SOMALI DEMOCRATIC REPUBLIC

CENTRAL RANGELANDS SURVEY

VOLUME 4

DYNAMIC RANGE RESOURCES

METHODS AND COMMENTS

RESOURCE MANAGEMENT & RESEARCH
16B WEST CENTRAL STREET
LONDON W.C.1

SOMALI DEMOCRATIC REPUBLIC

CENTRAL RANGELANDS SURVEY

VOLUME 4

DYNAMIC RANGE RESOURCES

METHODS AND COMMENTS

RESOURCE MANAGEMENT & RESEARCH
16B WEST CENTRAL STREET
LONDON W.C.1

THE SOMALI DEMOCRATIC REPUBLIC

CENTRAL RANGELAND SURVEY

VOLUME 4

THE DYNAMIC RANGE RESOURCES OF THE CENTRAL RANGELANDS

METHODS AND SOME COMMENTS ON THE RESULTS

R. M. WATSON M.A., Ph.D.,
C. I. TIPPETT

RESOURCE MANAGEMENT
AND RESEARCH

16B, WEST CENTRAL STREET
LONDON WC1 U.K.

TABLE OF CONTENTS

List of Figures

List of Tables

INTRODUCTION

This is the last of a series of volumes prepared by Resource Management and Research describing the methods and results of a survey undertaken in the Central Rangelands of the SOMALI DEMOCRATIC REPUBLIC, under contract agreements shown in Appendix 1.05.

The structure of reports has been described in volume 1 part 1.

This report describes the methods employed in the aerial census, the calibration and other weighting values, the sampling and flying schedules, and the important inferences concerning livestock migration.

The main data of the two censuses has been re-interpreted and re-tabulated for the three administrative regions MUDUG, GALGADUUD, HIRAAN, and for the 29 ecological zones and eight ecological classes.

And finally the human populations have been worked out from house occupation rates.

RAPID SURVEY & CENSUS TECHNIQUES

Decisions on alternative courses of action are made on the basis of information. Broadly speaking the effectiveness of any decision is a function of the volume and quality of information which has been assembled about the system within which the course of action is taken. Effectiveness is measured in terms of rates of movement towards a desired state based upon objectives which are probably arbitrary, for units of effort (i.e. expenditure of resources and/or energy).

The sorts of decision which large communities of people (usually Governments) make, typically concern exceedingly complex and inter-acting socio-economic and ecological systems. In these situations, even if an unambiguous and compatible series of objectives have been determined by some political process, it is very easy to expend enormous effort on an apparently simple course of action, only to see no movement in the desired direction (or even a negative movement) because of an overlooked element in the system.

Developing countries are in a particularly bad position to make plans because;

i) The information base available to evaluate alternative courses of action is usually very incomplete.

ii) In general these countries are attempting to change rapidly, that is, to 'develop'; in contrast developed countries are more concerned with maintaining a status quo. Therefore they are considering courses of action likely to generate fundamental and large changes.

iii) The field of 'development' is a battle ground for interested donor agencies (bilateral, multilateral, UN, etc.) whose principal motive in giving aid is ulterior, and whose level of motivation and technical competence severely limited. The possibility of an integrated approach by these agencies, in which the interests of a particular region become paramount, is remote. This situation imposes considerable additional responsibilities on the Government's own co-ordinating body.

iv) Political objectives are likely to show rapid and large changes as the political system of the country evolves.

In view of these phenomena Resource Management and Research have developed a series of techniques of rapid survey and census which meet many of the needs of developing countries in that they are;

i) designed to provide a comprehensive and uniform database of all the relevant elements of the systems about which decisions are to be made. Ultimately some optimization process for evaluating alternative courses of action can be built into this type of database.

ii) independent of any previously collected information. This point is of some significance. There is a strong tradition in agricultural statistics to employ the human census as a sampling frame. This is an unsatisfactory procedure (see Watson Tippett & Southworth, 1974, pp11-19, which are reproduced below) in most developing countries.

WATSON, TIPPETT & SOUTHWORTH 1974. Page 11 - 19.

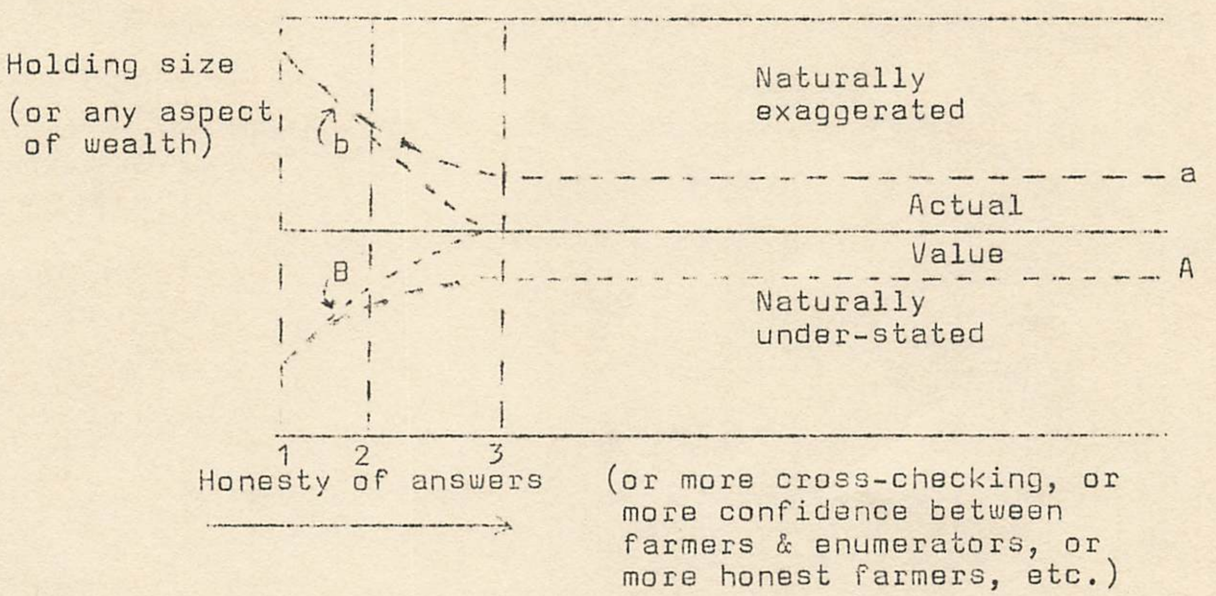
"Agricultural statistics traditionally in many countries are linked to human census data and employ as a sampling frame the human population census. While not discounting the significance of 'the decision-making unit' in undertaking agricultural systems, the consultants feel that the following serious limitations will apply to data collected using the human census as a sample frame:

(1) The first assumption made in such an approach is that there exists a good human census. Most human censuses, even in developing countries, are based on attempts at total instantaneous counts of the human population (again this seems, to the P.P.D. and the consultants, to reflect traditional thinking rather than the application of a problem-solving approach, which would surely indicate in many situations that some area based sampling procedure be employed), and so a 'poor' human census will be known to be of low quality only as a result of discrepencies or as a result of certain operational failings during the census. There will exist no quantitative correction for an attempted total census which has any statistical validity. Thus the first 'assumption' becomes an article of faith, which helps to explain the vigour if not fanaticism with which the human sample-frame is defended by its users.

(2) If there exists a good human census, the second limitation becomes this: by approaching agricultural statistics through the decision-making unit, i.e. through the farmer and his family, one becomes instantly dependent upon the good faith and honesty of the farmer. A subsistence farmer is sought by a government official by name, and is asked a series of questions relating to his material situation and practices. If there is a single country in the whole world where all taxation is indirect, this type of approach might work. The P.P.D. and the consultants suggest that the reader put himself in the position of the farmer, who is self-employed person, who fully appreciates that his government visitor has neither the resources, time nor motivation to pursue the truth or dishonesty of any of his replies to their ultimate stage. How likely is it that any farmer will declare his full material wealth, i.e. all his fields, all his livestock and poultry, all his houses, etc?

In summary it is felt that any information collected through human sample frame will embody massive and unmeasurable under-estimates.

It is frequently argued that the degree of under-estimation is consistent and can be measured as a bias, and that this bias can be corrected. Since this is true, the problem then becomes to decide when we have a 'true' estimate. Take the simple problem of holding size: our initial questioning of farmers, will produce, for example from a sample of 1000 farmers, a mean farm holding size of 1.8 ha. divided into 5 parcels. A more intensive investigation of say 100 farmers may give a mean holding size of 2.2 ha. over 6 parcels. If we correct the earlier estimates by a factor of 1.22, we have not necessarily eliminated bias - we have simply moved up a curve towards the truth, a truth which indeed may be unattainable by the method in question - see below:



(1), (2) and (3) are different applications of the questionnaire techniques of increasinf sophistication.

Curves A, B, a and b relate the sophistication of questioning (and expense) to the real value of the quantity under investigation.

In situations 'a' and 'b' there is a tendency for the information to exaggerate his answers: in case 'b' more sophisticated and expensive questionnaire techniques (type 3) are assumed capable of reaching the true answer from all farmers; in case 'a' even the most sophisticated and expensive questionnaire techniques are judged to be incapable of producing the true answer from all farmers (or indeed possibly from any farmer).

Situations 'A' and 'B' are the equivalents for a quantity about which there is a tendency for the informant to understate.

By application of different levels of questionnaire methods we may be able to construct the asymptotic curve postulated. However in most cases we will not be aboe to judge the position of the asymptote relative to the real value sought. This can only be done if some 'objective' as opposed to 'questionnaire' approach is adopted - such techniques are not easily applied through the human sample frame (see discussions later in this Chapter on objective area-based methods).

(3) The use of a human census sample frame frequently results in information being stratified and analysed in terms of ADMINISTRATIVE AREAS or other land units whose identity is primarily related to patterns of human organisation. This is true of Ethiopian agricultural statistics as currently presented, and leads us to make the following comments on the concepts of the 'AWRAJA' as a land unit in agricultural statistics.

It would be difficult to devise an administrative land unit having less suitability from the point of view of understanding the agricultural system (and consequently for planning relief measures for failures in the agricultural system. This is because Awrajas appear to combine the maximum range of ecological diversity possible within the Province. It is possible to appreciate the inadequacy of an Awraja classification if the CSO agricultural statistics are examined in the least bit critically. These 'statistics' are in any case based on a human 'census' frame of doubtful validity, thus being applicable to an area breakdown only if certain assumptions are made. Even discounting this, the Awraja means, for such quantities as land under cropping, reveal nothing of the underlying ecological associations, and embody such large standard errors as to be more misleading than helpful in agricultural planning exercises. Now that good maps are at last becoming available, it is most strongly recommended that at least agricultural statistics are presented in some more relevant land classification. The simplest and most readily available is the altitude zone.

It is appreciated that there are problems of 'conceptualisation' in a country for which there are no maps. However, it seems that this problem is now virtually overcome, and some effort should be made by all those concerned in planning to cease to conceptualise the country in terms of a collection of Awrajas. Information on any problems, be it numbers of people or location of relief efforts, is better conveyed on an accurate map. The maps in this report (Figures 3.3, 4.3, 5.3, 6.3 and 7.3) provide a perfect example of the superiority of this mode of expressing information which has spatial variables.

The same could be said of the WEREDA, with the reservation that as the unit of land becomes smaller it is more likely to have some ecological homogeneity.

(4) Finally the planning and execution of a sampling of statistics based on the human census frame does not allow the concentration of sampling effort to be placed in zones of certain characteristics and so will provide a less efficient means of collecting data for understanding systems.

These limitations can be overcome if an area frame is adopted for sampling, and if objective methods are used as widely as possible for collecting the information within each sample. Thus area-frame sampling (which automatically allows more objective data collection procedures) overcomes these limitations in the following ways:

(i) The grossing-up problem and the sample selection problem depends only upon the existence of maps. The nature of the geographic data base makes it much more likely that there can be good maps, than a good human census. Even in the Ethiopia, where good mapping is only just becoming available, the geographic data base is greatly superior to the human census information.

(ii) By approaching the collection of information from an area point of view, it is much easier to employ an objective method of data collection, e.g. photogrammetry, and the collection of data by questionnaire has the advantage in such situations that:

a) questions can be linked to objective data, to provide checks on replies and create an atmosphere in which the informant is more likely to answer honestly and accuratley;

b) questions do not need to be linked to the identity of the farmer;

c) only very few questions need concern a farmer's total resources.

(iii) The area frame allows information to be stratified and analysed in terms of units of land having homogeneous or common characteristics relevant to the use of those statistics (such as an ecologically stratiried area to be used in understanding the agricultural system), or in terms of the location characteristics of the sample.

iv) The planning and execution of sampling based on an area-frame allows sampling effort to be most efficiently concentrated for specific objectives.

There are of course drawbacks to the collection of area based data. The most serious of these is that only certain date will be linked to the household. Thus the information on the socio-economic implications of the land use will be less extensive than the information on the overall nature of the land-use system. It is the consultants' beliefe that in most developing countries, the levels of control of the agricultural system and the precision with which planning can be carried out are best served by a good overall understanding of the land-use (agricultural) system, rather than by detailed socio-economic surveys which can be only vaguely extrapolated to an uncertain countrywide position. Indeed it is our contention that such socio-economic surveys must be, above all other data, problem orientated, and should be collected only after the broad nature of the agricultural system is described and understood."

(iii) rapid and cheap, and therefore within the means of the country budget. This precludes the need to necessarily seek outside funding, with consequent avoidance of unproductive and time consuming entanglements with donor agencies.

(iv) problem-oriented. Each country has very specific problems not encountered in exactly the same mixture anywhere else. The consultants feel there is little to be gained and much to be lost in attempting to formulate survey and census techniques of international or regional applicability.

Furthermore the carrying out of surveys and censuses has become, in many countries, a tradition. Statisticians collect information on a regular basis by a range of traditionally established methods, merely for the purpose of producing statistical reports.

Frequently no recognition is taken of the usefulness of these statistics, nor their cost-effectiveness.

For example complete enumeration censuses are exceedingly expensive, demand high levels of infrastructural development, and use large numbers of skilled people. In none of the countries in which the consultants have worked has there been any justification for a complete enumeration census of people, livestock or agriculture in terms of the use or potential use to which the information will be put. Nor indeed have any of these countries the resources to carry out this sort of exercise in such a way as to produce a result which does not embody large amounts of bias. But nevertheless traditional total enumeration censuses are carried out without any objective testing of their efficiency compared with an appropriately designed sample survey.

(v) designed to use minimum number of highly trained people, and to make optium use of locally available personnel.

METHODOLOGY

1. HISTORY OF THE METHOD

Aerial survey and censusing using photography and/or visual counting is a method of some antiquity. Early balloonists reported counting boats and pleasure-craft more than 300 years ago and in the first World War aircraft and airships were used by both sides to make reconnaissance, which involved counting numbers of warships, vehicles, artillary pieces, tents, horses, and indeed every living thing. (This process became increasingly simple as the attrition of war removed all vegetation cover and reduced living things to countable quantities.)

The evolution of more reliable flying machines and the brief periods of peace in the skies between wars made it possible for scientists and other non-military persons to consider the use or aircraft for collecting information as a fairly long-term proposition, scarcely more dangerous than crossing Oxford Circus blindfold in the rush-hour. Aerial photography, photogrammetry, and remote-sensing are modern developments arising improbably from these early sporting pursuits.

Animals have been scientifically counted from light aircraft for more than 20 years (Petrides, 1953; Banfield, Flock, Kelsall, and Loughrey, 1955; Edwards, 1954; Gilbert & Grieb, 1957) and photography has been used to facilitate this counting for almost as long. (Grzimek & Grzimek, 1960; Turner & Watson, 1954; Watson & Turner, 1965).

The first sampling methods from aircraft were undertaken in North America almost 20 years ago (Schultz & Muncy, 1957; Siniff & Skoog, 1964), and the first stratified random sampling method in Africa was undertaken in 1966 by the senior consultant with the assistance of Dr. R.H.V. Bell (Watson 1967.)

By the year 1968 stratified random sampling using transect samples had been developed to the stage where a National Livestock

Census could be contemplated (Watson, 1968), and over the next four years in Kenya and neighbouring countries the senior consultant and other members of the company used stratified random sampling methods to census livestock, and survey land-use over almost 3.5,000,000 Km^2 of land, censusing more than 69 million livestock and more than 6½ million wild animals. These surveys have been tabulated in Table 4.1, and reports of the work are referenced as:

Watson 1969, 1970A, 1970B 1971, 1972A, 1972B.
Watson & Tippett 1971A, B, 1972A, B, C.
Watson Tippett & Tippett 1972, 1973A, B,
Watson, Tippett, Tippett & Marrian 1973A, B, C, D, E.
Watson & Tippett 1974 - 76 : 23 Volumes
Watson 1979

Over the course of these surveys there have been continual improvements in the method, and numerous tests of possible sources of error have been carried out. Basically, the starting point from which the technique has evolved in the aforementioned surveys is described in Jolly 1969A & B, and Watson 1968.

2. THE AERIAL METHODS USED IN THE CENSUS OF LIVESTOCK & WILD HERBIVORES IN THE SOMALI CENTRAL RANGELANDS.

This description of the method falls into seven sections: Stratification, sample selection, sampling strategy, sample demarcation and enumeration, sources of errors and corrections, analysės of results, and quality checks.

1. STRATIFICATION

The purposes of stratification in this type of census are:

a. to break up a heterogeneous land area into units of relative homogeneity (in ecological, and hence human-use terms), thereby enabling a more effecient estimation by sampling, and a smaller sampling error, i.e. a more precise estimate.

b. to provide units of land of convenient size for the actual flying programme which occupies 2 - 3 weeks. (for each census) This implies that one assumes livestock movements will be concentrated within a stratum, and will be relatively limited across stratum boundaries. This point is given further attention in section III below.

c. to enable the results to be understood, in terms of the distribution of livestock, in such a way that the underlying system of herbivors use of the range can be worked out. The traditional pattern of collection agricultural statistics by administrative divisions has appreciably retarded the development of a proper understanding of agricultural production system, and is probably a major factor in rendering most current data virtually useless for prediction purposes.

Clearly purposes a) and c) are not necessarily compatible, and a decision on which is to receive preference in stratification must depend upon the principal use to which the census is to be put. If the object is an accurate count, with no further work intended to build up the pattern of herbivors use of the region, then emphasis in stratification would be given to the actual distribution of livestock at the time of the census. If on the other hand it is intended to also understand the grazing ecosystem (as is the case in this census), with further counts in the future and at other seasons, then emphasis should be given to the more or less fixed ecological features of the area (geomorphology, soils, vegetation, drainage).

In Central Rangelands stratification was made by the senior consultant flying at between 1,000 and 10,000 feet above the ground using enhanced LANDSAT imagery at 1: 250,000 & 1: 100,000 topographical maps. The methods are described in volume 1 of this report.

Topography
Drainage patterns
Soil
Water source distribution
Vegetation
Human-use (mostly cultvation)

and the boundaries of land-units were plotted in flight on the 1,100,000 maps of the Province. It is fortunate that the current mapping,is of excellent quality. This greatly facilitated the plotting of stratum boundaries.

There is no simple quantitative basis for stratification. It is a process which depends heavily upon the skill and experience of the observer, and should not be attempted by inexperienced ecologists.

The LANDSAT imagery, was most useful for the precise plotting of stratum boundaries.

Altogether 29 ecotypes were recognised in the Central Rangelands and 91 strata were determined.

II SAMPLE SELECTION AND ORIENTATION

Samples take the form of transects flown in straight lines across a stratum. This type of sample is preferred because:

a. It maximises the amount of sample flying for unit cost.

b. It makes possible a precise measurement of the area of the sample in a way which could not be employed using quadrate samples.

c. With appropriate orientation of the sample transect (see below) sampling errors are appreciably reduced, with a corresponding increase in the precision of the method.

Given this form of sampling we can proceed to the very important questions of sample numbers, location and orientation:

a. number of samples.

There are of course simple, if tedious ways to determine the optimum number of samples required to produce estimates of known precision. For an unstratified sample :

$$n = \left(\frac{s}{k.\, \bar{d}} \right)$$

$$s = \sqrt{\frac{1}{n-1} \left(\Sigma d^2 - \frac{(\Sigma d)^2}{n} \right)}$$

d is the density of animals in a sampling unit
$\bar{d}$ is the mean density of animals over all samples
K is the level of precision required, expressed as proportion of the estimate represented by the standard error.

The use of such an expression to plan sample unit numbers is complicated by the fact that the census is aimed at a wide number of phenomena, and not just one feature. The consultants have found that an average of 11 - 12 samples per stratum, with rather more samples in strata with high densities of relevant phenomena, tends to give standard errors for numerous livestock types of less than 10%. In this survey the following rules of thumb were adopted:

Over the 91 strata an average of 11 - 12 samples were selected for each stratum. No stratum received less than 6 samples, and very few received less than eight. Any stratum found to have high densities of relevant phenomena (livestock, cultivation, houses etc.) after being previously assigned a small number of sampling units, was given additional samples.

b. Location of samples

Samples were selected at random with probability proportional to size, as recommended by Jolly (1969A). Sampling was with replacement (i.e. if a transect was selected twice it was used as two samples in the analysis, but only sampled once). The mode of sample selection is shown in Figure 02.1. Sampling with probability proportional to size neutralises the otherwise serious problem represented by the unequal size of sampling units.

c. Orientation of samples

Samples were oriented at right angles to the ecological axis of the stratum (see Figure 4.1).That has the effect of:

i) maximising the number of samples for unit flying effort (since the ecological axis is also usually the long axis of a stratum.)

ii) Maximising heterogeneity along the transect, and reducing it between transects.

In both cases there will be a consequent gain in precision through a reduction of sampling error.

III SAMPLING STRATEGY

The mobility of many of the features being censured has a marked influence on the sampling strategy. Ideally a census should be instantaneous; for practical purposes the aerial census of the Central Rangelands took 3 weeks. During this time migrating livestock (and wild animals) can make considerable movements. Migrating nomads will move up to 15 miles (24 km) in one day, and make such a movement as frequently as every three days for short periods of intensive movement.

The strategy adopted to minimise the bias which could result from these movements has been:

a. The main routes of movement, established by previous surveys and from aerial reconnaissance of cattle tracks have been plotted on the map.

b. Stratum boundaries were super-imposed on this, and by this means groups of strata were identified which had high probability of movement between them (see Figure 4.2).

c. These grouped strata were then flown so that continious strata were sampled successively, according to the scheme shown in Figure 4.2. The direction in which strata were covered was alternately with and against the known direction of livestock movement, so that any biases resulting from livestock crossing over strata boundaries between successive days sampling will tend to cancel out. It should be pointed out that the average distance between samples is about 4 Km, and during the day a time interval of never more than one hour (and usually a few minutes) separated the flying of successive samples. Therefore the chances that the same animals will be counted (or missed)on successive samples are slight, and there is the tendency for those biases to cancel out. On an average days flying a block of country of 60 - 80 Km length (along the animal's direction of movement) is covered.

The mobility of livestock could be a factor when samples are selected very close together, or overlapping. The procedure adopted here is as follows:

a) When sample strips are within 1 km of each other they are classified as 'close together'. (Observations of the disturbance caused by aircraft have shown this livestock more than 500m from the aircraft are not disturbed, and animals which are disturbed rarely move more than 6-700m away from the source of disturbance before settling down).

b) 'Close-together' samples are not flown successively (in the usual manner) but after an interval of one other sample (see Figure 4.3). Thus a longer time interval elapses between the flying of close together sample strips, during which animals have been disturbed will re-distribute. In any event the disturbance of animals by the aircraft has a very variable effect - as many animals move out of the adjacent "close together" sample as move into it, and any residual disturbance left after the extended time interval between samples should be a symetrical (& hence self-cancelling) bias. Over the whole census only 8% of samples were classified as close together.

IV. SAMPLE DEMARCATION AND ENUMERATION

a) Demarcation.

Samples are demarcated by an optical method. Two aluminium poles of 1cm thickness are fixed to the lift strut of the wing (see Figure 4.4) so that the observer looks through them to the ground in the area where the count is to be performed. The trigonometry of this system (see Figure 4.5) is such that the width of the transect is determined by:

- the position of the two demarcators on the lift strut,
- the angle of bank of the aircraft
- the nature of the terrain
- the altitude of the aircraft
- the position of the observer's head.

Let us consider these variables in turn, and discuss the implications they have for sampling.

Position of sample demarcators

Once a decision has been made about the width of the sample-strip desired the position of the demarcators can be fixed on the lift strut for the whole census. In some situations (but not for the Central Rangelands) it could be desirable to operate more than one sampling-strip width. For example very open (desert) strata would be sampled using strip-widths of 300-400m, whereas heavily wooded strata might be sampled using 100m or less sample widths. The most appropriate sample strip width is decided from a consideration of errors, as is discussed in V below.

In the Central Rangelands the aircraft was fitted with demarcators which gave a sample-strip width of 185m flying at 110m above the ground. We shall consider the way in which these measurements were made under section V below.

Angle of bank of the aircraft

If the aircraft is flown other than with the wings in a horizontal plane there will be a relative increase or decrease in the width of sample strip viewed between the demarcators. As was pointed out by Pennycuick (1969) & Watson, Parker & Allen (1969) symmetrical distribution of wing bank will produce an asymmetrical distribution of sample strip-widths. (A cursory examination of the trigonometry of the optical system of Figures 4.5A & B shown why this is the case: at fixed altitudes the width of the sample strip is clearly proportional to the tangent of the 'median viewing angle'.)

A system of estimating the magnitude of wing-bank and a consideration of the errors inherent in it are considered in V below.

Nature of the terrain

Any variations in the nature of the terrain will lead to variations in the sample strip width. In general these variations will tend to produce symmetrical errors of small magnitude. In the Central Rangelands the terrain is flat, and no special flying technique is required to maintain constant heights above the ground.

Where very hilly ground is encountered a special form of sampling, which was first described in Watson Tippett Tippett & Marrian (1973C), has to be used. This involves flying along the contours of steep hillsides, maintaining a fixed height above the ground. This height is then converted to a strip width by use of a function derived from a measurement of the mean angle of slope. The main features of this sampling system are shown in Figure 4.5C.

Altitude of the aircraft

The aircraft during the census was flown with King Kra 405 altimeter giving a continuous dial reading of height above ground. In addition a display light coupled to a pre-set 'decision' light indicated when the aircraft was above or below the desired height. This display light was positioned in the aircraft close to the observer's eye, so as to be in his field of peripherel vision.

The radar altimeter had been calibrated before the survey by an aerial photogrammetric method. Measurements made during the census flying indicated that the aircraft was flown at an average altitude of 110m (the decision height was set at 350 feet or 106.7m).

Variations in altitude along the transect have a symmetrical and liner affect on sample strip widths, which greatly simplifies their treatment as errors (see V below).

Position of the observer's head

The observer's head was maintained in a more or less fixed position throughout the census flying by lining up two marks on the forward perspex panel with the sample demarcators.

Having established an optical means of demarcating the sample width we have now to consider transect lengths. These have been worked out from the 1: 100,000 maps, with some supporting evidence from the flight times and ground-speeds recorded for all transects. The question has been asked "How do you know where you are on the map?". This is a perfectly reasonable question for a completely uninforeed layman to ask, and without covering fifty pages of this report with the details of dead-reckoning navigation, methods of off-setting for wind-drift, techniques for in-flight ground speed estimation, etc., it is impossible to answer it fully. Suffice to say that with 1: 100,000 maps, computational ability, experience, and a good knowledge of trigonometry any light aircraft pilot can position himself to within ½km of any point on the map. Obviously the pilot can position himself even closer to stratum boundaries.

By these means the sample strips dimensions are determined (i.e. length and average width) giving the sample units area, which is then used to translate numbers of livestock etc. into densities.

b) Enumeration

Assuming we now have a means of covering a known area of ground, how do we now determine the number of animals, or other relevant phenomena, on that strip of land?

The method employed in the Central Rangelands was as follows:

i) The aircraft were flown along the transects sufficiently slowly (60 mph to 75 mph), at a sufficiently low height (110m) (184m) and observers were scanning a sufficiently narrow strip for all animals and other phenomena in the transect to be spotted. The validity of this assumption and its justification are considered in section V below.

ii) As the aircraft approaches a group of animals or some other phenomena to be counted the item in question enters the decision area of the observer's field of view. In this region the observer decides:

Decision 1. Is the item going to be inside or outside the transect or is an answer to this question too difficult to make at this moment of position?

If the answer is 'definitely outside' the item is ignored and scanning ahead of the aircraft continues.

If the answer is 'uncertain at this point', the item is carefully followed to the position between the demarcators at which the exact strip width has been calibrated (see Figure 4.6). When the item reaches this line (which is marked, by a fine rod fixed between the demarcating rods) special attention is paid to the levelling of the aircraft, to the altitude, and to the position of the observer's head, so that a very precise decision is possible for items at the edge of the sampling strip.

If the answer is 'definitely yes' or finally at the exact demarcation position 'yes', a further decision must be made in answer to the question:

Decision 2. Can the item be satisfactorily counted by eye, or is it too numerous, or is it too concealed by vegetation?

If the answer is 'yes', then the group is counted by the observer, and the resulting count is recorded on the tape recorder. (Experience and experimentation has shown that groups of over 20 animals are difficult to count accurately, and groups of 20-30 animals can be counted by eye only in special circumstances - this point is considered in section V below)

If the answer is 'the item is too numerous for accurate counting', a photograph is taken using a 35mm camera and 50mm lens. The film used is Kodak Ektachrome X with film speed of 64 ASA. The exposure is made at a shutter speed of 1/500th of a second, which effectively freezes any movement there might be from aircraft and/or animal movement. (In 0.002 seconds, an animal running at 89Km/hour - the maximum speed possible for a small herbivore such as a gazelle - (Watson (1967) - running towards the aircraft which is travelling at 120Km/hour, the maximum speed used in animal censusing by the consultants, will have a relative displacement of 0.116m (i.e. 12cm) on the ground. At the scale of the photographs, which is on average about 1: 2400, 12cm of ground movement becomes translated into 0.005cm of 'blur' on the transparency. And so even in the most extreme situation which can be postulated it is clear that movement does not interfere with the countability of the animal on the transparency.)

The resulting transparency, which is recorded on the tape according to a film and frame reference number is counted under a binocular dissection microscope with 10 to 30 power magnification.

If the transparency has a scale of 1:2400, a 30 power magnification will give final image lengths for counting of about 19mm for cattle, and 5mm for young goats and sheep. The transparency is systematically scanned by the counter, who lightly scratches the surface of the emulsion with a fine pointed mounted needle as each field is scanned (the microscopes used for this work cover about $\frac{1}{4}$ of the frame in one field). Each animal on the frame is lightly pricked by the needle, leaving a small depression in the surface of the emulsion which is readily seen by the counter as it refracts light passing through the transparency. As the animal is touched with the needle it is mentally counted, and each group of 20 is recorded in the counting notebook.

In this way groups too numerous for satisfactory immediate visual counting on the transect are finally enumerated in conditions which allow checking and control.

If the answer is 'the item is in a situation where it is too concealed by dense vegetation for satisfactory counting' another procedure is adopted. It should be pointed out that grazing animals are very rarely found under cover so dense that they cannot be counted. This is because:

i) grazing animals feed on vegetation at ground level. This implies that they occur in areas where sufficient light reaches the ground to support a herb layer. Thus beneath a continuous and closed vegetation cover (such as a forest), there are unlikely to be any grazing herbivores.

ii) Discontinuous dense cover (i.e. woodland) when viewed obliquely by the travelling aircraft cannot conceal animals from the observer, except for short periods of time. At times of the day when animals are concentrated under shade-trees special attention is paid to areas in the shade of trees as the aircraft approaches. (See Figure 4.7)

iii) Generally only goats and sheep conceal themselves in large bushes, at the hottest times of the day. The behavious of groups of goats and sheep as the aircraft approaches is always to take flight and run away from the apparent source of noise. Thus concealed goats and sheep generally emerge from dense cover in response to the aircraft's approach.

However in the occasional cases where a count or photograph is not possible the observer does the following things:

a) He makes a mental note of the exact position the demarcating lines make on the ground. It is difficult for a layman to appreciate that the pattern of vegetation, small bare patches, tracks, dead trees etc., under the aircraft represent a unique and easily memorable view to the really skilled and experienced observer. This image can be held for several years. (The senior consultant for example memorised the exact position of more than 30 pairs of elephant tusks over the period 1968-1971, and made brief notes of their position. In subsequent years, all of these positions were flown over again, some of them on several occasions, and in no case was it not possible to spot the exact position of the skeleton (the tusks of almost half the elephant were found by poachers) or tusks.)

This will involve taking a new oblique view or low flying to move the group from out of a very dense patch of cover.

c) When the animals have been successfully counted or photographed he resumes flying the transect at exactly the same position, recording the 'time-out' on the tape recorder.

This then is the enumeration method. Two points which are frequently raised by layman, statisticians etc. are:

Question 1. Since the animals occur in groups is it possible to decide which animals fall outside the transect and which inside sufficiently quickly and precisely for errors not to occur?

The answer to this question is:

i) Large groups are photographed in any event, and it would be possible to separate those inside and outside the transect from the photograph, on which the sample sample demarcators are clearly visible.

ii) However at the moment of photography it is difficult to be certain that the wings are absolutely level (i.e. no bank), and in addition the group)i.e. herd, flock etc.) is something about which information is sought.

iii) Therefore the decision 'is the animal or other phenomena inside or outside the sample transect?' is based upon the convention that:

> If part of the group of animals, or whatever other item such as fields, houses, etc., is inside sample strip it is considered to be inside the sampling unit, and is photographed accordingly. Figure 4.8) However it is weighted by a factor $\frac{1}{n}$ in the computation, where n is the number of strips (including the one sampled) in which the group occurs.

Question 2. What happens if the group is too large to be photographed on one frame?

In this event the group is photographed on successive frames, and the overlap is plotted between frames by reference to individual animals and group-patterns. This method (see Figure 4.9) was described in Watson(1967) with reference to the counting of wildebeeste (Connochaetes taurinus albojubatus Thomas) from a complete aerial photographic cover.

The aforementioned methods can be used to count anything which is easily seen from a low-flying aircraft. As was pointed out by Graham & Bell (1969) the more 'specific search-images' the observer carries, the loss effeciently he can operate any single search-image. However with experienced observers this problem is reduced and enumeration along transects in the Central Rangelands was aimed at the following features (with the proviso that livestock were of primary importance):

1. All livestock - i.e. cattle, sheep, goats, camels, donkeys & horses and mules (grouped together)

2. All wild animals of duiker/gazelle size and larger

3. All houses and buildings

4. All Water Sources

5. All cultivated, fallow & abandoned lands.

Finally in this section of enumeration we have to consider a few special cases:

a. Fields/land areas

The enumeration of items of significant area (such as fields, grass cutting areas) is treated thus: the land area in question is timed by stopwatch as it passes a fixed point on the inner sample demarcator. These times are converted to lengths using the average ground speed of the aircraft. (see Figure 4.10)

b. <u>Flowing rivers & long riverine pools</u>

These are enumerated in terms of the number of times they intersect the inner marker on the lift strut. (see Figure 4.10).

V. ERRORS

Clearly the most important section of the methodology is concerned with errors. A considerable volume of literature has built up over the last few years in which various potential and actual errors have been examined (Caughley, 1972; Caughley & Goddard, 1972; Jolly 1969A & B; Watson, Jolly & Graham 1969; Watson, Freeman & Jolly 1969; Goddard 1967; Watson, Parker & Allen, 1969; Watson 1970C).

This report will consider all possible sources of error, more or less in the order in which they are encountered in the operation of the census.

Of course any human attempt at precise quantification is certain to embody 'error'.

"To err is human" is much truer in statistical terms than in any moral sense. This section of the report will not consider the errors which accompany every simple human operation - it must be assumed that the checking and conscientiousness of the consultant's team has reduced these errors to insignificantly small proportions. We shall therefore deal here with the errors of the census method.

Caughley (1972) pointed out the need to distinguish between precision and accuracy, and to make decision about the objectives of the census in terms of precision and accuracy in order to select the best experimental design. Essentially a precise estimate is one where sampling errors and balanced (symmetrical) bias errors are small; an accurate estimate is one where unbalanced, or asymmetric bias is small. Since this is the first census of livestock for the Central Rangelands more emphasis is placed on the need for accuracy, and accordingly any asymmetric bias is unnaceptable unless measured and and corrected.

1. Errors in sample demarcation and area measurement.

It is obviously impossible to fly an aircraft precisely at a fixed height above the ground along prescribed routes without wing bank, and with the observers head staying in exactly the same position. In arriving at an estimate for livestock and other quantifiable resources in the Central Rangelands we have assumed that this - indeed - was done. What are the errors in this situation?

a. The aircraft's height is variable. Throughout an earlier (S. Kordofan) census, the passenger in the aircraft (or the observer if no passenger was present) recorded the radar altitude reading to the nearest 5 feet at 5 minutes intervals. The results of this exercise are shown in Table 4.2 and figure 4,11.

When the observer was flying on a decision height setting of 390 feet his mean flying height was 401.87 $\pm$ 0.625 feet When a decision height of 350 feet was in operation the mean flying height was 361.41 $\pm$ 0.778 feet (Standard deviations are 24.98 and 27.33 respectively).

Figure 4.11, a histogram of heights recorded at 5 minute intervals along the transect shows a fairly symmetric distribution of errors round the mean.

However the height of the aircraft above the ground influences the size of the sample enumerated through its influence on strip width, and other factors must also be considered here:

b. The aircraft wing-plane cannot be held completely horizontal nor can the observer's head be always exactly at the same position. These errors have been measured in the following way - at the start and end of each day's flying the aircraft is flown along a line parallel with the airstrip across which a grid of white stones has been laid marked out in 5m intervals (see Figure 4 .12)

- between ten and twenty overflights are made at the operative decision heights for the day, and the observer records the strip-width from the white stones, and the exact radar altitude at the moment of crossing the grid (the BSG)

- the resulting data for strip widths are converted to the appropriate standard censusing heights of 110m (361.44 feet) using the expression:

$$SW_s = SW_r \times \frac{h_s}{h_r}$$

Where SW_s is strip width standardised for standard censusing height

SW_r is recorded strip width

h_r is simultaneous recorded radar altitude

h_s is standard censusing height.

- the vatiation in strip widths standardised in this way is the variation due to aircraft banking, eye movements and incorrect judgement of the position of the sample demarcators.

The results of this investigation are shown in Table 4.3 at 361.41 feet 5Y - 8AU gives a mean strip-width of 184.71 m with a standard deviation of 11.08 and a standard error of the mean of + 0.71 m

The distribution of errors is shown in Figure 4.13 and is more or less symmetrical. By combination of data of Tables 4.2 and 4.3 it is possible to deduce the sort of variations which occur in strip-widths during census flying.

Mean strip width is obviously the same (184.71m), but variances change to 149.08 and standard deviations to 12.21 m Distributions of errors remain symmetrical.

The variations in strip widths are shown by these data to be small and symmetrically distributed about the means.

c. The flying of an exactly prescribed route between two exactly fixed points is also impossible in practical terms. No objective measures have been possible of the errors inherent in this part of the method but the following observations suggest that errors are likely to be small and generally symmetrical:

i. During the flying of sample transects 'check points' are passed, and, if necessary, small adjustments of course can be made where the transect appears to be deviating from the prescribed track. By this method deviations of more than 1.0Km from track will be noted and corrected. Any deviations of more than 1.0Km were recorded and plotted on the map and the new transect length measured from the corrected flight track. Only 2.8% of transects had to be treated in this way.

To provide further checks on the transect length the times of start and finish of each transect were recorded, and these times were used in conjunction with known speeds to give an independent estimate of sample length. Where the map measurement of transect length differed from the time-calculated measure by more than 10% the transect length was changed to the mean of two independent measures. This was necessary for 1.5% of Sampling Strips

Errors in transect length resulting from deviations from track are not symmetrical, and are therefore <u>potentially</u> serious. On any transect, the <u>maximum</u> possible error is suggested to be determined by the following factors:

- a wander of 5^{o} from track is possible, but cannot continue to the stage where the actual track is more than 1 Km from the desired track;
- as an absolute maximum it cannot be expected that variations in track will exceed a constant ± 5 : this assumes that at no time will the aircraft actually be on track (see Figure 4.14)

Given these assumptions there is a maximum expectation of 0.4% under-estimation of transect lengths and a consequent 0.4% over estimation of numbers of animals etc. The minimum expectation will be for zero bias, and so the true position will lie between the two.

ii. The location of fixed points at which to start and finish transects is a fairly precise operation. Because of the distinct nature of stratum boundaries, it is possible to position for the start and finish of a transect closer than 0.5Km. Thus on an average transect of length 27Km (as was employed in South Kordofan) the maximum error would be ± 3.7%, with a symmetrical distribution.

It is possible that the positioning of stratum bounbaries on the map is inaccurate, with errors of up to 0.8 Km in some place (i.e a maximum variation of ± 5.9%). These errors are symmetrical, and, by virtue of the method of transect flying, will tend to cancel out (see Figure 4.15).

And so the transect area, as used in the calculations for estimation embody the following errors:

Symmetrical variations in width (standard deviations ± 6.00% and standard errors of mean width for all transects of ±0.36%)

Symmetrical variations in length with a <u>range</u> of between 0% and ± 10%

Asymmetrical variations in length of between 0% and – 0.4%

In consequence 95% of transect <u>areas</u> will not vary by more than 2 - 3% on either side of the mean.

A possible under-estimation of about 0.2% is also possible. The symmetrical errors will be in any event included in the variance of the estimate by the computations described later in this section. It is proposed to make a correction for the possible over-estimation resulting from course deviations of -0.2%. This correction is so small that no attempt is to be made to add a sampling-error component for the correction.

2. <u>Errors in sample enumeration</u>.

These are the most difficult errors to investigate and potentially the most serious.

The enumeration process involves several distinct and error-prone steps.

STEP 1: Spotting. The observer must exercise high and consistent vigilance along the transect. Phenomena can be missed because of observer failure (Graham & Bell, 1969; Mence 1969) or because of obscurement under vegetation cover, in houses or caves, or behind or under other animals.

There is no way of ascertaining how many items in the transect are missed completely (see section V11 below on quality checks) because of observer failure. However it is possible to make some inference on this phenomenon:

i. It would be unlikely that two different observers would miss completely, exactly the same groups of animals or other items, and any co-incidence between data from two observers suggests that groups being missed completely are of negligible significance. The very close agreement in results from the two observers on this census (Watson & Tippett) offers some support for the view that observer failure is not a major contributor of error (see results of observer testing in Section 6 below).

ii. The selection of flying height, strip widths and censusing speeds used in this and many other surveys and censuses carried out by Resource Management and Research. (see Table 4.1) has been based on trials carried out between 1968 - 1970 in Kenya. The most important of these were described in a report to the UNDP/FAO Kenya Range Management Project (Watson 1970c). Caughley (1972) carried out similar investigations for the Kenya UNDP/FAO Wildlife Management Project.

In these trials sample strips were flown at a range of heights, speeds and strip-widths, and the general result of this work was a series of species - species 'visibility-curves' (see Figure 4 .16). These curves essentially show continued increase in the numbers (i.e densities) of animals seen along transects as speeds are reduced, sample-strips are narrowed and heights above the ground are reduced. Predictably the larger more conspicuous animals, especially those occuring in large groups, cease to show significant increase in numbers before the smaller inconspicuous animals. The principal factor for the increase in densities observed is an improvement in the observers ability to 'spot' the animals as counting conditions improve. It was found, for experienced observers, that densities of livestock and larger more gregarious wild herbivores were virtually unchanged after speeds were reduced to 75 m.p.h. (120 k.p.h.) sample strips narrowed to 250m and observer heights lowered to 400 ft. (122m).

Some animals and other phenomena are concealed from the observer, and cannot therefore be counted. Trees and bushes are the commonest concealing agent, but sometimes animals are kept in houses. The following approach has been used to investigate this source of bias:

It has not been possible to estimate numbers of animals in houses in the Central Rangelands. Studies by RMR elsewhere show this could result in a 1-2% under estimate of numbers.

Livestock concealed by vegetation and other animals.

i. Groups of livestock constituting a representative sample of groups encountered during the census were followed during their movements through mixed vegetation.

ii. As they move these groups pass through various categories of cover (dense, medium and open), and as they pass from one cover category to another the group is either photographed or counted (depending on the number of animals in the group).

iii. The number of animals counted, either directly from the aircraft in open cover, or on the ground, or from a photograph in open cover at very low level is considered to be the 'true count'. The numbers of animals counted in open (from 360 ft height), medium or dense cover of the same group are then used to calculate a correction factor.

iv. Appendix I explainshow a correction can be made for small groups missed completely because of concealment by vegetation or other animals.

v. This type of bias correction has been applied for the last six years in the various censuses listed in Table 02.1 It is probably legitimate to use these data, together with the results of the groups counted in South Kordonfan since the cover categories, livestock types, group sizes etc., are similar.

It has to be appreciated that countimg error has also been measured in these trials - this point is considered in Section b) below.

From data collected in the Central Rangelands & imilar areas, animals concealed by vegetation or other animals and counting errors, contribute to under-estimations of numbers thus:

For cattle counted in all cover types in the Central Rangelands there is an underestimation of 9.5% (R = 1.095) with a variance of R = 0.00014647.

For sheep and goats counted in all cover types there is an under-estimation of 13.4% (R = 1.134) with a variance of R = 0.0001266.

For camels, donkeys, horses & mules in dense cover there is an under-estimation of 19.80% (R = 1.198) with a variance of R = 0.0009461.

For camels in medium cover there is an under-estimation of 6.4% (R = 1.064) with a variance of R = 0.0001225

For camels in open cover there is an under-estimation of 1.7% (R = 1.017) with a variance of R = 0.0000702

STEP 2. Identification As soon as the animal or other phenomenon has been spotted it must be identified. The only difficulties here are presented by the distinction between sheep and goats, and between certain agricultural & land uses . For large groups of sheep and goats, where the animals are closely bunched together it is frequently impossible to distinguish all animals in the group on the photograph. In such cases these animals have been estimated separately as sheep/goat (S/G). In addition even small groups which have been counted directly from the aircraft, especially if large numbers of young animals are present, are sometimes impossible to differentiate into sheep/goat components.
These animals are also entered as S/G.

It was found for the Central Rangelands that mixed groups of sheep and goats were common, with no preference for separate management of goats and sheep.

The division of groups which could not be differentiated into sheep and goats (necessary for arrival at estimates of sheep and goat separately) was accomplished by splitting each undifferentiated group by the ratio of differentiated sheep to goats for the stratum. i.e.

$$SG_u \times \frac{\sum S_d}{\sum G_d + \sum S_d} = \hat{S}_u$$

$$SG_u \times \frac{\sum G_d}{\sum G_d + \sum S_d} = \hat{G}_u$$

Where SG_u is the number of undifferentiated sheep and goats in a sample (or group)

$\sum S_d$ is the total of differentiated sheep in the stratum

$\sum$ denotes summation within a stratum

$\sum G_d$ is the total of differentiated goats in the stratum

S_u is the number of sheep estimated in the undifferentiated group (s)

G_u is the number of goats estimated in the undifferentiated group (s)

There are clearly two sorts of errors implicit in the estimates of goats and sheep which are not applicable to other livestock:

a) the differentiation of sheep from goats is difficult and embodies error. This type of error cannot be measured, and will be minimised only if all doubtful cases are referred to the SG category.

b) The application of a ratio-method for separating undifferentiated sheep and goats involves a sampling error. Fortunately only small proportions of the sheep and goats population were undifferentiated, and so the influence of this sampling error (which would itself probably be large) will be small on the sampling error for the whole population.

Np attempt has been made to quantify "the error of differentiation" of a) and b) above, and users of the estimates of sheep and goat produced in this census should therefore bear in mind that the sampling errors attached to separate goat and sheep estimates are under-estimations of the real error. The total sheep/goat sampling error is however unbiased.

In the case of land use there are particular problems in differentiating fallow & abandoned & land, and even land being prepared for cropping.

STEP 3: Demarcation decisions The identified animals or other item(s) approach the counting area under the aircraft, and a decision must be made as to whether they are inside or outside the transect, by the process described in section V b) above. This process has been designed to incorporate only symmetrical errors. No specific testing of the performance of observers in making the decision has been undertaken except in so far as a comparison of tbe performance of two observers has been made.

These tests are described below. Essentially two observers (one flying and observing, and one observing only, with positions changed for half the transects) flew in the same aircraft observing EXACTLY the same strip. The numbers of items identified by each observer as being inside the sample strip are shown in Table 4.4. To facilitate other comparisons each observer also recorded groups close to the edge of the sample. The data of Table 4.4. indicate a very close agreement between observers.

Any errors made in this decision will in any event be incorporated in the various and standard error estimates computed in the manner described later.

STEP 4: Counting The human counting process is remarkably prone to error (Watson, 1967, discusses some of these problems). Experience over the last decade of attempts to count groups of animals has shown that visual "remote counting" (i.e. the process of counting distant objects in which the eye alone registers each counted item) is particularly prone to error, and groups of more than 20 animals cannot be counted in this way without risk of alrge errors (Watson, 1972; Watson, Tippett, Tippett & Marian 1973). Field trials of the counting process were undertaken in the Awash Valley for the Awash Valley Authority (Watson, Tippett, Tippett & Marian, loc. cit.), in which groups of cattle, goats, sheep and camels of known size were marked by observers holding markers. These trials showed a very satisfactory position for groups of less than 25 animals, with very small and symmetrical errors.

For large groups there is a steady deterioration, with increasingly large errors and a growing tendency to underestimate numbers. In this census no groups of 25 animals have been counted visually, except on very special circumstances, such as when a group of animals is strung out along a track, with wide spacing between each individual.

On the other hand, "contact counting" (i.e. the process of counting in which the touching of the object or an image of it accompanies the mental registering of each item)is a relatively precise process.

Some errors resulting from visual counting are already in-corporated in the biases described above. Likewise the repeated photography of a group of animals in open cover, with the second photograph taken at lower altitude will measure counting error, as well as errore resulting from animals being concealed by others. In an attempt to establish the correction factor for counting error <u>additional</u> to the errors already measured,the following work was carried out:

a) a selection of small groups which were counted visually in open cover, were also photographed at the same altitude. These photographs were then countea.

b) a random selection of photographs of all sizes of groups were re-counted under better conditions (i.e. taking more time, higher magnification of microscope).

These data show no bias in visual counting $R = 1.0006$ (Variance = 0.000075), and a bias in physical counting of -2.01% ($R = 1.0201$) with a variance of 0.0003162.

<u>STEP 5:</u> <u>Recording</u> The results of sample enumeration are spoken directly into a tape-recorder. These results are played back at the end of each day and transcribed directly onto specially prepared forms.

Subsequently a sample of tape-recorded sections, comprising 8% of the total number of samples, were played back again and the entries in the computer forms checked. No errors or omissions were discovered in this check.

All photographs of larger groups were successfully developed, and all were ascribed to an appropriate sample.

It is concluded that recording errors are very small, and no correction is offered for them.

3. Errors attributable to observer differences.

A test of observer differences was made as follows:

Transects were flown with two observers in one aircraft; observer 1 acted as pilot on half the transects and observer 2 flew for the other half.

The sample demarcators were adjusted so that each observer was being flown along exactly the same strip.

The results of this experiment are shown in Table 4.5 and clearly show negligible differences between observers. Over all samples observer 1 saw 69 groups of recordable phenomena of which 10 were judged to be outside the transect. Observer 2 saw 70 recordable groups of which 9 were judged to be outside the transect.

Observer 1 saw 3 groups not seen by observer 2 and observer 2 saw 1 group not seen by observer 1. Observer 1 judged one group inside the transect which observer 2 thought to be outside, and observer 2 judged one group inside which observer 1 thought to be outside.

Of all items counted observer 1 counted 957 and observer 2 counted 965.

4. Errors in stratum measurement.

Strata were measured by use of the 2 Km. grid on the 1: 100000 maps (ie to the nearest 4 Km).

A further check on area measurements was achieved by addition of stratum areas for units of land measured by trigonometric means. The consistency of these checks shows errors in this process are very small (0.1 - 0.5%) and there is no reason to suppose any asymmetry in these errors.

5. Errors in computations.

The data transferred to computer forms were calculated manually to provide early indications of results, but no computation was made manually which was not ultimately checked by the computer. The comparison of manual summation of groups and group numbers on all the data sheets with computer calculated summations provided a good means of checking for punching errors. Punching errors were detected on only 0.18% of cards punched.

6. Sampling error

Finally a major error component is sampling error, which is a consequence of the inherent variability of the data being sampled. This is calculated from the expressions described in the following section (VI), but it must be recalled that the sampling error calculated in this way includes many other symmetrical errors considered above, althought true sampling error is undoubtedly the major component. The application of bias corrections (these biases themselves having been deduced from samples) will add further types of sampling error - see calculations of Sect on VI.

7. Summary of Errors and Proposed Corrections.

Table 4.6 summarises the investigations of errors and lists the corrections applied in this census.

VI. TREATMENT OF RESULTS.

The enumeration of samples was carried out as described above and the results entered on to printed forms. Data were punched from these printed forms, and after appropriate checking for errors and corrections, a programme was run which produced the following results.

1. <u>Uncorrected, estimates, densities and standard errors for all items observed on the transects.</u>

These are based on the expressions of Jolly 1969A, namely:

$$\hat{Y} = \sum_i Z_i \bar{d}_i$$

Where $\hat{Y}$ is an unbiased estimate of any item

$\sum_i$ denotes summation over all strata

Z_i is the area of any stratum $_i$

$\bar{d}_i$ is the average density of the item in stratum i (derived from the unweighted means from all samples in stratum i)

The variance of the estimate is:

$$\text{Var } \hat{Y} = \sum_i \left[\frac{Z_i^2}{n_i} \times \frac{1}{n_i - 1} \left(\sum d_i^2 - \frac{(d_i)^2}{n_i} \right) \right]$$

Where n_i is the number of samples in any stratum i

d_i is the density of the item in question in the samples of stratum

2. <u>Bias corrections</u>

Where applicable bias corrections are applied to estimates thus:

$$\hat{Y}_A = R\hat{Y}$$

Where $\hat{Y}_A$ is the adjusted estimate for any item for which a single correction factor R may be applied (for example one livestock type in dense cover)

R is the appropriate correction factor.

$\hat{Y}$ is the uncorrected population estimate

The new variance $V(\hat{Y})_A$ becomes:

$$V(\hat{Y})_A = R^2 V(\hat{Y}) + \hat{Y}^2 V(R)$$

Where $V(R) = \frac{1}{n(n-1)\,\bar{y}^2} \times \sum_{i=1}^{n} R^2(y_i - \bar{y})^2 - 2R(y_i-\bar{y})(x_i-\bar{x}) + (x_i - \bar{x})^2$

Where x is the true number of the item.
y is the observed number
and any missing groups are added to the pairs of figures be ore this calculation is made.

3. Exceptions - Land Use

The recording of fields & land use was performed by timing their passage past a marked point on the inner demarcators.
Time of passage over fields & different types of lands has been converted to a percentage for each transect, using the time for flying the whole transe t, taken from one of the aircraft stop watches.

4. Biomasses

Densities of animals have been converted to biomass density by the expression:

$$\bar{w} \times \bar{d} = B\bar{d}.$$

Where $\bar{w}$ is the population mean weight of the species in Kg.
$\bar{d}$ is the mean density of the species in the land-unit in question per Km^2
$B\bar{d}$ is the biomass density in Kg/Km^2

5. Human populations

Ground programmes have given a number of independent estimates of the average number of people to be attached to each type of occupied house. Human population densities are given by:

$$(\bar{n}_1 \times \bar{h}_1)+(\bar{n}_2 \times \bar{h}_2)\ldots\ldots\ldots\ldots\bar{n} \quad \bar{h}_x = \bar{p}$$

Where $\bar{h}_1$, $\bar{h}_2$, $\bar{h}_3$ ....$\bar{h}_x$ are densities of different types of houses in the land unit in question per Km^2

$\bar{n}_1$, $\bar{n}_2$ .... $\bar{n}_x$ are the mean numbers of people to be attached to each type of house (from ground surveys)

$\bar{p}$ is the density of people per Km^2 for the land unit.

VII. QUALITY CHECKS.

Much has been heard from F.A.O. statisticians examining the method about 'quality checks'. Over the last eight years much time and money has been spent by the consultants on attempts at simultaneous enumeration by a more accurate and precise method on livestock or some other item so that some independent check could be made of the whole method.

In the North Eastern Province (Kenya) Survey (Watson 1972A) independent ground samples of known size were enumerated. The sampling errors were large and no sensitive analysis was feasible for the results, even assuming the ground counting had been accurate (which it certainly was not) - Watson (1972A).

A quality check for a total aerial count of people was set up in Kenya in 1968 in which 11 different aircraft/helicopter teams attempted to count a known number of people in dense woodland. (Watson, Jolly & Graham 1969). In this simulation 65-75% of people were counted.

It is envisaged that no quality check will ever be worthwhile setting up to test aerial censusing because:

1. It is impossible, from the practical point of view, to EXACTLY record or prescribe the position of the transect which is sampled.
2. Even if it were it would not be possible or desirable to census it simultaneously, since the mobility of animals in the transect region is at its greatest when the aircraft f over (on account of disturbance by the aircraft).
3. The mobility of most items being censused makes it impossible to consider a transect as having more than the most ephemeral existence.
4. Therefore one is inevitably dealing with a comparison of independent samples.
5. Such are the nature of distributions of phenomena usually censused from the air that sampling errors for small areas censused by a fairly small number of samples are enormous. Any comparison of independent samples over small areas sampled with a few transects will be insensitive to the stage where a quality check is not possible (as, for example, on a ranch where the number of stock present are known)

6. Any attempt to produce an idependent estimate of livestock or any other phenomenon over a large area, using total estimation procedures on large numbers of samples will be:

   i. very expensive.

   ii. likely to incorporate so many errors as to be incapable of providing a quality check. (The original purpose of aerial surveys was to provide quality checks for ground-based estimations of livestock).

7. In view of the afore going most of the checks which the consultants and variuos clients have worked with in the last few years have aimed at particular <u>parts</u> of the method.

CALIBRATION, WEIGHTINGS AND SCHEDULES

Calibrations

Results of the various calibrations described in the previous section of this volume are:

- SAMPLING STRIP WIDTHS

OBSERVER 1	C.I.T	Dry season 1979:	184m
		Wet season 1979:	186m
OBSERVER 2	R.M.W.	Dry season 1979:	192m
		Wet season 1979:	188m

- SAMPLING HEIGHTS ABOVE THE GROUND

OBSERVER 1	C.I.T.	Dry season 1979:	385 feet (117m)
		Wet season 1979:	389 feet (119m)
OBSERVER 2	R.M.W.	Dry season 1979:	390 feet (119m)
		Wet season 1979:	384 feet (117m)

- Bias factors for animals obscured by vegetation and other animals (also applied to correct for animals, potentially visible but not seen)

CATTLE	1.095	(Wet and dry seasons)
SHEEP & GOATS	1.134	(Wet and dry seasons)
CAMELS, DONKEYS HORSES & MULES	1.198	(Wet and dry seasons)
WILDLIFE	1.255	(Wet and dry seasons)

The wildlife bias figure has been based on rather limited data (four groups of oryx and three of Clarke's gazelle moving through shrubland). some species a much higher bias factor should be anticipated.

WEIGHTINGS

The weightings which have been employed in preparing the tables of results (volume 2 part 1, and volume 3 part 1) are:

i) Biomass tables:

Mean population weights of herbivores censused are:

WET & DRY SEASONS –	Cattle	180 Kg	Ostrich	80 Kg
	Sheep and goats	16 Kg	Gerenuk	25 Kg
	Donkeys	150 Kg	Baboon	35 Kg
	Horses & Mules	200 Kg	Warthog	80 Kg
	Camels	304 Kg	Oryx	90 Kg
	Lesser kudu	40 Kg	Bush Buck	75 Kg
	Clarke's Gazelle	30 Kg		

DRY SEASON - other gazelle 18 Kg

WET SEASON-Soemmeringsgazelle 22 Kg

other gazelle (mostly Speke's) 12 Kg

ii) Water source tables

Weightings of " relative importance" applied to different types of water source in working out indices of relative water source abundance are:

- wells	2
- rain water pools (small)	1
- riverine pools	4
- flowing rivers	12
- small reservoirs	4
- large reservoirs	8
- berkad	4
- bore holes	10

SCHEDULES

The dry season census was carried out just before the start of the long (GU) rains, and filled the period 28 March to 24 April 1979.

The wet season census was carried out in the period 13 June to 2 August 1979. Rain was still falling throughout the survey area in June, but by the end of the census period the northern part of the area (MUDUG Region) was already becoming dry.

STRATIFICATION AND SAMPLING

STRATIFICATION

The land system units (see Volume 1 for a description of their characteristics and the methods whereby they are determined) have been used as strata in the sampling design.

Because ecological information on the area was collected throughout the study some modifications of land system unit boundaries (and hence areas) have taken place between the dry season and wet season censuses. These modifications were:

i) LSU 2 Dry season 145 Km^2: Wet season 580 Km^2.
This area was expanded northwards to move the Regional boundary to somewhere nearer its real position. (Only the crudest maps of the survey area have been available and these show a variety of boundary positions). This redrafting took place before the production of the Volume 2 series maps but after the census work was completed. The area censused, then, was 145 Km^2 in the dry season, but the maps in Volume 2 part 2 show an enlarged stratum 2.

ii) LSU 16 Dry season 2348 Km^2: Wet season 2544 Km^2.
This change has resulted from the absorption in LSU 16 of a small (196 Km^2) isolated fragment of LSU 24 (situated in 1:100,000 map sheet 50).

iii) LSU 24 Dry season 5740 Km^2: Wet season 5544 Km^2.
The change observed above has reduced the area of LSU 24 by 196 Km^2 (see Figures 2.01 and 3.01).

iv) LSU 31 Dry season 803 Km^2: Wet season 808 Km^2.
During the checking of LSU areas (after the completion of computer work on the dry season results) an error was found in the area measurements on map sheet 35 (1:100,000 scale). This was corrected for the wet season tabulations.

v) LSU 59 Dry season 1708 Km^2: Wet season 1648 Km^2.
The isolated fragment of LSU 59 (map sheet 70 - 60 Km^2) was combined as part of stratum 70 in the wet season census, since it was judged to be more typical of the alluviums than the arced silts.

vi) LSU 70 Dry season 1468 Km^2: Wet season 1538 Km^2.
This LSU has increased by 70 Km^2 as a result of the addition of LSU 59 (see above) and because the southern boundary of HIRAAN region was redrafted when more precise mapping of the Regional boundaries was found, giving 10 Km^2 more land.

vii) LSU 62 Dry season 2212 Km^2: Wet season 1216 Km^2.
Some 996 Km^2 have been removed from LSU 62 as a contribution to LSU 90 (a new LSU).

viii) LSU 71 Dry season 5376 Km^2: Wet season 4976 Km^2.
Some 400 Km^2 have been removed from LSU 71 as a contribution to LSU 90 (a new LSU).

ix) LSU 80 Dry season 504 Km^2: Wet season 576 Km^2.
LSU 80 has been expanded by the addition of the northern isolated fragment of LSU 81 (72 Km^2) on map sheets 66 and 73.

x) LSU 81 Dry season 2268 Km^2: Wet season 2196 Km^2.
As recorded above 72 Km^2 have been lost to LSU 80.

xi) LSU 73 Dry season 2988 Km^2: Wet season 1608 Km^2.
The creation of a new LSU (91) out of the southern section of LSU 73 (map sheets 79, 80 and 85) has removed 1380 Km^2 from LSU 73.

xii) LSU 91 Dry season nil: Wet season 1380 Km^2.
As noted above 1380 Km^2 have been taken from LSU 73 to create LSU 91.

xiii) LSU 90 Dry season nil: Wet season 1572 Km^2.
This LSU has been created from LSU 62 (996 Km^2) 71 (400 Km^2) and 8 (176 Km^2).

A reconciliation of the total areas in the dry season and wet season surveys reveals that the 176 Km^2 of LSU 8 was not removed in the preparation of the wet season tabulations. Thus the final corrected survey area becomes 132, 151 Km^2, and the area of LSU 8 should read 1048 Km^2.

None of these small changes or errors significantly alters the census results nor their implications (for example as a result of this error cattle are over-estimated in the wet season census by 291, sheep by 3900, goats by 2100 and camels by 587.)

SAMPLING

The number of sampling strips selected and flown in the dry and wet season surveys is set out in Table 4.7 by Land System Units.

A REGIONAL BREAKDOWN OF THE CENSUS INFORMATION

The data of volumes 2 part 1 and 3 part 1 have been restructured to give the approximate Regional totals and estimates which are set out in Table 4.8.

It has to be noted that, strictly speaking, these estimates do not refer to the Regions as they are described on the latest maps. Since the census was completed we have seen maps which show the southern boundary of GALCADUUD as appreciably further north of its position for the census.

Also the western limit of the census area (at 45° 00'E) has been determined by the military authorities, and there are about 9000 Km^2 of Hiraan Region west of the longitude.

These anomalies are illustrated in Figure 1.21(Volume 1 part 3).

From aerial reconnaissance it seems as though the western extension of HIRAAN Region has very similar ecological characteristics to those shown in LSU 59 and 77. As a first approximation we can use the densities of LSU 59 and 77 to provide "orders of magnitude" estimates for the livestock likely to be found in the uncensused parts of HIRAAN. These estimates have been included in Table 4.8.

A BREAKDOWN OF CENSUS INFORMATION FOR LIVESTOCK BY ECOLOGICAL ZONES & CLASSES & IMPLICATIONS OF WET & DRY SEASON DIFFERENCES

The data of volumes 2 part 1 and 3 part 1 have been restructured to provide estimates and densities for the ecological zones. These results are shown as Table 4.9 .

A further analysis has been made on this table to show the changes between dry and wet seasons. These changes are represented in a relative sense (wet season divided by dry season) and in absolute terms (wet season minus dry season).

The following are the main implications of these data:

i) Hemming's 1977 estimates (based on figures given to him by administration officers) for livestock in the Project area, covering 123,000 Km^2, (see p.18 of his unpublished draft report to IBRD - Central Rangelands Development Project - Range Ecology Survey).

were-4.7 million sheep
-7.4 million goats
-0.5 million cattle
-2.25 million camels

The two sets of figures produced by the dry and wet season censuses (for 132,000 Km^2) are:

- 1.5 million and 2.9 million sheep for dry and wet seasons
- 4.8 million and 8.1 million goats for dry and wet seasons
- .23 million and .39 million cattle for dry and wet seasons
- .31 million and .96 million camels for dry and wet seasons

Thus the figures given to Hemming in 1977 were probably appreciably over-estimated for all types except goats.

ii) The large differences between dry season and wet season estimates certainly is significant, and indicates a large movement of sheep and goats and camels into the project area between April '79 and June '79. The long rains of 1979 were heavier, more widespread and more prolonged than usual (according to the graziers), and in these circumstances excellent forage was produced over much of the project area. It is suggested that stock were drawn onto this green growth throughout the rains from the border area, from these parts of Somalia lying west of the de facto Territorial boundary with Ethiopia, and from the south.

The magnitude of the immigration may well have been magnified by the very poor short rains of 1978. At this time livestock which might normally spend most years entirely inside the C.R.P. Area will have been drawn to areas of permanent water and better forage conditions (i.e. principally south and west).

It is of course impossible to say what the normal magnitude of immigration and emigration is. But the consultants consider the densities observed in the 1979 dry season was probably depressed below the normal level as a result poor rains in October, November 1978, and the wet season densities were probably elevated above the normal level in response to prolonged and heavy rain over areas which respond favourably to such rainfall.

The conditions in the long rains of 1979 were excellent for forage production and parts of the Central Rangelands were seen carrying very high densities of stock, not unlike "GIZU" conditions seen occasionally in the Libyan desert in north western Sudan.

iii) It is clear that in both wet and dry seasons there are some consistent differences between ecological classes and zones in terms of their stocking rates. Some of these differences (for all stock combined, as a biomass density) can be seen in Figures 1.13 and 1.14 of volume 1 part 3. In very broad terms these biomass densities reflect the rainfall density gradients.

iv) Considering each livestock type the data of Table 4.9 show the following:

a) CATTLE

Cattle are rather uniformly distributed at low densities throughout the ecological classes, and to a lesser extent through the zones, except for a marked concentration in the Webi Shabeelle alluviums (Ecological class VI) at all times of the year, and a wet season concentration on the arced silts.

The least grassy clases (I & III) support marginally lower cattle densities than the others in both seasons.

Population differences between wet and dry season are not large, and probably reflect rather small eastward movements of cattle from the permanent water sources along the de facto Territorial border into classes I, II, III, & VIII and northward movements along the coast into class IV and inland into class V and VI.

Figure 1.27 illustrates the magnitude and positions of changes in cattle numbers, and the inferred movement patterns.

b) b) SHEEP

Sheep are not uniformly distributed and show a preference in both wet and dry seasons for the grassy ecological classes (II, IV & VI).

Sheep are much more migratory than cattle, and there has been a large influx of sheep in the wet season into all ecological classes except the Webi Shabeelle alluviums. The sheep population there (ecological class VI) is more or less static, suggesting a non-migratory population.

It must be inferred that sheep have entered the Project area from the west and south in the wet season. The magnitudes and locations of changes in sheep numbers, and the inferred movement pattern is shown as Figure 1.28 in volume 1 part 3.

c) GOATS

Goats are uniformly distributed in both wet and dry seasons (particularly so in the wet) with a tendency to concentrate in ecological classes of high proportions of low browse (i.e. I, III, V & VII).

They are about as migratory as sheep; very large numbers of goat have entered the Project area in the wet season, into all classes except VI & VII. Once again the Webi Shabeelle Alluviums (Class VI) appears to change very little between dry and wet seasons.

In a broad sense increases in goat numbers in any ecological class in the wet season are relatively the same as increases in sheep numbers. This is in part explained by the fact that most families own both goat and sheep, and graze them together.

It must be inferred that goat have entered the Project area from the west and south in the wet season. The magnitude and locations of changes in goat numbers, and the inferred movement pattern is shown in Figure 1.29 of volume 1 part 3.

d) CAMELS

Camels are non-uniformly distributed in the ecological classes but no obvious reference is evident for browse or grassy types.

Camels are the most migratory of all the livestock types, showing a threefold increase in the 1979 wet season from the 1979 dry season.

It has to be inferred that camels have entered the project area in the wet season from the west and south. The magnitudes and relative locations of changes in camel numbers, and the inferred movement patterns are shown in Figure 1.30 in volume 1 part 3.

v) No evidence collected on the ground, or which could be inferred from the two sets of distributions, will support the idea of any regularity in the timing or location of migratory movements. All informants insist that their migrations are virtually unconstrained and unprogrammed, depending on the climatic patterns over the predeeding few months.

vi) In the wet season census it was obvious that more very small stock were present in the herds and flocks, suggesting that there is seasonal breeding, in phase with the rainfall cycle. From information collected in Sudan, and general biological considerations, we can speculate on the role seasonal breeding might have played in temporarily increasing the livestock population between the dry season and wet season census.

One of the most synchronously breeding ungulate species is the migratory race of the wildebeeste (Connochaetes Taurinus Albojubatus Thomas) found in the Serengeti region of N. Tanzania. Watson (1967) showed that this animal is capable of compressing 90% of the population's births into a 21-day period.

Livestock are much less synchronous: the greatest compression we have recorded is something of the order of 40% of births over a 3 month period for goats in Sudan. It seems in view of this, unlikely that the populations of livestock in the Central Rangelands have increased by more than 20% between censuses, accounting for a small proportion of the observed increases.

vii) Finally the changes in densities of biomass, (both relative and absolute) have been illustrated in Figures 1.25 and 1.26 to convey an impression of the way grazing pressures can fluctuate over a three month period.

HOUSES, BUILDINGS, STRUCTURES AND PEOPLE

Densities of houses, buildings and other structures have been tabulated in Volume 2 part 1 and Volume 3 part 1 (tables 2.05 and 3.05 respectively). In Figures 2.09 and 3.09 of volumes 2 part 2 and 3 part 2 the densities of compounds has been plotted at 1:1,000,000 scale by land system units.

Compounds are the equivalent of households (see Volume 2 part 2) and Figure 2.09 and 3.09 show the relative distributions of human population in the dry and wet seasons of 1979.

House density information, somewhat consolidated to reveal its more interesting facets, has been tabulated for ecological zones and classes as Table 4.10. These data show:

i) There has been a substantial increase in nomadic houses between dry and wet seasons over the whole area (as one would expect with more livestock entering the area.)

ii) Permanent houses occur chiefly in towns and villages, and are so clumped that the estimates are very inprecise. During the wet season census sampling strips across towns and villages were not counted because of the risks inherent in flying over these larger urban concentrations. And so the wet season data for 1979 do not include any of the larger settlements (i.e. BUULO BARDE, HALGEN, BELEDWEYNE, MATABAN, DHUUSAMARREEB, GODINLABE, MAREER GUR, CEELBUUR, XARARDHEERE, MASAGAWEYNE, HOBYO, WISIL, CADAADO, GAALKACYO, BACAADWEYN, JIRRIIBAN, GAL HARRERI and AADAN YABAL).

The The dry season census was flown over all towns.

The substantial decrease in permanent houses from dry to wet season is a direct consequence of omitting these towns from the sampling strips.

iii) The reduced numbers of livestock enclosures "in use" is at first sight anom lous However, it seems that for the rapid migratory movements typical of the wet season, many families do not cut thorns and make livestock enclosures. Many nomadic houses were seen which were not accompanied by an enclosure; the stock is brought close to the house at night but not enclosed, it seems that livestock enclosures are a feature more of the dry season, when stock is held close to water for many weeks, or even months, at the same location.

iv) In the 1979 wet season it was decided to count all the abandoned livestock enclosures and not just those less than one year old. This was done to provide an idea of the intensity of livestock use (with emphasis on dry season use but not exclusively so) over the previous decade in the Central Rangelands. And so the dry season and wet season data on this feature are not comparable.

The densities of all abandoned livestock enclosures censused in the 1979 wet season are illustrated in Figure 1.15 of Volume 1 part 3.

Human populations can be derived from the "compound occupation rates", which in turn were investigated as part of the ground survey. Compound occupation rates found in 1979 in the Central Rangelands were:

- All nomadic types of houses 4.51 (n=102) persons
- All permanent houses 5.32 (n=101) persons

Using these data the population of the Central Rangelands has been computed and is shown in Table 4.11 for the ecological zones and classes. The overall estimates are:

- Dry season 1979
  - 322,370 settled people
  - 247,359 nomadic people
  - excluding the inhabitants of BELEDWEYNE, DHUUSAMARREEB & GAALKACYO
- Wet season 1979
  - 107,754 settled people
  - 339,538 nomadic people
  - excluding the inhabitants of:

BELEDWEYNE	Regional Capitals
DHUUSAMARREEB	
GAALKACYO	
BUULD BARDE	Other Towns
HALGEN	
MATABA AN	
GODINLABE	
MAREERGUR	
C EELBUUR	
XARADHEERE	
MASAGAWEYNE	
HOBYO	
WISIL	
CADAADO	

BACAADWEYNE	)	
JIRRIBAN	)	Other Towns
GAL HARRERI	)	
AADAN YABAL	)	

By deduction the towns listed above have a combined population of about 215,000.

In Figure 1.16 we have shown the density by ecological zones of permanent houses (as a mean of the dry and wet season density) and in Figures 1.17 and 1.18 we show the densities by ecological zones of nomadic houses in the dry season and wet season respectively.

ACKNOWLEDGEMENTS

Special thanks must be given to Dr. Abdulahi Ahmed Karani for his assistance, guidance and kindness, and to Dr. Poul Sihm who initiated the Central Rangelands Programme.

We have been ably helped by many people, but mention must be made of the work of J. B. Gillett and C. F. Hemming whose combined knowledge and great enthusiasm made the field work a pleasure.

Capt. Mohamed Hassan was our military liason officer and he smoothed our path most effectively. All the administrative staff of the National Range Agency in Mogadihsu and at Gaalkacyo and Beledweyne were most helpful, and generous beyond the call of duty - they are too numerous to name.

Finally Miss J.M. Nimmo, Miss L. Holman, Mrs. J. Spence, Miss G. Fisher, Miss P. Nevarde and Mrs. G. Wehrman have worked unsocial hours under some pressure to produce these reports and maps.

To all the above we are deeply indebted.

BIBLIOGRAPHY

BANFIELD, A.W.F., FLOCK, D.R., KELSALL, J.P. AND LOUGHREY, A.G. (1955). An aerial survey technique for northern big game. Trans.N. Amer. Wildl. Conf., 20, 519-530

BELL. R.H.V. (1970). The use of the herb layer by ungulates of the Serengeti National Park. Ph.D. Thesis. Manchester University.

CAUGHLEY, G., (1972). Aerial Survey techniques appropriate to estimating cropping quotas. Ken a Wildlife Management Project F.A.O. Nairobi. 13pp.

CAUGHLEY, G. & GODDARD, J (1972). Improving the estimates from inaccurate censuses. J.Wildl. Mgmt., 36. 135-140.

DAWSON, F.L.M., (1958). Observations on the corpora albicantia in the ovaries of normal and infertile dairy cows. J. Agric. Sci. 50, 322-330.

EDWARDS, R.T. (1954). Comparison of an aerial and ground census of moose. J.Wildl. Mgnt., 18 (3), 403-404.

GILBERT, P.F. & GRIEB, J.R. (1957). Comparison of air and ground deer counts in Colorado. J. Wildl. Mgnt., 21 (1), 33-37.

GODDARD, J. (1967). The validity of censusing black rhinoceros populations from the air. E. Afr. Wildl. J. 5. 18-23.

GRAHAM A. & BELL, R.H.V. (1969). Factors influencing the countability of animals. E. Afr. agric. for. J. 34 Special Issue. 38-43.

GRZIMEK, M. & GRZIMEK, B. (1960B). Flamingoes censused in East Africa by aerial photography. J. Wildl. Mgnt., 24. 215-217.

HUNTING TECHNICAL SERVICES, (1974). SouthernDarfur Land-Use Planning Survey. Ministry of Agriculture, Food & Natural Resources. Khartoum.

JOLLY, G.M. (1969A). Sampling methods for aerial censuses of wildlife poputations. E.Afr. Agric. For. J. 34 - Special Issue. 46-49.

JOLLY, G.M. (1969B). The treatement of errors in aerial counts of wildlife populations. E.Af. agric. for. J. 34 - Special Issue. 50-55.

MENCE, A.J. (1969). Psychological problems of conducting censuses from light aircraft. E.Afr. agric. for.J. 34-Special Issue. 44-45

PENNYCUICK, C.J. (1969). Methods of using light aircraft in wildlife biology. E.Afr. agric. for J. 34 - Special Issue. 24-29.

PETRIDES, G.A. (1953). Aerial deer counts. J. Wildl. Mgnt., 17 (1), 97-98.

SCHULTZ, V. & MUNCY, R.J. (1957). An analysis of variance applicable to transect population data. J. Wildl. Mgnt., 21 (3), 274-278.

SINIFF, D.B. & SKOOG, R.O. (1964). Aerial censusing of caribou using stratified random sampling. J. Wildl. Mgnt., 28 391-401.

TURNER, M.I.M & WATSON, R.M. (1964). A census of game in Ngorongoro Crater. E.Afr. Wildl.J., 2. 165-168.

WATSON, R.M. (1967). The population ecology of the Wildbeest (Connochaetes taurinus albojubatus Thomas) in the Serengeti Ph.D. thesis, Cambridge.

WATSON, R.M. (1968). A census of domestic stock for the pastoral regions of Kenya. Proposal to the Ministry of Finance & Planning, Nairobi. 17pp. typed.

WATSON, R.M. (1969). A survey of the large animal population in South Turkana. Geogr. J. 135. 529-546.

WATSON, R.M. (1969). Reproduction in Wildebeeste (connochaetes taurinus albojubatus Thomas) in the Serengeti region of Tanzania. J. Reprod. Fert.

WATSON, R.M. (1970A). Livestock surveys of Narok Kajiado & Kitui Districts. Ministry of Finance & Planning, Nairobi. 115pp typed.

WATSON, R.M. (1970B). Livestock surveys of Marsabit & Isiolo Districts. Ministry of Finance & Planning, Nairobi. 134pp. mimeo.

WATSON, R.M. (1970C). An investigation of errors in aerial counting. A report of field trials carried out at Kiboko for the UNDP/FAO Range Management Project.

WATSON, R.M. (1971). Land use in the Nguruman area of Southern Kenya. Ministry of Tourism & Wildlife, Nairobi.

WATSON, R.M. (1972A). Results of Aerial Livestock surveys of Kaputiei Division, Samburu District, & N.E. Province. Ministry of Finance & Planning. Nairobi. 188pp.

WATSON, R.M. (1972A). Wildlife in the Narok District Plan. Game Department, Ministry of Tourism & Wildlife, Nairobi.

WATSON, R.M. FREEMAN, G.H., & JOLLY, G.M. (1969). Some indoor experiments to simulate problems in aerial censusing E.Afr. agric. for J. 34 - Special Issue. 56-59.

WATSON, R.M., HUSSEIN, A.H., SABRY FARAJ ISMAIL, RAMZY MOHAMED MOBARAK, SAYED MOHAMED SHAMIM (1974). Livestock statistics in the Sudan. Report of the FAO Livestock Statistics Mission to the Sudan, and a proposal for a Livestock census. F.A.O. Rome. 53pp. mimeo.

WATSON, R.M., JOOLY, G.M., & GRAHAM, A. (1969). Two experimental censuses. E.Africa. agric. for J. 34 - Special Issue 60-63.

WATSON, R.M., PARKER, I.S.C., & ALLEN, T. (1969). A census of elephants and other large animals in the Mkomazi region of northern Tanzania . & Southern Kenya. E. Afr. Wildl. J. 7 11-26.

WATSON, R.M., & TIPPETT, C.I. (1971A). Aerial livestock and landuse surveys of the Giggiga area, Ethiopia. I August - September 1971. Livestock & Meat Board , Addis Ababa. 66pp. mimeo.

WATSON, R.M. & TIPPETT, C.I. (1971 B). Aerial livestock land-use and land potential surveys of the Shire Lowlands, Ethiopia. Livestock & Meat Board, Addis Ababa.

WATSON, R.M., & TIPPETT, C.I. (1972A). Aerial livestock and land-use surveys of the Giggiga area Ethiopia. II. February 1972. Livestock & Meat Board, Addis Ababa 46pp. mimeo.

WATSON, R.M., & TIPPETT, C.I. (1972B). Aerial Livestock and Landuse surveys of the Giggiga area, Ethiopia. III. Initial comparisons of the 1971 & 1972 surveys. Livestock & Meat Board, Addis Ababa. 35pp. mimeo.

WATSON, R.M., & TIPPETT, C.I. (1972C). Aerial livestock monitoring surveys for Samburu, Marsabit, Isiolo, Garissa, Mandera & Wajir Districts. Ministry of Finance & Planning, Nairobi. 124pp.

WATSON, R.M., & TIPPETT, C.I. (1973A). Aerial livestock and landuse surveys of the Giggiga area, Ethiopia. 1V. January 1973 & Final Report. Livestock & Meat Board, Addis Ababa. 86pp. mimeo.

WATSON, R.M., TIPPETT, C.I. ALLAN, T., TIPPETT, M.J., WATTS T.A.D. (1974). Aerial livestock and land-use surveys of of the N.E.Rangelands of Ethiopia. 1V August 1974. An extended survey area. Livestock & Meat Board, Addis Ababa. 47pp. mimeo.

WATSON, R.M., TIPPETT, C.I., & SOUTHWORTH, R. (1974). An aerial photogrammetric survey of agriculture in Ethiopia during the 1973 famine. Ministry of Agriculture, Addis Ababa. 341pp. mimeo

WATSON, R.M., TIPPETT, C.I., & TIPPETT, M.J, (1972). Aerial livestock and land-use surveys of the N.E. Rangelands of Ethiopia - I August/september 1972. Livestock & Meat Board, Addis Ababa.

WATSON, R.M., TIPPETT, C.I., & TIPPETT, M.J, (1973). Aerial livestock and land-use surveys of the N.E. Rangelands of Ethiopia - II January, 1973. Livestock & Meat Board, Addis Ababa.

WATSON, R.M., TIPPETT, C.I., & TIPPETT, M.J. (1973B). Aerial livestock and land-use surveys of the N.E. Rangelands of Ethiopia - III May 1973 & Final Report. Livestock & Meat Board, Addis Ababa.

WATSON, R.M., TIPPETT, C.I., TIPPETT, M.J., & MARRIAN, S.J. (1973A). An aerial livestock, land-use and land potential survey of Karago-Giciye, Rwanda. IBRD., Nairobi.

WATSON, R.M., TIPPETT,C.I., TIPPETT, M.J., & MARRIAN, S.J. (1973B). An aerial livestock and land-use survey of the Alledeghi plains, Ethiopia. Awash Valley Authority, A.A.

WATSON, R.M., TIPPETT, C.I., TIPPETT, M.J., & MARRIAN, S.J. (1973C). An aerial livestock and land-use survey of the Central Highlands of Ethiopia. Livestock & Meat Board, A.A.

WATSON, R.M., TIPPETT, C.I., TIPPETT, M.J., & MARRIAN, S.J. (1973D). Aerial livestock and land-use surveys of Isiolo and Samburu Districts. Ministry of Finance & Planning, Nairobi.

WATSON, R.M., TIPPETT, C.I., TIPPETT, M.J., & MARRIAN, S.J. (1973E). Aerial livestock, land-use and land potential survey of Lamu, Tana River and S Garissa District. Ministry of Finance & Planning, Nairobi.

WATSON, R.M., & TURNER, M.I.M (1965). A count of the large mammals of the Lake Manyara National Park: results and discussion. E.Afr. Wildl. J. 3. 95-98.

WATSON R.M. & TIPPETT C.I. (1975 - 77) Sudan National Livestock Census & Resource Inventory . 26 Volumes on aerial census part of programme. Ministry of Agriculture Food & Natural Resources. Veternary Research Administration. Box 293, KHARTOWN. SUDAN.

WATSON R.M. (1979) An Aerial Survey of Livestock & Resources in Sierra Leone - A National Survey. HUNTING TECHNICAL SERVICES, Borehamwood, UK.

APPENDIX 4.1

Note on modification for bias adjustments.

1. Firstly, try to ensure that the data for bias adjustments are collected from typical areas, so that the distribution of group sizes is similar to that in the sample transects (otherwise weighting might be required).

2. Use as much relevant data as is available for the density of cover and species concerned, whether or not all of the data comes directly from the area being surveyed and at the time of survey - provided, of course, that all data refer to similar conditions. The criterion for how much data should be obtained is best taken as the effect on final confidence limits; it should be possible to avoid any substantial increase in the limits.

3. Complete groups missed. As explained in the body of this report, bias corrections are at present calculated from groups of one or more animals seen from the normal counting height of about 400 ft. Clearly however, there is a chance of groups being missed completely. On the assumption that the probabilities of missing individuals are approximately mutually independent (though unlikely to be strictly true the assumtion will be adequate for the present purpose), the probability of missing an entire group can be estimated.

Let n_1 be total number of groups of size g_1

Let n_i be number of those groups actually seen.

Let p_i be probability of a given animal being missed in a group of size g_i (i = 1, 2, 3, ...)

1) First estimate each p_i from

$$p_i = \frac{\text{Total number of animals missed in groups of size } g_i}{\text{Total number present in those groups of size } g_i}$$

$$= \frac{\text{Total number missed in the } n_i' \text{ groups seen}}{n_i' \quad g_i}$$

2) If not too many animals are being missed, the adjustment for complete groups missed should not be necessary for groups greater than size g_I = 3 or 4.
Fit a linear regression of the p_i on the g_i (e.g. if g_i = 4, then there will only be 4 points for the regression). Then for each group size, i.e. g_i = 1, 2, 3, 4 (no data will have been collected for g_i = 1 for very obvious reasons!) estimate p_i from the regression line. This will give improved estimates which can now be referred to as p_i (i = 1, 2, 3, 4).

3) It can be shown that:

Estimated number of animals present (including missed groups) in groups of size g_i = estimates of $n_i \; g_i$

$$= \frac{n_i \; g_i}{1 - p_i^{\,g_i}}$$

$$= \frac{\text{Total number of animals seen (from 400') over all groups of size } g_i}{1 - p_i^{\,g_i}}$$

Since $p_i^{\,g_i}$ is the probability of missing a complete group of size g_i on the assumption of independence.

4) A correction factor, R, is then used to multiply the final population estimate over all strata or parts of strata having the appropriate density or type of cover. Thus:

$$\frac{1}{R} = \frac{\text{Total no. of animals seen over groups of all sizes (for that type of cover)}}{\text{Estimated no. of animls present.}}$$

i.e $R = \frac{\Sigma x}{y} = \frac{\bar{x}}{\bar{y}}$ when x and y are as defined in 6) below.

5) Effect on $V(\hat{Y})$.

Let $\hat{Y}$ be the population estimate for a geiven type of cover for which a correction factor R is to be applied. Then the adjusted estimate $\hat{Y}_A$ is given by

$$\hat{Y}_A = R\hat{Y}$$

and, since R and $\hat{Y}$ have been estimated from independent data,

$$V(\hat{Y}_A) = R^2 V(\hat{Y}) = \hat{Y}^2 V(R)$$

where

$$V(R) = \frac{1}{n(n-1)y^2} \times \text{expression below.}$$

$$\sum_{i=1}^{n} \left\{ R^2(y_i - \bar{y})^2 - 2R(y_i - \bar{y})(x_i - \bar{x}) + (x_i - \bar{x})^2 \right\}$$

6) For the above elements of data y, x will be the counts for each of the n groups of animals observed (y), and the corresponding true numbers (x), except that added to the data collected should be the expected number of groups of each group size, (g_i) that would have been missed entirely.

TABLE 1 - APPENDIX 4.1

Estimated Number of Groups completely missed

as a percentage of the number seen.

	g				
p	1	2	3	4	5
.01	1				
.02	2				
.03	3				
.04	4				
.05	5				
.06	6				
.07	8				
.08	9	1			
.09	10	1			
.10	11	1			
.11	12	1			
.12	14	1			
.13	15	2			
.14	16	2			
.15	18	2			
.16	19	3			
.17	20	3			
.18	22	3			
.19	23	4	1		
.20	25	4	1		
.21	27	5	1		
.22	28	5	1		
.23	30	6	1		
.24	32	6	1		
.25	33	7	2		
.26	35	7	2		
.27	37	8	2	1	
.28	39	9	2	1	
.29	41	9	3	1	
.30	43	10	3	1	

g = group size.

p = probability of a given animal being missed in the count as estimated fromthe regression of p on g

The table gives the expected number of groups missed as a percentage of the number of groups seen.

These additional pairs will look like:-

y	x
o	1
o	1
.	.
.	.
.	.
o	2
o	2
.	.
.	.
.	.
o	3
o	3
.	.
.	.
.	.
o	4
o	4
.	.
.	.
.	.

Where the number of such added pairs for a given group size

(g_i) is $$\frac{n_i \quad p_i^{g_i}}{1 - p_i^{g_i}}$$

i.e number of groups of that size seen x $$\frac{p_i^{g_i}}{1-p_i^{g_i}}$$

(When these additional y, x pairs have been added the computation is standard ratio method work)

The numbers of such groups that have to be added a e given Table 1 - Appendix 4.1.

APPENDIX 4.2

Adjustment for Bias (practical instructions)

Step 1 Estimate $\hat{p}_i = \dfrac{\text{Total no. of animals seen in groups of size } i}{\text{Total no. of animals present in these groups.}}$

for i = 2, 3, 4 (if insufficient data could extend to higher values of i).

Step 2. Fit linear regression of $\hat{p}_i$ on i to estimate p_i

as $p_1 = \alpha + \beta$; $p_2 = \alpha + 2\beta$; $p_3 = \alpha + 3\beta$, etc

where the regression is $p_i = \alpha + i\beta$

Step 3 . Look up these resulting four values of p (the regression coefficient, , may often be near to zero in which case all 4 values will be the same) in Table 1 which gives the estimated number of groups missed completely. e.g. if 50 groups of 2 animals were observed, and p_2 = 0.19, then the estimated number of groups missed is

$$\frac{4}{100} \times 50 = 2$$

Step 4. To the list observed (y) and true (x) counts should be added the estimated number of groups missed of each size.

For example, if 2 groups of 2 are estimated as missed then add

y	x
o	2
o	2

and similarly for other group sizes (1, 3, 4) then calculate bias factors in the usual way

FIGURE 4.1

SELECTION OF SAMPLES

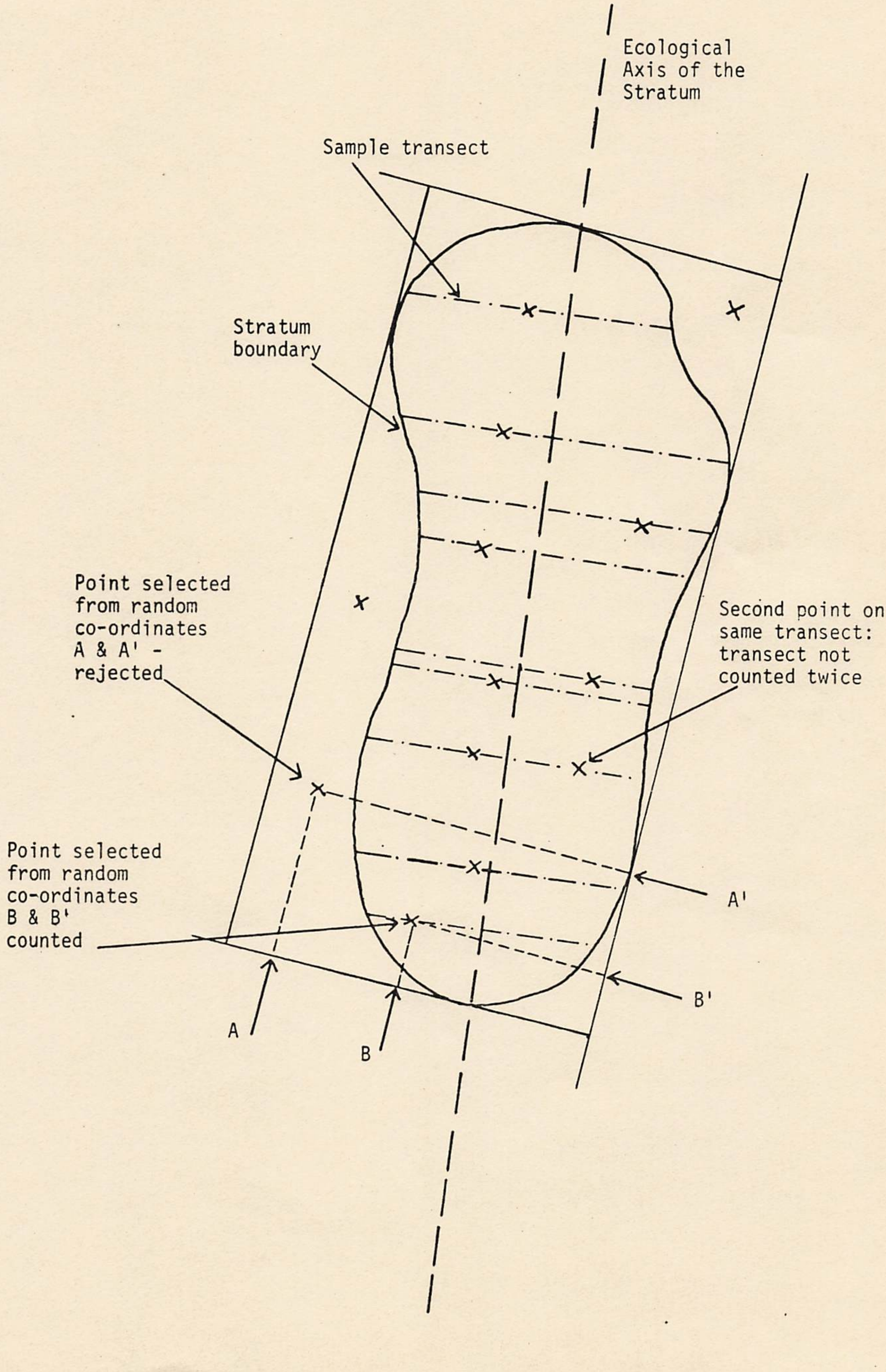


FIGURE 4.2

A SCHEME OF THE FLYING STRATEGY ADOPTED TO DEAL WITH MIGRATING LIVESTOCK

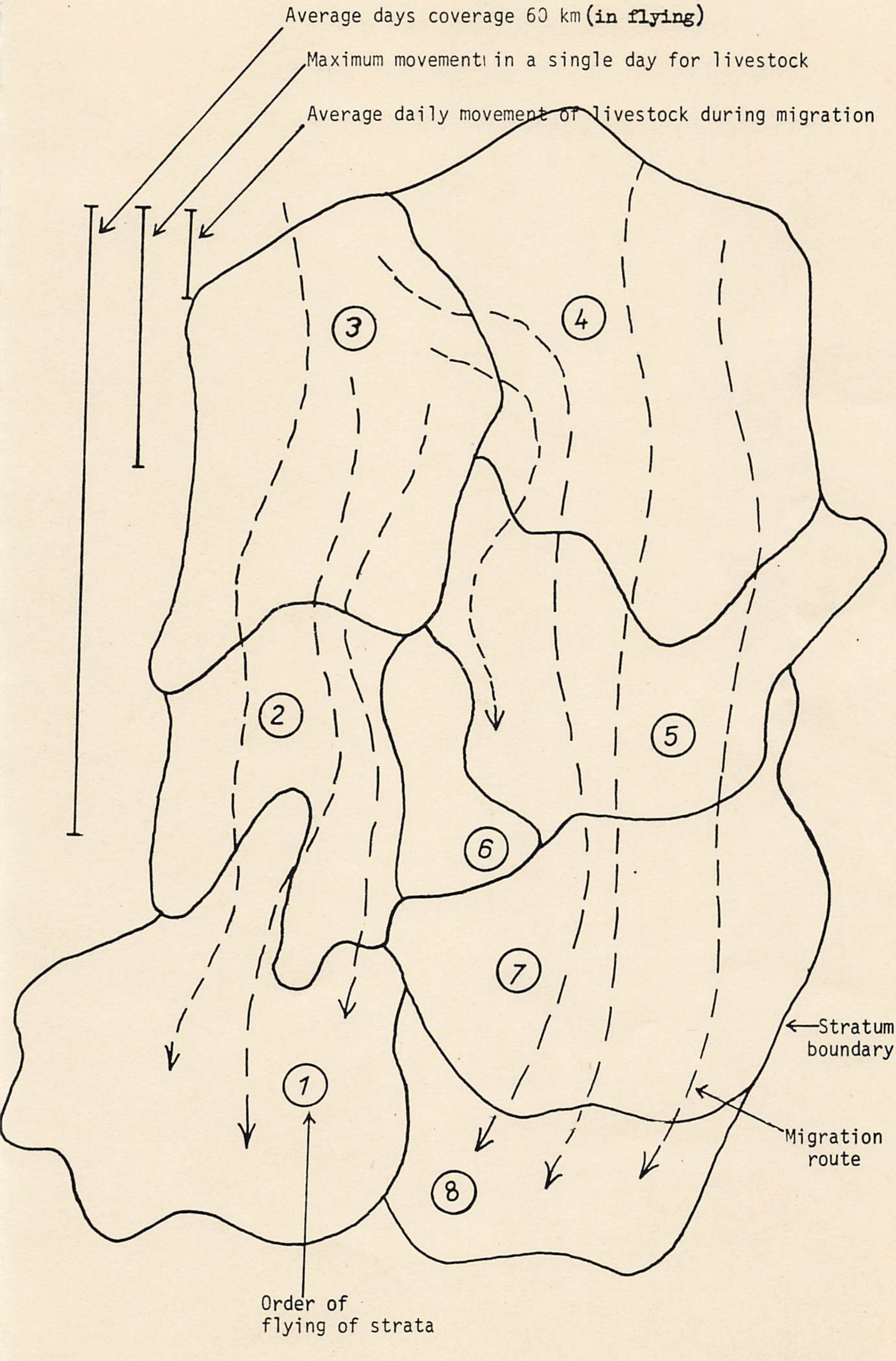


FIGURE 4.3

TREATMENT OF CLOSE TOGETHER SAMPLES

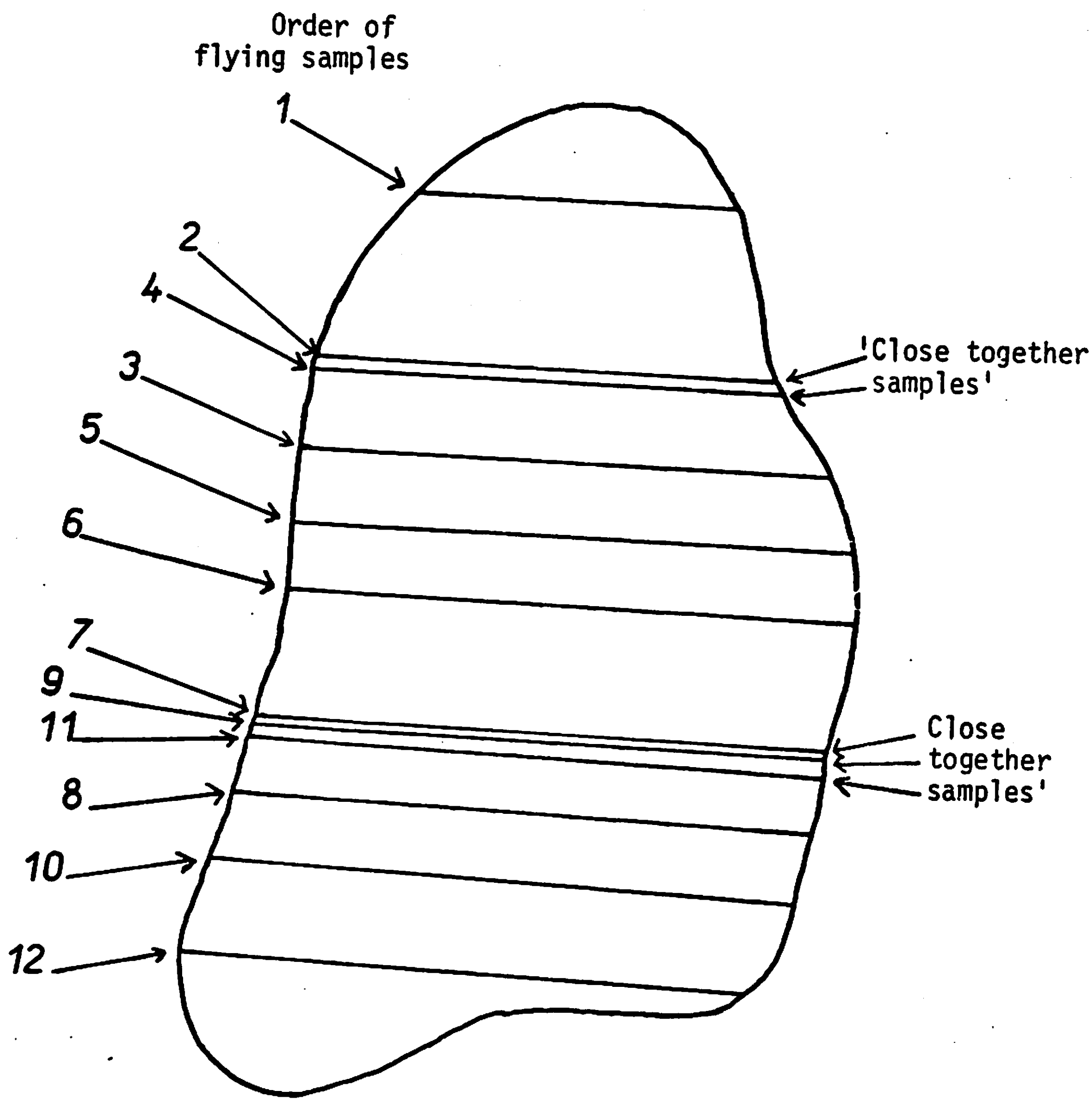


FIGURE 4.4

WIDE ANGLE VIEW OF THE SAMPLE DEMARCATORS IN POSITION
ON LIFT STRUTS OF PA 18 AIRCRAFT

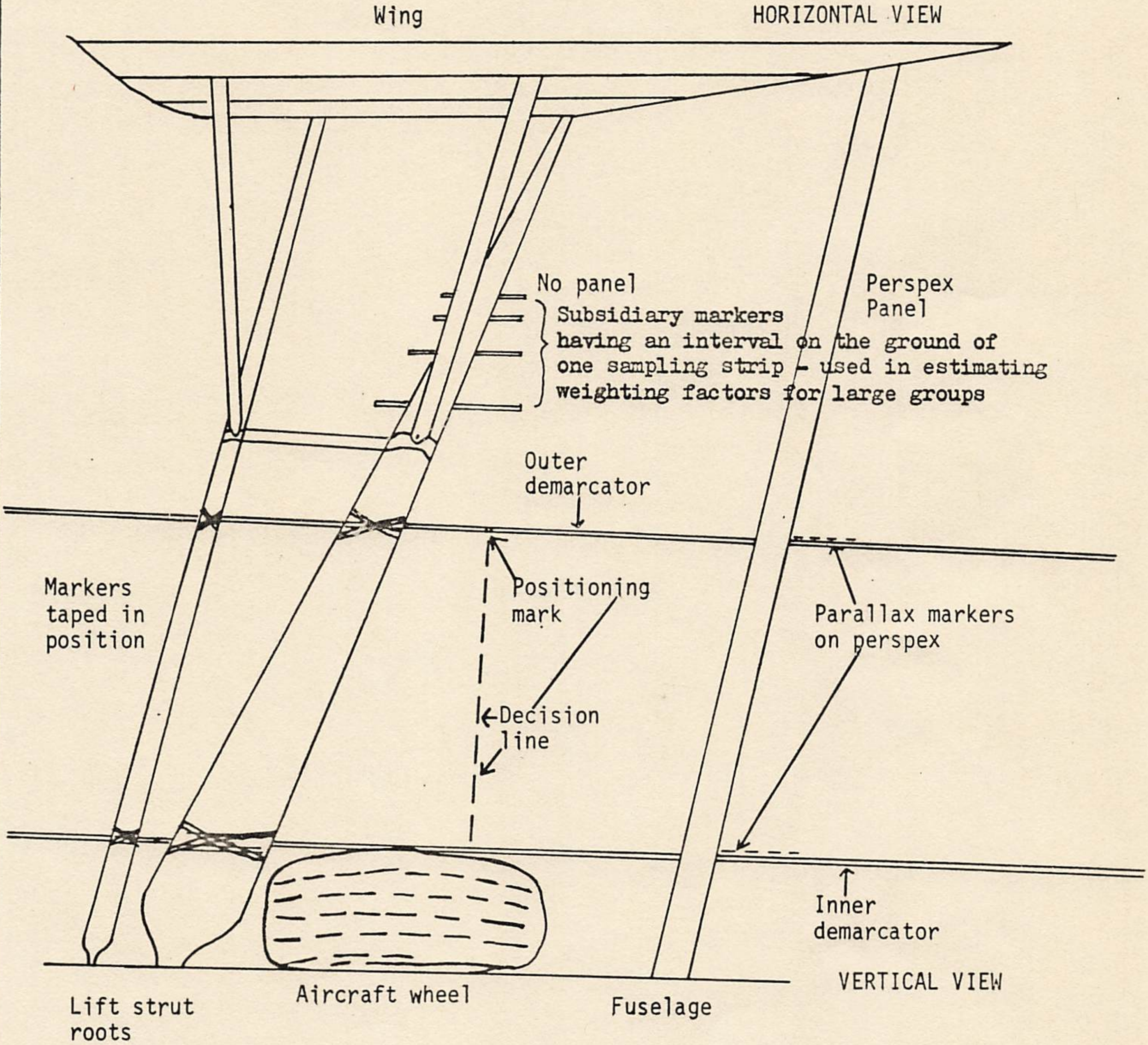


FIGURE 4.5A

TRIGONOMETRY OF THE COUNTING SITUATION - SECTION

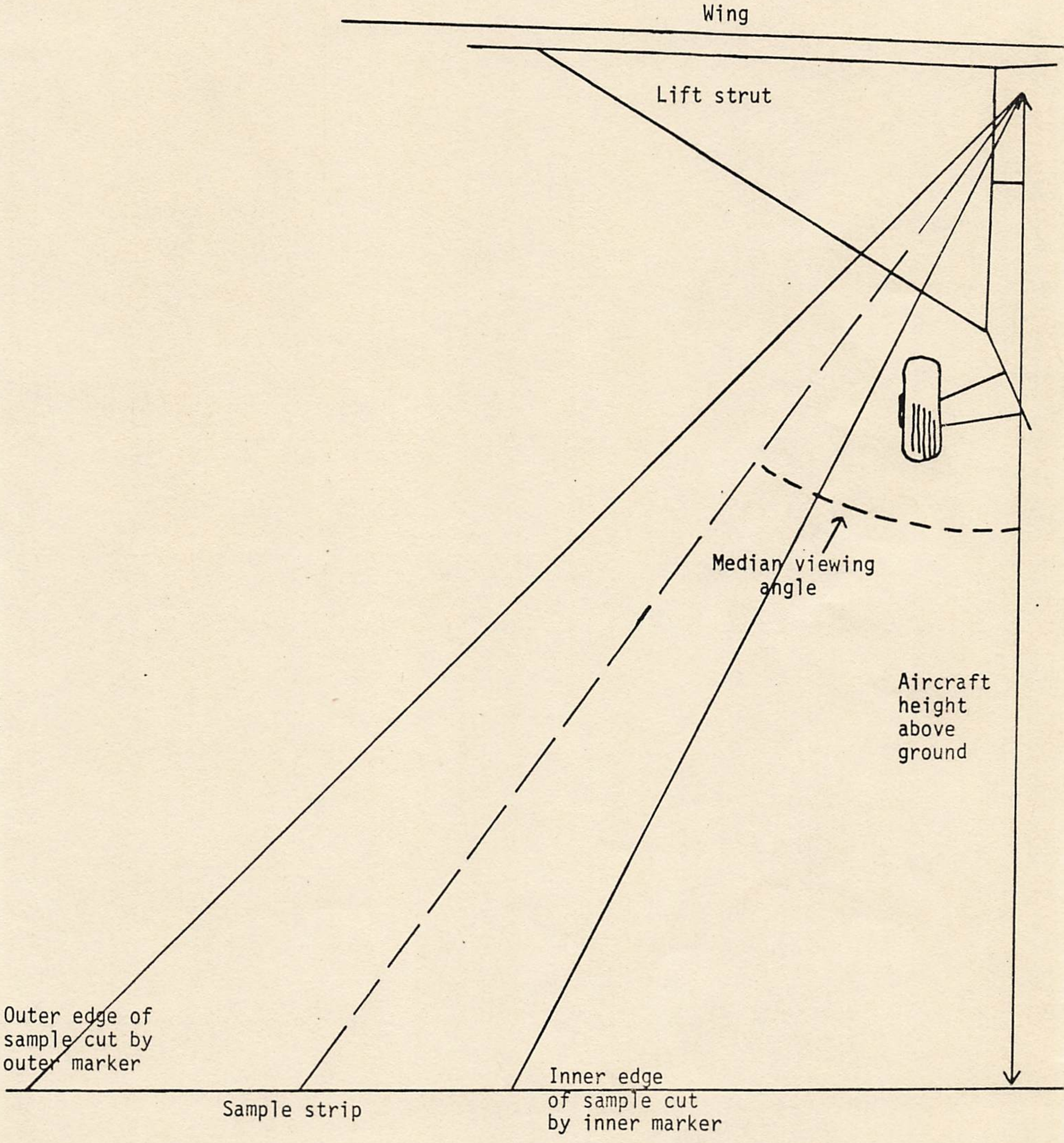


FIGURE 4.5B

TRIGONOMETRY OF THE COUNTING SITUATION - PLAN

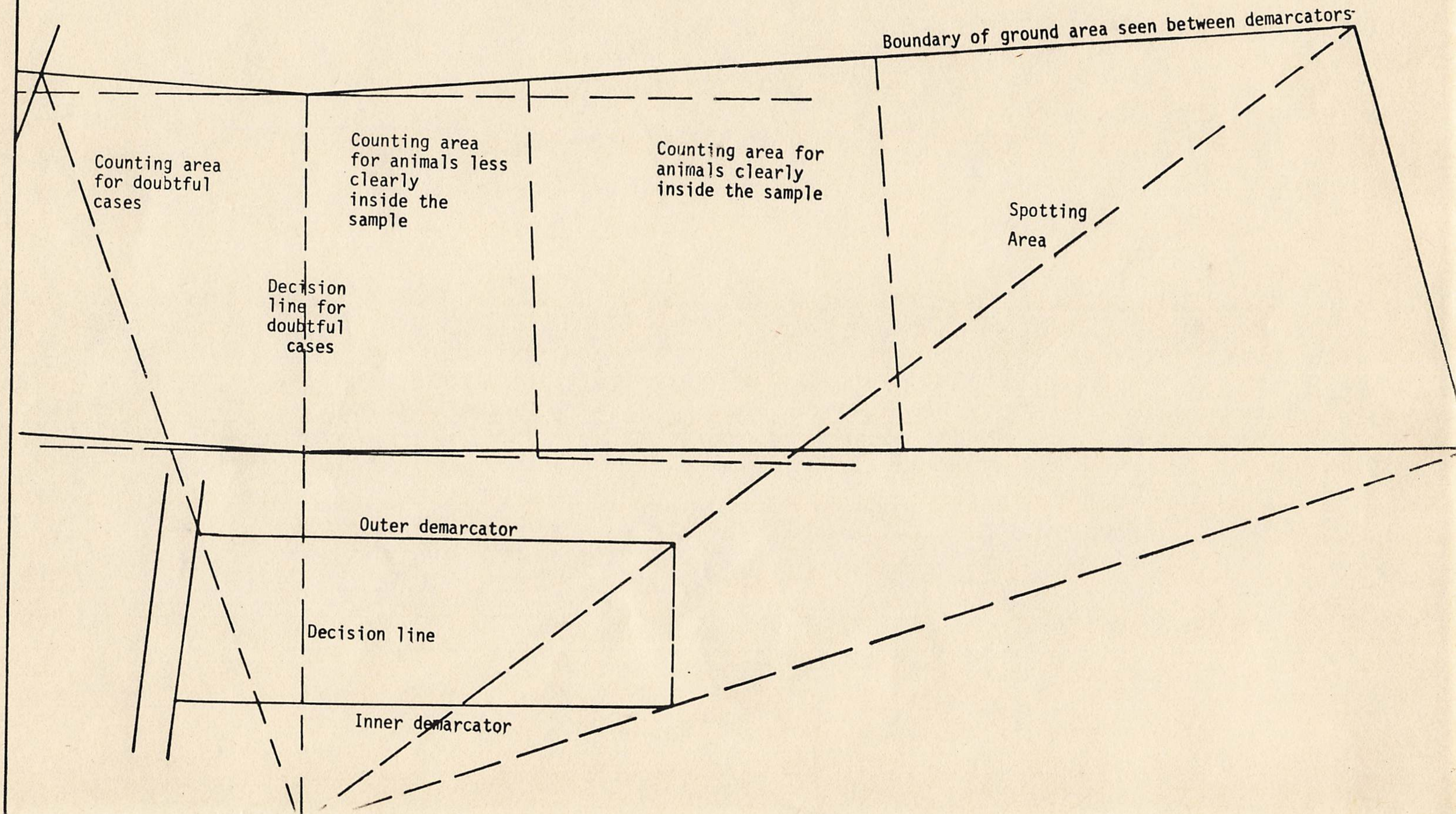


FIGURE 4.5C

AERIAL SAMPLING OF VERY HILLY TERRAIN

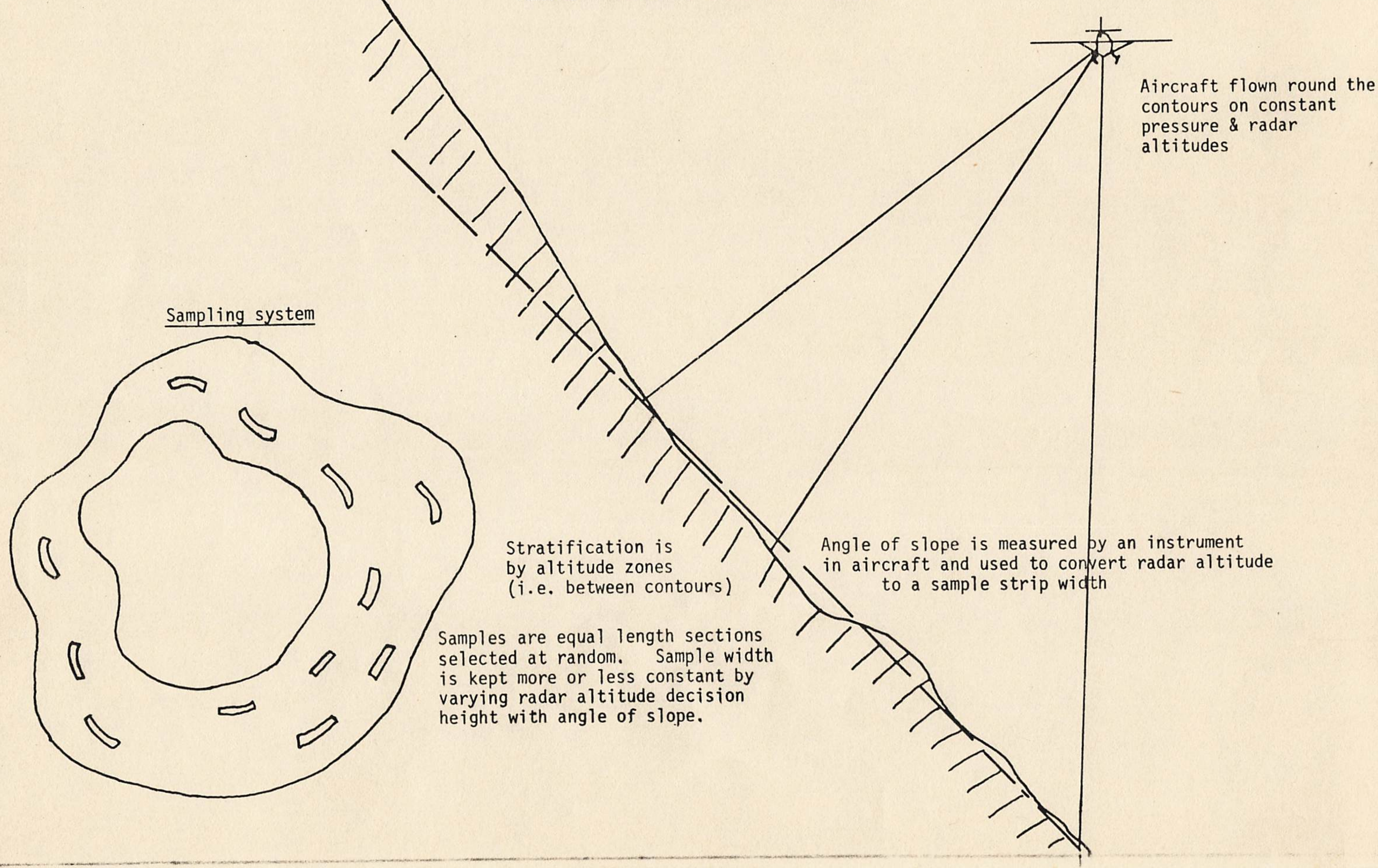


FIGURE 02.6

DIAGRAM OF DEMARCATION DECISIONS
(Aircraft proceeding with marked drift)

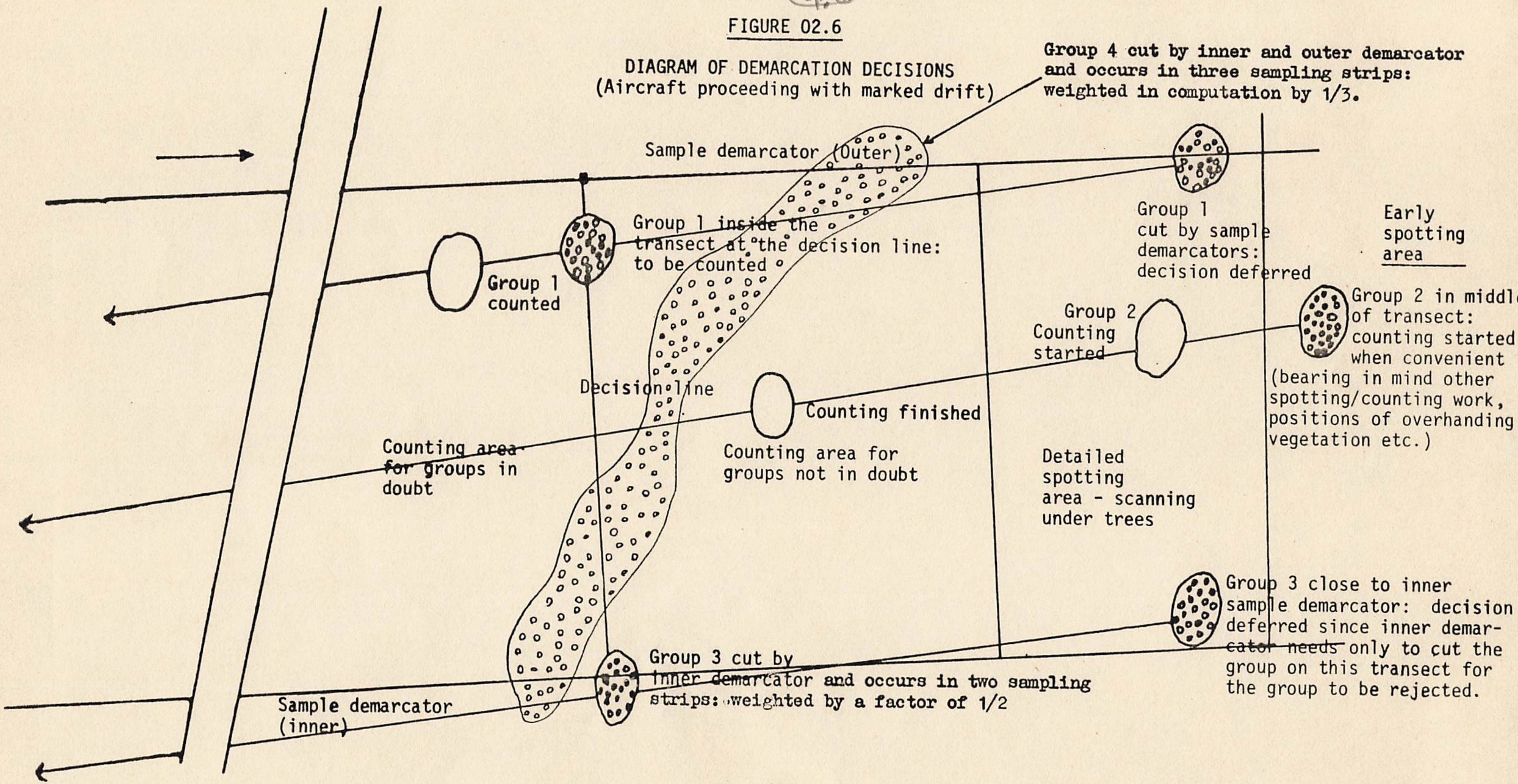


FIGURE 4.7

AERIAL CENSUSING AND VEGETATION COVER

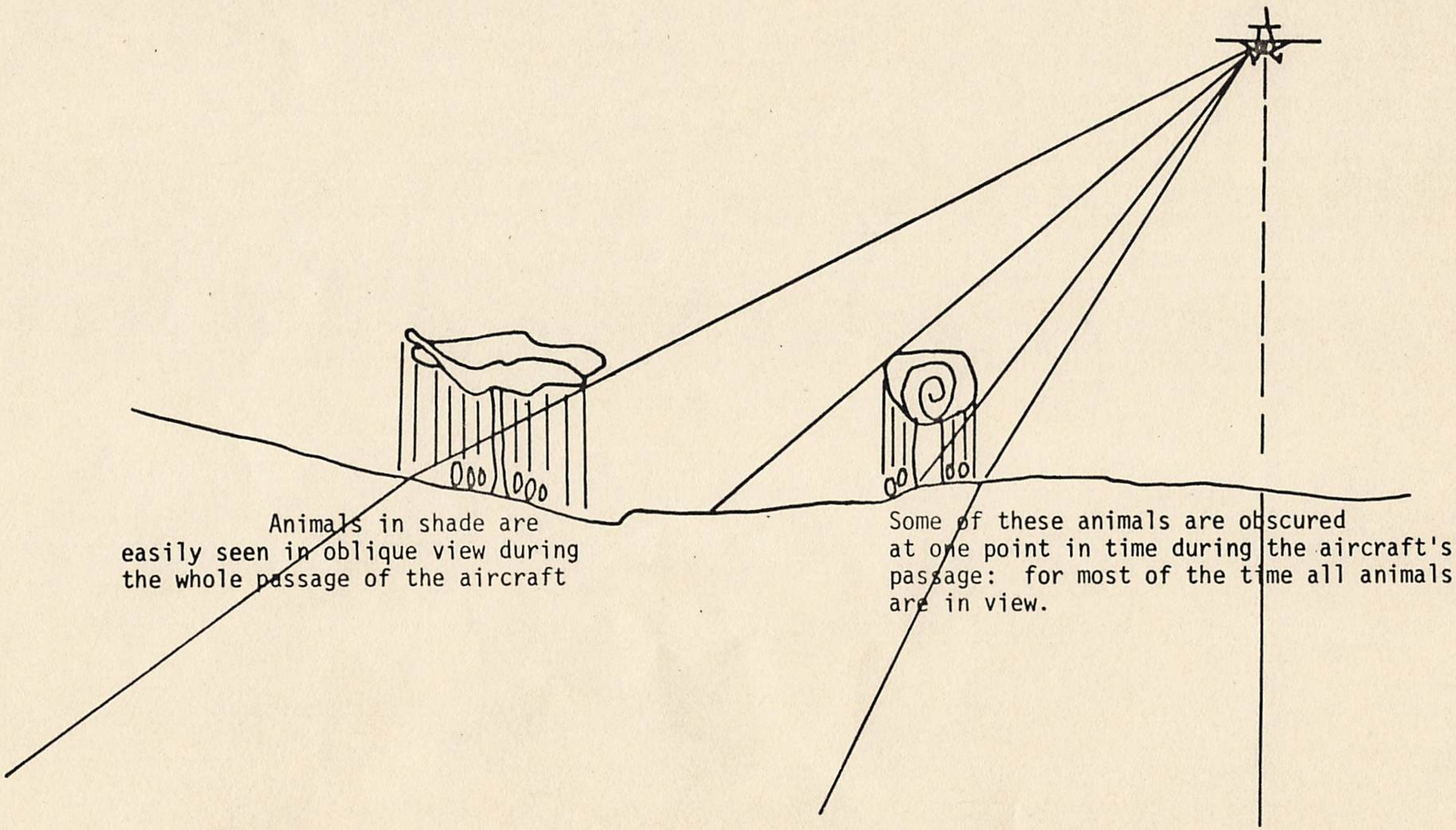
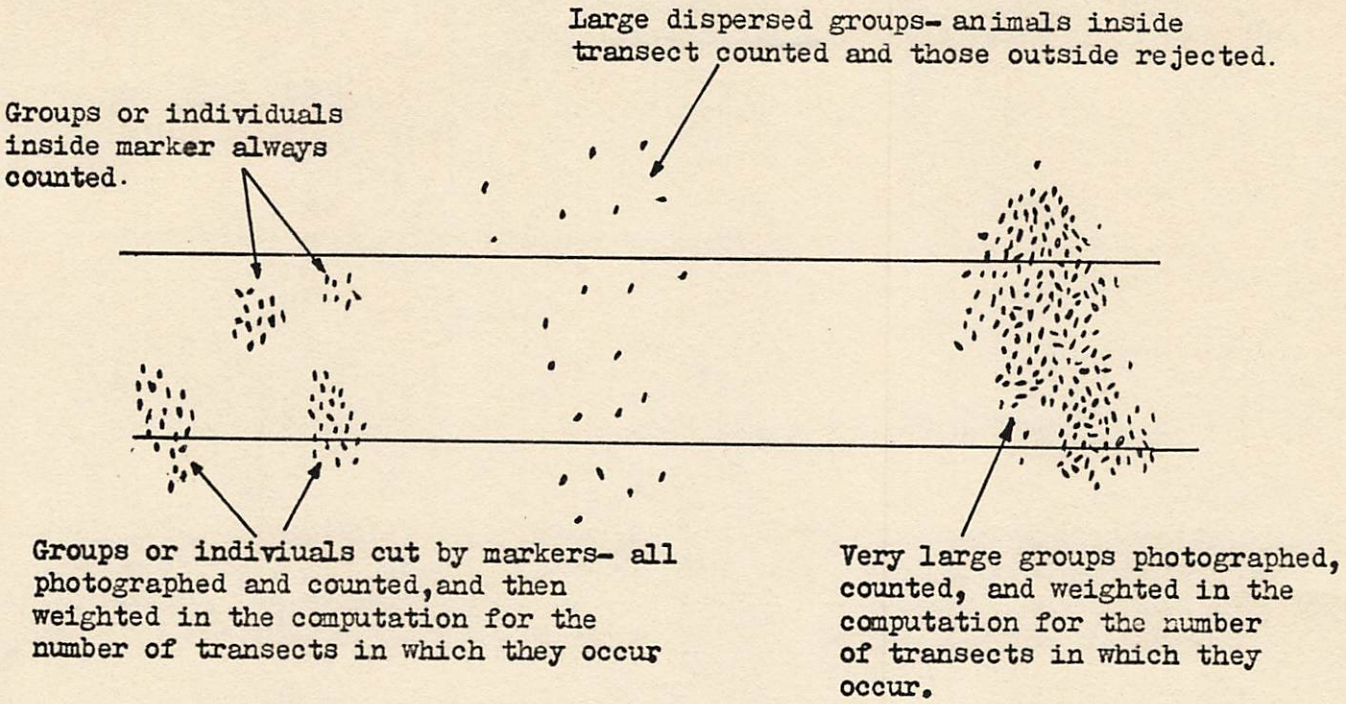
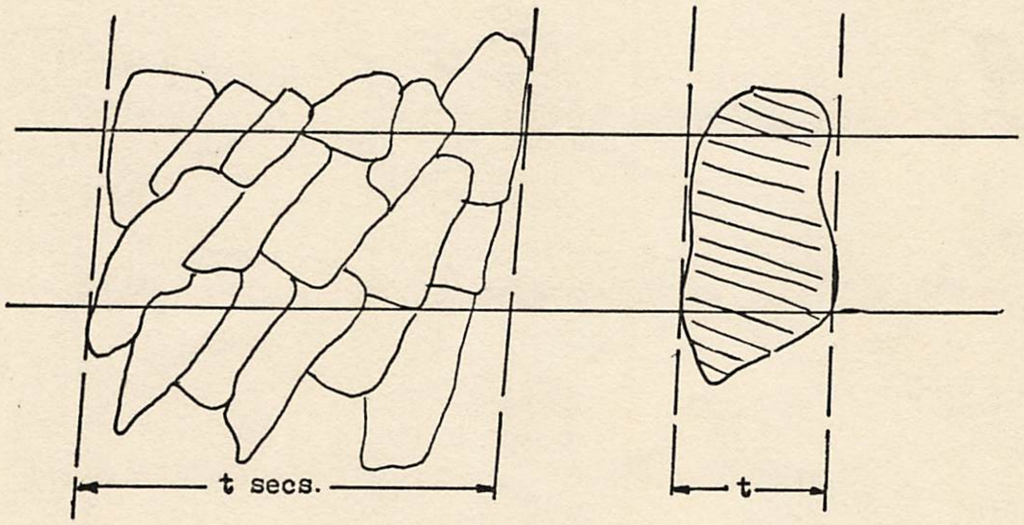


FIGURE 4.8

DEMARCATION OF GROUPS AND INDIVIDUALS

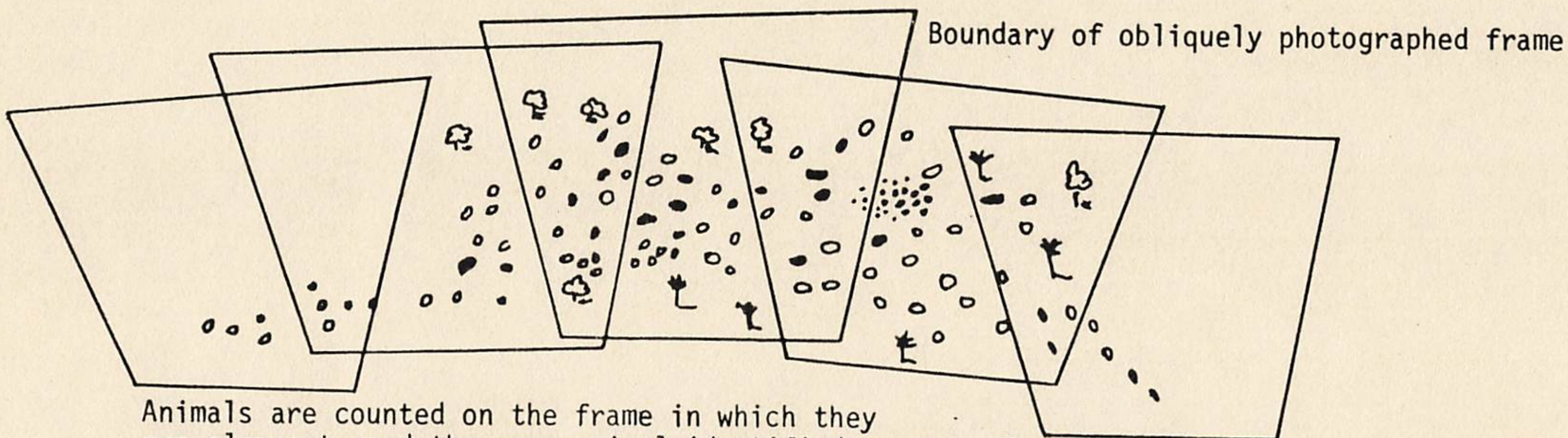




Continuous areas of cultivation and fields cutting inner sample demarcators- timed by stop watch as the aircraft passes over them, and time converted to length from known ground speeds.

FIGURE 4.9

COUNTING ANIMALS FROM OVERLAPPING FRAMES



Animals are counted on the frame in which they are clearest, and the same animal identified on the adjacent frame so that it is not counted a second time.

FIGURE 4.10

COUNTING OF SPECIAL CASES IN AERIAL CENSUSES

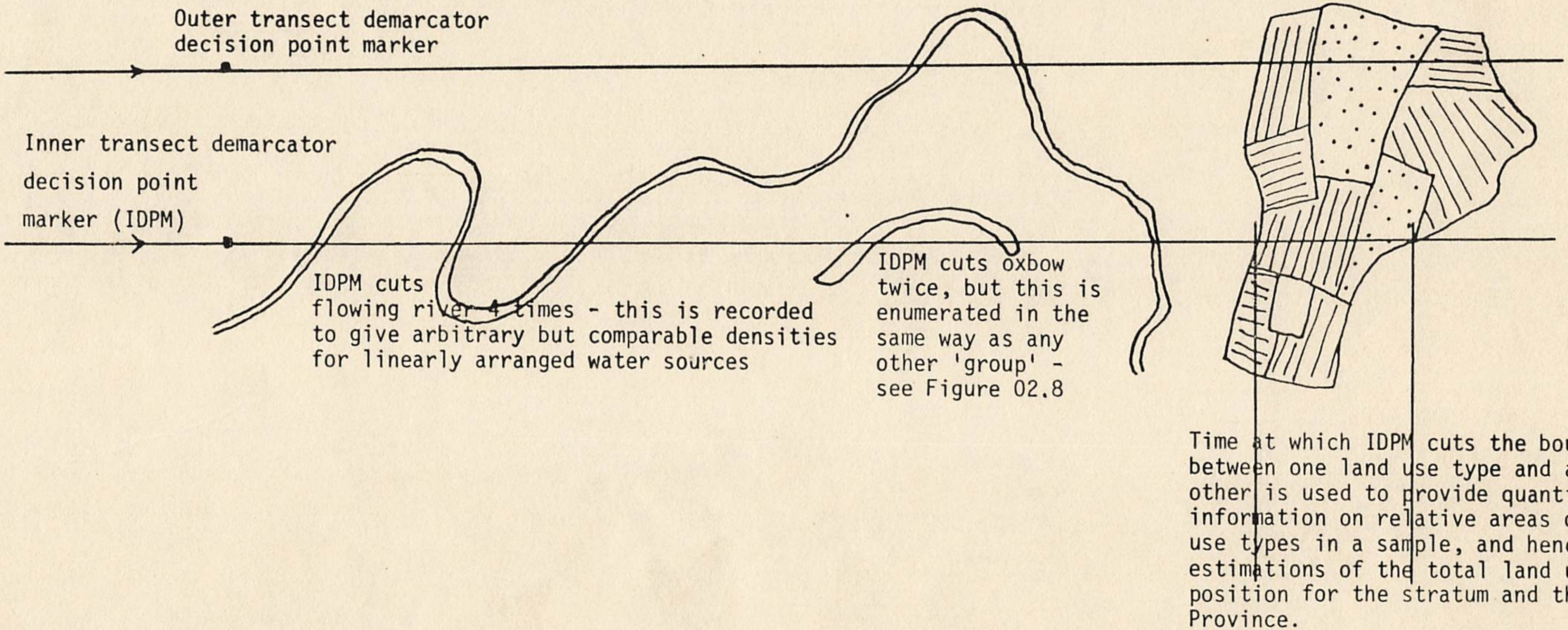


FIGURE 4.11

RADAR ALTITUDES RECORDED DURING THE LIVESTOCK CENSUS OF SOUTH KORDOFAN

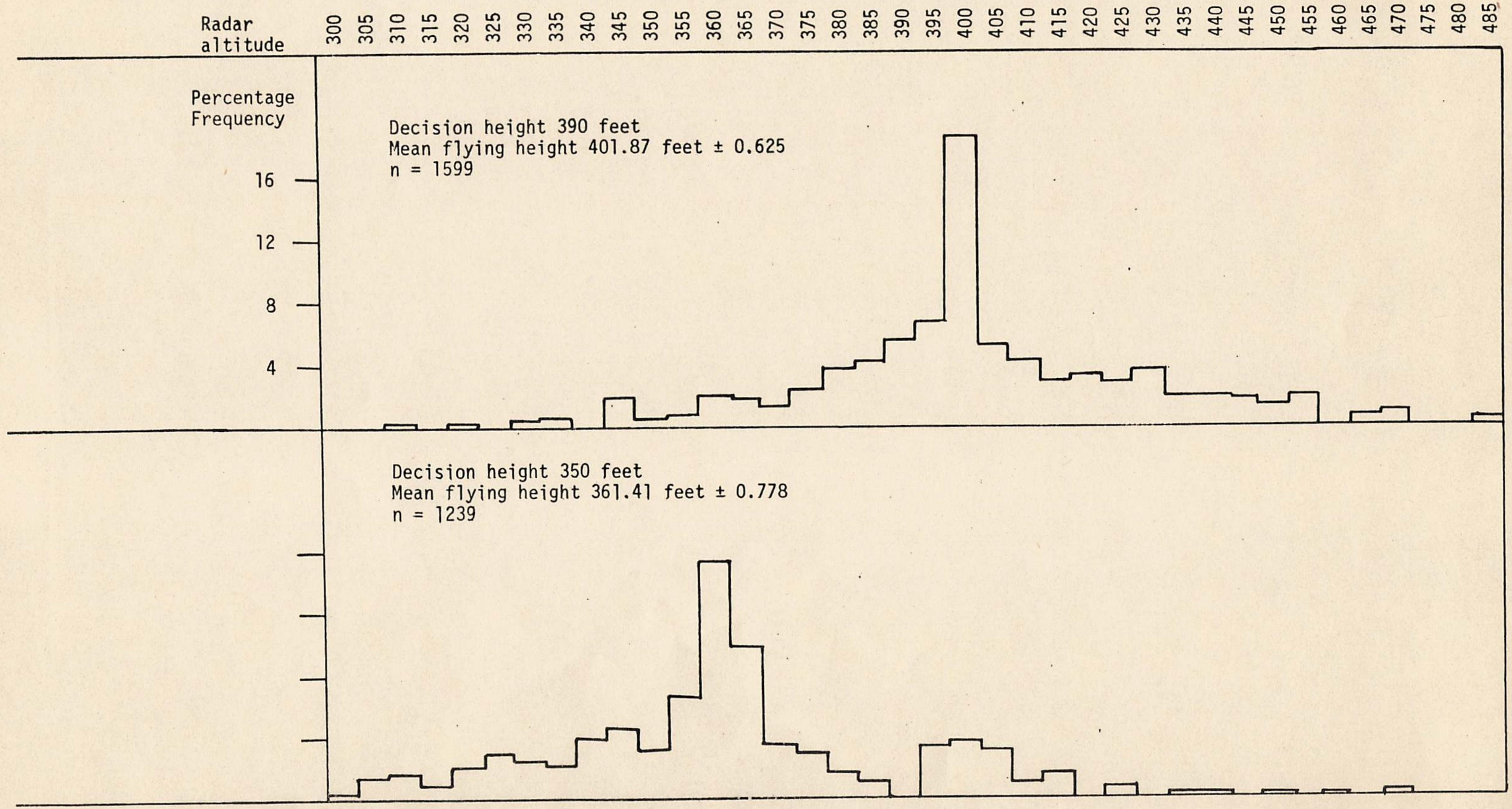


FIGURE 4.12

Calibration of strip widths

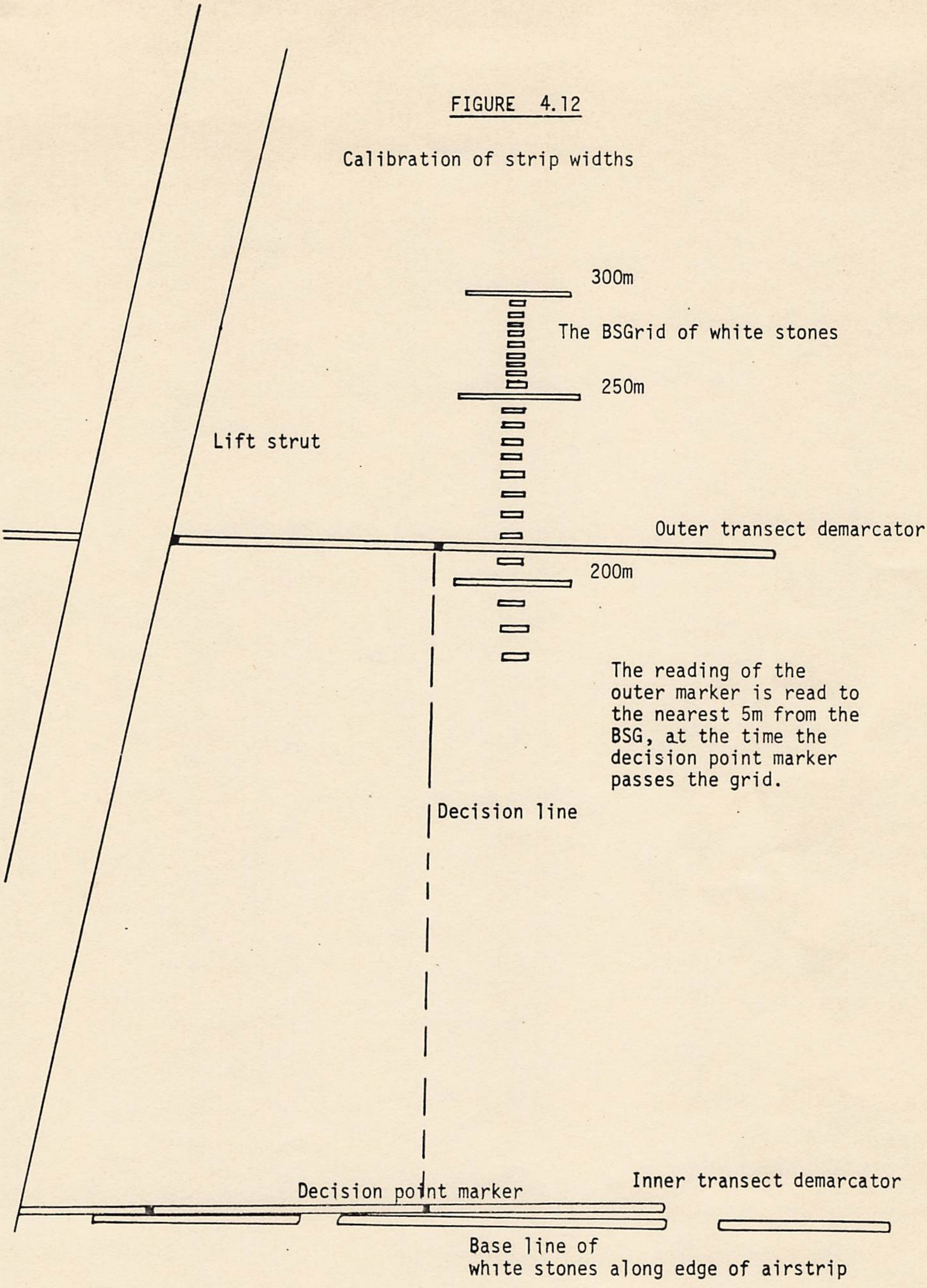


FIGURE 4.13

FREQUENCY DISTRIBUTION OF STANDARDISED STRIP WIDTHS

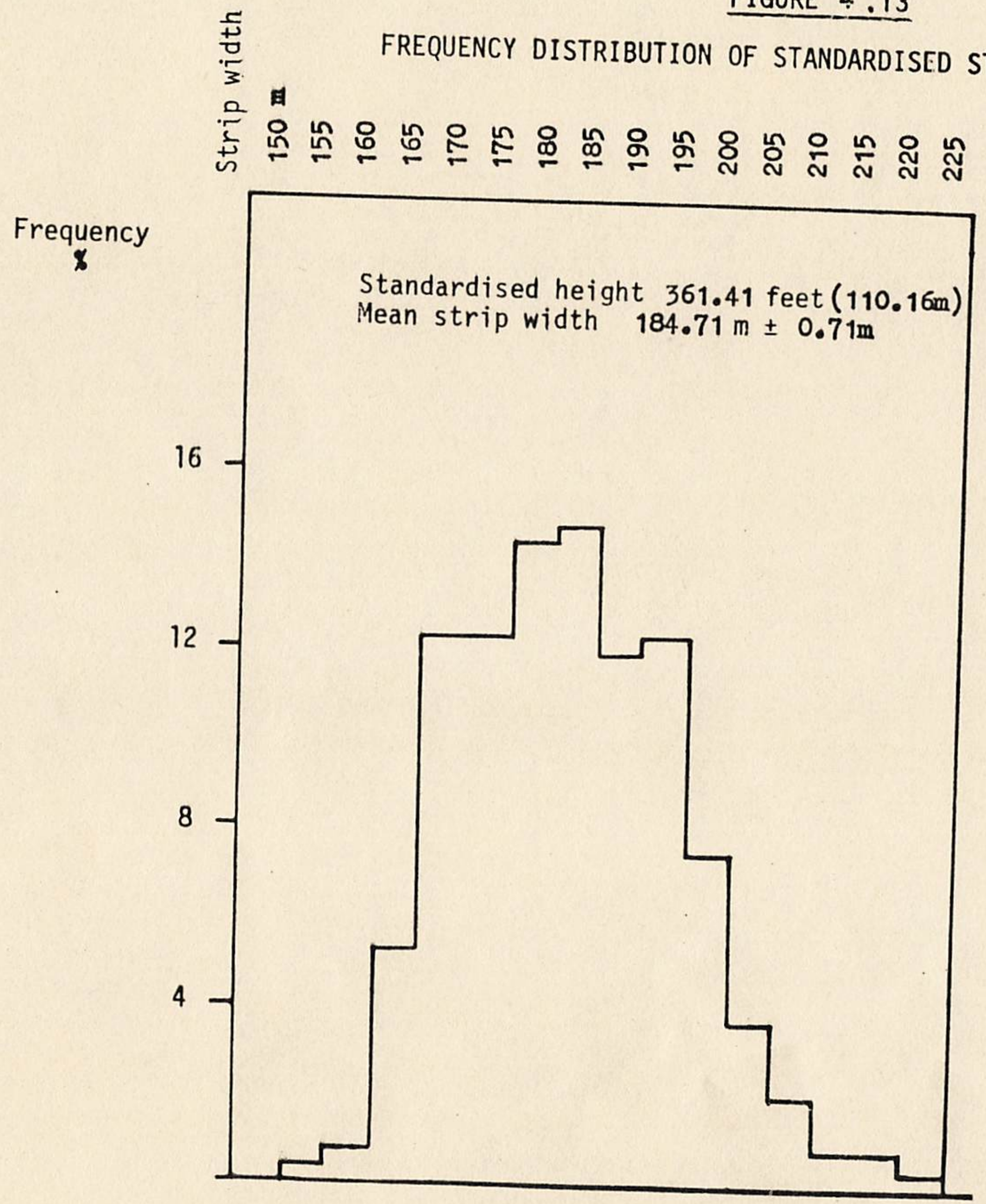


FIGURE 4.14

ERRORS RESULTING FROM WANDER IN AIRCRAFT TRACK
AWAY FROM SELECTED SAMPLE

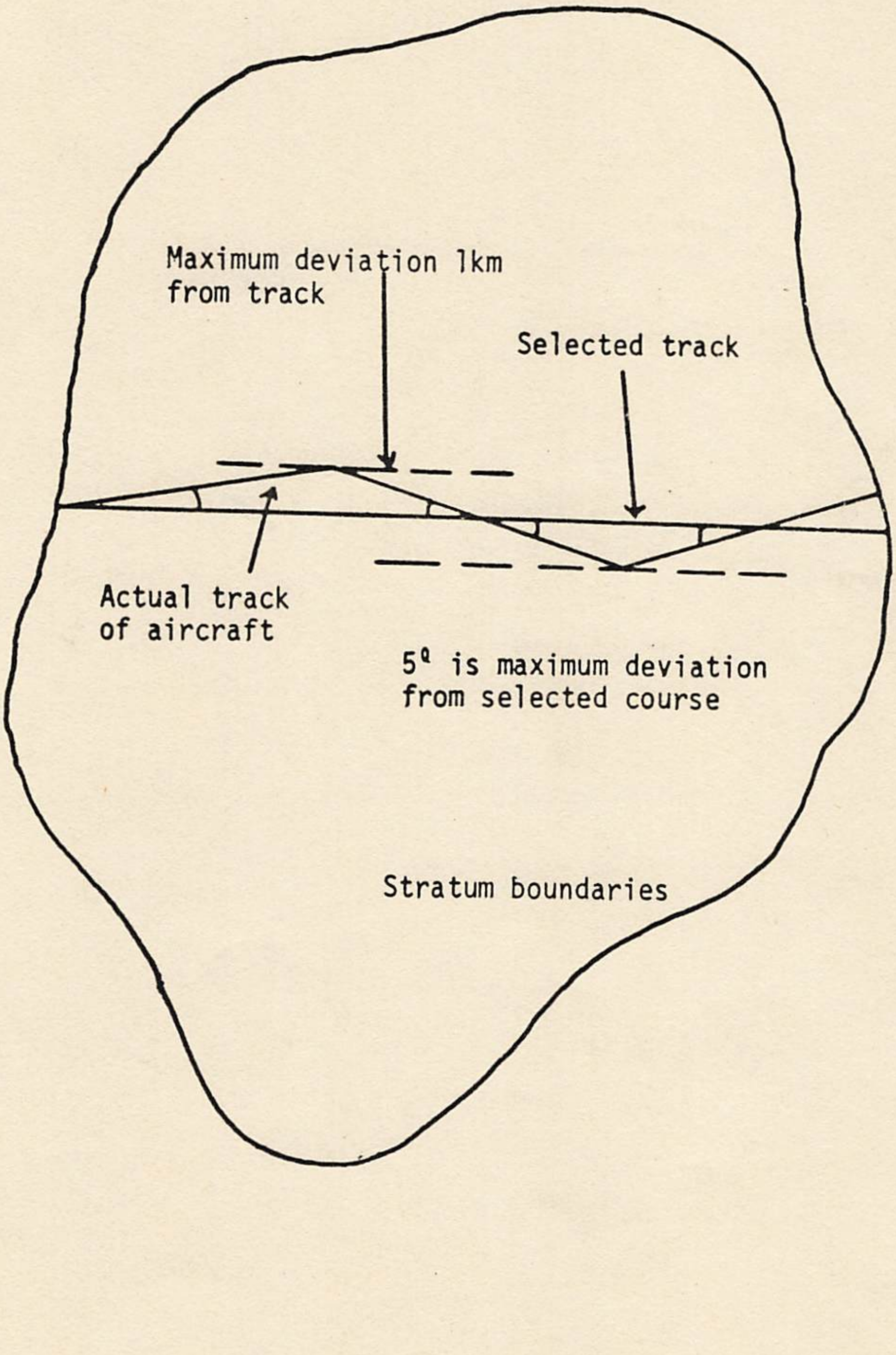
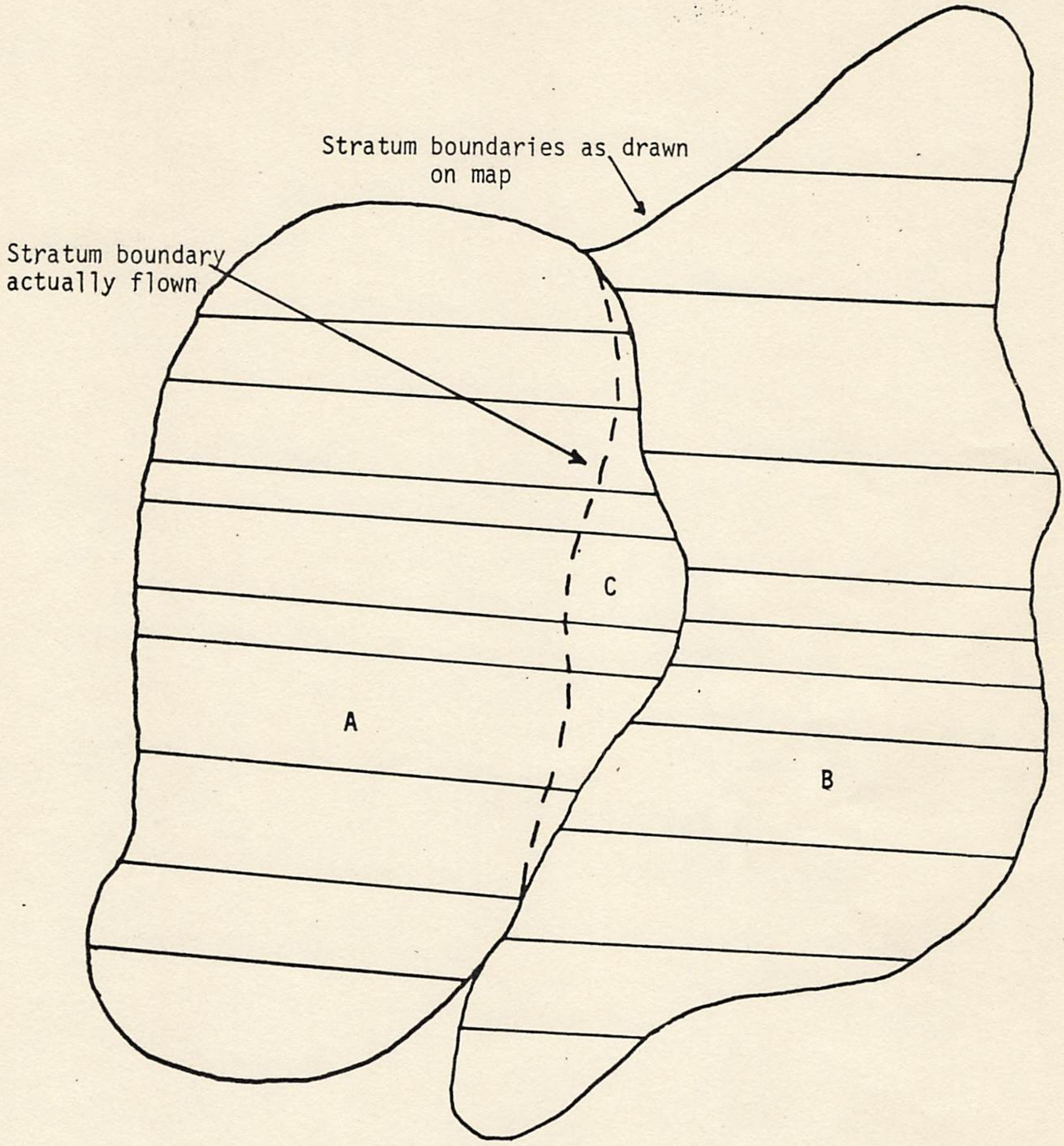


FIGURE 4 .15

ERRORS THROUGH INCORRECT POSITIONING OF STRATUM BOUNDARIES



As a result of the incorrect plotting of stratum boundaries on the map some of the samples in stratum A will have been measured as longer than they really are, with a resulting tendency to under-estimate densities. The stratum area however will be over-estimated by an area C, which will tend to cancel out this under-estimation

Likewise some samples in stratum B will be measured as shorter than they really are, with a tendency to over-estimate densities as a result. This tends to be compensated for by the under-estimation of stratum area by the quantity of area C

FIGURE 4.16

SPECIES SPECIFIC VISIBILITY CURVES

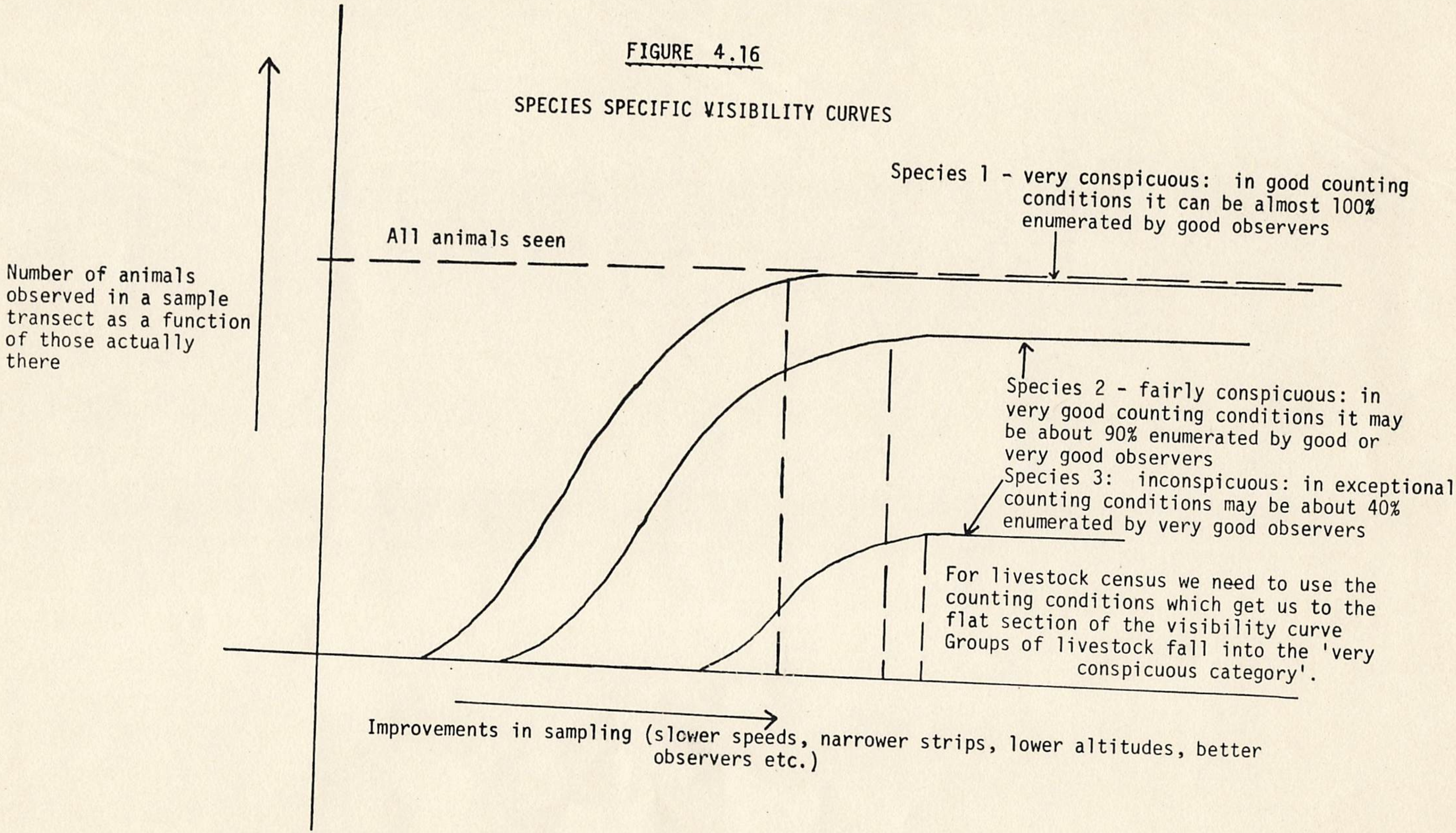


FIGURE 4.17

POSITIONING OF SAMPLE DEMARCATORS FOR TRIALS WITH TWO OBSERVERS

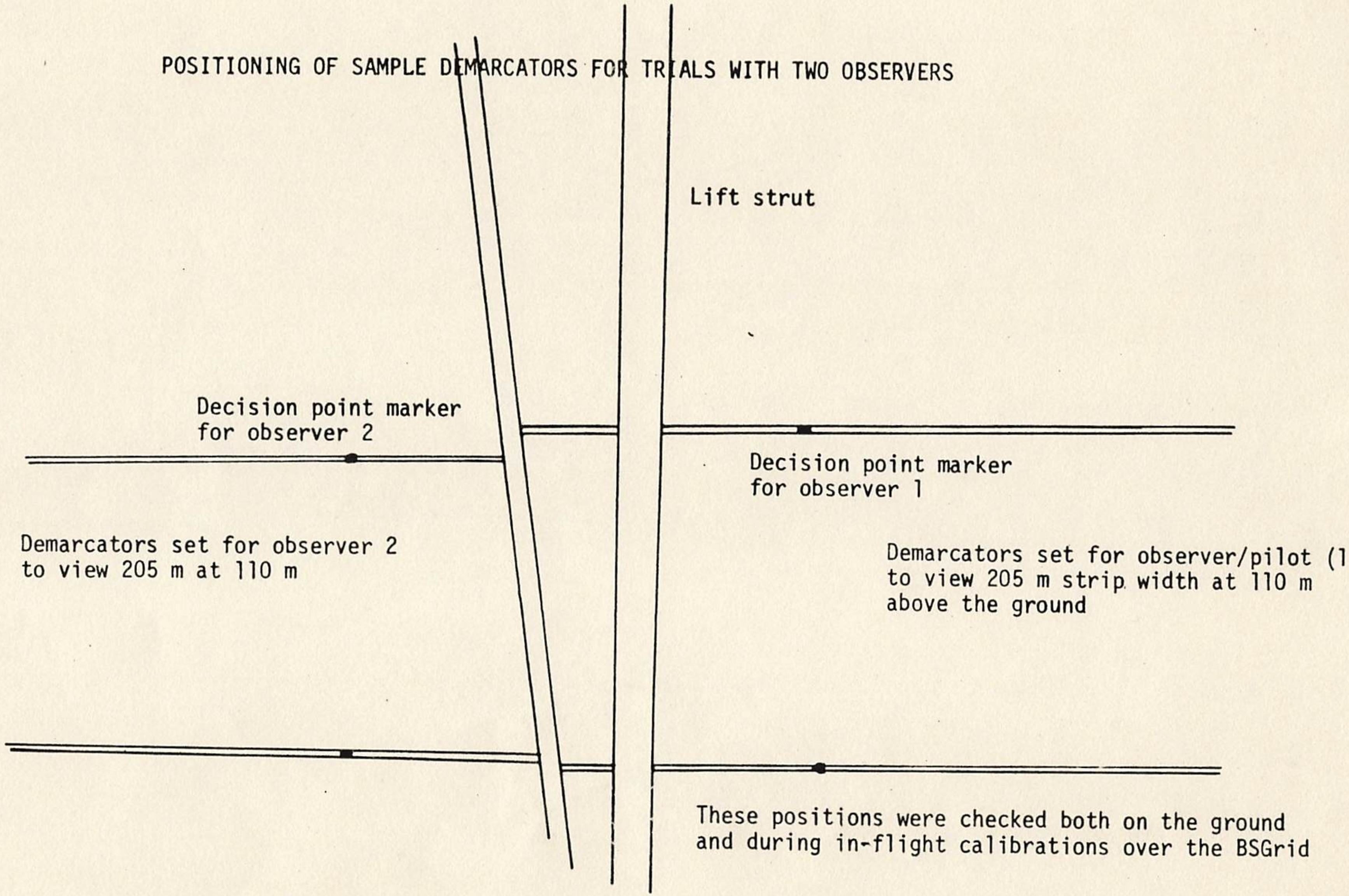


TABLE 4.1

A TABULATION OF AERIAL CENSUSES AND SURVEYS CARRIED OUT BY RESOURCE MANAGEMENT & RESEARCH SINCE 1968 (Excluding wildlife surveys).

NO.	LOCATION	DATE	AREA km^2	NUMBER OF LIVESTOCK	WILDLIFE	GROUNDWORK
1.	Kaputiei Division Kajiado District KENYA	1968	2,862	143,771	35,437	NIL
2.	South Turkana D. KENYA	1968	c10,000	c600,000	c5,000	NIL
3.	Samburu District KENYA	1968	20,478	797,946	75,746	Sampled for h'hold & pop parameters
4.	N.E. province KENYA	1969	122,911	1,066,995	200,000	"
5.	Narok District KENYA	1970	c17,000	c1,114,000	c800,000	"
6.	Kitui District KENYA	1970	24,000	c636,000	c100,000	"
7.	Kajiado District KENYA	1970	c22,000	c1,070,000	100,000	"
8.	Isiolo District KENYA	1970	c25,000	c227,000	250,000	"
9.	South Turkana D. KENYA	1969	c10,000	c600,000	c5,000	Nil
10.	"	1970	c10,000	c600,000	c5,000	Nil
11.	Ogaden ETHIOPIA	1971	c20,000	c1,500,000	c7,000	Nil
12.	"	1972	33,310	c1,890,000	10,275	Nil
13.	"	1973	33,310	1,121,442	10,778	Nil
14	N.E. Rangelands ETHIOPIA	1972	29,103	1,039,032	c2,000	Nil
15.	"	1973	29,103	982,792	c12,000	Nil
16.	"	1973	29,103	326,714	c12,000	Nil
17.	"	1974	78,598	909,258	32,137	Nil
18.	Shirre lowlands ETHIOPIA	1972	10,360	c80,000	c1,000	Nil
19.	Alledeghi Plains ETHIOPIA	1973	c10,000	c100,000	c12,000	Nil
20.	Central Highlands ETHIOPIA	1973	c110,000	c5,000,000	c2,000	Nil

TABLE 4.1

A TABULATION OF AERIAL CENSUSES & SURVEYS CARRIED OUT BY RESOURCE MANAGEMENT & RESEARCH SINCE 1968 (Excluding wildlife surveys)

NO.	LOCATION	DATE	AREA km^2	NUMBER OF LIVESTOCK	WILDLIFE	GROUND-WORK
21.	Eritrea, Tigre Wollo, Shoa & Haraghe Prov. ETHIOPIA	1973	110,000	Photogrammetric survey of crops with groundwork by 12 teams of 2 enumerators of households, crop histories, livestock holdings, etc., on a sample basis.		
22.	Karago/Giciye RWANDA	1972	c10,000	c30,000	Nil	
				Photogrammetric agricultural census coupled with investigations of households on a sample basis.		
23.	Isiolo District KENYA	1973	c25,000	c150,000	200,000	Nil
24.	Marsabit District	1970	c70,000	859,000	120,000	Sampled for h'-hold Pop. perameter
25.	Marsabit District KENYA	1973	c70,000	c450,000	100,000	Nil
26.	Tana River District KENYA	1973	c25,000	c700,000	250,000	Nil
27.	Lamu District KENYA	1973	c18,000	c80,000	c200,000	Nil
28.	Basuto TANZANIA	1969	c2,000	c14,000	c20,000	Nil
29.	Sudan (NATIONAL SURVEY)	1974-77	2,500,000	46,000,000	4,000,000	Sampled for house hold & population parameter of people & Livestock
30.	SIERRA LEONE	1979	72,000	1,089,000	-	Nil

This tabulation includes most of the important censuses carried out by RMR since 1968 in which livestock and agriculture have been the basic issues. All the flying (about 15,000 hours) has been done by R.M. Watson, C.I. Tippett and R.H.V. Bell. Not included here are any aerial surveys of wildlife, none of the ground based investigations of resources, nor any of the fresh-water and marine surveys. All the aforementioned surveys have been evaluated by the various clients, who include: IBRD, Kenya Government, Ethiopian Government, Tanzania Government, Rwanda Government, Awash Valley Authority, etc.

TABLE 4.2

RADAR ALTITUDE HEIGHTS RECORDED DURING CENSUS

Decision height 350 feet 107 m Mean flying height 110 m		Decision height 390 feet 119 m Mean flying height 122 m		Radar Altitude
= 1239 %	No. of Observations	= 1599 %	No. of Observations	
0.3	4			300
1.8	22			305
2.0	25	0.2	3	310
1.1	14			315
2.4	30	0.2	3	320
3.7	46			325
3.0	37	0.4	6	330
2.7	33	0.6	10	335
4.9	61			340
5.5.	68	2.3	37	345
4.0	50	0.6	10	350
8.1	100	1.0	76	355
19.0	235	2.3	37	360
12.2	151	2.2	35	365
4.5	56	1.7	27	370
3.7	46	3.0	48	375
2.0	25	4.9	79	380
1.2	15	5.2	83	385
		7.0	112	390
4.2	52	8.4	134	395
4.7	58	18.1	290	400
4.0	50	6.6	106	4o5
1.1	14	5.4	87	410
2.0	25	3.8	61	415
		4.1	66	420
1.0	12	3.7	59	425
		4.7	75	430
0.2	2	2.3	37	435
0.2	2	2.3	37	440
		2.2	35	445
0.1	1	1.6	26	450
		2.4	38	455
0.1	1	[illegible]	[illegible]	460
		0.9	14	465
0.3	4	1.1	18	470
				475
				480
		0.6	10	485

MEAN FLYING HEIGHT = 361.41 feet STANDARD ERROR OF MEAN = 0.778 feet.

MEAN FLYING HEIGHT = 401.87 feet STANDARD ERROR OF MEAN = 0.625 feet

TABLE 4.3

CALIBRATION OF STRIP WIDTHS

AIRCRAFT 5Y - BAU
Both Obeervers

Strip width in m. Standardised for 361.41 feet Height above ground	No. of Obser-vations.	As %
155	1	0.4
160	2	0.8
165	13	5.3
170	30	12.3
175	30	12.3
180	35	14.4
185	36	14.8
190	29	11.9
195	30	12.3
200	18	7.4
205	9	3.7
210	5	2.1
215	2	0.8
220	2	0.8
225	1	0.4
TOTAL	243	

Mean strip width 184.71

Standard error of Mean ± 0.71

Standard Deviation: 11.08

TABLE 4.4.

DEMARCATION DECISION ERRORS.

TYPE OF GROUPS	OBSERVER 1 Total Number	OBSERVER 1 Number of Groups Judged not Inside Sample by Observer 2 But Counted by Observer 1	OBSERVER 2 Total Number	OBSERVER 2 Number of Groups Judged not Inside Sample by Observer 1 But Counted by Observer 2
Livestock & Wild Animals	805 (32 groups)	1	805 (32 groups)	1
Houses & Buildings	70 (19 groups)	0	70 (16 groups)	1
Water Sources	5 (2 groups)	0	6 (2 groups)	0
Fields	77 (13 groups)	0	84 (15 groups)	0
All Groups	957 (66 groups)	1	965 (65 groups)	2

TABLE 4.5

TESTS OF OBSERVER DIFFERENCES

Groups in order of Occurance

OBSERVER												
Observer 1 (Pilot)	25C	16S	1GH	2St	8Cm	3W	19G/S	3SF	2CF	3GH	2Stb	2S
" 2	23C	16S	2GH	2St	9CM	3W	(16G/S)	4F	2CF	3GH	2Stb	
Observer 1 (Pilot)	113G/S*	2D	1PH	(1Cm)	26C	14F	3GH	(6GH)	(2K)	(2St)		
" 2	118G/S*	2D	1PH	4Cm	26C	8SF	7F	3GH	(8GH)	(2K)	(3St)	
Observer 1 (Pilot)	11GH	(4GH)	2K	3St	18C	5F						
" 2	9GH	2GH	(6GH)	2K	3St	17C	3F					
Observer 1 (Pilot)	18G											
" 2	18G/S											
Observer 1 (Pilot)	12C	2CF	8F	5G	20S							
" 2	12C	2CF	12F	5G	20S							
Observer 1 (Pilot)	2PH	1K	2St	104C*								
" 2	3PH	2St	98C*									
Observer 1	10S	(49G/S)*	3F	6SF	4CF	18C	4C	3F				
" 2 (Pilot)	10G/S	(52G/S)*	5F	6SF	6CF	19C	2C	3F				
Observer 1	2D	(3GH)	(4GH)	81C*								
" 2 (Pilot)	2D	(3GH)	(4GH)	79C*								
Observer 1	3DK	20St	2CF	2GH	(10GH)	16C						
" 2 (Pilot)	1DK	20St	3CF	8GH	16C							
Observer 1	3D											
" 2 (Pilot)	3D											
Observer 1	24C	2W	6SF	19F								
" 2 (Pilot)	24C	3W	4SF	2F	17F							
Observer 1	20G/S	14G/S	75S	4PH	18S	41C	21C	(16C)				
" 2)Pilot)	21S	14G	76S	3PH	18S	41C	21C	(180)	2DK			

C = Cattle; S = Sheep
GH = Grass Roofed House
Stb = Stable; W = Wall;
St = Food Store;
SF = Sorghum Field;
F = Unidentified Field;
CF = Cotton Field;
PH = Temporary Pastoralists;Hou
G = Goats
G/S = Goats & Sheep
K = Kitchen;
DK = Duiker;
Ost = Ostrich;
Cm = Camel

Footnote: Groups in brackets are judged to be outside transect
Groups marked * were counted from photographs

TABLE 4.6

SUMMARY OF ERROR INVESTIGATIONS.

Source of Error	Type of error (Sampling or Other)	Symmetric or Not	Means of Investigation	Magnitude	Corrections & Comments
Sample Demarcation & Area Measurement					
1. Aircraft Height	Other	Symmetrical	Recording during census	SD = ± 7.5%) SE = ± 0.2%) 361.41 ft.	Relevant only through sample area calculation via influence on strip width.
2. Strip widths (varying with wing-bank)	Other	Theoretically asymmetrical	Calibration during census	SD = ± 6.0%) 184.71m SE = ± 0.4%)	Relevant only through sample area calculation in conjunction with variations of aircraft height.
3. Strip Widths (All variations)	Other	Slightly Asymmetrical	Combination of 1 & 2	SD = ± 6.7%) SE = ± 0.45%) 184.71m	Relevant only through sample area calculation
4. Transect lengths (Wander from track)	Other	Asymmetrical	Assumption of 5% maximum consistent wander	A maximum underestimation of transect lenghts of 0.4%	An overall reduction in all estimates of 0.2% without changes in variances.

TABLE 4.6 continues.

SUMMARY OF ERROR INVESTIGATIONS.

Source of Error	Type of error (Sampling or Other)	Symmetric or Not	Means of Investigation	Magnitude	Corrections & Comments
5. Incorrect location of samples Start & finish positions	Other	Symmetrical	Assumption of 10% maxium error	A maximum under or over estimation of 10%	Relevant through sample calculation.
6. Sample areas	Other	Asymmetrical	Combination of 1 - 5	Approx. S.E. of ±1-1.5% for Symmetrical errors Approx. 0.2% asymmetrical error (Bias)	Expressed in "Sampling error" see 4 above
Sample Enumeratiom					
7. Spotting errors (Livestock in Houses)	Other	Asymmetrical	Ground investigation of random sample of houses	not applied in Central Rangelands.	Applies only to Livestock & adds to estimate with its own sampling error component. Very small additional numbers
8. Livestock concealed by vegetation and other animals	Other	Asymmetrical	Paired counts in open cover, medium cover & dense cover with true counts in open cover at 10 low heights above ground	Cattle 1.095 Sheep/goats 1.134 Camels, donkeys, horses & mules 1.198	Bias corrections made for livestock and additional Sampling error added. No corrections made for other phenomena eXcept all wild animals treated with correction factor of 1.225. (these errors include some counting errors).

TABLE 4.6 continued

SUMMARY OF ERROR INVESTIGATION.

Source of Error	Type of error (Sampling or Other)	Symmetric or Not	Means of Investigation	Magnitude	Corrections & Comments
9. Identification	Other	Symmetrical	None, but overall proportions of different livestock species can be compared with results of ground investigations.	Division of undifferentiated sheep/goats by stratum ratio for differentiate animals embodies quite large sampling errors.	Sampling error for sheep and goats separately is an under-estimate as calculated. For sheep and goats together sampling error is correct.
10. Demarcation decision	Other	Symmetrical	Tested by two observers enumerating an identical sample strip	Very small	None necessary. Any errors are already incorporated in "Sampling error" as calculated.
11. Visual Counting (Remote counting)	Other	Asymmetrical	Double counting of the same group in open cover visually counted and then counted on photographs as for whole census.	No Bias (R = 1.0006)	None necessary)

TABLE 4.6 continued.

SUMMARY OF ERROR INVESTIGATIONS.

Source of Error	Type of error (Sampling or Other)	Symmetric or Not	Means of Investigation	Magnitude	Corrections & Comments
12. Physical Counting (contact counting)	Other	Asymmetrical	Double counting of the same photograph, once as for whole census & once under higher magnification in more time.	A Bias of 2.01% (under estimation) for all animals counted from photographs.	Bias corrections of+2% made for animals whether counted on photographs or not. Additional sampling error added for livestock.
13. Recording	Other	Asymmetrical or Symmetrical	Checking of 8% of tapes and all films	Very small	None necessary
14. Observer Differences	Other	Both	Simultaneous observational/ flying by both observers looking at an identical sample strip	Differences very small	These would have influence on many errors (Particularly 7 & 10) no corrections necessary.
15. "Sampling Error"	Sampling	Symmetrical	Standard variance calculations on transect information	SE = ±8 - 15% for numerous livestock	The largest error, but embodies many small symmetrical biases in addition to true sampling error.

TABLE 4. 7

SAMPLING IN WET & DRY SEASONS IN THE CENTRAL RANGELANDS

LSU	DRY SEASON Number of Samples	WET SEASON Number of Samples	LSU	DRY SEASON Number of Samples	WET SEASON Number of Samples	LSU	DRY SEASON Number of Samples	WET SEASON Number of Samples
1	16	14	38	11	11	75	12	15
2	33	20	39	9	10	76	10	9
3	20	16	40	12	10	77	18	20
4	11	10	41	9	10	78	11	11
5	12	14	42	20	22	79	14	8
6	11	12	43	8	7	80	15	13
7	10	8	44	10	8	81	16	13
8	9	10	45	27	26	82	18	12
9	14	14	46	14	10	83	8	8
10	19	20	47	9	9	84	7	17
11	25	20	48	41	25	85	24	24
12	9	9	49	11	8	86	9	10
13	22	18	50	13	11	87	8	12
14	11	12	51	13	13	88	6	8
15	10	10	52	11	12	89	14	15
16	15	22	53	15	17	90	0	21
17	12	10	54	27	15	91	0	14
18	10	11	55	9	9			
19	10	10	56	10	9			
20	17	14	57	28	22			
21	25	23	58	8	6			
22	6	6	59	16	14			
23	9	11	60	27	20			
24	18	28	61	8	9			
25	17	19	62	13	22			
26	10	10	63	14	12			
27	11	9	64	12	10			
28	15	15	65	12	11			
29	8	6	66	10	16			
30	6	6	67	10	9			
31	19	21	68	15	13			
32	13	14	69	7	8			
33	6	12	70	15	23			
34	18	18	71	25	22			
35	8	6	72	29	20			
36	20	14	73	17	16			
37	29	25	74	15	18			

LIVESTOCK DENSITIES & ESTIMATES IN WET & DRY SEASONS 1979 BY ECOLOGICAL ZONES TABLE 4. 8

Season	ZONE No.	LAND SYSTEM UNITS ECOLOGICAL ZONES	AREA in km^2	CATTLE		SHEEP		GOATS		DONKEYS		HORSES/MULES		CAMELS	
				DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATES
Dry		N.W. Limestones (1,3,5,10,12,36,49)	11,274	0.104	1,173	3.658	41,235	13.276	149,674	o	o	o	o	1.690	19,048
WET	I.1	(1,3,5,10,12,36,49)	11,709	0.561	6,574	17.912	209,728	49.419	578,652	0.010	60	o	o	7.062	82,687
		WS/DS (Relative change)		5.394		4.897		3.722				oo		4.179	
		WS-DS (Absolute change)		+0.457	+5,401	+13.015	+168,493	+36.143	+428,978	+0.010	+60	o	o	+5.372	+63,639
DRY		TRANSITIONAL N.W. LIMESTONES/CENTRAL GYPSUM (48)	2,592	0.096	248	13.642	35,360	50.598	131,150	o	o	o	o	0.373	966
WET	I.2	(48)	2,592	0.570	1,477	17.784	46,096	31.915	82,723	o	o	o	o	3.150	8,164
		WS/DS (Relative change)		5.938		1.304		0.631			o	o		8.445	
		WS-DS (Absolute change)		+0.474	+1,229	+4.142	+10,736	-18.683	48,427	-18,683	o	o	o	+2.777	+7,198
DRY		TRANSITIONAL N.W. LIMESTONES/CENTRAL SAND OVER LIMESTONE (27.46)	1,384	o	o	11.121	15,391	51.921	71,859	o	o	o	o	1.757	2,432
WET	I.3	(27.46)	1,384	3.053	4,226	19.251	26,644	138.926	192,273	0.035	48	o	o	15.357	21,254
		WS/DS		oo		1.731		2.676		oo		o		8.740	
		WS-DS		+3.053	+4,226	+8.130	+11,253	+87.005	+120,414	+0.035	+45	o	o	+13.600	+18,822
DRY		S. LIMESTONES (16,25,47,89)	8,564	0.098	838	11.554	98,945	42.954	367,862	o	o	0.024	208	2.294	19,649
WET	I.4	(16,25,47,89)	8,760	2.719	23,816	11.392	99,797	88.720	777,188	o	o	o	o	6.355	55,667
		WS/DS		27.745		0.986		2.065		o		o		2.770	
		WS-DS		+2.621	+22,978	-0.162	-852	+45.766	+409,326	o	o	-0.024	-208	+4.061	+36,018

LIVESTOCK DENSITIES & ESTIMATES IN WET & DRY SEASONS 1979 BY ECOLOGICAL ZONES TABLE 4.8 Page 2

Season	ZONE NO.	LAND SYSTEM UNITS ECOLOGICAL ZONES	AREA in km^2	CATTLE		SHEEP		GOATS		DONKEYS		HORSES/MULES		CAMELS	
				DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE
DRY		TRANSITIONAL S. LIMESTONES/S.GYPSUMS (64)	504	8.234	4,149	17.374	8,756	114.017	57,465	o	o	o	o	9.053	4,562
WET	I.5	(64)		3.704	1,866	52.676	26,548	72.247	36,412	o	o	o	o	22.671	11,426
		WS/DS		0.450		3.032		0.634		o		o		2.504	
		WS-DS		-4.530	-2,283	+35.302	+17,792	-41.770	-21,053	o	o	o	o	+13.618	+ 6,864
DRY		TRANSITIONAL S. LIMESTONES/CULTIVATED STABILISED SAND DUNES (80,82)	2,260	4.960	11,209	10.719	24,225	51.224	115,766	o	o	o	o	3.035	6,858
WET	I.6	(80, 82)	2,332	6.686	15,591	11.062	25,797	27.803	64,837	o	o	o	o	0.491	1,146
		WS/DS		1.348		1.032		0.543		o	o	o	o	0.162	
		WS-DS		+1.726	+4,382	+0.343	+1,572	-23.421	-50,929	o	o	o	o	-2.544	-5,712
DRY		WEBI SHABELLE LIMESTONES (58,68,76,79)	2,660	4.573	12,164	19.197	51,063	50.743	134,976	0.110	293	0.025	66	2.535	6,744
WET	I.7	(58,68,76,79)	2,660	4.676	12,437	21.935	58,348	64.958	172,788	0.175	465	o	o	11.789	31,358
		WS/DS		1.023		1.143		1.280		1.591		o		4.650	
		WS-DS		+0.103	+273	+2.738	+7,285	+14.215	+37,812	+0.065	+172	-0.025	-65	+9.254	+24,614
DRY		W.SHABELLE MIXED LIMESTONES & HAUD ESCARPMENT (67,75)	1,700	3.701	6,291	8.922	15,167	61.415	104,406	0.049	83	o	o	1.923	3,269
WET	I.8	(67, 75)	1,700	6.809	11,576	4.920	8,364	53.680	91,256	o	o	o	o	2.705	4,599
		WS/DS		1.840		0.551		0.874		o		o		1.407	
		WS-DS		+3.108	+5,285	-4.002	-6,803	-7.735	-13,150	-0.049	-83	o	o	+0.782	+1,330

LIVESTOCK DENSITIES & ESTIMATES IN WET & DRY SEASONS 1979 BY ECOLOGICAL ZONES TABLE 4.8 Page 3

Season	ZONE NO.	LAND SYSTEM UNITS ECOLOGICAL ZONES	AREA in km^2	CATTLE		SHEEP		GOATS		DONKEYS		HORSES/MULES		CAMELS	
				DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE
DRY		ALL INLAND LIMESTONES (1,3,5,10,12,16,25,27,36,46,47,48,49,58,64,67,68,75,76,79,80,82,89)	30,938	1.166	36,072	9.378	290,142	36.627	1,133,158	0.012	376	0.009	274	2.052	63,528
WET		As above	31,641	2.451	77,563	15.844	501,322	65.087	1,996,129	0.018	573	o	o	60836	216,301
		WS/DS		2.102		1.689		1.777		1.500		o		3.331	
		WS-DS		+1.285	+41,491	+6.466	+211,180	+28.460	+862,971	+0.006	+197	-0.009	-274	+4.784	+152,773
DRY	II.1	N.GYPSUMS									o	o	o		
		(28,29,30,34)	2,144	3.414	7,320	2.730	5.853	3.558	7,629	o	o	o	o	0.655	1,404
WET		(28,29,30,34)	2,144	1.986	4,258	55.432	123,134	109.132	233,978	o	o	o	o	1.783	3,823
		WS/DS		0.582		21.037		30.672		o		o		2.722	
		WS-DS		-1.428	-3,062	+54.702	+117,281	+105.574	+226,349	o	o	o	o	+1.128	+2,419
DRY	II.2	CENTRAL GYPSUMS (37/57)	4,708	0.207	974	3.554	16,731	16.408	77,251	o	o	o	o	0.167	785
WET		(37/57)	4,708	1.501	7,066	32.535	153,175	48.592	228,772	0.033	157	0.151	711	4.123	19,412
		WS/DS		7.251		9.154		2.961		oo		oo		24.689	
		WS-DS		+1.294	+6,092	+28.981	+136,444	+32.184	+151,521	+0.033	+157	+0.151	+711	+3.956	+18,627
DRY	II.3	SOUTHERN GYPSUMS (31,32)	1,692	0.439	742	2.072	3,505	13.722	23,218	o	o	o	o	0.366	619
WET		(31,32)	1,687	1.729	2,916	2.753	4,644	17.854	30,120	o	o	0.117	198	4.030	6,799
		WS/DS		3.938		1.329		1.301		o		oo		11.011	
		WS-DS		+1.290	+2,174	+0.681	+1,139	+4.132	+6,902	o	o	+0.117	+198	+3.664	+ 6,180
DRY	II.4	W.SHABELLE GYPSUMS (33)	228	o	o	o	o	o	o	o	o	o	o	o	o
WET		(33)	228	18.893	4,307	112.223	25,586	261.854	o	o	o	o	o	33.684	7,679
		WS/DS		oo		oo		o		o			∞		
		WS-DS		+18.893	+4,307	112.223	+25,586	261.854	+59,702	o	o	o	o	33.684	7,679

LIVESTOCK DENSITIES & ESTIMATES IN WET & DRY SEASONS 1979 B[illegible]OLOGICAL ZONES TABLE 4.8 Page 4

Season	ZONE No.	LAND SYSTEM UNITS ECOLOGICAL ZONES	AREA in km^2	CATTLE		SHEEP		GOATS		DONKEYS		HORSES/MULES		CAMELS	
				DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE	DENSITY	ESTIMATE
DRY	II.5	W.SHABELLE GYPSEOUS ALLUVIUMS (77)	3,252	7.212	23,453	2.232	7,258	6.452	20,981	o	o	o	o	4.139	13,460
WET		(77)	3,252	7.700	25,040	1.030	3,349	16.755	54,487	o	o	o	o	10.876	35,368
		WS/DS		1.068		0.461		2.597		o		o		2.628	
		WS-DS		+0.488	+1.587	-1.202	-3.909	+10.303	33,506	o	o	o	o	+6.737	+21,908
DRY	II.6	TRANSITIONAL N&C GYPSUM/COASTAL LIMESTONES (42,50)	2,556	0.294	752	8.825	22,557	27.468	70,209	o	o	o	o	0.303	774
WET		(42,50)	2,556	0.265	678	81.410	208,084	90.773	232,017	o	o	o	o	2.54	6,492
		WS/DS		0.901		9.225		3.305		o	o	o	o	8.383	
		WS-DS		-0.029	-74	+72.585	+185,527	+63.305	+161,808	o	o	o	o	+2.237	+5,718
DRY	II.	ALL GYPSUM DOMINANTS (28,29,30,31,32,33, 34,37,42,50,57,77)	14,580	2,280	33,241	3.834	55,904	13.669	199,288	o	o	o	o	1.169	17,042
WET		As above	14,575	3.037	44,265	35.538	517,972	57.570	839,076	0.011	157	0.062	909	5.460	79,573
		WS/DS		1.332		9.269		4.212		oo		oo		4.671	
		WS-DS		+0.757	+11,024	+31.704	+462,068	+43.901	+639,788	+0.011	+157	+0.062	909	+4.291	62,531
DRY	III.1	N.SANDS OVER LIMESTONE (6,7,11,13,14, 15,17,38,39,40,88)	17,308	0.218	3,777	10.489	181,551	35.139	608,189	0.025	441	o	o	1.458	25,233
WET		(6,7,11,13,14,15,38, 39,40,88)	17,308	0.249	4,318	15.887	274,979	44.764	774,780	0.003	55	o	o	3.352	58,011
		WS/DS		1.142		1.515		1.274		0.120		o		2.299	
		WS-DS		+0.031	+541	+5.398	+93,428	+9.625	+166,591	-0.022	-386	o	o	+1.894	+32,778

LIVESTOCK DENSITIES & ESTIMATES IN WET & DRY SEASONS 1979 BY ECOLOGICAL ZONES TABLE 4.8 Page 5

Season	ZONE NO.	LAND SYSTEM UNITS ECOLOGICAL ZONES	AREA in km^2	CATTLE DENSITY	CATTLE ESTIMATE	SHEEP DENSITY	SHEEP ESTIMATE	GOATS DENSITY	GOATS ESTIMATE	DONKEYS DENSITY	DONKEYS ESTIMATE	HORSES/MULES DENSITY	HORSES/MULES ESTIMATE	CAMELS DENSITY	CAMELS ESTIMATE
DRY	III.2	CENTRAL SANDS OVER LIMESTONE(9,26,43, 44,45,63,85)	16,840	0.587	9,880	7.898	133,006	37.679	634,507	o	o	0.004	74	1.752	29,505
WET		(9,26,43,44,45,63, 85)	16,840	1.910	32,171	19.811	333,612	98.653	1,651,215	o	o	o	o	6.186	104,176
		WS/DS		3.254		2.508		2.618		o		o		3.531	
		WS-DS		+1.323	+22,291	+11.913	+200,605	+60.974	+1,016,708	o	o	-0.004	-74	+4.434	+74,671
DRY	III	ALL SANDS OVER LIMESTONE(6,7,9,11, 13,14,15,17,26,38, 39,40,43,44,45,63, 85,88)	34,148	0.400	13,657	9.212	314,557	36.391	1,242,696	0.013	441	0.002	74	1.603	54,738
WET		As above	34,148	1.069	36,489	17.822	608,591	71.044	2,425,995	0.002	55	o	o	4.750	162,187
		WS/DS		2.673		1.935		1.952		0.154		o		2.963	
		WS-DS		+0.669	+22,832	+8.610	+294,034	+34.653	1,183,299	-0.011	-386	0.002	-74	+3.147	+107,449
DRY	IV.1	N.E.COASTAL LIMESTONE (20,21)	2,816	o	o	1.971	5,550	5.411	15,236	o	o	o	o	o	o
WET		(20,21)	2,816	2.686	7,564	19.005	53,517	44.583	125,548	0.561	1.581	o	o	0.088	247
		WS/DS		oo		9.642		8.239		oo		o		oo	
		WS-DS		+2.686	+7,564	+17.034	+47,967	39.172	+110,312	+0.561	+1,581	o	o	+0.088	+247
DRY	IV.2	COASTAL GRASSLANDS STABILISED SAND DUNES(18,19,23,35,41, 55,60,72)	11,844	3.169	37,534	29.857	353,622	45.152	534,776	0.133	1,136	o	o	0.568	5,723
WET		(18,19,23,35,41,55, 60,72)	11,844	2.813	33,317	51.999	615,875	34.989	414,409	0.020	236	o	o	1,781	21,096
		WS/DS		0.888		1.742		0.775		0.150	-900	o	o	3.136	
		WS-DS		-0.356	-4,217	+22.142	+262,253	-10.163	-120,367	-0.113	-900	o	o	+1.213	+15,373

LIVESTOCK DENSITIES & ESTIMATES IN WET & DRY SEASONS 1979 BY ECOLOGICAL ZONES TABLE 4. 8 Page 6

Season	ZONE NO.	LAND SYSTEM UNITS ECOLOGICAL ZONES	AREA in km^2	CATTLE DENSITY	CATTLE ESTIMATE	SHEEP DENSITY	SHEEP ESTIMATE	GOATS DENSITY	GOATS ESTIMATE	DONKEYS DENSITY	DONKEYS ESTIMATE	HORSES/MULES DENSITY	HORSES/MULES ESTIMATE	CAMELS DENSITY	CAMELS ESTIMATE
DRY	IV.3	COASTAL WOODY ASSOCIATIONS(56, 61,65,66,73,87)	5,549	2.154	11,951	28.348	157,305	72.871	404,360	o	o	o	o	3.172	17,599
WET		(56,61,65,66,73,87)	4,169	2.980	12,422	7.283	30,359	32.179	134,153	0.032	135	o	o	11.871	49,491
		WS/DS		1.383		0.257		0.442		oo		o	o	3.742	
		WS-DS		+0.826	+471	-21.065	-126,946	-40.692	-270,207	+0.032	+135	o	o	+8.699	+31,892
WET	IV.4	ELEVATED CULTIVATED COASTAL STABILISED SAND DUNES (90) *	1,572	o	o	62.116	97,646	193.200	303,710	o	o	o	o	9.883	15,536
DRY		MOBILE OR RECENTLY STABILISED SAND DUNES(22,51,52,53, 54)	2,952	0.594	1,753	2.092	6.177	11.938	35.240	o	o	o	o	0.140	413
WET	IV.5	(22,51,52,53,54)	2,952	9.064	26,757	13.338	39,373	24.096	71,132	o	o	o	o	2.275	6,716
		WS/DS		15.259		6.376		2.018		o		o		16.250	
		WS-DS		+8.470	+25,004	+11.246	+33,196	+12.158	+35,892	o	o	o	o	+2.135	+6,303
DRY	IV.6	COASTAL PLATEAU GRASSLAND (86)	116	5.870	680	55.095	6,391	140.021	16,242	0,453	52	o	o	1.181	136
WET		(86)	116	11.277	1,308	52.931	6,139	102.607	11,902	0.587	68	o	o	12.534	1,453
		WS/DS		1.921		0.961		0.733		1.296		o		10.613	
		WS-DS		+5.407	+628	-2.164	-252	-37.414	-4,340	+0.134	+16	o	o	+11.353	+1.317
DRY		ALL COASTAL L.SYST UNITS (18,19,20,21, 22,23,35,41,51,52, 53,54,55,56,60,61,65. 66,72,73,87)	23,277	2.230	51,918	22.728	529,045	43.212	1,005,85	0.070	1,188	o	o	1.068	24,871
WET		As above +90)	23,469	3.467	81,368	35.916	842,909	45.202	1,060,852	0.086	2,020	o	o	4.028	94,539
		WS/DS		1.555		1.580		1.046		1.229		o		3.772	
		WS-DS		+1.237	+29,450	+13.188	+313,864	+1.990	+54,998	+0.016	+832	o	o	2.960	+69668

* 90 & 91 are new Land System Units.

LIVESTOCK DENSITIES & ESTIMATES IN WET & DRY SEASONS 1979 BY ECOLOGICAL ZONES TABLE 4. 8 Page 7

Season	ZONE NO.	LAND SYSTEM UNITS ECOLOGICAL ZONES	AREA in km²	CATTLE DENSITY	CATTLE ESTIMATE	SHEEP DENSITY	SHEEP ESTIMATE	GOATS DENSITY	GOATS ESTIMATE	DONKEYS DENSITY	DONKEYS ESTIMATE	HORSES/MULES DENSITY	HORSES/MULES ESTIMATE	CAMELS DENSITY	CAMELS ESTIMATE
DREY	V.1	UNCULTIVATED STABI-. LISED SAND DUNES (84)	1,508	0.807	1,216	2,977	4,489	28,352	42,754	o	o	o	o	5.084	7,666
WET		(84)	1,508	0.954	1,438	26.676	40,227	167.428	252,481	o	o	o	o	68.659	103,537
		WS/DS		1.182		8.961		5.905		o		o		13.505	
		WS-DS		+0.147	-222	+23.699	+35.738	+139.076	+209.727	o	o	o	o	63.575	+95.871
DRY	V.2	CULTIVATED STABI-LISED SAND DUNES (4,8,62,71,81)	11,852	2.011	23,833	13.607	161,265	49.154	582,570	o	o	0.076	830	3.492	41,391
WET		(4,8,62,71,81,91*)	11,764	3.748	44,097	17.621	207,292	57.182	672,689	0.093	1,091	o	o	4.415	51,938
		WS/DS		1.864		1.295		1.163		oo		o		1.264	
		WS-DS		+1.737	+20,264	+4.014	+46,027	+8.028	+90,119	+0.093	+1,091	-0.076	-830	+0.923	+10,547
DRY		ALL STABILISED SAND DUNES (4,8,62,71,81,84)	13,360	1.875	25,049	12.407	165,754	46.806	625,324	o	o	0.068	830	3.672	49,057
WET		(4,8,62,71,81,84,91)	13,272	3.431	45,535	18.650	247,519	69.708	925,170	0.082	1,091	o	o	11.715	155,475
		WS/DS		1.830		1.503		1.489		oo		o		3.190	
		WS-DS		+1.556	+20,486	+6.243	+81,765	+22.902	+299,846	+0.082	+1,091	-0.068	-830	+8.043	+106,418
DRY	VI.1	WEBI SHABEELLE PALE ALLUVIUMS(69,70,83)	2,172	19.137	41,565	24.995	54,289	24.017	52,165	0.600	1,303	o	o	4.018	8,728
WET		(69,70,83)	2,242	20.576	46,131	27.711	62,129	31.491	70,602	1.141	2,558	o	o	13.032	79,218
		WS/DS		1.075		+1.109		1.311		1.902		o		3.243	
		WS-DS		+1.439	+4,566	+2.716	+7,840	+7.474	+18,437	+0.541	1,255	o	o	+9.014	+20,490

* 90 & 91 are new
Land System Units

LIVESTOCK DENSITIES & ESTIMATES IN WET & DRY SEASONS 1979 BY ECOLOGICAL ZONES TABLE 4. 8 Page 8

Season	ZONE NO.	LAND SYSTEM UNITS ECOLOGICAL ZONES	AREA in km^2	CATTLE DENSITY	CATTLE ESTIMATE	SHEEP DENSITY	SHEEP ESTIMATE	GOATS DENSITY	GOATS ESTIMATE	DONKEYS DENSITY	DONKEYS ESTIMATE	HORSES/MULES DENSITY	HORSES/MULES ESTIMATE	CAMELS DENSITY	CAMELS ESTIMATE
DRY	VI.2	WEBI SHABEELLE DARK ALLUVIUMS (78)	964	1.021	984	14.968	14,429	32.161	31,003	o	o	o	o	14.806	14,272
WET		(78)	964	13.458	12,973	7.533	7,261	11.300	10,893	o	o	o	o	18.064	17,413
		WS/DS		13.181		0.503		0.351		o		o		1.220	
		WS-DS		+12.437	+11,989	-7.433	-7,168	-20.861	-20,110	o	o	o	o	+3.258	+3,141
DRY		WEBI SHABEELLE ALLUVIUMS(69,70,78, 83)	3,136	13.568	42,549	21.913	68,718	26.520	83,168	0.415	1,303	o	o	7.334	23,000
WET			3,206	18.435	59,104	21.644	69,390	25.420	81,495	0.798	2,558	o	o	14.545	46,631
		WS/DS		1.359		0.988		0.959		1.923		o		1.983	
		WS-DS		+4.867	+16,555	-0.269	+672	-1.100	-1,673	+0.383	+1,255	o	o	+7.211	+23,631
DRY	VII.1	HAUD-TYPE(24,74)	9,652	2.700	26,059	7.019	67,746	50.802	490,344	o	o	o	o	6.472	62,464
WET		(24,74)	9,456	2.489	23,537	12.302	116,325	72.967	689,976	o	o	o	o	6.354	60,088
		WS/DS		0.922		1.753		1.436		o		o		0.982	
		WS-DS		-0.211	-2,522	+5.283	+48,579	+22.165	+199,632	o	o	o	o	-0.118	-2,376
DRY	VIII.1	N.W. ARCED SILTS(2)	912	1.156	1,054	0.195	177	0.987	900	o	o	o	o	1.217	1,109
WET		(2)	912	22.204	20,250	22.566	20,580	105.465	96,184	o	o	o	o	129.638	118,229
		WS/DS		19.208		115.723		106.854		o		o		106.523	
		WS-DS		+21.048	+19,196	+22.371	+20,403	+104.478	+95,284	o	o	o	o	+128.421	+117,120

LIVESTOCK DENSITIES & ESTIMATES IN WET & DRY SEASONS 1979 BY ECOLOGICAL ZONES TABLE 4. 8 Page 9

Season	ZONE NO.	LAND SYSTEM UNITS ECOLOGICAL ZONES	AREA in km^2	CATTLE DENSITY	CATTLE ESTIMATE	SHEEP DENSITY	SHEEP ESTIMATE	GOATS DENSITY	GOATS ESTIMATE	DONKEYS DENSITY	DONKEYS ESTIMATE	HORSES/MULES DENSITY	HORSES/MULES ESTIMATE	CAMELS DENSITY	CAMELS ESTIMATE
DRY	VIII.2	S.W.ARCED SILTS (59)	1,708	1.845	3,151	6.282	10,729	27.428	46,847	o	o	o	o	10,865	18,557
WET		(59)	1,648	0.470	774	14.045	23,146	36.120	59,525	o	o	o	o	17.911	29,517
		WS/DS		0.255		2.236		1.317		o		o		1.649	
		WS-DS		-1.375	-2,377	+7.763	+12,417	+8.692	+12,678	o	o	o	o	+7.046	+10,960
DRY		ALL ARCED SILTS (2,59)	2,620	1.605	4,205	4.163	10,906	18.224	47,747	o	o	o	o	7.506	19,666
WET		(2,59)	2,560	8.213	21,024	17.080	43,726	60.824	155,709	o	o	o	o	57.713	147,746
		WS/DS		5.117		4.103		3.338		o		o		7.689	
		WS-DS		+6.608	+16,819	+12.917	+32,820	+42.600	+107,962	o	o	o	o	+50.207	+128,080
DRY		CENTRAL RANGELANDS	131,711	1.767	232,750	11.410	1,502,772	36.653	4,827,579	0.025	3,308	0.008	1,178	2.386	314,365
WET		CENTRAL RANGELANDS	132,327	2.929	388,885	22.276	2,947,754	61.774	8,174,402	0.049	6,454	0.007	909	7.274	962,540
		WS/DS		1.663		1.952		1.685		1.960		0.875		3.049	
		WS-DS		+1.172	+156,135	+10.866	+1,444,982	+30.121	+3,346,823	+0.024	+3,146	-0.001	-269	+4,888	+648,175

2/1159

TABLE 4.9

APPROXIMATIONS OF REGIONAL ESTIMATES AND DENSITIES FOR LIVESTOCK, WILDLIFE, HOUSES & BUILDINGS, WATER SOURCES AND CROPPING IN THE CENTRAL RANGELANDS

SEA-SON	ITEM	MUDUG D	MUDUG E	GALGADUUD* D	GALGADUUD* E	HIRAAN TO 45° E D	HIRAAN TO 45° E E	HIRAAN W OF 45°E D	HIRAAN W OF 45°E E
DS	CATTLE	0.824	51,236	1.589	71,365	4.476	110,151	4.529	40,757
WS		1.728	108,847	3.127	140,226	5.705	139,812	4.085	36,765
DS	SHEEP	11.488	714,455	12.503	561,512	9.217	226,806	4.257	38,313
WS		25.850	1,628,098	21.710	973,415	14.129	346,241	7.538	67,838
DS	GOATS	33.739	2,098,333	39.998	1,796,335	37.912	932,912	16.940	152,460
WS		49.663	3,127,906	79.692	3,573,210	60.119	1,473,286	26.438	237,938
DS	DONKEYS	0.021	1,316	0.007	313	0.068	1,679		
WS		0.034	2,161	0.028	1,270	0.123	3,023		
DS	HORSES	0.002	123	0.022	977	0.003	78		
WS	& MULES	0.011	683	0.005	226	-	-		
DS	CAMELS	1.135	70,616	2.628	118,008	5.110	125,742	7.502	67,518
WS		6.088	383,448	5.897	264,421	12.841	314,672	14.349	129,542
DS	LESSER	0.014	892	-	12	-	-		
WS	KUDU	0.034	2,171	0.005	234	0.034	827		
DS	CLARKE'S	0.074	4,578	0.118	5,297	0.031	755		
WS	GAZELLE	0.120	7,558	0.097	4,343	0.159	3,892		
DS	OSTRICH	0.130	8,080	0.030	1,361	0.036	874		
WS		0.671	42,264	0.455	20,406	0.109	2,667		
DS	GERENUK	0.033	2,081	0.008	357	0.039	967		
WS		0.074	4,647	0.034	1,505	0.150	3,664		
DS	OTHER	0.354	22,012	0.393	17,644	0.058	1,431		
WS	GAZELLE	0.810	50,991	0.450	20,187	0.006	153		
DS	BABOON	0.031	1,929	-	-	-	-		
WS		0.015	955	-	-	0.006	139		
DS	WARTHOG	0.040	2,495	0.050	2,234	0.060	1,482		
WS		0.082	5,163	0.087	3,908	0.152	3,719		
DS	ORYX	0.055	3,435	0.107	4,788	-	-		
WS		0.070	4,417	0.108	4,845	0.005	133		
DS	BUSHBUCK/	-	-	0.022	985	0.027	676		
WS	SOM.GAZELLE	0.153	9,630	0.139	6,220	0.044	1,085		

TABLE 4.9 — Page 2

BIOMASS DENSITIES Kg/Sq. Km.

		M		G		H	
DS	CATTLE	148.320	230	286.020	424	805.680	916
WS		311.040		562.860		1026.900	
DS	SHEEP	183.808	299	200.048	274	147.472	187
WS		413.600		347.360		226.064	
DS	GOATS	539.824	667	639.968	957	606.592	784
WS		794.608		1275.072		961.904	
DS	DONKEYS	3.150		1.050		10.200	
WS		5.100		4.200		18.450	
DS	HORSES AND	0.400		4.400		0.600	
WS	MULES	2.200		1.000		-	
DS	CAMELS	345.040	1097	798.912	1296	1553.440	2728
WS		1850.752		1792.688		3903.664	
DS	ALL	1220.542	>36%	1930.398	>48%	3123.984	>51%
WS	LIVESTOCK	3377.300		3983.180		6136.982	
T	→	2298.9	(2784)	2956.7	(2088)	4630.5	(1568)
DS	ALL	29.612	>34%	28.494	>43%	12.654	>39%
WS	WILDLIFE	86.961	(2749)	65.498	(2322)	32.460	(2562)
DS	ALL	1250.154		1958.892		3136.638	2115
WS	HERBIVORES	3464.261		4048.678		6169.442	4561
							3338

DENSITIES OF WATER SOURCES OBSERVED

DS	WELLS	0.308	0.297	0.030
WS		0.330	0.486	0.034
DS	RAIN WATER	0.018	0.016	0.054
WS	POOLS	-	-	-
DS	RIVERINE	-	-	0.006
WS	POOLS	0.001	-	-
DS	FLOWING	0.001	0.004	0.058
WS	RIVERS	-	-	0.038
DS	SHALLOW	0.002	0.001	0.009
WS	RESERVOIRS	-	0.001	0.002
DS	LARGE	-	-	0.004
WS	RESERVOIRS	0.004	0.011	0.002

TABLE 4.9 Page 3

DS	BERKAD	–	0.004	0.010
WS		0.007	0.003	–
DS	BORE	–	0.003	0.005
WS	HOLES	–	–	–
DS	INDEX OF	0.659	0.714	1.001
WS	WATER SOURCE	0.730	1.077	0.555

DENSITIES OF BUILDINGS HOUSES AND OTHER STRUCTURES

DS	TIN ROOFED	0.019	0.635	0.647
WS	HOUSES	0.001	–	0.012
DS	GRASS ROOFED	0.002	0.128	0.388
WS	HOUSES	–	0.006	0.048
DS	NOMADIC	0.261	0.591	0.634
WS	DOME HOUSES	0.535	0.737	1.185
DS	OTHER	0.020	0.131	0.071
WS	DWELLINGS	0.041	0.348	0.236
DS	LIVESTOCK	1.058	0.699	0.931
WS	ENCL. IN USE	0.572	0.747	0.949
DS	ABANDONED	1.040	0.330	0.279
WS	LIVESTOCK ENCL.	4.413	6.499	7.509
DS	COMPOUNDS	0.240	1.249	1.667
WS		0.471	0.829	1.171
DS	LIVESTOCK	0.060	0.167	0.113
WS	SHELTERS	0.037	0.149	0.133
DS	GRAIN	0.001	0.048	0.001
WS	STORES	0.026	0.203	0.069

PERCENTAGES OF LAND UNDER CROPPING USE

DS	FALLOW	0.577	1.687	1.942
WS	LAND	0.212	0.828	0.598
DS	PREPARED &	0.326	1.275	1.343
WS	PLANTED	0.442	0.917	0.868
DS	FALLOW &	0.903	2.962	3.285
WS	CROPPED	0.655	1.746	1.466

TABLE 4.9 Page 4

DS	ABANDONED	0.283	1.845	1.741
WS		0.759	2.661	5.016
DS	CURRENT & REC.	1.187	4.802	5.026
WZ	CROPPING	1.415	4.407	6.481

≠ Assumes 9000 Km^2 of Hiraan is west of 45^o oo'E and densities of censused items is the mean of those of LSU 77 and 59 - a very approximate figure.

* Estimates will be slightly over estimated (5%?) since the census boundary extends south of the region.

DENSITIES OF HOUSES & OTHER STRUCTURES IN THE 1979 WET & DRY SEASONS BY ECOLOGICAL ZONES AND ECOLOGICAL CLASSES

ECOLOGICAL CLASS & ECOLOGICAL ZONE	ALL PERMANENT HOUSES		AVERAGE	ALL NOMADIC HOUSES		LIVESTOCK ENCLOSURES		ABANDONED LIVESTOCK ENCLOSURES		COMPOUNDS	
	DRY SEASON	WET SEASON	WET & DRY	DRY SEASON	WET SEASON	DRY SEASON	WET SEASON	DRY SEASON	WET SEASON	DRY SEASON	WET SEASON
N.W.LIMESTONES											
1	o	o	o	0.1509	0.6046	1.1440	0.7598	1.1823	5.7737	0.1509	0.5520
2	o	0.0220	0.0100	0.2700	0.3430	0.5520	0.3100	0.2770	3.3460	0.2700	0.2980
3	o	o	o	0.6089	0.7775	0.9567	0.9289	2.7440	4.0969	0.6089	0.7023
4	0.0049	o	0.0025	0.2704	0.5174	0.9179	0.5703	0.3432	7.5909	0.2602	0.5129
5	o	o	o	0.4670	o	0.2680	o	0.0670	2.8250	0.4670	o
6	0.1600	0.4363	0.2982	0.2570	0.3185	0.8888	0.3978	0.2820	4.6570	0.4170	0.7548
7	0.0051	o	0.0026	0.3509	0.8962	0.9284	0.8442	0.1934	8.3856	0.3560	0.8601
8.	0.1847	0.1414	0.1631	0.7788	1.5527	1.4805	1.5144	0.3971	8.1765	0.9430	1.6541
I.1-8	0.0235	0.0416	0.0326	0.2755	0.5846	0.9862	0.6832	0.7326	6.1770	0.2933	0.6150
ESTIMATES	744	1,316	1,031	8,717	18,497	31,204	21,617	23,180	19,5446	9,280	19,459
GYPSUM DOMINANTS											
II.1	o	o	o	0.0234	0.5623	0.9723	0.5107	1.1758	5.2807	0.0234	0.4324
2	o	0.0304	0.0152	0.0859	0.3837	0.5908	0.4654	0.7131	2.2717	0.0859	0.3894
3	12.3115	o	6.1558	2.5676	0.1600	1.1842	0.2843	0.4012	4.6726	9.3691	0.1600
4	o	o	o	o	2.449	o	0.8160	0.3490	6.0940	o	2.4490
5	0.0910	o	0.0455	0.2590	0.4340	0.2160	0.3190	0.1610	5.8740	0.3500	0.4000
6	o	o	o	0.7293	0.3963	1.6748	0.6804	0.7042	4.0354	0.7020	0.3963
II.1-6	1.4275	0.0098	0.7187	0.5141	0.4298	0.8128	0.4616	0.6146	4.1651	1.3168	0.4050
ESTIMATES	20,806	143	10,475	7,493	6,264	11,847	6,728	8,958	60,706	19,192	5,903

TABLE 4.10

ALL SANDS OVER LIMESTONE											
III.1	o	0.0032	0.0016	0.2731	0.3438	1.7146	0.5775	1.2239	6.0465	0.2524	0.3570
2	0.3493	0.0207	0.1850	0.5238	0.6033	0.5170	0.6330	0.3281	4.4102	0.8591	0.5450
II.1-2	0.2506	0.0118	0.1312	0.3967	0.4718	1.1240	0.6049	0.7821	5.2396	0.5516	0.4497
ESTIMATES	8,557	403	4,480	13,547	16,111	38,382	20,656	26,707	178,922	18,836	15,356
ALL COASTAL LAND SYSTEM UNITS											
IV.1	o	o	o	0.0522	0.4880	0.4836	0.3480	3.1503	4.4020	0.0348	0.3103
2	0.2669	o	0.1335	0.5282	1.3314	0.5299	0.3597	0.6523	2.7229	0.4620	0.2539
3	0.1309	o	0.0655	0.2225	0.3735	0.5008	0.3557	0.0826	15.7182	0.3351	0.3468
4	–	1.3010	0.6505	–	0.8800	–	1.2890	–	3.6640	–	2.2080
5	o	o	o	0.0612	o	0.1852	0.1926	0.5906	1.1019	0.0475	o
6	o	o	o	0.9540	0.6540	0.8370	0.3270	o	1.4610	0.9060	0.3270
IV.1-6	0.1579	0.0871	0.1225	0.3248	0.8590	0.4418	0.3987	0.7962	5.0857	0.3073	0.3765
ESTIMATES	3,706	2,044	2,875	7,623	20,160	10,369	9,357	18,686	119,356	7,212	8,836
STABILISED SANDDUNES											
V.1	0.1400	0.1610	0.1505	0.4550	1.2610	0.3920	1.6150	0.0730	6.8580	0.5960	1.2060
2	0.3897	1.1621	0.7759	0.6465	0.8305	0.8996	1.3925	0.0571	5.9659	0.9897	1.7312
V.1-2	0.3613	1.0484	0.7049	0.6247	0.8794	0.8419	1.4178	0.0589	6.0673	0.9450	1.6715
ESTIMATES	4,795	13,914	9,355	8,291	11,671	11,174	18,817	782	80,525	12,542	22,184

VI.1	1.8580	2.1629	2.0105	1.2261	4.1419	2.0310	1.8446	.1884	3.8819	2.3001	4.1507
2	0	0.1850	0.0925	0.8410	1.4210	1.2400	1.5230	.0340	5.1540	0.8410	1.6060
VI 1-2	1.2993	1.5682	1.4338	1.1103	3.3238	1.7932	1.7479	0.1420	4.2644	1.8614	3.3855
ESTIMATES	4,166	5,028	4,597	3,560	10,656	5,749	5,604	455	13,672	5,968	10,854
HAUD TYPE											
VII.1	2.9650	0	0.6070	1.0236	0.8183	0.6855	0.7632	0.4456	8.4391	4.0012	0.8088
	2.9650	0	0.6070	1.0236	0.8183	0.6855	0.7632	0.4456	8.4391	4.0012	0.8088
ESTIMATES	28,037	0	5,740	9,679	7,738	6,482	7,217	4,214	79,800	37,835	7,648
ALL ARCED SILTS											
VIII.1	0	0	0	0.1270	0	1.7260	0.1900	3.3240	11.1940	0.1270	0
2	0.0510	1.0490	0.5500	0.2110	1.6180	1.8770	1.4220	0.2120	6.7350	0.2490	1.2930
VIII.1-2	0.0328	0.6753	0.3541	0.1811	1.0416	1.8232	0.9831	1.3207	8.3234	0.2055	0.8324
ESTIMATES	84	1,729	906	464	2,666	4,667	2,517	3,381	21,308	526	2,131
ESTIMATES FOR CENTRAL RANGELANDS	69,411	25,804		62,299	95,805	126,442	92,761	86,797	753,337	114,983	95,540

TABLE 4.11

HUMAN POPULATION DENSITIES AND ESTIMATES FOR THE ECOLOGICAL CLASSES AND ECOLOGICAL ZONES OF THE CENTRAL RANGELANDS IN THE DRY SEASON* AND WET SEASON**.

ECOLOGICAL ZONE	SEASON	SETTLED PEOPLE D	SETTLED PEOPLE E	NOMADIC PEOPLE D	NOMADIC PEOPLE E	ALL PEOPLE D	ALL PEOPLE E
I	DS	0.1226	3880	1.2188	38563	1.3414	42443
	WS	0.2174	6877	2.5894	81928	2.8068	88805
II	DS	5.1505	75068	1.5725	22919	6.7230	97987
	WS	0.0481	702	1.7895	26082	1.8376	26784
III	DS	1.1361	38796	1.5246	52064	2.6607	90860
	WS	0.0584	1993	1.9787	67569	2.0370	69562
IV	DS	0.5348	12551	0.9326	21886	1.4674	34437
	WS	0.1844	4328	1.5417	36182	1.7261	40510
V	DS	1.8422	24449	2.7002	35838	4.5424	60287
	WS	4.8360	64183	3.4388	45640	8.2748	109823
VI	DS	5.3397	17119	3.8682	12402	9.2078	29521
	WS	5.7736	18511	10.3740	33260	16.1478	51771
VII	DS	15.8236	149628	4.6310	43791	20.4546	193419
	WS	-	-	4.3028	40687	4.3028	40687
VIII	DS	0.1676	429	0.7847	2009	0.9523	2438
	WS	1.7418	4459	2.2775	5830	4.0193	10289

* EXCEPTING THE THREE REGIONAL CAPITALS

** EXCEPTING ALL THE LARGE TOWNS AND VILLAGES (SEE TEXT)