MONITORING THE ILLEGAL KILLING OF ELEPHANTS

AERIAL SURVEY STANDARDS FOR THE MIKE PROGRAMME

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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 is aerial surveys of selected savanna sites to obtain estimates of numbers of elephants and elephant carcasses. Such surveys repeated over time can provide 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 is 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 method to be used. The choice of method affects accuracy, precision and efficiency. However, differing circumstances may demand different choices and one survey may even be made up of areas that need to be 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

Crucially, data must be comparable to data from previous surveys. Data that are collected during an aerial survey should include information that may not be essential to producing elephant population information, but may be required for future analyses for validation of data from a series of surveys.

A brief outline of each of the methods is provided as a background to this document but 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, and while they are intended to improve both precision and accuracy, in practice there are significant drawbacks (Griffin *et al.* 2003; Kruger *et al.* 2008) It therefore does not justify the inclusion of this alternative among methods used in the MIKE project, so it will not be considered further.

Total Counts

Total counts are intended to count every single animal in the designated area. They are conducted by flying along flight lines that are extremely close together. These flight lines may not necessarily be straight lines and depend on the terrain, the shape of the area and on the known distribution of elephants.

The method has the advantage that many of the problems of sampling (calibration, height recording, design and analysis) are avoided and hence greatly simplify the surveyor's task.

While, in principle, total counts are the most precise and accurate, as long as search rate standards are achieved (see note 13), there are potential shortcomings that should be borne in mind:

- The "dead" zone below the aircraft may be inadequately covered from adjacent flight lines, causing animals to be missed
- Navigation along closely-spaced flight lines has to be extremely accurate throughout the survey to ensure all the ground is covered
- When the search rate is high enough to ensure that no animals are missed, some may be counted twice because of the close spacing of flight lines

- The resources to carry out the amount of flying required for total counts are seldom available or justifiable
- A total count is generally not practical for large areas unless it can be divided into smaller strata that can be counted simultaneously

When many blocks are, of necessity, not counted simultaneously, movement of animals during the survey constitutes a source of variance not reflected in the absolute precision assumed for a total census. This precision could be measured by counting some blocks twice. Where bias, i.e. undercounting due to an inadequate search rate is suspected, some strata should be repeated at higher search to obtain an estimate of bias.

Total counts 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 100km^2. This last standard is recommended because such an area can be covered at a sufficiently high search rate within one flight and it is feasible to identify all groups seen so that none are counted twice.

Transect Sample Counts

Transect sample counts are carried out by flying at a fixed height above ground level along transects spaced apart as required for the selected sampling intensity. Pairs of rods are attached to the aircraft struts at a fixed distance apart according to the required "strip width". Observers count animals seen between these rods. Analysis of the information provides estimates of densities within each stratum which can be combined to provide an overall estimate for the sample area.

Transect counts are appropriate when there are fewer resources available and/or when the acceptable precision requires a lower sampling intensity than 100%. However, for any sample over 70% in a small area. it is usually easier, and not much more expensive, to conduct a total count (bearing in mind the above caveats).

It can also be impractical 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 (for example, two surveys of the same area at, say 20% sampling intensity).

For Transect Sample Counts, a constant height above ground level should be maintained as accurately as possible using a radar altimeter or other suitable equipment. This is only possible over ground which is mainly flat.

Block Sample Counts

Block sample counts are conducted by dividing the survey area into small (about 10 km^2 and no larger than 20km^2), equal sized "blocks". A number of blocks are selected at random according to the required sampling intensity. A total count is carried out in each block.

Block 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 where-ever transect counts can when the specialised 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

1	a	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**
	b	Sampling effort of less than 70% required	**…………..………………. 4**
2	a	Area to be counted smaller than 100 km^2	**……………… Total Count**
	b	Area to be counted 100km^2 or more	**……………………..…. 3**
3	a	Resources are available to cover all subunits, nearly simultaneously, at a search rate of less than 1.5 km^2/min	**…………..…. Total Count**
	b	Not as in 3a	**…………….…………. 4**
4	a	More than 20% of the survey area has escarpments or hills with slopes of more than 30% for a height exceeding 200m	**……. Block Sample Count**
	b	Not as in 4a	**…………….…………. 5**
5	a	Equipment (radar altimeter etc) necessary for Transect count is in place	**... Transect Sample Count**
	b	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 rather than to use the strictly applicable methods, as given above.

STANDARDS FOR AERIAL SURVEYS

Superscripts in this part refer to notes (pp 15 – 19) 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), which should be stated in the report, making clear the hypothesis which the survey result will test, or the question being asked.

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 and be consistent with those of previous MIKE surveys.

1.2 Stratification

The survey area is usually divided into a number of subunits (strata), if possible, based on known populations. To maximise precision, the stratum boundaries contain similar densities of the species to be counted. It is acceptable to change stratum boundaries from a previous survey to accommodate changes in population distributions or other requirements, as long as the overall survey area boundary is **not** changed.

Should a MIKE site not conform to a stratum, then the survey data must be collected in a manner that allows the data for the MIKE site to be extracted.

The strata are:

- each of uniform topography and ecology [1]
- contain homogeneous densities of animals[1]
- are large enough to contain more than 15 sampling units at the desired sampling intensity[2]
- have boundaries defined digitally [3]
- 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

- These must be oriented along the ecological gradient, within other constraints[4]
- They should be selected systematically[5]
- 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]

- Each block should be a rectangular quadrat no larger than 15 km^2
- Blocks should be selected systematically or randomly from a grid covering the entire stratum
- 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 ET06-03-07 for the seventh transect of the third stratum of Etosha in 2006.

1.4 Sampling intensity

Survey design should maximise precision within the available resources[7]. The overall effort to be expended depends on the precision required by the objective of the survey which, for the purposes of MIKE, is to have an 80% probability of detecting a 40% decline over two surveys[7] at a site. A PRP[7] greater than 20% will meet this objective. Therefore, when resources permit, sampling intensity should be increased if the PRP exceeds this value.

2 EQUIPMENT

2.1 Aircraft

Safety is crucial and it is important that a suitable aircraft is used, that only experienced pilots are employed and that all standard flying safety procedures are adhered to (quality of fuel, amount of fuel, flying conditions including temperature and terrain etc).

Where possible, the same type of aircraft should be used for all surveys of any given area unless the different aircraft can safely fly at the same speeds safely, have similar altitude control, noise, comfort, similar visibility (state of Perspex should be similar) and communication between crew members.

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

Those aircraft not considered useful for transect sample counts, such as Piper Super Cub, Christen Husky, Bellanca Scout or helicopter, can be used in addition to the smaller Cessnas. Other types may also be feasible but low speeds in mountainous terrain can be dangerous and must be well within the aircraft's capability.

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 record of the route flown during the survey must be kept for all survey types. This is used to confirm that the entire survey is completed, that transects were flown accurately and there were no undue deviations from the required track.

A GPS is essential for navigation[10]. It must possess all the following facilities:

- moving map display
- ability to upload and download position information
- ability to continuously record position (track log function)

2.4 Altimeter

- For maintaining and recording height on transect surveys the aircraft must be fitted with a radar altimeter. This may be replaced by a laser rangefinder provided equivalent results can be obtained.
- The radar altimeter must be calibrated prior to and occasionally (if the survey is over a long period) during the survey. This can be done by comparing the reading of the radar altimeter with that of the pressure altimeter (set to zero on the ground) while flying over the point where it was zeroed.

2.5 Intercom

The aircraft must be fitted with a 4-place intercom and headsets for ease of communication among the crew. It should have a cut-out switch to enable the pilot to use the radio while the other crew members remain in contact over the intercom.

2.6 Tape (digital) recorder

Using a tape recorder is an option and useful depending on the frequency of sightings and density of animals in the survey area.

2.7 Photographic equipment

It is generally agreed that the inclusion of photographs, particularly of large herds, would be of some benefit. However, the practicalities of this may make their usefulness questionable.

The following need to be considered when using photographs to validate sightings by the observers:

- It must be ensured that the focal length and position of the camera are such that exactly the same is recorded by the camera as the observer sees between the marker strips (i.e. the camera must record the same survey strip)
- Photographs may be less useful than human eyes at "spotting" animals under trees
- If the observer activates the camera when a group is seen, there is still no correction possible for groups the observer misses
- The observer's ability to control the camera with minimum of distraction should be facilitated, e.g. by the use of a suction mount

Bearing these considerations in mind, a change in technique from not using to using cameras should be calibrated by repeating a survey, or part of one, with and without cameras.

3 CREW

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

The crew must include a recorder as well as two observers. If observers are expected to write their sightings they will have to take their eyes off the survey strip.

3.1 Pilot

Commercial pilot or pilot with a minimum of 1000 hours flying experience.

3.2 Recorder

This should be a wildlife biologist with appropriate experience of surveys, an ability to take recordings (sightings and positions) rapidly and accurately, to make decisions during the course of the flight and to supervise all in-flight procedures.

3.3 Observers

Observers should have adequate experience and training. They must 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 the strip and estimate the 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 across numbered markers clearly marked at 10m intervals on the ground
- Though left and right values are obtained, it must be carried out for *pairs* of observers (i.e. if one observer fails to see the calibration numbers, then that pass is omitted from the calibration series)
- Height is recorded on each pass overhead the markers
- Height should be varied between 250 and 350 feet a.g.l.
- 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 no more than 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. Flights in the middle of the day are usually not useful as animals tend to rest under trees and are then easily missed.

4.3 Survey period

Surveys must cover the entire survey area within as short a time as possible. It is not acceptable to allow long periods to pass between counts of strata. This is particularly important for elephant which are known to move rapidly in response to environmental conditions (rainfall, disturbance etc). Nor is it acceptable to conduct part of the survey during one season and continue the rest during another for similar reasons.

4.4 Ground speed

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

4.5 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] or less. If necessary, 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 (the track log) must be recorded on the GPS and down-loaded to a computer at the end of the flight.

4.6 Height above ground level

Height should be maintained close to 300ft above ground when flying transects and recorded every 30 seconds. The height should be the same for successive surveys (i.e. it should not be changed from 300ft on one survey and then to, say, 350ft the next survey). Where previous surveys have used a different height standard, it is preferable to maintain that standard.

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.

4.7 Search Rate[13]

The following are commonly acceptable search rates:

Transect and block counts:	1 - 1.5 km^2 / minute ($\equiv$ 60 – 90 km^2 / hour)	1 - 0.67 minutes/km^s
Block counts with crew of 2:	<1 km^2 / minute (<)	1 minute/km^2
Total counts:	1 - 1.5 km^2 / minute	1 - 0.67 minutes/km^s

The search rate should never exceed 1.5 km^2 per minute (40 seconds per km^2) and preferably should aim to achieve 1 km^2 per minute to improve carcass estimates.

4.8 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].

4.9 Observing - general

4.9.1 Search pattern should concentrate within the strip, with attention on the inside marker[15]. i.e. the search should start on the inside marker out to the outer marker.

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

4.9.3 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

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

4.9.5 Care should be taken to avoid observer fatigue – there should be no more than 8 hours flying each day and time should be planned to include rest days when needed

4.10 Observations to be recorded

4.10.1 Each flight[18]

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

4.10.2 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]
- Weather

4.10.3 Each sighting

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

4.10.4 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)

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

4.11 Optional additional Protocols to be recorded

- Ground speed on transects (this is obtainable anyway from the tracklog) Animal groups larger than 10 may be photographed (taking into consideration the points mentioned above)
- Presence of fire

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 table should report, for each stratum:

- estimated number of animals
- number of animals seen in the sample
- additional animals seen[30]
- variance of estimate[31]
- 95% confidence interval
- PRP(Percentage Relative Precision)
- 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, the actual sampling intensities for the stratum (as opposed to the planned 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
- Mean ground speed and search rate for each stratum. Mean height flown for the survey and its standard deviation
- A comparison of left and right observers
- description of file names and formats for digital data submitted (see 6.2)

5.2 Additional information

5.2.1 Originals

Original data sheets should be submitted without transcription.

Original calibration data should also be submitted

5.2.2 Digital copies of data

The following information should be submitted electronically, on disc or via the internet:

- 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).

- If photographs have been taken, these should be included with, for each, details of the location and count data (both photo and visual)
- Maps of all subunits and blocks (if used)
- The GIS files defining each stratum and sampling unit
- A comparison of left and right observers

The above standards are intended to be the minimum necessary to meet the data requirements of the MIKE project. However, no standards can ensure a perfect result, so there will always be room for improvement in equipment and methods. Where new methods can be shown to give an improved result, these can be adopted. However, when that is done, the comparability of previous results for the area with the improved results must be ensured.

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. Overall sampling effort sufficient to detect a change of the required magnitude (Steidl *et al.* 1997) should be determined in advance. The MIKE target is being able to detect a real decrease of 40 % between surveys, given a β(the probability of making a type II error) of 0.2 and α(probability of a type I error) of 0.05. This can be achieved if PRP is 20% or better. The PRP (Percentage Relative Precision) is defined as the 95% confidence limit expressed as a percentage of the estimate (i.e.($SE_{\hat{Y}}.t(for\ \alpha = 0.05)\ /\hat{Y}).100\%$)). While, for one site, an 80% probability of detecting a 40% change over two surveys appears a weak objective, if these targets can be met for all sites the detectable change overall should decrease to <10%. This will improve as more surveys are done. If overall sampling effort is, as far as possible, divided among sites and strata so as to optimise the precision of the final result (Appendix I) further improvement can be made in the overall result. In doing this, precision at individual sites is variable and many would not meet standard 1.4 - a good overall result is a

trade-off against meaningful results at a local level.

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 be safe at low speeds and have sufficient power to operate safely with full fuel and rhe required passenger load under a range of conditions. Those types in common use are listed, but others may fit the requirement.

   The Cessna 208 (Caravan) is sometimes used but is likely to show dissimilar flight characteristics to the other Cessnas (and Partenavia). It has other disadvantages such as running cost, weight, refuelling practicalities and safety at slow speeds, Analyses of differences between this and previously used aircraft would be needed and this may be beyond the financial resources of the project.

   For total and block counts, many types of aircraft will suffice, but, where safety permits, slower flying types are preferable. Helicopters are sometimes 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 transects 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 method.

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 (see note 25).

17. The decision point on the strip marker (i.e on the rods or streamers) 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 (if two or more aircraft are used), must appear on all sheets - examples of data sheets are given in Appendix III.

19. The track log 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 or <1km.

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 (and transects with little information) 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). This is not applicable if the GPS has enough memory for the entire survey, although downloads per flight are recommended.

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

  Bull and family groups are recorded separately mainly because illegal hunting may impact the two categories differently.

- *elephant carcass*. There are four categories required by IUCN (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.

The importance of recording carcasses and reporting carcass estimates and carcass ratios (see note 29) cannot be over-emphasised. While a survey whose sampling intensity meets standard 1.4 is likely to fail to detect a population decline of less than 40%, a loss of a proportion of the population will result in a several-fold increase in the number of carcasses which makes number of carcasses by far the most sensitive indicator of population change.

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 decomposition.

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

29. A comparison of carcass estimates between surveys gives an estimate of excess mortality. When no previous result is available, carcass ratio is useful. This is calculated according to Douglas-Hamilton *et al.* (1991). Expressed as a percentage, carcass ratio is defined as: $\frac{No.of\ carcasses}{No.of\ carcasses+no\ of\ live\ elephants}.100\%$

The background value of the ratio under natural mortality is usually 5% or less. As a rule of thumb, a value greater than 15% can be taken to indicate unsustainable losses.

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 (true when groups are randomly spaced), which often does not hold over a wide range of densities, due to clumping. 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. (n.b. Ns and $A\sqrt{d}$ give the same weights because $s^2 \propto d$ (when the distribution of groups is random) and $N \propto A$)

The calculation is easier to follow in an example. Table A1.1 demonstrates allocation of effort between strata based on real data:

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

Stratum	Estimate	*s*	Area	Sample area	Sample %	Sample *n*	Sample *N*	Weight *Ns*	Weight Rel.	New sample area	New sample %	New sample *n*
1	921	2.630	16118	1669.0	10.36	104	1003.7	2639.1	0.1174	507.9	3.15	32
2	697	4.106	2699	278.9	10.33	26	251.6	1033.0	0.0460	198.8	7.37	19
3	1509	7.468	3709	381.0	10.27	34	331.0	2471.7	0.1100	475.7	12.82	42
4	895	17.028	1466	152.4	10.4	15	144.3	2457.0	0.1093	472.8	32.25	47
6	886	7.322	2337	240.0	10.27	19	185.0	1354.6	0.0603	260.7	11.15	21
6	1284	11.223	2662	275.8	10.36	20	193.0	2166.6	0.0964	416.9	15.66	30
7	590	6.907	2245	232.3	10.35	20	193.3	1335.0	0.0594	256.9	11.44	22
8	470	5.566	1818	185.8	10.22	17	166.3	925.8	0.0412	178.2	9.80	16
9	736	4.873	2296	236.9	10.32	26	252	1228.0	0.0546	236.3	10.29	26
10	1864	9.645	4371	450.0	10.3	51	495.4	4778.0	0.2125	919.5	21.04	104
11	1993	14.61	2135	223.8	10.48	15	143.1	2090.6	0.0930	402.3	18.84	27
Tot				4325.9				22479.3	1.0000	4325.9		

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 5. 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 (4325.9) 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 193.3 in stratum 7); s_i is the square root of the sampling variance in stratum i (e.g. 6.907 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 (4325.9 in the example) ; A_i is the area of stratum i (e.g. 2245 for stratum 7); and p_i (%) is the percent sample to be taken (eg 11.44% in the case of stratum 7).

The original design in the example (which has uniform sampling) gave a percentage relative precision of 22%. The predicted improvement brings this to 18% which, in the example, is within standard 1.4.

If, for any reason, a different sampling intensity is desired in a stratum (e.g. when the required sampling intensity is too small to give a reliable result), this can be substituted and only the overall precision will be affected. Another approach is to consolidate several low density strata into a single stratum large enough for sufficient sampling units (stratum 1 in the example is a consolidation of 5 original strata). There can also be occasions where the procedure returns a sampling intensity of greater than 100% for a stratum. In such cases the sampling intensity should be set to 100% for that stratum (i.e. a total count can be carried out in it), and the remainder of the available sampling effort should be reallocated among the remaining sites according to the protocol. Where the assumptions of a total count cannot be met (e.g. when the stratum is too big, or a suitable aircraft is not available) it would be more straightforward to carry out five 20% surveys and combine the results.

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.

A remaining source of error is that, while empirical variances are used, the prediction of a new variance for a different sample size still depends on the assumption that $s^2_y \propto \bar{y}$ (groups are randomly distributed) whereas clumping causes $s^2_y \propto \bar{y}^x$ (in this example x =1.3) which implies a different exponent should be used to calculate the weights for sample allocation. However, in the absence of good information about the variation of x over populations and time, the assumption of random distribution is used as a default.

The above protocol could also be applied at a regional level to optimise the overall result from MIKE, given previous results (see note 7).

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:

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

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

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

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_{xy} = 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 (α = 0.05 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. As sites may have different data needs and requirements may be added over time as methods improve, it is difficult and perhaps counter-productive, to set a standard for data sheets. However, while the use of the examples is not a standard in itself, the same information as required on these sheets should be recorded, regardless of sheet design. The examples were not developed for the MIKE project, but have been found, from the experience of the author, to facilitate the recording of data.

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

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 the data columns continue on the back of the sheet (with the margin on the right side of the back). When few observations are being made per unit, several units can be recorded on the same sheet. Provided that the sheet is ruled off between each unit and the time and position of start and end, as well as the unit identification code, are written in below the ruling. This economises on sheets and assists in their carriage and storage – not a minor consideration when there are several hundred sampling units.

CALIBRATION SHEET

Survey . . . . Location . . . . Date . . . .

Aircraft . . . . Pilot . . . . Recorder . . . .

Left Observer . . . . Right Observer . . . .

	Left		Right		W = 10 x (out-in+1)		Corr. = W x 300/ht		Corr.
Height	In	Out	In	Out	L	R	L	R	L + R

Mean ______

SE ______

AERIAL SURVEY DATA SHEET (TRANSECT)

SURVEY .... **STRATUM** .... **Aircraft** .... **DATE** .... **am / pm**

Complete once per flight

PILOT .... TAKE OFF TIME ....

RECORDER .... LANDING TIME ....

LEFT OBSERVER .... STRIP WIDTH: LEFT ....

RIGHT OBSERVER .... STRIP WIDTH: RIGHT ....

TRANSECT No. .... Transect spacing ....

Start time .... **Start Waypoint** .... S .... E

End time .... **End Waypoint** .... S .... E

Mean height
....

Waypt. file: ....

Waypt. No.	SIGHTINGS (Species, Number seen) LEFT IN STRIP	LEFT OUT	RIGHT IN STRIP	RIGHT OUT	NOTES

Height
Record every 30 secs

PTO /

AERIAL SURVEY DATA SHEET (BLOCK COUNT)

SURVEY.................................... Aircraft .... DATE........................ am / pm

STRATUM ....

Complete once per flight

TIME: Take off .... Landing ....

Pilot.. Recorder..

Observers...

Waypoint file: ....

Block No.	Wpt. No.	Sightings (Species, Number seen) In	Out	Notes/ Times: start / end

Rule off between blocks

AERIAL SURVEY DATA SHEET (TOTAL COUNT)

SURVEY.................................... Aircraft .... DATE....................... am / pm

Complete once per flight

TIME: Take off .... Landing ....

Pilot.. Recorder..

Observers..

Stratum .... Time: Start....................... End.......................

Waypoint file: ....

Line No.	Wpt. No.	Sightings (Species, Number seen)		Notes /times
		In	Out	
Rule off between flightlines				