700 feet above ground level. Two observers, sitting in tandem behind the pilot, both counted each group of animals as they were encountered, and most groups larger than about ten were photographed.

As soon as counting started it became immediately apparent that whereas the hippos were not reacting to the aircraft the crocodile were vanishing into the water as soon as it approached. Counting of crocodile was therefore abandoned and the objectives of the exercise were changed. Rather than attempting a total count of hippos per se, we concentrated primarily on obtaining a correction factor for the visual observations made on the sample flights.

4.2 Hippopotamus

Comparisons between the visual counts off photographs gave a correction factor for hippos of 1.12. This correction factor was applied to all the estimates of hippos made on the three censuses as well as to the estimates made on the total count.

3145 hippos were counted along the 121 kilometers of river, giving a mean figure of 26 hippopotamus per kilometer of river line. The estimate for hippopotamus in the impact area (Table 7) is 8988. Dividing this number by 330 kilometers of river line in the impact area gives an overall figure of 27 hippopotamus per kilometer of river line.

Figure 7 and the computer distribution maps show that hippo are quite evenly distributed along the rivers, apart from the Ruaha reach which has considerably more than elsewhere. Below is presented an analysis of the numbers of hippos along different parts of the river. The figures were obtained from the early dry season and late dry season estimates.

River section	Kilometers	Total hippo	Hippo/km of river line
Lower Rufiji	75	2200	29.33
Upper Rufiji	146	3017	20.66
Ruaha	46	2058	44.74
Kilombero/Luwegu	63	1713	27.19
TOTAL	330	8988	mean = 27.24

These estimates from the total count and from the sample counts refer to those hippo visible on the surface of the water. No corrections have been applied for the number of hippo that were under water. Detailed ground work will have to be carried out in order to estimate this proportion.

4.3 Crocodile

The only estimates for crocodile are those from the sample counts. Even more so than with hippo, these counts are subject to time-of-day biases due to the movements of crocodile into and out of the water. Indeed, the estimates of crocodile are to be considered as minimum estimates only. Detailed ground work will be needed to study the diurnal movements onto land and the proportion of the population which is under water.

The estimates given below for crocodile along different stretches of the river are based on the mean annual estimates of carnivore density corrected for those carnivores which were not crocodile.

River section	Kilometers	Total Crocodile	Crocodile/km river line
Lower Rufiji	75	163	2.17
Upper Rufiji	146	232	1.59
Ruaha	46	10	0.22
Kilombero/Luwegu	63	44	0.70
TOTAL	330	449	mean = 1.36

4.4 Population Changes in Hippopotamus and Crocodile

In 1964, I.S.C. Parker carried out intensive aerial and ground surveys of crocodile and hippopotamus along an 80 km reach downstream from the Shuguli Falls*. This stretch of river corresponds to the 'Upper Rufiji' of this study.

Parker estimated a total of 242 crocodile of 5' or greater in size, or 3.03 per kilometer of riverline. Furthermore, he estimated from night counts and from counts at baits an additional 313 crocodile of less than five feet in length. The ratio of crocodiles below and above five feet in length varied along the river, with the smaller ones being more common downstream. This was interpreted as showing a pattern of movement of young crocodile into and out of the swamps below Stiegler's Gorge.

Along this same stretch of river, 1728 hippos were counted giving a mean of 21.6 per kilometer of river line.

It would therefore appear that hippos are currently at the same density as they were in 1964, and have recovered from the marked decrease following the droughts. In contrast, crocodile now appear to be at about one half of their 1964 density.

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* Parker, I.S.C. and A.D. Graham (1964). An Assessment of crocodile numbers in the Rufiji river between Shuguli Falls and the confluence of the Rufiji and Ruaha rivers. Report to: Tanzanian Game Division, Dar es Salaam : Wildlife Services Ltd., Nairobi.

TABLE A.1 to TABLE A.7

Table A.1

seasonal percentages of categories of grass greeness

	count 1 April	count 2 July	count 3 October
brown	-	2	48
yellow/brown	-	9	20
yellow	-	31	19
yellow/green	43	56	13
green	57	2	-
N	706	706	706

Table A.2

seasonal percentages of photospectrometer ratios

ratio band	count 1 April	count 2 July	count 3 October
0.9	-	-	2
1.0-1.9	3	18	81
2.0-2.9	7	50	14
3.0-3.9	31	26	2
4.0-4.9	28	5	1
5.0-5.9	16	1	-
6.0-6.9	8	-	-
7.0	7	-	-
N	706	706	706

Table A.3

analysis of variance of photospectrometer ratios
as a function of categories of grass greeness

	mean ratios		
	count 1 April	count 2 July	count 3 October
brown	-	1.67	1.45
yellow/brown	-	1.85	1.51
yellow	-	2.59	1.69
yellow/green	4.26	2.69	1.75
green	4.94	2.91	-
F ratio	28.52	38.8	15.14
p =	<0.001	<0.001	<0.001
grand mean	4.64	2.67	1.55
s.e.	0.07	0.03	0.02
L.S.D.	0.18	0.08	0.06

s.e. : standard error

L.S.D. : least significant difference between any two means at $p = < 0.05$

Table A.4

two-way analysis of variance of photospectrometer ratios as a function of categories of grass greeness and of woodland cover density (percent). Data from count 2 (July) only.

	% cover density of woody vegetation		
	0-9.9%	10-19.9%	>20%
brown and yellow/brown	1.71	1.72	2.00
yellow	2.26	2.54	3.01
yellow/green and green	2.64	2.89	3.29

anovar table

source	df	ss	ms	F	variance component
subgroups	8	83			
rows (grass greeness)	2	42	21.00	46.7	23%
cols (cover density)	2	38	19.00	42.2	20%
interaction	4	3	0.75	1.7	2%
error	545	246	0.45		
total	553	329			

L.S.D. = 0.08

Table A.5

two-way analysis of variance of photospectrometer ratios as a function of vegetation types at different seasons. Within season anovars are separate one-way analyses.

	count 1 April	count 2 July	count 3 October	% canopy cover
combretum woodland	4.6	2.8	1.6	15%
miombo woodland	5.0	3.1	1.8	23%
open woodland	3.9	2.0	1.4	9%
bushland	3.7	1.8	1.4	7%
grassland	4.5	2.2	1.2	5%
swamp	1.1	1.8	1.7	5%
acacia woodland	4.1	1.8	1.5	18%
F ratio	13.52	26.87	3.86	
variance component	33%	49%	12%	
p =	<0.001	<0.001	<0.01	
L.S.D.	0.24	0.10	0.08	

2-way anovar

source	F ratio		variance component
vegetation types	27.1	p =<0.001	5%
seasons	710.0	p =<0.001	91%
interaction	7.7	p =<0.001	1%

Table A.7

correlations between seasonal rankings of vegetation types by grass greeness categories (G), photospectrometer ratios (R) and woodland canopy cover (C).

	count 1	count 2	count 3
	G:R:C	G:R:C	G:R:C
combretum	6:2:3	3:2:3	6:3:3
miombo	4:1:1	2:1:1	3:1:1
open	3:5:4	6:4:4	4:6:4
bush	5:6:5	5:6:5	2:5:5
grassland	2:3:7	1:3:7	1:7:7
swamp	7:7:6	4:6:6	7:2:6
acacia	1:4:2	7:6:2	5:4:2

spearman rank correlations:

(i) within seasons (df = 6)

rs G.R.	0.29	0.71	-0.57
rs G.C.	0.05	-0.25	-0.21
rs R.C.	0.57	0.39	0.57

(ii) between seasons (df = 20)

rs G.R. 0.79 $p = <0.001$

rs G.C. 0.35 (n.s.)

rs R.C. 0.81 $p = <0.001$