CHAPTER 3

METHODS

3.1 SURVEY REGIME AND DESIGN

3.1.1 Review and Choice of Aerial Sampling Technique.

The size of the study area, the survey zone, was calculated to be 42200 km^2. It was decided, because of its size, it should be aerially surveyed, using transect sampling.

Two most common transect sampling techniques applied in aerial animal surveys are the random sampling (incorporating both the simple and stratified random sampling) and the systematic sampling techniques.

In the simple random sampling procedure, the choice of units to be sampled is random, each unit standing an equal chance of being chosen. To achieve this, the survey zone is divided up into smaller sampling units (which are often grid-cells). These sampling units are all numbered and from a table of numbers corresponding to the units, a random choice of the requisite number already determined for sampling is made. The randomly chosen units are then surveyed. The order in which they are surveyed is not important.

In stratified random sampling, a procedure described by Tanner (1978) as the most sophisticated and efficient method of sampling, the entire survey zone is divided into sub-areas or strata, depending on the criteria used for stratification. The strata may be decided on the basis of habitat types or some other delimiting factors such as known population density gradients. Sampling units are then chosen by a simple random sampling process, separately and independently, within each stratum. The advantage of stratified random sampling is that population estimates may be obtained separately with high precision for each stratum, and these may then be combined into an estimate which has greater precision for the whole survey zone (Tanner 1978). Also greater precision may be obtained by intensifying sampling in the high density stratum or strata to decrease variance. The disadvantage of this procedure is that it demands prior knowledge about the survey zone and its resources to enable demarcation of stratum boundaries.

Unless this knowledge exists, a pre-survey inventory of the resources of the survey zone has to be undertaken to locate the stratum boundaries. One major and general disadvantage of the random sampling technique is its inefficiency in mapping distribution of animals and other land resources of the survey zone, while its one major and general advantage is that of ease of statistical analysis of data acquired by it.

In the systematic sampling technique, the sampling units are organised into, and sampling in some sequence. However, the starting point is chosen randomly. The main advantage of this technique is that all the sampling units are covered and in addition to population estimates, this allows systematic mapping of distributions of animals and the other resources of the survey zone. Its major disadvantage seems to be a lack of clear-cut statistical methods of analysing data acquired by it and resort has to be made to statistical methods developed for the random sampling technique.

The two techniques are, however, related. The general theories relating to both the random and systematic sampling techniques have been compounded by Cochran (1977), while the actual application of the two techniques in aerial surveys has been discussed by Jolly (1969a) emphasising the former, and Caughley (1977) and Norton-Griffiths (1978) dealing with both. Gwynne and Croze (1979) have discussed the aerial operational aspects of the systematic sampling technique, the systematic reconnaisance flights, as applied in East Africa. Cochran (1977), in his treatment, has shown how analysis of systematically acquired data has to use, with modification, the mathematical formulae developed for data acquired by stratified random sampling. Caughley (1977) indicates systematic sampling as a special case of random sampling without replacement, although it differs from the latter by avoiding practical navigational problems usually associated with survey of units randomly chosen. According to both Cochran (1977) and Caughley (1977), systematic sampling has several advantages over random sampling:

(i) it is the best means of mapping animal distributions while also allowing determination of population densities and estimates from the same single survey;

(ii) it is more precise than simple random sampling when the variance within the systematic samples is larger than the variance of the whole population;

(iii) it is precise when units within the same sample are heterogeneous, and imprecise when homogeneous.

However, systematic sampling still lacks an exact model for the determination of standard error of the estimate. In this instance, the standard error is calculated from models of the estimate's variance for stratified random sampling without replacement. This treatment may return an unbiased estimate while over-estimating the variance and the standard error and setting wide confidence limits (Norton-Griffiths 1975, Pennycuick, Sale, Price and Jolly 1977, Caughley 1977, Caughley, Sinclair and Wilson 1977).

In summary, therefore, systematic sampling has more relative advantages than random sampling. The principal one, considered especially in this study, was its ability to allow determination of population densities and estimates, albeit with possible wide variances and standard errors, which may be of similar reliability to random sampling, and in addition, its ability to allow determination of animal distribution patterns. Population abundance and animal distribution were some of the major aims of the present study. For this reason, the systematic reconnaisance flight was chosen as the aerial sampling method for the present study. Random sampling would have wasted a lot of valuable time because of too many inter-unit dead time flights.

3.1.2 The Survey design

3.1.21 General: In order to complete the study in fourteen months as well as satisfy the objectives, special attention was paid to the design of the surveys. The following were considered the essentials of a potentially successful plan:

(i) Choice of a sampling fraction that would enable a reasonable coverage of the study area, to permit higher confidence in mapping animal distributions;

(ii) Choice of a flight plan that would adopt the height, speed and attitude appropriate for aerial counting;

(iii) timing of surveys in order to cover the two main seasons experienced in that part of the world, summer and winter;

(iv) observer relief.

To achieve the foregoing, map sheets at the scale of 1:250000, covering the whole study area were obtained. They were overlain, first with one-degree squares, then these were divided into 10km x 10km grid-squares, referred to in this study as grid-cells. Since the shortest distance across the study area was north to south, it was decided flight directions should be north-south, and therefore that was chosen as the transect alignment. Transect lines running north-south were drawn through the middle of each grid-cell. Altogether thirty-one transects were fitted over the study area this way. Twenty-three of them were of equal lengths, each 150km long, while the rest were of various lengths, varying from 50km to 140km. The transect interval was 10km. The transects were numbered from west to east, i.e. transect number 1 was the most westerly and number 31 the most easterly. They were, however, flown sequentially in reverse order from 31 in the east and nearer to base, to transect 1 in the west and furthest from the base.

It was decided the transect strip-width should be 200 metres per observer i.e. on either side (total of 400 metres for the two sides). The observed strip-width of 200 metres on either side of a flight path is within the ranges generally accepted for aerial surveying (Norton-Griffiths 1978), and was considered appropriate because the area is generally scattered trees to open woodland.

3.1.22 The Sampling Fraction: The sampling fraction or sampling intensity was calculated to be 4.0% of the study area. To calculate this, a baseline was drawn across the study area from east to west, its length determined from the map scale, and the total number of transects that could fit across it determined as the quotient of baseline length and total transect strip-width. The sampling fraction was then determined as the total number of transects in the study area divided by this quotient and multiplied by 100 to give a percentage. The formulae used were:

$$N = \frac{L}{W} \qquad ....(1)$$

and

$$f = \frac{n}{N} \times 100 \qquad ....(2)$$

where **L** = length of the baseline (km) = 305km
W = total strip-width (km) = 0.4km

	N	=	total number of transects that could be fitted across the baseline = 762.5
	n	=	total number of transects to be sampled = 31
and	f	=	sampling fraction in percentage

The alternative calculation of the sampling fraction is as a ratio of total area of transect strips to total area of study zone, i.e.

if	a	=	area of transect strip (km^2)
	A	=	area of study zone (km^2)
and	f	=	sampling fraction in percentage

then $f = \dfrac{\sum_{n} a}{A} \times 100$ where $\sum$ means summation and n refers to the nth transect

In this study $\sum a$ = 1688 km^2
A = 42200 km^2
and n = 31
thus $f = \dfrac{1688 \times 100}{42200}$ = 4.0%

3.1.23 The flight plan: The chosen nominal flight height was 91.4 metres above ground level. At that height it was considered visibility would be at its optimum under normal conditions within those habitat types.

The nominal flying speed was chosen as 160 kph. It was considered at that speed an observer, at approximately 91 metres height, searching a strip-width of approximately 200 metres under those conditions would not be overtaxed through difficulty of visibility, wide search and fast fly-past. It was also considered that that speed was fast enough to cover the long transects and study area within a reasonably short time, thus reducing observer fatigue, and yet slow enough to allow moderate rates of search and count. Various researchers have adopted their own frames depending on their particular needs (Norton-Griffiths, 1978, Caughley, 1979b). However, a trial was considered necessary to check the practicability of the choices. In a four-hour reconnaisance flight organised to test this, there was general acceptance at the end by the survey team, having compared the higher and lower altitudes, as well as faster and slower speeds, that those choices were acceptable.

The aircraft that were used in the study were both high-wing, a Cessna 206 and a Cessna 210.

3.1.24 Timing of Surveys: Seven survey flights were planned and flown. The original plan had been to fly them at the frequency of one survey every two months, but during the course of the study intervening circumstances (see Chapter 4) put some of the surveys out of phase and schedule.

The original plan had been to fly so as to cover the approximate seasonal characteristics shown, thus:

September (1983)	End of dry period
November (1983)	Moist period
January (1984)	Wet period (Summer)
March (1984)	Moist period
May (1984)	Beginning of dry period (beginning of winter)
July (1984)	Peak of dry period (end of winter)
September (1984)	End of dry period

However, all the seven surveys were flown as follows:

September	1983
November	1983
January	1984
April	1984
June	1984
August	1984
September	1984

The average duration per survey was five days with half-a-day's break, and four and a half days without a break. The average surveying day was nine hours with transect time of seven hours inclusive of inter-transect time. The working day started at about 0600 hrs and ended about 1730 hrs with about 4 hours of lunch and rest break. The transect surveys generally started at about 0630 hrs and ended at about 1100 hrs, resumed again at about 1500 hrs and ended for the day at about 1730 hrs. Towards, during and immediately after winter, when the days were shorter, the lunch/rest break was shortened to compensate for late starts and early finishes. The long breaks of 4 hours were found very necessary, especially during the hot season because it was felt adequate time had to be set aside to allow the survey team to eat and rest. The hours chosen for actual transect surveys were based on likely times of animals greatest activity and exposure i.e. visibility. Between 0630 hrs and 1100 hrs animals were found to be still out in the open, even at the peak of summer, while between 1100 hrs and about 1430 hrs most were found in shade. This was observed during positioning flights, some of which lasted up to 30 minutes.

Four observers were available for the study. Three were responsible for counting and the fourth (the author) was responsible for recording counts and observation of other environmental factors. The three counting observers, always occupying the rear seats, alternated such that only two were available for counting each day while the third stayed behind in camp resting. Half-a-day's break was at times allowed where general opinion required it. The pilot and the author had no relief for the entire duration of the study, other than the occasional short breaks of half a day. All the three counting observers were given time off at the end of each survey. This overall arrangement of observer relief and breaks was found attractive by the counting observers and it was the view of the author that it helped maintain the motivation, and the high morale which was observed during the whole study. It is hoped that it equally heightened observer vigilance during observations.

3.1.3 Data recording

All observations on animal counts and environmental factors were recorded on data sheets prepared with appropriate columns. Each transect grid-cell was divided into two five-kilometre sub-units and information recorded for each sub-unit separately. The identification number of the sub-unit was entered under the column labelled sub-unit on the data sheet. Other columns on the data sheet were for transect number, time of crossing from one sub-unit to the next, geographical coordinates as read off the navigation system, left or right animal counts and a series of other information. Observations on environmental factors were recorded under a column labelled "Other info." (Other information). The data sheet also provided for recording of other details on appropriate spaces shown in the specimen in Appendix 2.

3.2. ANIMAL COUNTS

3.2.1 Marking of Strip-width.

The nominal strip-width, once determined, was marked on the aircraft, using the method described by Pennycuick and Western (1972), and Norton-Griffiths (1978) (illustrated in Fig. 3.1). Basically a person sitting comfortably in an aircraft on level ground has his eye at a height h above ground. Looking out through the window of the aircraft, he sees obliquely, point A, just off the aircraft but not hidden by the fuselage and not far off the side of the aircraft. This point is at some angle off the nadir. From that point to another one, set off the aircraft, is the distance w and further off the nadir; call this second point B. The distance between A and B is w units of measurement. When the aircraft is in flight, if the same position is maintained by the observer, and he looks out through the same lines of sight as for points A and B, then a similar relationship will be maintained between the new height H, and width W, where H is the flight height and W the new distance between A and B at that flight height.

If, while on the ground, a mark was made on a wing-strut on a line of sight to A, say mark "a", and another on a line of sight to B, say mark "b", then these marks will aid the observer, in flight, maintain the same angle of view to observe the new width W, at flight height H. Mathematically assuming level flying, the relationship is expressed as:

$$\frac{w}{h} = \frac{W}{H}$$

or

$$w = \frac{hW}{H}$$

Since W, the nominal transect strip-width, and H, the nominal survey height are usually predetermined, in this study as 200 metres and 91.4 metres respectively, then by measuring h, the height of the eye above ground level, while maintaining the same viewing angle enables calculation of w which in turn enables calibration of the strip-width. The streamers are then attached to marks "a" and "b" such that when in flight, they trail out behind the wing-strut. The area between them, projected down, defines the nominal strip-width. The mark "a" may be replaced by using the lower aircraft window seal

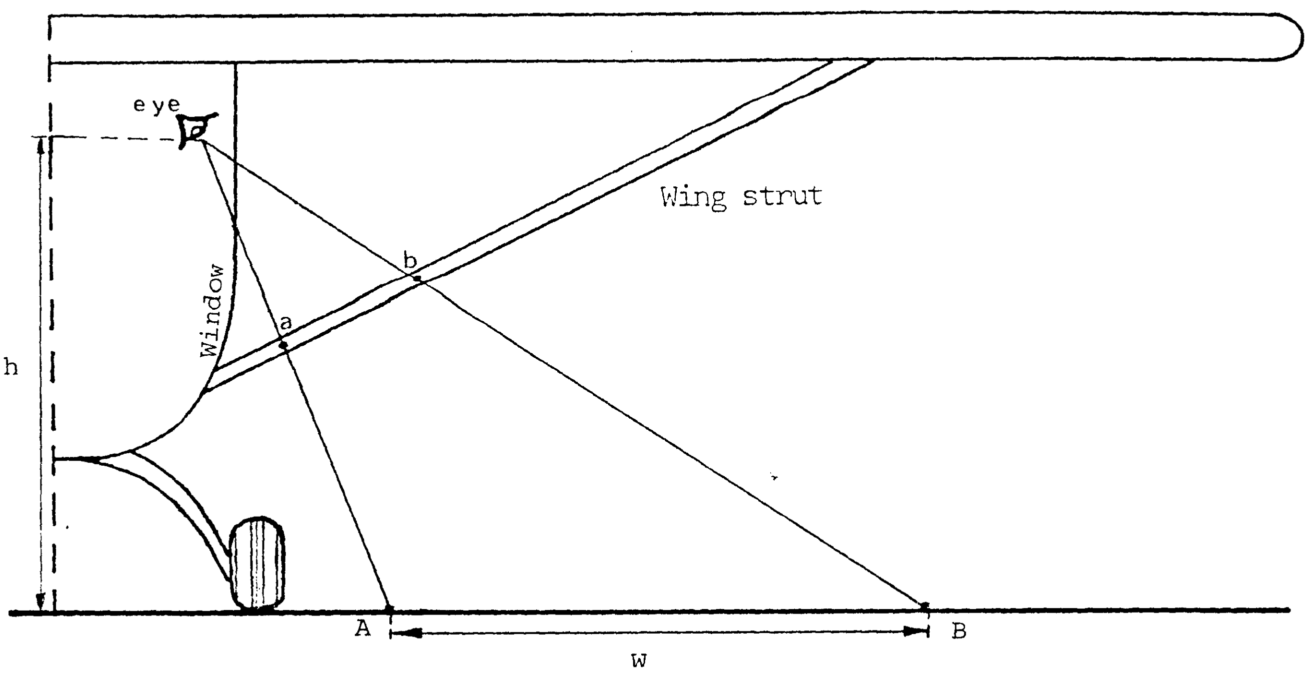


FIG. 3.1 Marking of Strip-width and Fixing the Position of the Streamers.

If h is the height of the observers eye above the floor
w is the ground measurement marking the extent of the stip-width
W is the nominal transect strip-width
and H is the nominal flight height

then $\frac{w}{W} = \frac{h}{H}$

or $w = \frac{Wh}{H}$

The streamers are attached to the wing-strut at marks a and b.

in its place and no inner streamer is attached.

However, these ground-based determinations should be calibrated against specific marks on the ground, of a known distance equivalent to the decided strip-width. This is done by flying over these marks at the prescribed nominal height. If the streamers coincide with these marks on the ground, the strip-width as marked by the streamers is fixed; if not the streamers are adjusted until they match the ground marks. This may involve several take-offs and landings.

Another problem arises, if the aircraft used is strutless and streamers cannot be used. In that case, marks "a" and "b", that would normally be put on the wing-struts, are put on the window. A modification of the mathematical relationship accommodating this change has been advanced by DHV Consulting Engineers (DHV 1980 Vol. IV) and is shown in Fig. 3.2. The triangulation principles remain the same, though.

The first method of marking the strip-width was, in this study, applied when using the Cessna 206 which had wing-struts and the second when using the Cessna 210 which was strutless. The Cessna 210 was used in six out of the seven surveys. Calibration flights were performed on both until the streamers and the window markers, respectively, were approximately matching the ground markers placed 200 metres apart. Thereafter semi-permanent marks were made on the windows and struts and corresponding measurements taken so that they could be re-marked each time a new survey started without having to go through the same drill again. This was especially necessary because the aircrafts were used for other varied purposes and this meant windows and struts had to be cleaned between surveys.

Observers counted only animals seen in between the streamers or the window marks, depending on the aircraft used.

3.2.2 Height maintenance.

Height was maintained by use of the King KRA10 Model radar altimeter, reading from 40 to 2000 feet. Since the radar altimeter was calibrated in feet, it was set at 300 feet flight height which equalled approximately 91.4 metres. It was fitted with an audio alarm system which was triggered as soon as the height dropped below 300 feet, and a visual alarm system which illuminated a lamp as soon as

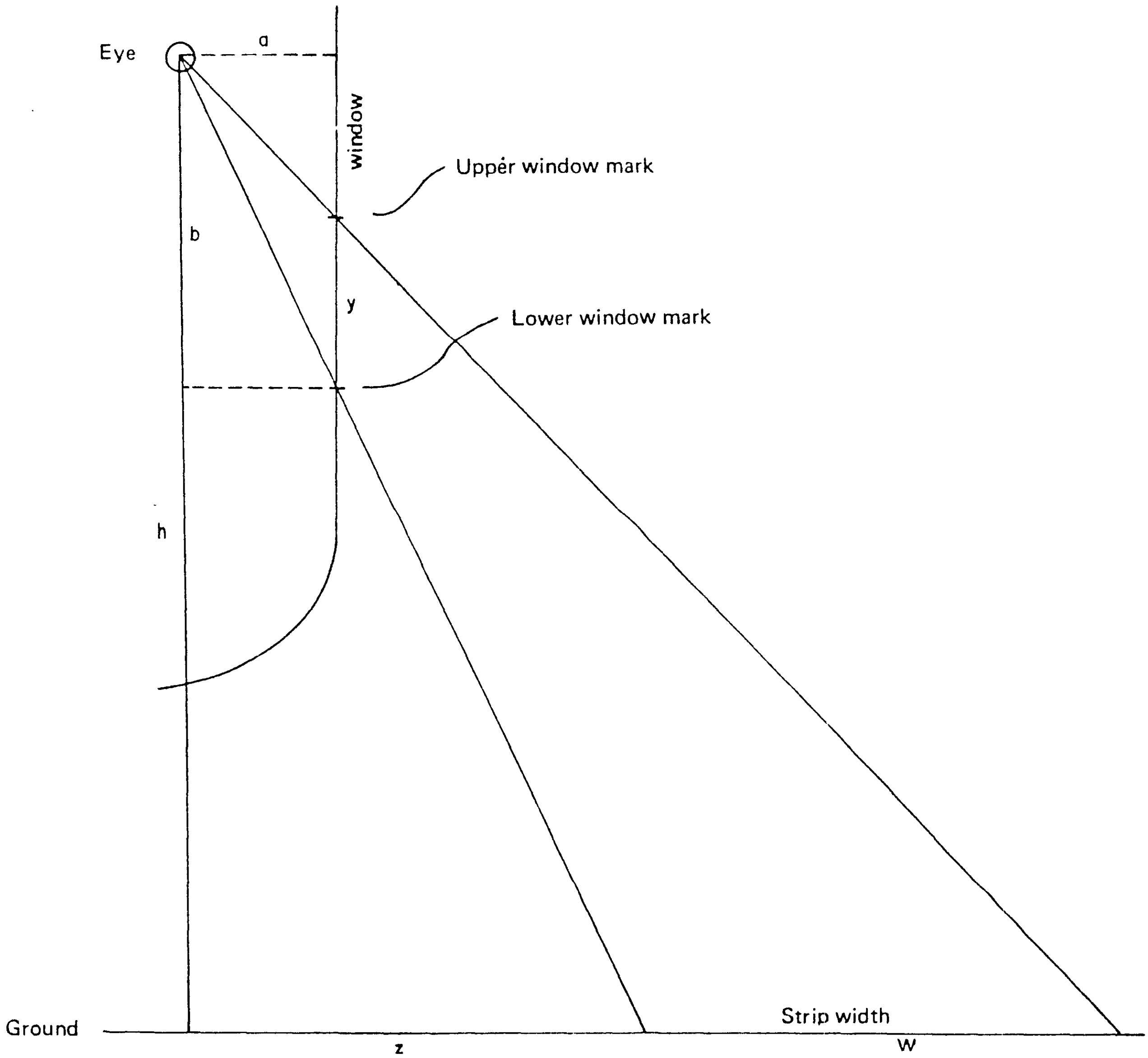


FIG. 3.2 Fixing the positions of window markers defining the strip-width on strutless aircraft (Adapted from: DHV 1980 Vol. IV).

In Calibrating the positions on the aircraft window of the upper and lower marks (i.e. calculating the distance y) for any combination of desired aircraft flying height and strip width.

let
a = distance of observer's eye from window
b = height of observer's eye above lower window mark
h = desired height of observer's eye above ground
W = desired strip width
y = distance between window marks

then $a:b = z:h$, or $z = \frac{a}{bh}$

or $(W+z) : h = a : (b-y)$

hence $y = b - \frac{a}{\frac{W}{h} + \frac{a}{b}}$

the height exceeded 300 ft. Height was therefore strictly controlled by the pilot by appropriate responses to the alarm systems.

3.2.3 Navigation.

Navigation over a more or less featureless countryside, flying a transect length of 150 km, on dead course, at low altitude and slow speed would be a challenge to any pilot. To overcome this navigation problem, which is difficult even over short distances, some researchers have placed markers on the ground at specified intervals, and have navigated by flying parallel to these ground markers. This method is practicable over short distances. This navigation method has been observed by the author in Kinchega National Park and Ivanhoe as applied by the Australian CSIRO wildlife research team. The two areas are relatively small with longest transects of perhaps 30 kilo- metres. This method would not be practicable over long distances because of the initial problem of not being able to align the markers unless by use of surveying instruments like the theodolite, which would be both time-consuming and expensive.

On this study, navigation was by use of the Omega Navigation/ Very Low Frequency System (Omega/VLF). Information about the Omega/VLF operation is given by Global Navigation Inc. 1975, and Tracor Inc. 1982. The Omega Navigation System is an inter-continental navigation system using radio transmissions in the very low frequency class (10-30kHz) to provide worldwide Great Circle navigation capability from a known point. Very low frequency transmissions have ranges of between 9600 and 16000 km. These transmissions are least affected by local atmospheric conditions. The transmissions used by the Omega/ VLF system are emitted by both the Omega Navigational Network radio stations and the United States Navigational Communications Very Low Frequency stations. There are altogether 15 stations comprising Omega/VLF world network, and these are located in Europe (two countries), U.S.A. (six locations), South America (one location) West Africa (one location) the Indian Ocean (one location) Australia (two locations) and Japan (two locations).

All the stations transmit in a synchronised manner to avoid interference and the phasing is stable. Thus the four qualities of Omega/VLF transmissions which make them especially suitable for worldwide accurate navigation are their worldwide location, long range capability, phase-stable signals and virtual freedom from local atmospheric conditions.

The hardware used on this study for plugging into the Omega/VLF navigation network was the Global Navigation System model GNS-500A in the Cessna 210, and the Tracor Model 7800 Omega/VLF Navigation System in the Cessna 206. Although the two models have slightly different programming procedures and details, they will nonetheless be referred to as the ONS/VLF equipment. Only their over-riding similarities are considered.

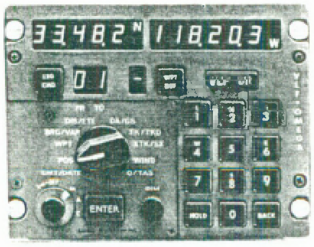
The ONS/VLF equipment has three basic units, the Control Display Unit (CDU), the Receiver Computer Unit (RCU) and the Antenna Unit. The GNS-500A has an additional Optional Equipment Unit (OEU) which also houses a standby battery. The three basic Units are shown with their descriptions in Fig. 3.3.

The ONS/VLF equipment's mode of operation, involves the pilot first determining his waypoints at predeparture and defining them in terms of their geographical coordinates. Waypoints are points of destination or to be touched en-route. Before departing, the pilot enters the date and the Greenwich Mean Time the latter is used as a reference time-scale, and together with the date are used for automatic computation of diurnal shift error corrections of variations in very low frequency signal properties. These properties change with time of day and behave differently depending on whether it is day or night time. Other information also entered at pre-departure following the date and Greenwich Mean Time, are the geographical coordinates of the departure point to be used for ranging, and the magnetic variation used for automatic bearing corrections. The Tracor 7800 Model was pre-programmed with the magnetic variation while the GNS-500A was manually fed with this value. Once these first four data elements have been fed in, additional waypoints and other navigation related inputs may be made. These latter include leg changes i.e. changing from one waypoint to another; entry of true air-speed, to be used for computation of ground speeds, and true wind speed to enable computation of wind speed and its direction. At this stage initialising of the systems VLF mode alerts the ONS/VLF computer to make available on the display unit the computed or corrected present

COMPONENT DESCRIPTIONS

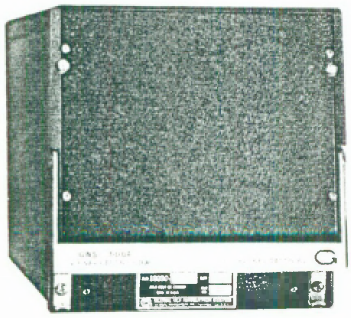
Control Display Unit (CDU)

The CDU is located in the cockpit and serves as the link between the pilot and the computer. It contains all necessary controls and displays for the system's operation.



Receiver Computer Unit (RCU)

The RCU contains the system power supply, the VLF receivers, the computer, and the interfacing circuits required. This unit is remotely mounted and contains no operational controls.



Antenna

The externally mounted Blade Antenna contains a preamplifier built into its base. On some aircraft the flush mounted ADF sense antenna may be used in conjunction with an optional ADF/VLF Antenna Coupler.

Fig. 3.3 The Omega/Very Low Frequency equipment with component descriptions (Source: Global Navigation Inc. 1975)

position, bearing and distance to the next waypoint, the estimated time en-route and estimated time of arrival at this next waypoint (if in flight), drift angle off-course, the wind speed and direction and the cross-track distance and direction.

The present position is automatically corrected while on the ground, and determined in flight, by the computer calculating the distance and bearing from the input coordinates to the geographical position of each Omega/VLF transmitter. On the ground, this distance and bearing will not change with time, while in fight they will. As the aircraft flies along, the distance and bearing to these transmitters relative to the starting point change by some phase angle and by comparing these changing phase angles, the computer is able to determine the distance and the direction of movement of the aircraft since its last position. It then uses this information to calculate the current position and displays its coordinates. Three transmitter stations are required as the minimum for the source of transmissions necessary for the ranging computations.

Thus, with the system which continuously informs the surveyor where he is, the speed he is travelling at, his direction of travel, his deviation from the predetermined course, navigation is simplified significantly and long distance aerial surveying becomes practicable. On this study, waypoints were the starting and end-points of each transect. The outputs used frequently were, the present position, the track angle deviation, the waypoints and ground speed.

The surveying speed of 160kph was displayed as ground speed in nautical miles per hour (approximately 90 nautical miles per hour). The pilot had to maintain this speed by constantly referring to the ground speed indicator on the display unit. By similarly checking the course deviation indicator mounted independently from the display unit, he was able to make course corrections timeously. It had been decided by the author no deviations should be allowed to exceed 200 metres if counts and observations too far away from the transect centre were to be avoided. Since the predetermined meridians were being flown, it was easy, even without reference to the course deviation indicator, to see when a deviation was developing just by observing a meridian change. Corrections of these minor deviations was by application of rudder to yaw back onto course. This was done in order to avoid banking with its errors and biases. Wind induced course changes were handled by trimming.

The ONS/VLF navigation equipment could also be hooked on to the auto-pilot and placed in the automatic mode when all the foregoing would now be all handled automatically. One of the ill-effects of flying by auto-pilot, was steep banking in course corrections, and more acutely at the end and beginning of transects when the aircraft would be going out of one waypoint (end of transect), going into inter-transect space and going onto a new waypoint or beginning of a new transect. In these situations, the auto-pilot applied maximum bank. Secondly, the auto-pilot was found to be unable to handle turbulent conditions. Because of these disadvantages of the auto-pilot, most of the transect flying was by the pilot.

The accuracy of the ONS/VLF equipment (GNS-500A model) for navigation in aerial transect sampling was evaluated by DHV (1980 Vol IV) in Botswana. They did this by checking its position error to the nearest one-tenth of a degree against time. This was done during the course of their surveys by recording the position error every time they passed over a primary trigonometric station or after returning to a starting point. From the statistical analysis of this, they found that even after six hours of flight, it was rare to register an error of more than three minutes of arc. They concluded that the instrument could be taken as accurate to within two kilometrtes after an hour or more of flying.

From the present study, it was observed that in almost all the surveys, the same paths were being flown. There were some pans, sand-dunes, boreholes, corners of ranches etc. that made physical reference land marks and in almost all the surveys, the same positions relative to them were being overflown. The specific examples were Morwamosu Pan/Village, a corner of Phuduhudu Ranch, Kang Pan/Village, Lokalane Borehole, Lotlhake Basarwa Village, Ngwamotsoko's farm borehole, Tshane and Lehututu Pans/Villages, Nxang/Monong Pans/ Villages, corner of Ncojane ranches, Ncojane/Kule Pans/Villages and numerous pans and sand-dunes. It was thus concluded that the equipment's accuracy as observed qualitatively by this study agreed with the quantitative evaluation by the DHV (1980) Vol IV).

However, there were several instances when the equipment behaved erratically. In two instances it blacked out at take-offs. The fault was later traced to the power failure of the standby power-pack of the system. In a few cases, it behaved erratically during transect flights resulting in a zig-zag pattern over the transects. The fault was traced to a mechanical wearing off of some system components. The transects had to be reflown. Thus in cases where the ONS/VLF equipment was fully operational, it performed well and relieved the pilot of the considerable task of navigation and mental slide rule computations of flight parameters.

Navigation and speed are considered, therefore, to have been well controlled in this study.

3.2.4 Animal Counts and Recording.

Counting of animals was done by two rear seat observers. Each observer searched for and counted animals found within the strip demarcated by the streamers trailing from the wing-struts, or, in the case of the Cessna 210, the marks made on the window. The need to maintain the posture adopted when the markings and calibrations were made, during counting, was emphasised. All animals falling outside the defined strip were ignored. Where a group was intersected by a marker, only the portion of the group falling between the streamers or window markers was counted. All wild animals bigger than the steenbok and domestic stock bigger than sheep, goats and dogs were counted. No differentiation was made on age or sex. The young and mature individuals of both sexes were grouped together and counted as if they were all adults of the particular species. During the transect flight, the counting observers were expected not to take their eyes off the ground, so that they continuously searched their respective halves of the strip-width. Their only duty was to count animals and announce each count for recording elsewhere.

Recording was done by the front seat observer. The respective counts were recorded under the column in the data sheet appropriate to the observer who made the count. Contrary to the author's expectation interference by aircraft noise was not significant and the counting observers did not have to shout loudly. There was no confusion either in identifying which of the observers announced a count as their voices came out clearly and could be easily identified. The only situations where some confusion occurred was when many animals were encountered at the same time by the observers and counts announced simultaneously. This situation was resolved by repeating the announcements. However these situations were rare.

It had originally been planned to use tape-recorders for recording. This plan was dropped for several reasons:

(i) there was no power outlet for the tape recorders on board the aircraft and their individual power packs were not sufficient for prolonged operation,

(ii) transcribing of tape was considered likely to be time consuming, more especially that it would have not been possible for the rear-seat observers to make cross-references to the navigation information, which would be recorded elsewhere; time would then be spent cross referencing the counts and their localities;

(iii) a tape recorder malfunctioning without the knowledge of the observer would have meant a loss of records;

(iv) the use of tape recorders deprived other crew members of access to local counts as they were made whereas announced counts kept them informed of localities of observations; and

(v) announced counts broke the monotony of the lulling aircraft noise.

Another technique of recording which was considered was that observed used by the Australian wildlife researchers at Kinchega National Park. In this technique counts are accumulated mentally, and at specified intervals a timed alarm, which lasts for seven seconds goes off. During this time the observer records his counts on a data sheet. The disadvantages of this technique, which militated against its application in the present study, were considered to be:

(i) it cannot be applied in a multi-species count, and where large concentrations of animals are observed;

(ii) the counting observer is also responsible for recording the data on the data sheets and thus he must cease counting while he records. Animals may therefore be missed during this period. Although this may be corrected for statistically, it would diminish the quality of information available for mapping distributions;

(iii) if the timing device malfunctioned and the alarm failed to go off, then the observer prolonged the mental record and increased the risk of loss through forgetting.

The technique however, has the distinct advantage of relieving the observer of the prolonged stare at the ground which could cause eye fatigue. This technique was not considered suitable for the current study where over five different species of animals, often in large numbers and mixed when encountered, were being counted.

It had been planned to photograph herds over ten animals, in order to use these photographs as accurate counts and for determining counting bias. This was not done because only one camera was available, and, secondly a few trials at aerial photographing of herds proved difficult. In all the cases, the herds were flown past before the photograph was taken. It became clear that more practice was required before the technique could be mastered and be of use in the study. A different approach was devised for determining counting bias and correction factors in this study. This approach is discussed elsewhere in this chapter.

3.2.5 Biases and errors.

3.2.51 General: Aerial counting has a number of draw-backs which tend to influence the results. When undertaking aerial counting, certain conditions must be met if the densities and population estimates are to be considered reliable. Height, speed, strip-width, level flying, visibility and counting, must be rigorously controlled to ensure consistency. In a case of distribution inventory, where interest is in the presence or absence of animals, the emphasis may differ, for example banking effects would not be considered as critical as for surveying for population estimates.

Each of the above factors has certain errors or biases associated with it. A bias is here defined as a persistent, one directional deviation in the results. For example, if an observer persistently undercounts or overcounts, then he is biased towards undercounting or overcounting respectively. An error occurs where there may be a fluctuation around the determined standard, for example, if the pilot flies above the prescribed height, then at it for a while, then next below it in a random fashion, then he creates an error with respect to height maintenance. Error increases variance and decreases precision while bias decreases accuracy. An evaluation of biases and errors is made in Chapter 4, in some detail.

In this study, the errors and biases relating to height, speed, strip-width, banking, visibility and counting were considered and controlled in several ways discussed below:

3.2.52 Height: The radar altimeter, already described, was used for monitoring height above ground level. The pilot was asked to ensure no significant variations occurred around the predetermined nominal height. He was greatly assisted in this task by the alarm system fitted to the radar altimeter, which alerted him to any changes in flying height. It is suggested this system of monitoring height above ground level, although it could not eliminate variations in height, at least moderated them and enabled the ups and downs to cancel out. No correction factors were quantitatively determined for height in this study, it being presumed that the practical corrections were adequate to nullify them.

The effects of height on counting animals have been discussed by Pennycuick and Western (1972) for African animals, Caughley (1974) as a general review and by Caughley, Sinclair and Scott-Kemmis (1976) for Australian animals. They all concluded that increased height led to a decline in the proportion of animals detected. This, Caughley (1974) indicates is a result of a changing mean distance between the observer and the animal, a changing mean number of obscuring items between the animal and the observer, and the changing rate of eye movement. At increased height, the mean distance between the animal and the observer increases, and the mean number of obscuring items decreases, with the resultant decrease in eye movement.

3.2.53 Speed: Counts are affected by speed (Caughley 1974, Caughley et al 1976, Melton 1978). The general effects of increased speed are that the ground is covered at a faster rate and thus the time available to search, locate and count the animals is decreased. The rate at which the eye must move in searching, locating and counting animals must increase, leading to increased eye fatigue, and the resultant reduced efficiency. Melton (1978) found that in Umfolozi Game Reserve in South Africa, slow helicopter speed gave an increase in counts of certain species of animals. Therefore irrespective of whether a fixed or non-fixed wing aircraft is used for counting of animals, speed is an influential factor, the slower the speed the better the count.

The advantage of increased counts with reduced speed is exploited when photography is applied and counts are later made from the photographs. Basically, what is being done, is counting from a photograph when the speed is zero, and in this way, increased, and therefore more accurate counts are made.

In this study speed was monitored using the ONS/VLF equipment already described. Any indicated changes were corrected by appropriate power resettings. It is hoped these practical steps eliminated the effects of the occasional speed changes.

3.2.54 Banking: When an aircraft ceases to fly level and banks to one side, the strip-width is affected. The effect on the strip-widths on either side of the aircraft is not the same. While the strip-width on the inside bank narrows and the one on the outside widens, the narrowing and widening margins are not the same (Pennycuick 1969, Pennycuick and Western 1972). The widening proportion tends to be much greater than the narrowing one. Because of this disproportionate change in the strip-widths, a reverse bank will not cancel out the first error, but instead compounds it. The net effect of variations in bank angles then is widening of the combined strip-widths. When the strip-width is widened, the tendency is to overcount because those animals that would have been left out of the normal strip-width are included inside the widened one and are counted.

On this study, banking errors were checked by adopting and maintaining level flying. Where a need arose for correction of off-course deviations, rudder was used to yaw back into course instead of banking.

3.2.55 Strip-Width: It has been shown above that the strip-width is affected by banking. Similarly, it is also affected by height above ground level. A gain in height increases the strip-width while a loss decreases it. This is demonstrated in the mathematical relationship used and discussed in marking of strip-width. In that relationship the strip-width is directly proportional to height. By therefore maintaining the prescribed height above ground level, and level flying, the strip-width will not vary from when it was calibrated.

On this study, therefore, maintenance of strip-width was by strict control of height and level flying.

3.2.56 Visibility: Sightability of animals is a function of cover, weather condition, lighting condition, behaviour of animals, colour of animals, as well as of speed, height and strip-width at which sampling is done (Caughley 1974, Bayliss 1980). Thick cover, cold or hot weather, heavily overcast sky, crypticity of animals, tone of coat, fast speed, high altitude and wide strip-width all create difficult sighting conditions which lead to general undercounting. Correcting for visibility biases and errors, therefore becomes a relatively difficult task, for it means all the contributors to the problem must be zeroed. Vegetation cover becomes one of the most complicated to correct for, as it means each vegetation category must be considered individually. This was beyond the scope of this study, since the above considerations require experimentation, and the constraints beyond the control of the author, did not enable such investigation work. It was therefore assumed animals were all equally conspicuous under all surveying conditions for the duration of the study. However, control of speed, height and increases in strip-width were all done as already discussed.

3.2.57 Counting Bias: In East Africa a combination of counting and aerial photography is usually done during aerial survey and from this the counting bias is determined (Norton-Griffiths 1978). Groups larger than a certain number, depending on the species being counted, are photographed while being also visually counted. Counting bias is then estimated by the second model of Jolly (1969b) as the simple ratio of what the observer counted on all groups to the total or exact number of animals from the photocount.

In this study photography in conjunction with visual counting proved difficult for the reasons already given. The counting bias was then determined by a different approach under laboratory conditions. A series of photographs, not all aerial, were collected from all sorts of materials including clippings from brochures, magazines and actual photographs. An attempt was made to have various types of vegetation more or less represented in the various clippings and photographs. The margins of these photograph materials were treated as the boundaries of the strip-widths. Single species were counted alone, then associations created by putting two or more different single species photographs together but side by side and asking the observer to count all animals seen on all. Ten seconds, the time estimated as generally available to the observer to count animals in an aerial survey at the nominal speed of 160kph was allowed as the duration for each count. Thereafter the photographs would be collected, rearranged and swapped, then counted by a different observer. Nine such photograph groups were used.

From the photocounts and the observed counts, the counting bias was determined for the small and big animals separately. Springbok was the only small animal.

From Jolly (1969b) second model,

$$\hat{B} = \frac{\Sigma X_y}{\Sigma X_z}$$

Where $\hat{B}$ is the estimated counting bias,
ΣX_y is the sum of all animals (big or small) counted by each of the observers in all the photographs, and
ΣX_z is the sum of all animals (big or small) accurately counted from the photographs.

From the above, six sets of counting bias, two for each observer, for each category of species, were determined. These are shown in Table 3.1.

All animal counts in the study, in excess of ten animals were divided by the above correction factors to give the corrected counts which were then used in the determination of densities and population estimates. The big animal counts for observer OG were not corrected because the correction factor was higher than unity and would have resulted in lowering the count. Caughley (1974, 1976, 1977), has repeatedly argued that aerial counts have many factors influencing their accuracy and in all cases, undercounting, even by experienced observers, occurs. He has argued that even under refined techniques the counting error cannot be eliminated, and was suggested the

TABLE 3.1 Counting bias determined for the three observers for the big and small animals.

Animal type	Observer and Counting Biases ML	OG	KP
Big	0.98	1.21	0.63
Small	0.90	0.95	0.58

Note KP, the newest observer, undercounted by a bigger margin.

acceptance of the alternative that even the best of the observers, under most favourable conditions of observation, will fail to observe many of the animals at which he is staring. It was therefore considered highly unlikely that observer OG could count one hundred per cent of what he saw, let alone more, for he could not count the animals which were not there.

The case of OG above demonstrates some of the shortcomings of this adopted method of determining counting bias. Some of these will be discussed in detail in Chapter 4.

3.2.58 Assumptions: In undertaking counts in this study, the following overall assumptions were made, subject to consideration given to the various causes of bias and errors:

(i) that the whole sample area was indeed searched;

(ii) that all the animals in the sample area were located although not necessarily, all counted, and the application of the determined counting bias corrections improved the counts;

(iii) that the fraction of 4% of the total area surveyed, contained 4% of the overall population; and

(iv) that the sampled area was representative of the entire study area.

3.3 ANIMAL DISTRIBUTION

Animal sightings made by the rear seat observers were recorded as counts. These constituted presence of that species in that 0.2 x 10km cell. Where no sightings were made this constituted absence. One immediate weakness of this method of recording presence and absence of animals is that the area searched is restricted to the strip-width, whereas there could be animals within the grid-cell sub-unit, seen but not registered, because they fall outside the strip-width and are not counted. Secondly if the observer searches and does not sight animals that may be there, an entry of absence is made when in actual fact there may be animals there. However, since the distributions were to be based on recorded densities it was considered this recording design did not compromise the objectives.

3.4 HABITAT

3.4.1 Vegetation.

Community types, species composition of common tree and shrub species, tree and shrub condition, and herbaceous plant cover and condition were determined and their distributions investigated.

3.4.11 Vegetation Community Types: These were identified and classified subjectively for each grid-cell sub-unit. Four successive identifications were recorded for each of the first four aerial surveys and thereafter compared. Where there was 75 per cent or more agreement between identifications, the community type was classifed as belonging to that category. Where there was 50 per cent agreement, the community type was classified on the basis of its relationship to a neighbour with the highest frequency. Where this neighbouring community type was one of those constituting the 50 per cent under consideration, i.e. if for example, the scattered tree community type was scored 50 per cent and for the same grid-cell sub-unit the scrubland community type was scored 50 per cent and the nearest neighbour in the adjoining cell sub-unit with the highest frequency was scrubland, then the community type for that grid-cell sub-unit would be classified as scrubland.

The community types identified from the air were inspected on the ground to compare the aerial distinction with the ground observation. Location of sites was not difficult because almost all the types were invariably represented in areas traversed by roads or tracks. The aerial distinction was then verified by this ground inspection. The community types with their respective descriptions, identified in the study area, are listed below.

Type	Description
Grassland	Plains, predominantly grass covered, which had isolated trees or were treeless and had sparse shrub intermix.
Scrubland	A category where trees were isolated and bushes and shrubs predominated, with the herbaceous layer cover varying from sparse to moderate.
Scattered tree	A category where trees were common but scattered on areas that could otherwise be grassland.

Open woodland	A category where there was a more or less even distribution of trees, neither scattered nor dense, and there was a more or less corresponding even distribution of interspersing herbaceous plant layer and shrub understorey.
Park Woodland	A form of open woodland with a marked absence of, or very little, interspersing shrub understorey, but with sparse to abundant herbaceous plant matter.
Clumped Woodland	A category where pockets of open to dense woodland thickets occurred irregularly on a grassland background.
Dense Woodland	A category where the tree canopy was significantly denser than in open and park woodland, but not so as to obliterate the view of the bare soil, herb or shrub understorey.

3.4.12 Tree and Bush Species Composition: The definitions adopted in this study were that any woody perennial plant three metres and above was classified as a tree while below that, as a bush, with a shrub being a lower level of bush. The usually adopted understanding of a bush being multi-stemmed and a tree having a single trunk was found unsuitable because species like *Ziziphus mucronata, Terminalia sericea, Acacia mellifera, Acacia fleckii, Lonchocarpus nelsii* and a few others found in the study area grew to substantial heights and thicknesses, yet they were generally multi-stemmed. It was therefore found convenient to classify woody plants in this area on the basis of height rather than stem characteristics. From these definitions, therefore, all trees pass through a stage of being bushes.

Species composition was made subjectively by judging which tree or bush species appeared to be dominant. Only the most common species were considered. Observations of these were made from the air.

Although the tree species of the area were well-known to the author, specimens were collected for further identification at the Ministry of Agriculture herbarium in Gaborone.

The most common trees and bushes found in the study area were the six already mentioned as well as *Acacia erioloba, A. luederitzii, A. hebeclada, Grewia flava,* and *Boscia albitrunca. Acacia hebeclada* and *Grewia flava* are bushes.

3.4.13 Plant Condition and Cover: (1) Herbaceous layer cover and condition were judged subjectively and qualitatively. Herbaceous plants, for purposes of this study, referred to non-woody plants including grasses, herbs and forbs. Grass was, however, found to be more predominant, as seen from the air, than either herbs or forbs.

Degrees of cover and condition were recorded as below for each grid-cell sub-unit.

Degree of Cover	Description
Bare	No herbaceous plants seen, the soil completely exposed.
Sparse	Isolated tufts of grass, herbs or forbs, or grass stubble on a predominantly bare soil.
Moderate	Predominantly presence of herbaceous plants especially grass, with prevalence of intermittent and scattered patches of bare soil.
Good	Near complete cover of herbaceous plants, with very few patches of bare soil showing.

Condition status	Description
Fawn	No greenness at all.
Fawnish green	Grass stalks fawn but bases green or mixture of fawn and green herbs in equal proportions.
Green	The whole tuft of grass, forb or the herb all green with little or no fawn plant material seen.

(2) Tree and shrub condition were recorded the same way as for herbaceous plant conditions, but with the following descriptions:

Condition	Description
Defoliated	No leaves at all.
Leafing	Setting of green leaf buds, or subdued tinge of green leaves discerned as a generally green hue.
Green	The whole tree or shrub canopy green.

An attempt was also made to deduce general plant condition from the Landsat colour composite imagery. This was found difficult because the various prints did not have uniform exposure tones which would have enabled a more systematic comparison. It was also difficult to match subjective observations with those from Landsat imagery because the dates of Landsat and aerial observations did not coincide. Therefore using Landsat imagery for mapping plant condition was dropped.

3.4.2 Bushfires.

Bushfires were recorded as presence of fire scars or as burning. A nil record meant absence. An attempt was made to age the fire scars. This proved difficult because no aging criteria, easy enough to interpret from the air, could be determined. Only the two extremes of old scar and new scar could be determined but this was considered of limited benefit.

An attempt was made to use Landsat imagery for location of fire scars over the entire study area. This proved difficult because no distinction could be made between scars caused by fire and scars caused by harvester termite activity.

3.4.3 Harvester termites.

Harvester termites *Hodotermes mossambicus* were found to be a conspicuous element of the habitat. Their possible effect on especially herbaceous plant matter was investigated.

The presence of harvester termites was indicated by the presence of small earth mounds, up to 13cm high and 30cm diameter at base. These were more conspicuous in areas bare of herbaceous plant cover or only sparsely covered.

It was noted that some similarities existed between harvester termite mounds and mounds associated with rodent activity. These similarities and dissimilarities were first checked on the ground, then viewed from the air to establish their differences. Thereafter the distinguishing characteristics were used in aerial observations.

The mounds made by the Damara mole-rat, *Cryotomys damarensis* resembled those made by the harvester termite, but they were distinguishable because they were relatively bigger, up to 40cm high, and up to 60cm base diameter. Although this was used as the main distinguishing characteristic, old and eroded mole-rat mounds could still be confused with the harvester termite mounds.

Termite mounds could also be confused with soil mounds associated with rodent holes. The distinguishing difference here was the open holes near the mounds associated with rodent burrows.

The presence of the harvester termite, as reflected by the characteristic mounds, was recorded qualitatively in terms of the degrees of infestation as follows:

Degree of Infestation	Description
Nil	No mounds noticed.
Light	Very few soil mounds, scattered over a predominantly moderate or good herbaceous plant covered area.
Pocket	Restricted presence, especially to around trees and tree clumps, but otherwise not generally spread over the whole area.
Moderate	Wide-spread over the whole area in equal proportions to moderate herbaceous plant layer.
Heavy	Predominence of soil mounds on bare soil or sparse herbaceous plant cover.

3.5 THE PHYSICAL ENVIRONMENTAL FACTORS

3.5.1 General.

The physical environmental factors were divided into two main categories - those that varied on a daily or seasonal basis and those that were permanently fixed. The first were referred to as environmental variables while the latter were called the environmental invariables.

3.5.2 The environmental variables.

The following environmental variables were observed and evaluated:

3.5.21 Surface water: its presence was recorded whenever it was encountered inside the strip-width during the aerial survey observations. The nil record indicated absence.

3.5.22 Temperature and Wind: data for these were obtained from the Tshane Meteorological Station in the study area and the overall monthly summaries for the area, from the Gaborone Meteorological Department Headquarters.

3.5.23 Rainfall: rainfall and cloud cover were recorded qualitatively during the aerial observations. Quantitative data were obtained from the Tshane and Gaborone Meteorology Stations.

3.5.3 The environmental invariables.

Data for mapping the distribution of environmental invariables like pans, sand-dunes, drainage systems and soils were extracted from Landsat imagery. Although their presence was also recorded during the aerial surveys, the information obtained from Landsat imagery was found to be more useful because of its synoptic nature. The imagery was therefore used as the main data source, except in the case of soil characteristics which could not be easily read from the imagery, because of vegetation cover influences. In that case the information obtained from the Landsat imagery was supplemented with that obtained from the aerial and ground observations.

In inspecting soil distributions in this study, it was found easier to identify the soil categories, from low level flying, initially by local nomenclature then use the descriptions of Leistner (1967), Eldridge and Bulawa (1978), DHV (1980) and Mafoko and Kgatlwane (1984) to allocate them to appropriate groupings. As will be seen in Chapter 5, local names are more specific and less descriptive and make field recording, especially aerial, easier. Ground inspection confirmed this usefulness.

To obtain data from Landsat imagery, prints covering the study area, at a scale 1:250000 were obtained for different seasons during the study period. These were then interpreted in terms of presence and distribution of pans, san-dunes, drainage patterns and identifiable soil characteristics.

3.6 LANDSCAPES.

The physical and biological (flora) factors are usually combined to delineate land systems. A land system is defined in terms of an area with recurring patterns of topography, soils and vegetation (Department of National Development 1979, Townshend 1981). In order to delineate land system, it may be necessary to delineate first land regions which may be decided principally on the basis of surface relief charactersitics i.e. landforms.

Information of soil and vegetation types may be available from several sources including satellite imagery, aerial photographs and field observations.

Although it would have been preferable to delineate land systems in this study, the final map scale was found to be too small for sensible delineations. Land regions and landforms were instead mapped. To delineate land regions, the Landsat images were inspected for areas with similar topographical features and these were then mapped. The landscape map was then produced.

3.7 LAND USE PRACTICES

3.7.1 General.

Several current principal land uses were investigated in order to relate their distribution to those of domestic and wild animals and to look for effects of land uses on animals. Stated national policies, where they existed for each land use practice, were studied and occasionally supplemented by inter- viewing the senior management personnel of the respective managing Government Ministries.

3.7.2 Settlements.

Existing settlements were identified from the current maps. Temporary settlements were identified from aerial observations and from oral enquiries from members of the remote-area-dwelling communities, composed primarily of Basarwa (Bushmen) tribes.

Permanent settlements were those villages which were known to have existed at their present locations for no less than fifty years, while temporary or new settlements were those which were occupied on a seasonal but regular basis.

3.7.3 Communal areas.

These were areas in the immediate surroundings of the permanent settlements and used communally for grazing and ploughing. A more or less arbitrary radius of ten kilometres from the centre of the village was taken as communal land. The distance of ten kilometres was partly based on the understanding that it was likely to be within grazing limits of cattle if they had to drink on a daily basis. Water points were all at the centres of villages.

3.7.4 Cattle ranching.

Distribution of existing cattle ranches or farms was mapped from Landsat imagery and locality maps. New, undemarcated or planned ranches were mapped from the ranch locality plan sheets.

3.7.5 Conservation Areas.

The national park boundary was mapped from existing national maps while the wildlife management areas were mapped from their proposed site maps. The wildlife management areas are proposals of the late 1970s.

3.7.6 Mineral prospecting sites.

These were identified by the existence of ground traverses or cut-lines put in by geological surveying teams. Prospecting areas were also mapped from locality sites of prospecting licences issued by the Botswana Department of Geological Surveys to the various mineral prospecting companies.

3.7.7 Communications.

Roads (graded) were mapped from Landsat imagery. Tracks were mapped from existing maps supplemented by field observations made during the aerial and ground reconnaisance.

CHAPTER 4

THE FEASIBILITY OF AERIAL ANIMAL SURVEYS

4.1 INTRODUCTION

Surveying in this study is defined as an organised search for some element or elements of the environment to establish their presence or otherwise, their quantity and/or their quality, and their distribution. The elements of the environment considered are the biotic ones (animals and vegetation), the physical (soils, physiography etc.), land uses, meteorological (temperature, rainfall, cloud cover etc.) etc. These are discussed in details in Chapters 2 and 3.

Some of these elements, like many physical ones, may be inventoried in a once only survey. Others, like seasonal changes in vegetation condition and seasonal changes of animal densities and distribution, require repeated surveys. This chapter reviews the feasibility of these repeated surveys in so far as they apply to aerial surveying of animals in this study. It is important that the techniques used in repeated aerial surveys of animal densities and distributions must be maintained the same between surveys to ensure that differences in the data depict actual distribution changes, and do not result from differences in survey techniques. The steps taken to maintain standard conditions in all the repeated surveys in this study were discussed in Chapter 3.

4.2 HUMAN FACTOR IN AERIAL SURVEYING

4.2.1 General.

Any surveying makes psychological and physiological demands on the surveyor. The quality of the data collected and results obtained from analysis of the data is therefore dependent upon the observers' state of mind and physiological condition. Although the presence of these physiological and psychological problems of aerial survey are recognised (Mence 1969), their analysis and quantification does not seem to have been attempted.

Several steps are involved in counting animals from the air. They are:

(i) <u>Search</u>: a process whereby there is a deliberate visual hunt for the animal;

(ii) <u>Location</u>: the actual sighting of an animal;

(iii) <u>Identification</u>: the recognition of patterns on the animal that will classify it in a certain often preconceived category of species or sex or age-class; and the

(iv) <u>Actual count</u>: where the sighted and identified animal group is enumerated.

All these steps require concentration if consistent and meaningful observations are to be recorded. However, concentration itself is a state of mind and is subject to influences from within and from outside the body i.e. the physiological and external stimuli.

<u>4.2.2 Psychological</u>.

Several factors may lead to loss of concentration. These are:

(i) <u>disorientation</u>: when in flight, the aircraft banks in course corrections, going into or coming out of a transect, and as in turbulent conditions. When the aircraft stabilises again for level flight, the observer may have become disorientated. Since it is natural to be always aware of proper directions, an observer will unconsciously stop concentrating on the steps enumerated above, while he is trying to re-orientate himself. During this state of mind he might not register sightings of animals even when he sees them.

(ii) <u>distraction</u>: the observer, while searching, might detect a scene that takes his attention away from what he was searching for. For example, he might come up against a carcase being fed upon by vultures. His attention is immediately diverted to this spectacle and he ceases to search for the animals he is supposed to observe. He will resume the search again only when the scene is out of his sight.

(iii) <u>drowsiness</u>: an observer confined in a small space such as a cockpit of a light aircraft, with a monotonous and lulling drone of the engine, encountering occasional groups of animals after long intervals of flight, may doze off. He cannot detect any animals while in that state.

(iv) mesmerisation and hallucination: staring at the ground for a long time without encountering any animals may lead to mesmerisation, where the observer may be just looking, seeing things down there but not consciously registering their presence or nature. This may include his seeing the animals he is supposedly looking for and still not consciously register their presence. Mesmerisation may also lead to hallucination where imagined things are seen as if real.

(v) mental fatigue: in cases where observations have been going on for too long, and the observer has made a consistent and sustained effort to stay vigilant, a threshold is sooner or later reached where he cannot maintain himself in a state of mental alertness simply because he is mentally tired from concentrating. When he reaches that stage the degree of concentration is diminished. The Australian National Parks and Wildlife Services and CSIRO provide for relief by allowing recording intervals during which there is a break from observation while the counts are recorded. The advantages and disadvantages of that procedure have been discussed in Chapter 3.

4.2.3 Physiological tolerances.

Physiological tolerances of the body also have influence on concentration. Concentration can be maintained if there is some moderate degree of comfort. Comfort generally is lacking in a light aircraft.

Discomfort may be brought about by several factors:

(i) nausea and vomiting: during flights some people become nauseated and may vomit. It is almost, if not absolutely, standard practice to carry "sick-bags" in the aircraft. Vomiting is not only painful but also messy. Even some apparently hardened flyers including pilots may succumb. During the fieldwork part of this study, on one occasion a second pilot joined the observation team and when he was informed he was going to occupy the rear-most seat in the light aircraft, he was particularly worried about probably becoming sick.

The rear-most seats are the most uncomfortable as they are too far off to the back, off the centre of gravity of the aircraft and subject to greater instability. The stability, and therefore relative comfort, improves towards the front and an observer who otherwise vomits when in the rear seat may be comfortable and not vomit in the front seat. The front seat is therefore likely to be the most preferred observation point.

During vomiting, the observer's attention is taken away from observation. This process may last for some time even up to five minutes and the lingering after-effects may increase this period. Thus flying at 160kph means a distance of about fifteen kilometres may be covered in that five minutes before an observer has recovered well enough to start observing again. On this survey that would mean three five-kilometre grid-cell sub-units would have passed unobserved. Drowsiness may follow the vomiting session often not immediately but after about fifteen minutes or so. In this study, the combined fraction of observation flight time spent nauseated and/or vomiting on average by all sick observers was estimated at 5% during the November 1983 and January 1984 summer surveys each, while during the cooler period of April 1984 to August 1984 surveys, this fraction was estimated at 2% each survey. The September 1983 and 1984 surveys averaged between the two extremes. The lingering after-effects of nausea and/or vomiting most probably increased this fraction.

Some of the additional causes of nausea and vomiting include excessive intake of food or alcoholic drinks before flying, indigestion and constipation. A reduction or avoidance of food or alcoholic drinks intake before flying may improve the situation. However, indigestion and constipation may be lingering after-effects of the previous day's or night's feeding and these are hard to control. They cannot be controlled by taking laxatives before flying for that would induce a situation much worse than vomiting. It may be possible to use drugs that control nausea but their side-effects must be of the types that do not lower psychological or other perceptions. The best overall general control would appear to be a strict choice of types of foods and the quantities eaten, both before each daily observation flight and after the last observation flight for the day. In brief during the survey period, observers who usually succumb to this problem must modify their eating habits.

Despite the above, not all observers suffer nausea. For those who do not suffer, regulation of food intake, but not alcoholic drinks, is not important. Alcoholic drinks, other than having influence in stomach upsets, also dampen mental perceptions and judgement which in turn affect concentration. Control in the case of alcohol therefore is by avoidance of intake.

(ii) <u>urination:</u> the degrees to which individuals can contain urine differ. Some will have higher frequencies of urination than others. A full bladder induces considerable physical discomfort. Since a fixed-wing aircraft cannot land just anywhere on request, the observer must be able to endure the entire observation flight without clearing his bladder. These may be durations of up to four or more hours before the next landing.

Although it may be possible to use bottles as urine receptacles in flight, it appears it is not a regular practice to carry these along. However, their use would mean the observer must temporarily cease observing while he voids urine. Another disadvantage is that female observers would have difficulty using them.

The main causes of urination are the types and quantities of fluids consumed. Drinking too much water or fruit juices, or eating high-water-content fruits like oranges and watermelons leads to a greater kidney filtration activity. This results in rapid accumulations of urine in the bladder until some threshold is reached when the bladder must be cleared. At this point the containment of urine is both physical and mental. If this is prolonged a breakdown may occur and the urine must then be voluntarily voided or else involuntary action takes over and urine starts flowing.

(iii) <u>posture discomfort</u>: Observation flights require a certain sitting posture to be maintained by the observer for the entire duration of the flight. A change of that posture may mean a different observation angle and therefore an altered strip-width. The subsequent biases and errors associated with changing strip-widths discussed in Chapter 3 are then introduced.

The standard sitting position is facing front but with the head turned sideways and the eyes looking out and downwards. This strains the neck muscles and in order to relieve them, the tendency is then to twist the body sideways. This then strains the abdominal muscles and creates pressure on the waist. A relief may also be obtained by adjusting the seat and leaning backwards. These turns, strains and pressures are painful and they cannot be ignored by the observer. There therefore is always divided attention between observation and correction of sitting postures. Besides this element of divided attention to observation, the viewing or observation angle can never stay the same.

The instability of the aircraft is an additional cause of discomfort. The rolls, bumps and vibrations as well as noise add to the discomforts of flying.

(iv) cabin temperature and heat stress: summer is the most uncomfortable time to observe in. Cabin temperature rises very rapidly and in a non-airconditioned cabin it may exceed the external air temperature. In this study the cabin-mounted thermometer showed cabin temperature 9 to 10C° higher than external air temperature as long as the sun shone into the cabin. These high cabin temperatures, ranging between 34° C and 39° C depending on the time of day caused considerable discomfort. Vomiting occurred in summer when the cabin temperature rose above 34° C in calm weather although it occurred at temperatures as low as 28° C in windy conditions in all seasons. High temperatures also induced a lot of sweating. Sweating usually preceded vomiting.

The combined effects of sweating and vomiting meant the observer was also losing mineral salts from his body. This in turn would lead to other problems like drowsiness, headache and general lethargy. This most likely reduced the efficiency of the observer.

Winter and cool days observations were found more comfortable. Cool days in summer were always associated with presence of cloud (58% and 21% cloud cover in November 1983 and January 1984 surveys respectively). This also meant animals were out in the open more. Observations made during these times may be expected to have been better than those made during the high-temperature high-heat-stress period. The bitter cold of winter (an average of 1° C in the June 1984 survey) was only felt before take-off since after take-off the heater could be turned on. Therefore only high temperatures with their associated heat stress are considered not suitable for observation flights.

(v) height: air is densest near the ground and becomes thin with increase in altitude. This air can induce rapid onset of fatigue, headache, drowsiness and general lethargy. However, a height of 90 metres, the survey height, is not considered high enough to create this problem, but then individual people respond differently to different levels of stimuli. Only experimentation could conclusively determine the extent.

(vi) odour: The cabin of a light aircraft is small. This means a smell of anything soon spreads throughout the cabin and may induce various reactions, the most common being nausea and vomiting. Sweat, tobacco smoke, vomit, rectal gas and bad breath are some of the things that have offensive and uncomfortable smells. Other than tobacco smoke and bad breath, these can be very difficult to control. No observer can be insensitive to these odours and while the reactions to them may differ between individuals, they cause attention even if momentary, to be diverted from observation to them.

Although attention has been focussed on observers mainly, pilots are not likely to be immune to the discomforts of flying. Just as the responsibilities of observing are the observers', the pilot's responsibilities are for proper flying. Lack of concentration could have more disastrous consequences than the observers' failures. However, pilots can be relieved by autopilots as far as maintaining flight is concerned but not in relieving full bladders. There is therefore an equal need for pilots to modify their habits including eating ones during surveys if they are to maintain proper levels of concentration.

4.3. ANIMAL BEHAVIOUR AND CHARACTERISTICS

4.3.1 General.

Animal behaviour is another factor that requires consideration in evaluating feasibility of aerial surveys. Different animals respond differently to presence of the aircraft. Their daily activities, responses to weather conditions, movements, and ease of identification are also matters of importance in aerial survey.

4.3.2 Presence of aircraft.

An aircraft is noisy. Flying low also produces some reactions from animals. Some animals may hide when they hear an aircraft flying overhead while others will flush and run. Cryptic animals like kudu and big cats are difficult to survey from the air because they will hide rather than expose themselves. This may then produce highly biased observations.

Other species like gemsbok, eland, hartebeest, wildebeest and springbok will flush when they detect an aircraft flying overhead. The fleeing animal may go in any direction, but it appears they almost always flee off the direction of the aircraft's flight. This means they flee generally perpendicular to the strip flown. Such fleeing directions mean an animal may be able to leave the strip-width as marked by the streamers before it is counted and it is therefore left out of the counts. Since the fleeing reaction is an escape from the aircraft, a net loss of counts may be experienced as there will be no animals likely to run towards the aircraft and therefore into the strip-width observed. This net loss of counts may create a false impression of low densities overall. Secondly, an observer who sees animals that a while ago were inside the strip-width and are now just outside, may be tempted to count them as if they were inside the strip-width. This would also bias the counts towards higher densities. It should be noted here that counting animals outside the strip-width is likely to be difficult to correct for even mathematically because the areal extent outwards away from the streamers, over which counting took place, can never be known and can never be uniform. This is the reason why there is always strong emphasis not to count any animals outside the strip-width. In this study, however, in most cases (over 80%) animals started fleeing when the aircraft was almost over them. By then they had been counted.

4.3.3 Weather and Vegetation Cover Influences.

Hot and sunny weather tends to drive animals into the shade. This means the animals become partially hidden. Unless they flush and show, they may be missed altogether. Cold weather on the other hand encourages animals to go out into the open. This means more animals are sightable and may be counted. However, the thicker the cover, the more difficult it is to see the animals even when they may not be deliberately hiding. This means animals that prefer denser vegetation types are liable to be undercounted more than those which prefer open vegetation types. The study area is mainly open woodland to grass savanna. Bayliss (1980) has examined the effect of weather on kangaroos' sightability as well as the effects of vegetation cover on their visibility. He has demonstrated the importance of these factors in aerial survey.

4.3.4 Movements.

Some animal species are highly mobile. The wildebeest for example is probably the most highly mobile species in the study area. This mobility creates a possibility for double counts of groups. For example if the transects are spaced 10 kilometres apart, it is possible for a group counted in the last transect the previous day to have moved into the next unobserved transect 10 kilometres away by the following day. This group may then be counted again when this next transect is flown. However, it is assumed that any movement into the transect is compensated for by movement out of it. This assumption presupposes the movements are random but fails if the movements are directional such as in a migration.

4.3.5 Identification.

When a search is made and the animal is seen, it has to be immediately classified into any of the categories known beforehand. The categories may include the member species, sex and age. The study may require classification into all the three categories. However, in aerial counts, concentration is on identification and counting the identified members of the species. Colour is probably the single most used identification mark with other characteristics used as back-up.

However, in some cases some species have more or less similar colour such as the eland and the kudu. In a multi-species survey, these may be found occurring together. The identification process has to sort them out before they are counted. Secondly, the young of some species, for example the blue wildebeest, does not have the same colour characteristics as the adults. These young must also be sorted out into the right species group before counting. Thirdly, the young of some species may resemble in colour and size, the adult of another species, for example a young hartebeest has an almost similar colour characteristics and almost as big as the steenbok, and when slightly grown almost resembles the colour of a springbok being almost the same size also. The young of one species may also resemble in colour the young of another species, for example the young of wildebeest, gemsbok and hartebeest look almost alike for about a week after birth. To the observer who is familiar with all the species studied and the characteristics of their young, the distinguishing characteristics are obvious. The inexperienced observer will fumble. However, the process of sorting and counting even to the experienced observer is related to time and must influence the final count. Ten seconds is not adequate. In multi-species observations, encounters of all species of interest in a group or locality with their respective young, during their common breeding period may occur with regularity and in such a case the counts are likely to be even more incorrect. In this study, associations of eland, wildebeest, gemsbok, hartebeest, springbok and their young occasionally all occurred in the same herd betweeen September 1983 and April 1984.

4.4 OTHER ENVIRONMENTAL FACTORS

4.4.1 General.

Environmental factors such as visibility, temperature differences, rainfall, wind, vegetation and terrain conditions also play an important role in aerial survey of animals. Their influence on distribution of animals has to be considered in the design of any study in which the aerial survey technique is used. In such a design the obstructive influence of these factors in the actual counting process has to be planned for.

4.4.2 Terrain.

One advantage of flying is that the observation platform is raised to some height and from that vantage point a wider area is examined. In other words, it enables a more synoptic appreciation than the ground survey of the area under observation.

Because of the elevated and mobile observation point, obstacles such as thick forests, ditches, rivers, hills etc. can be overflown without having to divert the direction of surveying movement. Caughley and Grigg (1981) undertook an aerial survey of about 207000km^2 of South Australia in which six large lakes as well as parts of the Flinders range of mountains had to be overflown. On the ground these barriers would have been insurmountable and skirting them would have meant more time and navigation problems.

Secondly because aerial survey is fast, it enables big areas to be covered relatively quickly and cheaply. The South Australia study referred to above best illustrates this point. It cost about $17000 altogether or about $0.08 per km² at 1 per cent sampling intensity.

4.4.3 Visibility.

Perhaps the most commonly discussed of the factors influencing accuracies in aerial surveys is visibility. Caughley (1974) and Bayliss (1980) have given a comprehensive cover of the various aspects of this factor. Visibility problems have been discussed in Chapter 3. From those discussions it was concluded it was difficult to quantify all aspects relating to visibility. This means the causes of the visibility problems have to be reduced by rigorous practical control procedures. However some of these causes, like vegetation cover influences, are difficult to correct for quantitatively where many vegetation types are involved. They are equally difficult to minimise by practical control procedures.

Two other aspects that may contribute to visibility problems are those of reflective coats of animals and blending with the surroundings. The phenomenon of "shining" animals has been mentioned by Smithers (1971) in relation to the red hartebeest. He said some markings on the red hartebeest had irridescence which in some lighting conditions gave them a "plum" sheen. The irridescence could be so pronounced in some lights that when the animal stood facing one in bright sunlight shining from the rear, the markings on the face shone "white as if the face had a white blaze". Finch (1972) has said light coat colours such as of the eland in East Africa are able to reflect up to 22% of incident light, while that of Coke's hartebeest reflect up to 42%. In the present study wildebeest and springbok coats were observed to show some irridescence. In fact the springbok appeared to have noticeably reflective characteristics in the mid-afternoons with the sun still relatively high.

The effect of reflective coats may contribute to the problems of visibility of animals by reducing sightability. The reflective characteristics coupled with vegetation cover and other background objects could make a stationary animal difficult to detect given the shortness of time available to the aerial observer to search. Also animal body orientation and posture in relation to the sun may minimise detectability. For example, an animal viewed from the sunward side may be difficult to see for two reasons - one because of reflection and secondly because it covers its own shadow which would otherwise help in its detection. Viewed from the opposite side to the sun, it is easier to detect because its darker side would be more visible as well as its shadow. Thus animal body orientation in relation to the sun is also an important factor to consider in aerial surveys. However animals tend to assist in their detectability by reacting to the aircraft's presence by moving.

The nature of the background may also play an important part in disguising animals. A freshly burnt area could provide a black background for the blue wildebeest and make it difficult to detect the wildebeest. The red kangaroo *Macropus rufus* is not easy to detect from the air against the red soils. Its white belly and tail tip are often used as identification and locational aids.

4.4.4 Climatic influences.

In addition to the effect of temperature as already discussed, rainfall and wind effects may contribute to problems of counting animals from the air. When heavy rain falls, especially if hailstorm, animals will take shelter under trees. It may also be so heavy that the area below is shrouded in white spray thus reducing visibility considerably. In such a case the survey may not be continued unless conditions show improvement ahead.

Heavy wind creates turbulent conditions and a lot of banking occurs, with the subsequent problems of banking errors. On bare or sparsely covered soils, wind will pick up dust and blow it about. The dust may be heavy and cause considerable reduction in visibility. Animals may also shelter from such dusty conditions.

If wind persistently blows from one direction, it also forces a crabbing flight. The effect of crabbing is discussed later in this chapter.

4.4.5 Vegetation.

Various vegetation types have differing influences on the difficulty or ease of detection of ground based objects being aerially studied. Dense woodland provides a canopy barrier that hides most of what is below it while open woodland will allow more objects to be seen.

At the other extreme, open grassland provides no canopy problem. Large animals are therefore likely to be relatively easier to count in vegetation types providing thin or no canopy cover and become more difficult to count with increasing canopy cover.

Data quality obtained is likely to be better for those species that prefer more open vegetation types than for those preferring dense tree cover. This may be one reason why cryptic animals like kudu are difficult to study by aerial survey methods because they will keep more to dense woods and thickets and are thus difficult to detect.

An aerial multi-species survey must therefore consider the effects of each vegetation type separately for each species, and determine correction factors for each combination separately. This procedure would, without doubt make the exercise that much more involved, and since the correction factors would have to be determined from experimentation the process could become considerably expensive and time-consuming.

One option available is to stratify the survey area by vegetation types and undertake the aerial surveys on a priority basis in each. In this procedure, the stratum with the vegetation type suspected to be the most important is done first, then move on to the next one down the line etc. This way each vegetation type would be treated as an entity in which correction factors could be determined for different species of animals. This would be an ideal situation but would not save on time or costs. Indeed this would mean more dead time spent flying between the strata, for one vegetation type may be scattered all over the study area with intervening different vegetation types. The to-ing and fro-ing would waste valuable time and money.

Another option is to generalise by grouping together the various vegetation types and using one correction factor for all comparable ones. Since the frequencies of occurrence of the various vegetation types are not likely to be the same, the vegetation type with the most occurrence could be used as the standard for determining such correction factors. Aerial survey data obtained from that type of frame would not be of the same quality as that obtained for specific, separately framed and independently surveyed vegetation types.

Since vegetation as a source of food and shelter for the animals must play an important role in animal surveys, its influence in aerial animal surveys requires more attention when plannning surveys.

4.5 SURVEY MATERIALS

4.5.1 General.

Aerial survey is a sophisticated technology. It also carries some risk. Because of these two characteristics, the technique has tended to demand more care and attention than ground based techniques. The equipment used is expensive and requires considerable capital expenditure. It must therefore be well looked after. Human life is universally considered more precious than that of other lifeforms. Risks to it must be eliminated or reduced to insignificance. In aerial survey, the risk cannot be eliminated for the platform is influenced by some forces outside the control of the surveyor. The force of gravity and the atmospheric conditions (heavy or thin air, winds and thunderstorms), controlled by natural laws, are major sources of risk both to the observation team and the platform used.

The equipment used must include mobile platforms capable of maintaining flight in a specified direction. The specified areas must be covered at specified times, heights and speeds. Observations must conform to certain standards as well as the recording methods, for example photographs that are to be transformed to maps must include specified details.

The above are considerations to be borne in mind when planning aerial surveys.

4.5.2 Equipment.

The standard surveying platform for aerial surveys is nowadays either an aeroplane or a helicopter. These provide the surveying platform. Hot air balloons are apparently no longer used for any regular survey aerial work.

The ideal platform should be stable, should provide bird's eye view, should be comfortable and should be relatively safe. The light aircraft is able to provide a bird's eye view while safety is maintained by proper servicing and piloting. Stability and comfort are lacking.

The discomforts of flying have already been discussed. Stability is a problem that no one can do anything about. Convection air currents, wind, the force of gravity, shifting of position or change of posture within the cabin all produce a variation in aircraft attitude. Because of the instability, biases and errors arising from banking and other related changes in attitude instability cannot be eliminated. Instability is characteristic of all the off-the-ground platforms including even the space satellites which are outside the influence of surface winds and storms. Even for these space platforms, there must be a constant check and correction of attitude (Richason Jr. 1978b).

Navigation has been identified as an important element in aerial surveying. Until 1978 when the DHV commenced their studies in Central and Southern Kalahari of Botswana, aerial surveying in the country relied on navigation by the pilot. A pilot can fly straight, in addition to the standard instrumentation of the light aircraft, only by reference to natural features like hills, rivers etc. or by reference to ground installations like navigation markers where the distances are short. Most of Botswana and especially the west is practically flat and featureless.

The use of the Omega/VLF navigation equipment (described in Chapter 3) since 1978, has permitted flying of long distance transects with accuracy. It is now the standard equipment fitted to all the Botswana Wildlife and National Parks light aircraft.

The use of sophisticated equipment calls for availability of appropriate maintenance services. These services are expensive. The capital and maintenance costs of the Omega/VLF navigation equipment are currently too high and are likely to restrict possession and use of this equipment to big public institutions like Governments. However, there are advantages in possessing this equipment for surveying expansive areas which are more or less featureless such as in parts of Australia.

4.5.3 Services.

Aerial survey can succeed only with back-up services, including ground transport and of maintenance facilities with an adequate supply of spare parts for the aircraft, its mounted equipment and the vehicles themselves.

One of the problems of aerial animal surveys is that the temporary base for field operations is usually far away from maintenance facilities. A fault, which may be minor, may end up disrupting the

TABLE 4.1 Survey Phasing as Affected by Problems with Survey Equipment

Survey No.	Scheduled for	Done	Delay	Causes and Results of Delay
1	1983 September 22-27	September 22-27	None	None
2	1983 November 25-30	November 25-30	None	None
3	1984 January 26-31	Jan. 31- Febr. 4	One Week	(1) Aircraft overheated at beginning (2) Navigation system gave trouble towards the end. Last four transects not flown.
4	1984 March 26-31	April 8-13	Two Weeks	Navigation system not working properly at the beginning
5	1984 May 26-31	June 20-23	three and one half weeks	Damage to aircraft by a lunatic on first day of scheduled survey
6	1984 July 26-31	August 29- September 3	5 weeks	Navigation system gave trouble and had to be completely serviced
7	1984 September 25-30	September 29- Oct.3	One week	Damage to aircraft undercarriage in a separate activity

survey by several days to even weeks. Since any fault in the functioning of the aircraft cannot be tolerated, the aircraft has to be flown back to the maintenance depot, which may be several hundreds of kilometres away. There it may spend days to weeks awaiting fitting of some part. In a case where sophisticated equipment such as the Omega/VLF equipment is used, a malfunction of the system, with the aircraft itself operational, still means both must be removed from surveying. The aircraft then ends up being grounded while the equipment is checked and repaired. Where surveys were supposed to be phased at specific intervals, these phases may be disrupted.

The gravity of the above problems manifested itself during this study. The seven surveys were originally planned to be flown at two-monthly intervals but this phasing was not achieved for the whole study. Table 4.1 shows the particular times the surveys were flown as well as the causes and results of the disruptions.

The delays in attending to the aircraft and navigation equipment faults arose in many cases from having to order parts from outside the country. In other cases the navigation system had to be dismounted and sent away for repairs.

Ground transport problems were not acute as there was always some relief vehicle available. However, field break-downs were also common. Vehicles were used for transportation of fuel, extra personnel and belongings and for ground work.

4.6 DATA QUALITY

The problems of aerial surveying discussed above have a bearing on the quality of the data and results obtained. Because some of the problems cannot be corrected for absolutely, assumptions are usually resorted to. The effects of some problems on the quality of data obtained from surveys are examined below.

4.6.1 Assumptions.

In Chapter 3, four assumptions, generally made for aerial animal surveys, were enumerated. The implications of these assumptions are considered.

(i) **Assumption 1:** That the whole sample area is searched.

Here the sample area refers to the transect and its sub-unit portions defined by strip-widths and marked by streamers for searching.

The psychological and physiological problems of aerial observations have been discussed above. The eye that searches, locates, identifies and counts the animals is subject to eye fatigue. Various problems lead to loss of concentration. The type and condition of vegetation, the weather and other factors all make searching of every square metre of the sample area difficult. It is impossible to estimate how much area, even under considerable concentration and optimum visibility conditions is left unsearched. There is no systematic search pattern that the eye must follow. There is thus a random darting to and fro, back and forth, and doubling-over searching movement. This search is also influenced by the limited time available to fly past a particular point. Thus the time available to search, chaotic eye-search pattern, the fatigue status of the eye, the size of the area to search, the influence of the various visibility factors, make it difficult to search the whole sample area.

Methods for quantifying biases and errors do not seem to include this factor of search efficiency. Since the seriousness of this search efficiency factor has only been considered but never quantified (Hone, 1981) the quality of data and results obtained from aerial animal counts still requires improvement.

(ii) **Assumption 2:** That all the animals in the sample area are located.

This assumption is closely related to the first. It is now generally accepted that not all animals in a sample area are usually located. Locatability or sightability of animals is also a function of behaviour of animals, weather conditions, vegetation type and conditions, lighting conditions and other factors listed in Chapter 3. It is also a function of search efficiency. If an animal happens to be on that spot that is missed during the search, then it will not be located and it will not be counted.

Visibility and counting biases which are usually determined to provide correction factors for animal counts, help in improving the quality of data that is otherwise diminished by the sightability or locatability factor. The quantification of these biases, however, only considers some of the factors and does not provide answers to all the contributory influences. If it was possible to locate and count all the animals in a survey, there would be no current argument about whether counts can be used as accurate population measures or as indices of population measures, neither would there be a question of having estimates instead of exact population numbers.

(iii) **Assumption 3:** that the sample fraction of the total area counted contained the same fraction of the overall population.

This assumption presupposes that the population distribution is uniform. It is highly unlikely that there is ever a uniform or normal distribution of wild animal populations. This means random or systematic surveys will cover some areas that have no animals in them at all and miss out on others that have animals. A skewed distribution means no uniformity, and in such a situation the counted fraction may not contain the same fraction of the overall population in the whole survey area.

(iv) **Assumption 4:** That the sampled area is representative of the entire study area.

Study areas will invariaby have different types of soils, vegetation, topography, landscape and where inhabited will also have land use types such as farming areas and settlements. Each sample area is therefore unique in many ways. Because there can be differences in habitats within the study area, the sampled area will not be representative of the whole study area. However, in a systematic survey, all the various sectors of the study area are covered. This means, although the sampled areas may not be representative of the whole area, by covering more sample areas, an approximation to such representativeness can be made.

From the foregoing, it can be concluded that the assumptions are adopted only to try and by-pass unsurmountable problems but not to provide solutions to the problems themselves.

4.6.2 The Counting Bias.

In Chapter 3, a laboratory method for determining counting bias in this study was described. One of the results of that method showed that an observer could have a counting correction factor of more than unity. The application of this correction factor to any counts would have the effect of lowering the count. No observer ever counts one hundred per cent of what he sees (see Chapter 3).

Some of the shortcomings of the method employed in this study for determining correction factors include the influence of speed, behaviour of animals, boundaries of the strip and the effectiveness of artificial noise created. Counting animals from the photos is not the same as counting the animals from the air. When counting the animals from the air, several other influential factors are present - the relative speed of the aircraft, movement (which may involve hiding, flushing or running) of the animals, the extent (boundaries of the strip) of area over which a search is made as well as visibility factors. The effect of each on counting of animals from the air has been discussed. However, counting from photographs reduces some of those effects to zero. Some of these factors are examined below.

There are two methods which can be employed in determining counting error using photographs. One, under laboratory conditions, involves using photographs to simulate the counting arena. The photographic slides with a known number of animals are projected onto a screen and the observer is asked to count the animals in the slides for a given length of time. Alternatively the observer is given photographs with a known number of animals and asked to count animals on them for a given length of time corresponding to the approximate time usually available when counting from the air. The counts the observer makes are compared with the already known photocounts on the slides or photographs and the ratio is taken as the counting error. It is then used as the correction factor for his subsequent field counts. This is the method which was adopted in this study.

The second method, which is field based, involves the photographing of a herd that is also being visually counted then later comparing the visual counts with the photocounts. That ratio is then taken as the counting error and is used as a correction factor for the observer's subsequent field counts.

These two methods have one thing in common. Both use photocounts as the accurate counts. Photocount in this section refers to counts made from photographs by slowly counting and recounting until there is a definite conclusion that a specific number of animals is on the photograph.

Photocounts are considered accurate because they are obtained under the most favourable of conditions. The influence of aircraft speed and instability does not exist, the rate of search is reduced i.e. a long deliberation can be made over the photographs, the animal movements do not exist and the strip-width boundaries can be re-emphasised by shielding off the area outside the strip-width. A close-up inspection can be made of the photographs. Although visibility factors cannot be reduced to zero, like many of the factors above, they are nonetheless held constant. This means, for example, only one type of vegetation can be represented at any one instant of time when the photograph was taken. It does not thereafter change. The visibility conditions as represented on the photograph may also be unique to that particular site at that particular time.

Caution is expressed on applying correction factors obtained from photocounts, be it under the first or second method. As shown above, conditions will be peculiar to the site of the photograph from which photocounts are made. It has already been shown that as the aircraft moves along many factors interact with the observer and influence his counting ability. This means the counting proficiency and therefore error will vary with conditions. It was shown in Chapter 3 that there was a need to develop separate correction factors for different sizes of animals and secondly different correction factors were required for different vegetation types and cover. It has also been shown under Assumption 4 in this chapter that each sample area or site is strictly speaking unique. Therefore, applying a correction factor derived from a few photocounts taken from unrepresentative sites under unique conditions, to the rest of the counts in the study area may diminish the quality of the results.

4.6.3 Effects of Crabbing on Strip-width Counts.

When the strip-widths are marked on either the aircraft windows or the wing struts, it is usually assumed the aircraft will be flying straight over the transect centre line with the streamers position over the strip-widths position on the ground [Fig. 4.1(a)]. The atmospheric disturbances, especially wind, usually cause a change in attitude of the aircraft so that instead of flying straight with the nose over the transect centre line, it flies sideways (crabwise) at an angle to it [Fig. 4.1 (b) and (c)]. This is called crabbing. The nose of the

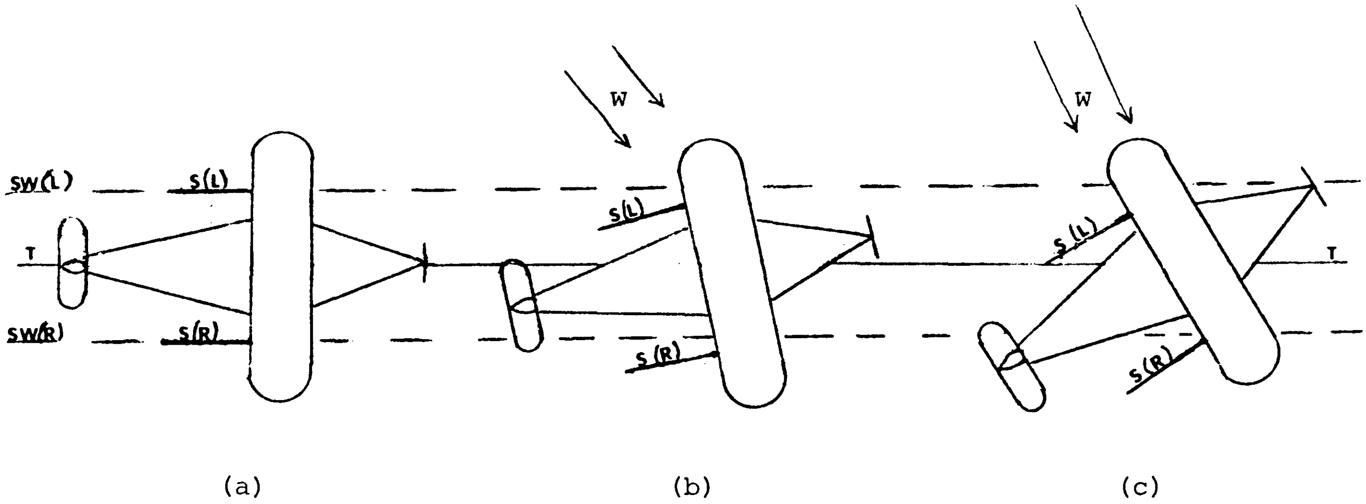


FIG. 4.1 Crabbing Attitudes

SW(L) =	Strip-width left	S(L) =	Streamer left
SW(R) =	Strip-width right	S(R) =	Streamer right
W =	Wind direction	T =	Transect centre line

(See text for discussion)

aircraft is usually turned into the wind to maintain the bearing of transect flight otherwise the aircraft is blown off course and transect. The degree of turn into the wind is determined by the strength and direction of the wind as shown in Fig. 4.1 (b) (c).

When the crabbing attitude is adopted, the marked strip-widths as defined by the streamers S(L) and S(R) on the aircraft cease to be parallel to the strip-widths SW(L) and SW(R), on the ground to the transect centre line T. Fig. 4.1 (a), (b), (c) shows the relative positions of the aircraft nose, the streamers, the transect centre-line and the two strip-widths on either side of the transect centre line.

At position (a) the streamers are directly over and parallel to the ground positions of the strip-widths, with the aircraft nose over the transect centre line. This is the correct heading for accurate positioning of the observers over the transect strip-widths inside which they count animals. Counts made inside the streamers by both observers accurately match the strip-widths on the ground.

At positions (b) and (c), the nose of the aircraft is off the transect centre-line because of wind (W) effect. The streamers are no longer directly over, and no longer parallel to, the ground positions of the strip widths. They are off-set by some angles from the ground strip-widths just as the aircraft nose is off-set from the transect centre-line. The observers are accordingly off-set from the correct position over the ground strip-widths. The left observer now counts the animals in a small part of SW(L) while the right observer counts inside even a smaller part of SW(R). However since the relative positions of the streamers to the aircraft and the observers are unchanged, the observers are in fact still counting the correct streamer strip-widths but in the wrong ground-strip-width positionings.

The counts that each observer makes are recorded in columns corresponding to the left observer and right observer. These are the counts which are then identified with the ground strip-widths SW(L) and SW(R) irrespective of the attitude they were obtained in. It can however be seen that the streamer strip-width counts obtained from positions (b) or (c) would not truly represent the location of the counts on the ground strip-widths.

The second problem with crabbing is that the "correct" strip-width area scanned by the observer actually increases. In normal flight position (a) the forward, backward and lateral scans are confined to the correct limits of the ground strip-widths as defined by the streamers. The correct area is therefore being scanned and the forward and backward scans need no limiting because they are on the correct path. However, in the crabbing position, the streamers are off-set from the correct ground strip-width path, and now define a false strip-width which is now at an angle to the correct one. The scan pattern, although still forward and backward on the now false strip-width, is now actually zig-zag across the correct path on the ground strip-width. Since there is no limitation to the forward and backward extent of this now incorrect scan, a much greater area is covered than the correct strip-width. How much more area is covered can be quantified by evaluating the search patterns. This would mean determining the limits of each forward and backward search pattern outside the boundaries of the correct strip-width path. Unless this is done, the error factor and the extent of bias cannot be determined for the counts.

On this study, the windiest period was August/September. Other survey periods were comparatively calmer. It is estimated that the September 1983, August 1984 and September 1984 surveys experienced about 20% crabbing influence and others about 5% each. Wind blows occurred mostly from around 0900 hrs to 1100 hrs and during the mid-afternoons. Banking was also associated with these turbulent conditions and thus contributed the same relative percentage influences to the respective surveys.

4.6.4 Time-Space Considerations.

Although aerial surveys are relatively fast and usually cover a lot of area quickly, in some cases the survey area may be very big and require several days to complete. The present study area of 42200 Km^2 required about five days to complete.

The east-west straight line distance of the survey area was approximately 290 kilometres. This had to be covered in five days giving the displacement coverage rate of approximately 60 kilometres per day or six by 10-km transect-intervals per day. The north-south displacement for the longest transects was 150 kilometres.

If animal movement is considered, 60 kilometres is not a particularly long distance for trekking animals. Trekking springbok were observed by J. D. Le Riche to cover about 50 kilometres per day in the South Western part of the study area and the Gemsbok National Park (Child and Le Riche 1969), while a herd of eland was observed by E. Le Riche to cover about 80 kilometres in one day in the Kalahari Gemsbok National Park (Parris 1971). Wildebeest spoor left between sunset and sunrise have been followed the following day by the author, on horseback for over 50 kilometres. The significance of these long distance movements on animal aerial counts can be considerable. It can be seen how it becomes possible to double count or do multiple counts of one group of animals that is moving around or in one direction if it can cover up to fifty or even less kilometres per day or per night. It is also possible to miss them altogether.

Animal movements are generally believed to be associated with the search for food or water or both. Animals can apparently sense rain storms and surface water at considerable distances. This means if in one day water becomes available in one part of the study area and the animals sense this fifty, sixty or so kilometres away from where they were counted that day, and they start moving towards this water source, then they may be encountered again the following day and counted again. Where the movement is random, a respite may be taken from the assumption that the multiple counting of one group is counter-balanced by the moving out of other groups before they are counted. The effect of changing vegetation condition on movements may be similar to that of water, for example a lapse of five days is long enough to have herbaceous plants germinate and become green. In this study it was found that a survey could start from one end with the vegetation looking fawn or trees defoliated and by the time it ended, five days later, the trees would be in moderate leaf and the herbaceous layer green. While these differences might have something to do with distribution of moisture gradients, they can also show seasonality and therefore time-changes especially if occurring during the transition season like spring (September-October). Animal responses to these vegetation condition gradients, if there is no uniformity of condition because of the influence of moisture gradients, may produce the same effect on counts as by surface water changes.

4.7 BENEFITS OF AERIAL SURVEY

Although much of the foregoing review has concentrated on identifying problems of the aerial animal surveying technique and in the process has tended to identify its deficiencies, the technique still has considerable benefits. Other than being fast, able to overcome the problem of physical obstacles, and relatively cheap, a lot of other information on the environment can be gathered on the same survey. Chapter 3 has already identified areas where information was also gathered on the environment during these flights in this study. Such information may help explain the patterns of observed distributions and this can be more rewarding for management purposes than absolute counts which have limited use.

The various types of information that can be obtained from aerial surveys in addition to animal counting have been elaborated by Jarman (1979). This information includes among other things, recording of sex and age categories of animals seen, within-group dispersion characteristics, activity patterns of individuals sighted, observed habitat usage or avoidance as well as other environmental factors. Suffice it to say much scope exists for the technique to continue to be one of the most favoured when large areas are to be surveyed.

4.8 SUMMARY

Aerial animal survey is a complex technique. Considerable strides have been made over time to refine it but its technicians still face considerable problems and challenges in perfecting it. This review has shown that problems arise from the human biological limitations of the participants in aerial observation. No degree of planning can wholly overcome these limitations. The animals themselves behave and react unpredictably both in response to the presence of the survey equipment and independently as components of the ecosystem. The physical environment imposes certain restrictions on accurate counting.

The recognised effect of these combined problems is the reduced confidence in the quality of the data collected under their influence. The impact of this set-back has been reduced by meticulous planning of aerial surveys. Where practical steps can be taken to lessen the impact of some of these problems, these are usually incorporated in the design of the survey. The additional move to reduce the impact of the set-backs is by identifying those factors whose influence can be quantified. The quantified values are used as correction factors. However not all the problems have been overcome and therefore the technique must continue to be refined. Because of the foregoing, counts obtained from aerial surveying are best used as indices and not as absolute population measures because they would not be best suited for the purpose. Absolute population numbers as Caughley (1977a, 1979b) says, are in any case unnecessary luxuries, and serve minimal management purposes on their own (Jarman 1979).

Despite the operational problems and their partial corrections, aerial surveying has considerable advantages. Besides counting animals, other information on various constituents of the environment can be gathered during the same flight. This is especially important because other methods which are surface-based would require more time, manpower and financial resources to obtain the same information base. Time, manpower and financial resources are usually big constraints in any survey, ground based or aerial.