MONITORING THE ILLEGAL KILLING OF ELEPHANTS

AERIAL SURVEY STANDARDS

FOR THE MIKE PROGRAMME

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TABLE OF CONTENTS

INTRODUCTION

The system for Monitoring of Illegal Killing of Elephants (MIKE) was established under the supervision of the CITES standing committee as a result of Resolution Conf. 10.10 of the parties to CITES. Its main objective is to measure levels and trends of illegal hunting of elephants in Africa and Asia (Doc 11.31.2, presented at the 11th conference of the parties).

Part of the monitoring under this initiative will be aerial surveys of selected savanna sites to obtain estimates of numbers of elephants and elephant carcasses. Such estimates will be repeated over time as a means of detecting changes in elephant numbers and mortality at the selected sites. In order that this be done as effectively as possible, it will be necessary to use methods which are efficient in producing accurate and precise results which are comparable over all sites and which remain comparable over time within sites.

Arising from this is a need for standards to be set as a means of maintaining the uniformity and comparability of surveys. This report has been commissioned by the MIKE project to set those standards for aerial surveys.

There are several types of aerial survey, each appropriate to a different situation, which may be used under the MIKE project and for which standards must be set. The criteria for which method
to use comprise the first standard.

The core of the report is a statement of the standards for each aspect of the surveys. It is not the purpose of this document to write a manual of survey methods - suitable texts already exist and are referred to. However, where this is felt necessary to illuminate the needs for particular standards, additional notes and references have been provided. These have been placed in a separate section in order that the standards remain concise and clear. Appendices have been provided on topics where coverage in detail is more helpful than a reference to literature, ie: calculation of required effort; optimising of effort among strata and sites; Jolly's method ; and specimen data sheets.

AERIAL SURVEY METHODS

As there are a few options for the aerial survey method to use, standards depend on the options selected. The choice of method affects accuracy, precision and efficiency, although differing circumstances may demand different choices and one survey may even be made up of areas surveyed by different methods. There are four different approaches, classified as follows:

- Complete census:
  - *Total counts*
- Sample counts:
  - Fixed sample methods:
    - *Transect sample surveys*
    - *Block sample surveys*
  - Variable sample methods:
    - *Distance counts*

The methods are described well elsewhere (Norton-Griffiths,1978, Gasaway *et al.*1986, Craig, 1993, Mbungua, 1996, Douglas-Hamilton, 1996, Jachmann, 2001) except for aerial distance counts, which are only covered in general terms in Buckland (1993). Distance counts require more equipment, preparation and analysis than a transect sample count, but may add both precision and accuracy. However, the degree of improvement is not known and may be slight for elephants, which does not justify the investment of including this alternative among methods used in the MIKE project, so it will not be considered further.

Broadly speaking, **total counts** are the most precise and accurate, as long as search-rate standards are adhered to (see note 12) . However, there are seldom the resources to carry them out and they should only be considered when there is a precision requirement that dictates a complete census, when a stratum of a survey requires a high coverage within the overall design or when the survey area is less than 100 km^2. Executing a total count of a larger area can prove difficult unless it comprises strata which can be covered simultaneously.

Transect sample counts are carried out when there are fewer resources available and/or when the precision requirement demands a lower sampling intensity than 100%, although for any sample over 70% in a small area it is usually easier, and not much more expensive, to carry out a total count. It can also be practically difficult to meet the assumptions of a sample count for intensities exceeding 40%; in such cases the necessary coverage can be obtained by carrying out two or more independent sample counts at a lower sampling intensity.

Transects should be flown at a constant height, which is only possible over ground which is mainly flat. **Block sample counts** are necessary in mountainous areas, because the sampling units (blocks) can be searched as convenient for flying the terrain - ie not necessarily in straight lines - and height does not have to be kept constant. Block counts can also be done anywhere transect counts can in the event that the additional equipment necessary to fly transects, particularly a radar altimeter, is not available. However, they are much less precise at the same level of effort than transect counts, so the latter are carried out in preference, when possible, to maximise cost-effectiveness.

The above criteria are embodied in the following key, which comprises a simple repeatable protocol for selection of the method.

KEY FOR SELECTION OF METHOD

1a Sampling effort required to meet survey objective (or, in the case of a stratum, sampling effort required to obtain optimum allocation among strata) is more than 70% 2

1b Sampling effort of less than 70% required 4

2a Area to be counted is less than 100 km^2 **Total count**

2b Area > 100 km^2 3

3a Resources are available to cover all subunits, nearly simultaneously, at a search rate of < 1.5 km^2/min **Total count**

3b Not as in 3a 4

4a More than 20% of area has escarpments with slopes of more than 1 in 3 for a height exceeding 200m **Block sample count**

4b Not as in 4a 5

5a Equipment (radar altimeter etc.) necessary for transect-count is in place **Transect sample count**

5b Not as in 5a **Block sample count**

The above is intended for the initiation of a series of surveys. Where previous surveys have been done it may be preferable to repeat the methods in the interests of obtaining a comparable result than to use the strictly applicable methods, as given above.

STANDARDS FOR AERIAL SURVEYS

Superscripts in this part refer to notes in the next section, which elaborate points as necessary.

1 SURVEY PLAN

This section deals with standardisation of approaches involved in planning and design of aerial surveys. The plan will depend on the objective of the survey (see 1.4) and should be clearly stated.

1.1 Boundaries

The limits of the survey area should be clearly defined at the outset and stored digitally. They should conform to agreed MIKE site boundaries.

1.2 Stratification

The survey area should be divided into subunits (strata) which:

X are each of uniform topography and ecology [1]
X contain homogeneous densities of animals[1]
X are large enough to contain more than 20 sampling units at the desired sampling intensity[2]
X have boundaries defined digitally [3]
X are allocated a 2 or 3 character code for identification

1.3 Sampling units

Where the survey is not a total census, a representative sample will be selected. Sampling units can be transects or blocks.

1.3.1 *Transects*

X These must be oriented along[4] the ecological gradient, within other constraints [4]
X They should be selected systematically[5]
X each transect should be described by positions of start and end points. These should be in a suitable electronic format for uploading to a GPS.

1.3.2 *Blocks* [6]

X each block should be a rectangular quadrat no larger than 15 km^2
X should be selected systematically from a grid covering the entire stratum
X each block (quadrat) is described as a vector of the corner points. These should be stored electronically in suitable format to upload to a GPS.

1.3.3 *General*

Each sampling unit should have an ID consisting of a number prefixed by the stratum code, eg ETO03-07 for the seventh transect of the third stratum of Etosha.

1.4 Sampling intensity

The overall effort to be expended depends on the precision required, which derives from the objective of the survey[7] . A 30% population decrease between surveys should be detectable 10 % of the time. Survey design should maximise precision[7].

2 EQUIPMENT

2.1 Aircraft

2.1.1 *Transect sample counts*

Cessna 180, 182, 185 or 206 or Partenavia are commonly used, but others may also meet requirements[8].

2.1.2 *Block and total counts*

Piper Super Cub, Christen Husky, Bellanca Scout or helicopter can be used in addition to above. Other types may also be feasible.

2.2 Strip markers

For transect counts, there must be two markers on each side of the aircraft to mark the inner and outer sides of the strip. These should be rods securely clamped to the struts[9].

2.3 Navigation equipment

A map of the area should be carried (also see 4.4).
A GPS is essential for navigation[10]. It must possess all the following facilities:

X moving map display
X ability to upload and download position information
X ability to continuously record position (tracklog function)

2.4 Altimeter

For maintaining and recording height on transect surveys the aircraft must be fitted with an analogue radar-altimeter. This may be replaced by a laser rangefinder provided equivalent results can be obtained.

3 CREW

The standard crew for a four or six seater aircraft is Pilot, recorder, left observer and right observer.

3.1 Pilot

Commercial pilot or pilot with 1000 hours survey experience

3.2 Recorder

Wildlife biologist with appropriate experience of surveys.

3.3 Observers

Observers should have at least 80 hours of experience. They will have the ability to:

- physically carry out air surveys
- correctly identify species and carcasses
- generate a consistent calibration
- correctly estimate numbers in large groups
- correctly determine whether observations are in or out of strip and estimate number in the strip

For 2 crew operation on a block count, both pilot and observer/recorder must have experience of aerial observation

4 METHODS

4.1 Calibration of transect strips [11]

- Calibration must be done by flying over numbered markers on the ground
- Though left and right values are obtained, it must be carried out for *pairs* of observers
- Height is recorded on each pass overhead the markers
- At least 20 replicate passes should be performed per calibration
- Standard error of mean calibrated strip width should be less than 5% of the mean calibrated strip width
- Strip width should be 300 - 400 m (150-200m per side) at 300 ft. above ground.

4.2 Times / Season

Surveys should preferably be carried out at the best time of year for visibility, usually the cool, dry season. Flights should be at the best time of day for observation, depending on local conditions.

4.3 Speed

Transects and total counts should be flown at 100 mph or less. Blocks (quadrats) should be flown at 70mph or less

4.4 Navigation [12]

Transects are flown by reference to the GPS[12]. The aircraft should remain within 50m either side of the predetermined flight line. Total-count strata are covered using parallel flight-lines about 500m apart, flown by reference to the GPS[12]. Blocks are also covered by flying on flight lines spaced at about 500m[12]. Lines may be curved and orientated as required by terrain. A hard-copy map showing blocks or transects should be carried. Tracks of all flights are recorded on the GPS.

4.5 **Height**

Height is to be maintained close to 300ft above ground when flying transects and recorded every 30 seconds. On blocks and total counts, height is at the discretion of the crew and takes into consideration optimal height for sighting animals as well as safety.

4.6 **Search rate** [13]

Transect and block counts:	1 - 1.5 km^2 / minute (≡ 60 – 90 km^2 / hour)
Block counts with crew of 2:	<1 km^2 / minute (<)
Total counts:	1 - 1.5 km^2 / minute (-5 km^2 / min(300 km^2/hour)in some cases[13])

4.6.1 *Commuting, positioning and counting*

The ratio of commuting time to counting time should be minimised[14]. Records of flying times spent on searching/counting, positioning between sampling units and commuting should be kept[14].

4.7 **Observing - general**

4.7.1 Search pattern should concentrate within the strip, with attention on the inside marker[15].

4.7.2 Observers should restrict attention to the species of interest - in this case elephants and elephant carcasses[16]. Other observations should be secondary

4.7.3 Confirmation that a sighting is within the strip should be made for each sighting by reference to the strip markers[11]. Numbers in and out for groups that are partially out of the strip should be determined[17]. Groups > 25 should be photographed to check the real-time estimate.

4.7.4 On a block count, whether an observation is in or out of the sampling unit is determined by reference to the GPS[17].

4.8 **Observations to be recorded**

4.8.1 *Each flight*[18]

Aircraft registration
Crew names
Time of take off and landing
Survey name
Date
Tracklog[19]

4.8.2 *Each sampling unit*[20]

Survey name
Stratum name
Sampling unit name/number
Time of start
Time of finish
Position of start[21]
Position of end[21]
Height in feet above ground every 30 seconds[22]
Filename for Waypoint[23]

4.8.3 *Each sighting*

Species/observation
Number seen
In or out of strip
Left or right of aircraft
Notes
Position[24]

4.8.4 *Species/observations that must be recorded*[25]

Carcass 1
Carcass 2
Carcass 3
Carcass 4
(Remark whether tusks present in carcass)
Elephants in family group
Elephants in bull group
Other species, depending on local requirements (but see 4.7.2)

4.8.5 Codes used to record species on data sheets should be clear and consistent[26]

5 REPORTING

5.1 Narrative report [27]

This should contain the following elements:

5.1.1 *Background*

- location, dates, area description
- previous information (eg past surveys)
- objective
- design, stratification, sampling
- power of design[28]

5.1.2 *Results*

Tables of results for strata and combined results for strata, separately for:

- elephants
- elephants in family groups
- elephants in bull groups
- carcass 1
- carcass 2
- carcass 3
- carcass 4
- carcass ratios[29]

Each species tables should report, for each stratum:

- estimated number
- number seen in sample
- additional animals seen[30]
- variance of estimate[31]
- 95% confidence limits
- density
- maps for each species/attribute with stratum boundaries and showing sighting positions

There should be a narrative with any other notable results, eg remarks on carcasses seen.

5.1.3 *Discussion*

At least the following should be included:

- difference in numbers and precision compared with previous surveys
- implications of changes in numbers
- implications of carcasses seen
- comments and problems encountered

5.1.4 *Literature*

- Sources for previous information on the survey area should be quoted
- Sources of methodology/design unique to the survey should be quoted.

5.1.5 *Appendices*

- details of methods
- crew details
- sampling information: strata, sampling design, areas, sampling intensities
- flight information: dates and times, sampling flying, positioning and commuting flying
- map of strata and sampling units
- map of strata with tracks actually flown
- calibration data, including variance estimate
- description of file names and formats for digital data submitted (see 6.2)

5.2 **Additional information**

5.2.1 *Original data sheets*

These should be submitted after checking, but without transcription

5.2.2 *Digital copies of data*

- The following information should be submitted on disc:
- Stratum boundaries (GIS vector files)
- Track logs (actual records of tracks flown, in GIS format)
- List of strata with: names, areas and sampling intensities
- List of species/observations giving alphabetic code (used as identifier in digital records of sightings) numeric code and description
- Sampling unit descriptions consisting of 1 record for each unit with the following fields:

    name; number; longitude/latitude of start; longitude/latitude of end; width of strip; time of start; time of end

- Description of each sighting consisting of 1 record for each sighting with the following fields:

    stratum; sampling unit; species alphabetic code; species numeric code; number seen; in/out; left/right; longitude (decimal degrees); latitude (decimal degrees).

NOTES

1. Areas are divided into strata:

- to permit different methods appropriate to the terrain to be carried out in different parts of the area (eg. Gasaway *et al.* 1986)
- to improve precision, given a constant effort, by dividing into areas of differing densities (Caughley 1977; Jolly 1969), where these are known
- to create areas that are easier to cover in a short time (Norton Griffiths 1978).

Where none of these are applicable, stratification is not necessary.

2. Caughley (1977) recommends at least 30 sampling units. This is less important for systematic designs.

3. Clearly establishing the boundaries is usually the first requirement of a survey plan. A series of boundary coordinates stored digitally provide a concise and repeatable description.

4. Along the ecological gradient, eg from river to dry savanna, means cutting *across* ecological zones or zones likely to have different elephant densities; see Norton Griffiths (1978). Transects should also be oriented to avoid flying directly into the sun in early morning and late afternoon.

5. For strict statistical validity, and where distribution information is not a high priority, sampling units should be selected at random (Norton Griffiths 1978; Caughley 1977). The design of the MIKE project also requires this (IUCN 1998). However, systematically spaced transects should be used in MIKE because they are in regular use in existing survey protocols for the MIKE sites, because they improve survey repeatability, give better information on distribution and offer design options such as returning to the same units on successive surveys.

6. For the purposes of these standards, blocks are compact sampling units whose boundaries are completely defined in advance. They are searched until all animals within them have been counted (Jachmann 2001; Mbungua 1996). Blocks are equivalent to what Caughley (1977) refers to as quadrats and are not blocks in the sense of Douglas-Hamilton (1996), who uses the term with reference to strata making up a total count census.

7. It should be determined in advance that overall sampling effort is sufficient to detect a change of the required magnitude (Steidl *et al.* 1997). In the case of MIKE it has been suggested that the probability (given a β of 0.2 and α of 0.1) - of detecting a real decrease of 30 % between surveys - is the target. Overall sampling effort should, as far as possible, be divided among sites and strata so as to optimise the precision of the final result; this is demonstrated in Appendix I.

8. The aircraft type is based on a requirement for a four (or more) seated high- wing aircraft with lift struts to which strip markers may be attached. The type must also have sufficient power to operate safely with full fuel and passenger load under a range of conditions. Those types in common use are listed, but others may fit the requirement.

   For total and block counts, many types of aircraft will suffice, but slower flying types are preferable. Helicopters are necessary for mountainous terrain.

9. Streamers with funnels are often used (Norton Griffiths, 1978) as strip markers. Rods are now preferred (Mbungua, 1996) because they provide a rigid frame of reference within which to count. However, the rod-clamp design must be extremely secure so that the rod position may not move during the survey and so that they are aligned correctly to the line of flight. Streamers are better than poorly designed rods.

10. Garmin GPS 12, GPS II plus or GPS III are ideal. The GPS will be used to navigate between transects, follow the transects and, in block counts, decide whether sightings are within the block. It will also record the track of the aircraft at 20 second intervals and be used to store sighting positions. The GPS will be expected to display transect or blocks in relation to aircraft position during the flight.

11. Calibration methods are described in Norton-Griffiths (1978). The aircraft is flown at a range of heights at right angles to a runway on which numbers are painted at 10m intervals. These numbers should be at least 1m high and spaced at 10metres. Inner and outer numbers within the strip markers are read by observers as they pass abeam. The calibration sheet in Appendix III illustrates what is recorded and how this is processed.

12. For transect and total counts with parallel flight lines, the correct track is maintained by following virtual transects on the moving map display of the GPS. In the case of blocks, the block is located by flying to the virtual block on the GPS, searched by flying lines within the block which are traced on the GPS display by the tracklog function. These are visually kept about 500m apart and the tracks displayed in real time are used to ensure complete coverage.

13. The probability that animals will be seen is strongly affected by height, speed and strip width (Caughley 1974; Caughley *et al.* 1976). Surveys done at different speeds and strip widths are therefore not comparable. A height of 300ft above ground is a standard for most surveys of elephants. As a measure of comparability, it has become common to characterise surveys in terms of searching rate, which integrates strip width and speed and which is expressed in area searched per unit time (eg Said *et al.* 1995) or time to search unit area (eg Gasaway *et al.* 1986).

    Most series of sample survey for elephants have, by trial and error, converged on a search rate of approximately 1km^2/minute. Total counts seldom come near this rate, which is not too much of a problem, provided that a total and sample count of any area are not compared. (For comparability with previous total counts in areas of good visibility it may be necessary to use search rates of up to 5km^2/minute). However, common standards should enable the broadest possible comparability - there is no reason why a total count may not be considered equivalent to a 100% sample count provided search rates are similar and therefore no reason why a stratified sample count should not include some strata which are totally counted. In block (quadrat) sample-counts, where blocks are flown as a total count would be, it is important that search rates are comparable with other sample counts. Where there is a two-man operation and there is, in effect, only one observer per side, search rates should be better than 1km^2/minute.

14. Much of the flying on a survey is "dead time" - time not spent counting but commuting from base to the survey area, positioning between sampling units on a sample count or turning outside the stratum onto the next flight line in a total count. It is not possible to set standards for proportion of time to be spent counting, but records should be kept. This is facilitated by the times recorded on data sheets (times of take-off and landing and start and end times for transects, blocks and flight-lines - see Appendix III). The on-site coordinator should also keep records of flights with no survey component, eg commuting and calibration flights, for accounting purposes.

15. The way the strip is searched affects the potential for undercounting bias: too much time spent searching the far side of the strip or beyond may result in nearby animals, which should be the easiest to see, being missed. This would result in more of an undercount than missing difficult-to-see animals. The observers' attention should, therefore, be on the inside edge of the counting strip, sweeping the field of vision out to the far edge every few seconds. This is known as "guarding the line" in distance sampling (Buckland *et al.* 1993) and although the MIKE surveys will not be distance counts, it is nevertheless a useful detail to borrow from that methodology.

16. The species for which the observer develops a search image will tend to be seen preferentially. It is therefore essential to ensure that the observers have a search image dominated by the species of primary interest. In the present case this is elephants, although priority should be given to elephant carcasses, which are difficult to see and difficult to classify into the four categories but which will nevertheless give better information on population status than the numbers of live animals.

17. The decision point on the strip marker should be marked with tape and should be the same point at which calibration sightings were made (ie the point abeam the observer). For blocks (quadrats) in/out decisions are made with reference to the GPS navigation system which shows the position of the aircraft in relation to the block boundaries, shown as a virtual block on the GPS moving map display.

18. Only the top sheet need be filled in for some information, but date, times (at least am or pm) and aircraft registration, must appear on all sheets - examples of data sheets are given in Appendix III.

19. The tracklog facility (which keeps a continuous record of position) of the GPS should be set to record while the survey is being carried out. The recording frequency should be set to 20 seconds.

20. With transects, a separate sheet should be used for each, as some information (mean height, start and end information) will be different for each transect. With blocks this wastes paper - several can be put on each sheet, but each must be ruled off at start and end and the start and end time for each recorded on the line (see example data sheets in Appendix III) .

21. Position of the start of the transect should be the read from the navigation system as the transect is begun (similarly for the end of the transect). However, this should be the same as the position being used to display the transect on the GPS, so it is strictly not necessary to record again, although writing it down provides the redundancy necessary to check that the correct transect was flown. Where mistakes are unlikely, the names of the endpoints (eg 21A and 21B) can be written here, but this must be checked on the GPS display. Position need not be recorded for a block, but the block ID should be read from the GPS, as they are often done out of sequence.

22. Height is recorded at regular intervals to obtain a good measure of the average height on the transect in order to correct the strip width when doing the analysis. This is done from the radar altimeter to the nearest 5 feet. Note that it is not recorded for each sighting but independently and preferably every 30 seconds. Height is not recorded on a block count.

23. Position data recorded during the flight in the GPS will be downloaded into files after the flight. Sightings for all transects covered during that flight will go into one file although there will be a different file for each flight. The file name must therefore appear on all data sheets so that there can be no doubt where any transect's data is (see 24).

24. Positions of animal sightings should be recorded on the data sheet from a position read from the GPS. The position may also be recorded by marking it with the GPS and then entering the waypoint number allocated by the GPS on the data sheet. Such electronically recorded sightings should be downloaded after the flight into a file whose name is recorded on all the data sheets for the flight (see 23).

25. The following information on animal sightings must be recorded:

- elephant family groups. These are defined as herds in which females and young are present. Any bulls in the group count as part of the group
- elephant bull groups. These are single animals or groups which contain no females or juveniles
- elephant carcass. There are four categories required by CITES (1998). These are also as described in Douglas-Hamilton (1996):

  Carcass 1: Fresh (<1 month). Still has flesh giving the body a rounded appearance. Vultures probably present and ground still moist from body fluids
  Carcass 2: Recent (<1 year). Rot patch and skin still present. Skeleton not scattered
  Carcass 3: Old (>1 year). Clean bones, skin usually absent, vegetation regrown in rot patch
  Carcass 4: Very old (up to 10 years). Bones scattered and turning grey.

26. Standard codes should be adopted in the electronic dataset, ie: LaF = family group; LaM = bull; LaC1 = Carcass 1; LaC2 = Carcass 2; etc. These may be difficult to use when recording sightings on the data sheet as they're counter intuitive; personal shorthand in the recorder's language is much easier to use (eg EleB for elephant bull). *This should be consistent within a survey and the meanings of the shorthand codes must be clearly stated in notes accompanying the data sheets.* In the case of carcasses care must be taken not to confuse the number seen with the number describing the state of composition.

27. The MIKE data are relevant at higher levels than the individual survey, which is not representative at the national level and may only be marginally meaningful for the site, in the short term.. Nevertheless, the narrative report may be able to give some local relevance to the result. This is at the discretion of the national coordinator and the standard recommends aspects that might be covered.

    More importantly, the report will interpret the results being handed on to the next level to aid collation of the overall results.

28. The power of the design to detect changes of the required magnitude should, strictly, have been calculated prior to the survey (Steidl *et al.* 1997), although it is still rare that this is done.

29. Carcass ratio is calculated according to Douglas-Hamilton *et al.* (1991).

30. Additional animals seen are those seen outside of the sampling units, but within the stratum.

31. Variance should be calculated according to Jolly (1969) - see Appendix II.

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APPENDIX I: OPTIMAL ALLOCATION OF SURVEY EFFORT

Whatever the overall sampling intensity, sampling each stratum at the same sampling intensity will not usually give the best result. The precision of the survey can be maximised by optimising the distribution of the effort among sampling strata using prior information on variance.

Cochran (1963) gives this as: $a = R\Sigma a / \Sigma R$, where a is the area of the sampling units in the stratum, Σa is the total area of the sample for all strata and R is the "relative variation factor", which is a weight for the stratum's contribution to the overall effort.

Where only estimated densities are available, $R = A \sqrt{d}$, where A is the stratum area and d is the animal density, has been used (Craig 1993), but this makes the simplifying assumption that the number seen is proportional to its variance, which may not hold over a wide range of densities. It is better to use actual variances when these are known. Then $R = Ns$ (Gasaway *et al.* 1986) where N is the potential number of sampling units in the stratum and s is the square root of the variance between sampling units.

The calculation is easier to follow in an example. Table A1.1 demonstrates allocation of effort between strata using real data from Etosha

Table A1.1 : Calculation of allocation of effort between strata

				Sample				Weight		New sample	
Stratum	Est	*s*	Area	area	%	*n*	*N*	*Ns*	Rel.	area	%
1	9	0.553	584	125.1	21.42	13	60.69	33.54	0.0055	15.5	2.66
2	177	2.118	2945	250.3	8.5	24	282.35	597.92	0.0979	277.1	9.41
3	1163	8.646	4167	956.7	22.96	86	374.56	3238.55	0.5301	1500.9	36.02
4	213	2.955	4301	423.6	9.85	29	294.42	869.96	0.1424	403.2	9.37
6	168	4.255	478	45.6	9.55	6	62.83	267.30	0.0438	123.9	25.92
7	362	3.444	4843	1029.6	21.26	68	319.85	1101.53	0.1803	510.5	10.54
Total			17318	2831.1				6108.80	1.0000	2831.1	

In the table columns 2 to 8 are from a previous survey. s is the square root of the variance in number seen between sampling units and is not the same as the standard error of the estimate (see Appendix II for definition). n is the number of sampling units and N is the maximum possible no of sampling units ie N = column 7 × column 4 ÷ column 2. The weight, Ns, is column 3 × column 8, while the relative weight (column 10) is column 9 ÷ sum of column 9. The new area of the sample for each stratum (column 11) is the total sample area (2831.1) multiplied by the relative weight. Column 12 expresses the new sample as a percentage.

In terms of a formula, the sampling intensity to be allocated is:

$$p_i\,(\%) = 100 \,.\, (N_i \,.\, s_i / \Sigma N \,.\, s) \,.\, \Sigma a / A_i$$

where N_i is the maximum possible number of sampling units in stratum i (eg 319.85 in stratum 7); s_i is the square root of the sampling variance in stratum i (eg 3.444 in stratum 7); $\Sigma N \,.\, s$ is the sum of the products $N_i \,.\, s_i$ over all strata; Σa is the target total sample area to be divided among strata (2831.1 in the example) ; A_i is the area of stratum i (eg 4843 for stratum 7); and p_i (%) is the percent sample to be taken in (eg 10.54% in the case of stratum 7).

Note that if, for any reason, a different sampling intensity is desired at a site (eg 2.66%

sampling is too little to give a useful result for stratum 1; strata 5 and 8, which had no elephants, nevertheless have to be covered), this can be substituted and only the precision will be affected. There can also be occasions where the procedure returns a sampling intensity of greater than 100% for some strata. In such cases the sampling intensity should be set to 100% for that stratum (ie a total count should be carried out in it), and the remainder of the available sampling effort should be reallocated among the remaining sites according to the protocol.

If N and s are not directly known (they are often not reported), but the standard error of the estimate and the sampling intensity (p) are, $SE\sqrt{p}\sqrt{A}$ is a good approximation to Ns

The above protocol could also be applied at a regional level to optimise the overall result from MIKE, given previous results listed in the African Elephant Database (Barnes *et al.* 1999).

APPENDIX II: METHOD OF ANALYSIS

Where sample aerial counts are done, Jolly's method for unequal sized sampling units (sampling units are transects or blocks) is appropriate (Jolly, 1969). Calculation of the estimate and its variance, is as follows:

$$R = \frac{\sum y}{\sum z}$$

$$\hat{Y} = Z.R$$

$$Var\hat{Y} = \frac{N(N-n)}{n}.(s_y^2 - 2.R.s_{zy} + R^2.s_z^2)$$

where:

$\hat{Y}$ = estimate of animals in stratum

y = number of animals counted in sampling unit

Z = total area of stratum

z = area of sampling unit

R = mean density of animals in sampling units

n = number of sampling units in stratum

N = number of possible sampling units in stratum $(N = n.Z / \sum z)$

s_y^2 = variance between numbers of animals counted in sampling units

s_z^2 = variance between areas of units

s_{zy} = covariance between animals counted and areas of units

$Var\hat{Y}$ = population variance of stratum; the standard error is the square root of this

95% confidence limits are calculated from the standard error × *t* (Student's *t* for p = 0.95 and n-1 degrees of freedom, which is approximately 2 for large n). The 95% range is the estimated number of animals ± the confidence limit. Where the confidence limits are greater than 100% of the estimate, the lower limit can be taken as the actual number seen.

APPENDIX III: AERIAL SURVEY DATA SHEETS

The following examples of data sheets are included as an additional illustration of the recording of observations, as required in section 4.8 of the standards, which might thereby be made clearer.

The first data sheet is used for strip width calibration, and in addition to in-flight recording, can be used to complete the calculations.

Three types of in-flight data recording sheet are shown, for transect sample, block sample and total count respectively. In each case it is intended that data recording continues on the back of the sheet.