# MONITORING THE ILLEGAL KILLING OF ELEPHANTS

# DUNG SURVEY STANDARDS FOR THE MIKE PROGRAMME

March 2006

Compiled and edited by S. Hedges and D. Lawson

for the CITES MIKE Programme

CITES MIKE Programme
Central Coordinating Unit
PO Box 68200
Nairobi KENYA
Tel: +254 2 570522
Fax: +254 2 570385
Email: nigelhunter@citesmike.org
Website: http://www.cites.org/eng/prog/MIKE/index.shtml

# Acknowledgements

This document is based on the work of the CITES MIKE Dung Survey Task Force:

Richard Barnes, University of California at San Diego

Steve Blake, Wildlife Conservation Society

Ken Burnham, Colorado State University

Bob Burns, University of Reading

Holly Dublin, IUCN/SSC African Elephant Specialist Group (Facilitator)

Lori Eggert, Smithsonian Institution

Simon Hedges, Wildlife Conservation Society

Richard Ruggiero, US Fish & Wildlife Service

Karl Stromayer, US Fish & Wildlife Service

Martin Tyson, Wildlife Conservation Society

Arun Venkataraman, CITES/MIKE (Rapporteur)

Additional inputs were kindly provided by Nigel Hunter (CITES/MIKE), Fiona Maisels (WCS), Andy Plumptre (WCS), and Samantha Strindberg (WCS).

# Contents

# Preface

In 1997, at the 10th meeting of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Conference of the Parties (CoP), the Parties resolved to establish a monitoring programme across the entire range of the African and Asian elephants [Resolution Conf. 10.10]. It was intended that this programme would facilitate decision-making by the Parties regarding the protected status of elephants. It was also the first attempt to provide a systematic and detailed assessment of the impact of the Parties' decisions to allow, restrict, or suspend trade in a particular species (and/or its parts and derivatives). The Monitoring the Illegal Killing Of Elephants programme, now known by its acronym, MIKE, was endorsed at the 41st meeting of the CITES Standing Committee in February 1999.

The MIKE programme was discussed again at the 11th CoP in 2000, which led to a revision of Resolution Conf. 10.10, and the objectives previously agreed were broadened to include 'establishing an information base to support the making of decisions on appropriate management, protection and enforcement needs' and 'building capacity in range States'. The MIKE programme currently has the following aim: 'To provide information needed for elephant range States to make appropriate management and enforcement decisions, and to build institutional capacity within the range States for the long-term management of their elephant populations.' More specific objectives within this aim are: (1) 'To measure levels and trends in the illegal hunting of elephants'; (2) 'To determine changes in these trends over time'; and (3) 'To determine the factors causing such changes and to assess to what extent observed trends are related to CITES changes in listings or ivory trade resumptions' (www.cites.org/eng/prog/MIKE/index.shtml).

The MIKE programme plans to achieve these objectives through a site-based system of collecting data on elephant population trends, the incidence and patterns of illegal killing, and the effort and resources employed in detecting and preventing illegal hunting and trade. The MIKE programme is also charged with developing and using a standardized methodology for data collection and analysis.

Much of the elephant population monitoring under this initiative involves dung-count based surveys in forest sites to obtain estimates of elephant population size. These surveys will be repeated over time to detect changes in elephant numbers at the selected sites. In order that this monitoring be done as effectively as possible, MIKE survey teams must use standardized defensible methods that are capable of producing accurate and precise results, and which are comparable over all sites and remain comparable over time within sites. Arising from this is a need for a set of standards to ensure the quality and comparability of the programme's survey results. This document was commissioned by the MIKE programme to set those standards for dung count based population surveys.

Specifically, these Dung Count Population Survey Standards are the product of a task force that was set up by the MIKE programme with the objective of writing these standards. The MIKE Dung Survey Task force met in October 2003 to decide on an appropriate dung count based survey method, suggest a standardized protocol for this method, and review practical problems faced by dung counts and other survey techniques in forests.

## What is included in this Standards document and what is not

There are several essential parts to a dung-count based population survey: estimating dung-pile density, estimating dung decay (= disappearance) rates, and estimating defecation (= dung production) rates. The core of this document is a statement of the minimum standards necessary for each of these essential parts. This document is not intended to be a manual of survey methods or statistics because suitable texts already exist. However, where it was felt necessary to explain the need for a particular standard in detail, supplementary notes and references have been provided. In addition, annexes have been provided on topics where it was felt providing further detail was more helpful than a reference to the literature.

The method of estimating dung-pile density included in these Standards is the line transect (Buckland et al. 2001). In recent years, a number of so-called ‘recce’ (reconnaissance) survey methods have been used in conjunction with line transects in an attempt to improve the precision of dung count based surveys. However this use of ‘recce’ methods to estimate elephant dung-pile density is not endorsed by the MIKE Technical Advisory Group (TAG) and is not therefore included in these Standards.

In contrast, the use of what are here called recce-survey transects (RSTs) to quickly estimate dung-pile encounter rates during pilot surveys (to aid the design of formal line transect based surveys) is uncontroversial and is described in detail.

For those interested, additional information about other uses of ‘recce’ methods is included in Annex 4.

Estimating elephant abundance from fecal DNA based capture–recapture methods is a new and promising method, especially for the small elephant populations that exist in much of West Africa and Southeast Asia (Eggert 2003). However, standardized methods have yet to be finalized and the uses of fecal DNA based capture–recapture methods are not currently approved by the MIKE TAG. Nevertheless, since these methods were discussed as an alternative to dung count based survey methods by the MIKE Dung Survey Task Force, various sections of this document discuss pilot survey data-gathering methods that will provide guidance about the likely utility of these fecal DNA based methods.

## How to use this Standards document

The most important section of the book is Chapter 3, and especially Section 3.2, which provides a decision-making workflow (rather like a taxonomic key) to help you decide which methods to use and to guide your survey planning and design process. The other chapters provide the additional detail; particularly relating to field methods, that you will need to understand the planning and execution of a dung count based survey, as well as providing pointers to the relevant literature.

Good statistically defensible survey design is vital for the success of the MIKE programme. Designing wildlife surveys is a complex process and requires specialist knowledge. For these reasons it is essential that you seek advice from your Sub-regional Support Officer (SSO), the MIKE statisticians, and if necessary the MIKE Technical Advisory Group (TAG) when designing a MIKE survey. It is also important to emphasize that all survey designs must be approved by MIKE statisticians before any fieldwork begins.

# 1. An introduction to dung counts

## 1.1 Theoretical basis

Indirect survey methods such as dung-counts are useful when the sign produced by the animals (dung-piles in this case) are more suited to the available survey methods than the animals themselves (because they live in concealing habitat types such as forests).

There are two main types of dung count: fecal standing crop (FSC) methods and fecal accumulation rate (FAR) methods. FAR methods measure the rate of dung-pile accumulation between two points in time. This is achieved by making two visits to the same plots or transects and counting the number of dung-piles deposited since the first visit. Provided the interval between visits is shorter than the most rapidly decaying dung-pile's lifetime, animal abundance can be calculated by adjusting fecal accumulation rates by the mean defecation rate over the period of accumulation. FSC methods, by contrast, determine dung-pile density (without revisiting areas) and relate this to dung-pile decay rate and mean defecation rate (Neff 1968; Putman 1984; McClanahan 1986; Laing et al. 2003; Campbell et al. 2004).

FAR methods are not endorsed by the MIKE TAG for elephant surveys for a number of reasons. Most importantly, FAR methods are very time-consuming and thus more expensive and labour-intensive than FSC methods that do not require repeat visits. Use of FAR methods also reduces the proportion of the survey area which can be covered, since time which could be spent surveying new transects or plots is spent revisiting old ones. The use of permanent transects is also problematic in areas of dense vegetation, since elephants are likely to preferentially use the cut transects and so the estimates of dung-pile density produced from counts along such transects are likely to be biased (Barnes 1996; Buckland et al. 2001; Nchanji & Plumptre 2002; Hedges & Tyson 2002).

For the FSC methods used by the MIKE programme, one must estimate dung-pile density and then use knowledge of the expected number of dung-piles per elephant to convert this into an estimate of elephant density. Following Buckland et al. (2001), if $R$ is the estimated dung-pile density (number of dung-piles per unit area) and $c$ is the estimate of the mean number of dung-piles per elephant available to the surveyors during the time they conducted the survey, elephant density is estimated by $R/c$. To obtain an estimate of the mean number of dung-piles per elephant available to the observer during the survey period, one must estimate mean dung-pile production rate (defecation rate) per elephant per time period. One must also estimate mean dung-pile lifetime or decay rate.

The mathematics of the relationships among animal abundance and animal sign (e.g. dung-pile) abundance via sign creation and survival probabilities are discussed in detail by Buckland et al. (2004). The theory and practice of using distance based sampling methods (including the line transect methods prescribed in this document) to estimate dung-pile densities are explained in a book-length treatment by Buckland et al. (2001). Additional useful discussions, particularly relating to dung-pile decay rates can be found in Hiby & Lovell (1991), Barnes et al. (1997a), Plumptre (2000), Marques et al. (2001), Nchanji & Plumptre (2001), Hedges & Tyson (2002), Laing et al. (2003), and Campbell et al. (2004).

## 1.2 Application

The use of dung-count based survey methods to assess animal population size and trend is well established (for reviews see Neff 1968; Putman 1984; Barnes 2001; Buckland et al.

2001:183–189). The use of the technique for elephants, primarily those living in forest environments is also well established (e.g. Barnes & Jensen 1987; Dawson & Dekker 1992; Barnes 1993, 1996; Barnes et al. 1997b; Hedges et al. 2005).

Can dung counts really provide accurate estimates of animal abundance? In practice, dung counts have been shown to give estimates that are as accurate as other methods for a wide range of mammals, including elephants, and even for lizards (Barnes 2001). Furthermore, dung counts have the advantage that they give estimates that are more precise than aerial sample surveys of elephants and other large mammals (Jachmann 1991; Barnes 2002). This is because dung counts record the accumulated presence of animals over the preceding weeks and months, so the variation between transects is low. Even when the variance in defecation and decay rates is combined with the variance in dung density, the variance of the final estimate of elephant abundance is still modest. In contrast, aerial surveys and terrestrial sighting-based surveys record the instantaneous distribution of animals, and the variation between transects is usually high, giving estimates with wide confidence limits (Jachmann 1991; Barnes 2002).

Nevertheless, like other sample survey methods, dung counts will only provide good estimates if close attention is paid to detail and the assumptions are not violated. There are a number of issues which need to be addressed when planning dung counts, of particular concern are: (1) optimal survey designs for estimating dung-pile density, (2) consistent classification of dung-piles into stages to facilitate decay rate monitoring (3) the appropriate methods for estimating dung-pile decay rates, (4) defecation rates, (5) the particular problems posed by small populations, and (6) age determination of elephants from dung dimensions. It is the purpose of this Standards document to ensure that the MIKE programme's survey teams conduct dung counts in the most appropriate manner using what are the currently accepted best methods.

# 2. Where and when are dung count based surveys appropriate for elephants?

## 2.1 Where are dung counts appropriate?

### 2.1.1 Small populations and the problem of precision

As already mentioned, dung counts are generally used when dung-piles are easier to find than the animals themselves because, for example, the animals live in concealing habitat types such as forests. As we saw in Section 1.1, dung counts can produce more precise estimates than direct sighting based survey methods such as aerial surveys (Jachmann 1991; Barnes 2002). Nevertheless, a feature of most sampling methods is an inverse relationship between precision and population size (Taylor & Gerrodette 1993; Barnes 2002). That is, sample counts of small populations usually have a large coefficient of variation (CV). During samples of small populations, only small numbers of dung-piles will be recorded along transects. Thus dung count based surveys of small populations of elephants (like many of those that exist in the forests of West Africa or Southeast Asia) will probably give poor estimates of little use for assessing population trends.

How small is too small? Unfortunately, it is difficult and likely misleading to try and formulate a rule of thumb of the kind 'dung counts should not be used where one suspects that elephant population density is less than n/km$^2$'. This is true for a number of reasons:

1. dung-pile density does not just depend on elephant density, it is also depends on dung decay rates. So, if decay rates are low dung-pile density may still be sufficiently high to allow us to estimate the latter with adequate precision;
2. terrain is important. In difficult terrain, where it is very time consuming to conduct line transects, it may not be possible to complete a sufficient number of transects to achieve adequate precision in an appropriate time frame irrespective of elephant density (while in areas of easy terrain the same elephant density would lend itself to line transect surveys);
3. dung count based estimates of elephant density depend on the precision of our estimates of dung decay and dung production rates, as well as our estimates of dung-pile density, and so if our estimates of these other parameters are precise (e.g. with CV < 5%) then we can tolerate less precise estimates of dung-pile density;
4. in addition, for most forest sites the current 'estimates' of elephant abundance or density are in fact little more than guesses (Blake & Hedges 2004), and may well be substantial underestimates of the true elephant population size (see for example Blouch & Haryanto 1984:9; Blake & Hedges 2004:1197; Hedges et al. 2005:43–44). Therefore, deciding whether dung count based survey methods are likely to be appropriate on the basis of an existing 'estimate' may well preclude the use of dung count methods when they would in fact be appropriate.

For all these reasons, in the absence of good data for a site it will be necessary to conduct a pilot survey to estimate dung-pile encounter rates and to use these estimates to determine whether dung counts are appropriate for the site in question. By appropriate we mean: 'is the estimated total line length required to achieve the target coefficient of variation achievable with the resources available in the time available?' Pilot surveys are discussed in more detail in Chapter 3.

The general approach to estimating the total line transect length necessary to achieve a specified coefficient of variation from a pilot survey is given by Buckland et al. (2001). The relevant equation is:

$L = (b/\{cv_t(\hat{E})\}^2).(L_o/n_o)$

where

$L$ = estimate of total line length to be surveyed to achieve target coefficient of variation

$b$ = dispersion factor (= variance inflation factor)

$cv_t$ = target coefficient of variation

$\hat{E}$ = density estimate

$L_o$ = total length of all pilot transects combined

$n_o$ = total number of dung-piles found on all pilot transects combined

Estimation of *b* poses some difficulty from a short pilot survey, however Eberhardt (1978) provides evidence that *b* would typically be between 2 and 4 independent of *n*; and Burnham et al. (1980) provide a rationale for values of *b* in the range 1.5–3. Both Burnham et al. (1980) and Buckland et al. (2001) recommend the use of $b = 3$ for planning purposes. Another consideration is that *b* will be larger for surveys where the detection survey has a narrow shoulder, as in dung surveys (Buckland et al. 2001).

As an example, let us consider a short pilot survey where $L_o = 40$ km and $n_o = 160$ dung-piles (an encounter rate of 4 dung-piles / km). If we use $b = 3$ and a target coefficient of variation for our dung-pile density estimate, $cv_t(\hat{E})$, of 0.10 (= 10%) we see that the estimated total line length that we will need to survey to achieve the target coefficient of variation

$L = (3/(0.1)^2).(40/160) = 75.0$ km

Whether conducting a formal survey with 75 km of line transects is achievable with the resources available and within the necessary time frame for the site in question must then be assessed. The results of the pilot survey will also inform this decision since they will allow one to estimate the time required to conduct surveys in the site.

Clearly, before one can make these calculations one must also decide on an appropriate target CV for the estimate of dung-pile density for the site in question. This decision will need to be made in collaboration with the MIKE SSO for your area and the MIKE TAG's statisticians. It is possible, for example, that a CV of 20–25% for the dung-pile density estimate would be acceptable if the CV for the defecation rate and the site-specific dung decay rate were low (≤ 5%); if however they are significantly higher, then a target CV of ≤ 10% for the dung-pile density will more likely be needed.

In those cases where dung count based surveys are not appropriate because they are unlikely to return sufficiently precise estimates, fecal DNA based capture–recapture techniques should be considered (Eggert et al. 2003; see Chapter 3 and Chapter 9).

Furthermore, in sites where it is not possible to find a regular supply of fresh dung-piles (for monitoring dung decay; see Chapter 5), DNA-based capture–recapture techniques should again be considered.

### 2.1.2 Swamps and other inundated areas

Seasonally flooded areas can often be accommodated by appropriate timing of survey and dung decay monitoring work so that all fieldwork coincides with non-inundated periods.

Permanently flooded areas however pose real problems, as dung surveys cannot be conducted in flooded areas. Therefore, it likely that surveys in areas with significant areas (> 5%) of permanent swamp or similar landscape/vegetation types (which are used by elephants) such as Central Africa, will underestimate elephant density by an unknown amount.

## 2.2 What is the best time to conduct dung counts?

You should aim to conduct both the pilot survey and the subsequent formal survey during the same time of year (or at least during the same season) in order to minimize the problems caused by seasonal elephant movements. For example, the geographical limits of high- and low-density strata may vary significantly between wet and dry seasons in some areas.

In addition, dung count based surveys should not span seasons in order to avoid problems caused by possible significant seasonal changes in elephant defecation rates.

If the area is seasonally inundated, then conduct the count in the dry season (see Section 2.1.2).

In areas where the elephants eat large amounts of fruit during certain periods of the year, dung count surveys should be conducted outside of the periods of fruit availability. This is because eating large quantities of fruit likely increases the elephants' defecation rates therefore making selection of appropriate defecation rates for converting dung-pile density to elephant density problematic (see Chapter 6).

# 3. Planning and conducting dung count surveys: pilot surveys and formal surveys

## 3.1 Preamble

Sometimes it is difficult to assess which population survey method is the appropriate choice for any given forest site. There may therefore be a need to collect preliminary data during a pilot survey phase in such sites. In addition to helping you select the appropriate survey methods for your site, a pilot survey will also allow you to predict the logistical problems your survey teams are likely to face, test operational procedures, and provide training for the survey teams and others involved in the MIKE programme in your country.

This chapter will help you decide whether you will need to conduct a pilot survey before conducting a formal survey, and which methods to use for these surveys.

## 3.2 Methods: what to do and what order to do it in

**1) Preliminary data-gathering phase**

a) Determine the geographical limits for the site you are planning to survey. Determine whether your site is geographically open or closed, i.e. does the site's elephant population only use the site (a closed population) or is it likely to use areas adjacent to the site (an open population)?

  i) if open, seek advice from your SSO and the MIKE statisticians;

  ii) if closed, continue.

b) Obtain topographic maps and if possible satellite images for your site. Aerial photographs would also be good to have, but are not essential.

c) Prepare a digitised geo-referenced basemap for your site and incorporate this into a GIS database.

d) Compile all available reports and other data relating to elephant distribution and abundance for your site.

e) Talk to people familiar with your site, and compile any relevant information obtained.

**2) First decision-making phase (in consultation with your SSO)**

a) Is a large proportion (>5%) of your site permanently inundated (e.g. is covered by swamp)?

  i) if yes, seek advice from your SSO and the MIKE statisticians;

  ii) if no, continue.

b) If there are already dung count survey data for your site from previous surveys (including non-MIKE survey data) do the dung-pile encounter rates suggest that (1) a line transect based survey will achieve an adequate coefficient of variation (CV) for MIKE purposes within an appropriate timeframe (typically ≤ 3 months) and (2) that it will be possible to find a sufficient number of dung-piles for dung disappearance rate monitoring (typically 120 fresh dung-piles in representative areas within your site; see Chapter 5)?

i) If yes, you will be able to move straight to the formal survey phase and will therefore need to plan for a line transect based dung count survey with pre-survey dung-pile disappearance rate monitoring (go to # 6 in this sequence).

ii) If no, then you will need to consider a fecal DNA based capture–recapture survey design. This decision will need to be taken in consultation with your SSO and the MIKE TAG. If the decision is to proceed with a fecal DNA based survey, you will need to conduct a fecal concentration (FC) survey (go to # 7 in this sequence).

iii) If no dung count survey data exist, which will be the situation in most cases, you will need to conduct a pilot survey (go to # 3 in this sequence).

**3) Planning a pilot survey**

a) You now need to decide which methods to use for the pilot survey. This involves deciding whether the dung count method or the fecal DNA based approach is likely to be the method of choice for the formal survey. You will need to make this decision using all available data about likely elephant population size and distribution in the site. For instance, there may be previously collected data such as general wildlife surveys using camera traps or animal signs, ranger reports, etc.

i) If however there are no previously collected data for the site, or if you consider the existing data to be unreliable, or if you cannot decide from the available data whether line transects are likely to be appropriate (because you cannot use these data to infer likely dung-pile encounter rates) then two important aims of the pilot survey will be to determine dung-pile encounter rates to see whether dung counts will be appropriate for the formal survey; and to stratify the site by expected elephant density (stratification will help improve the precision of your population estimates). Recce-survey transects (RSTs) will be used to meet these two aims (see # 4 in this sequence and Chapter 7).

(1) You should <u>also</u> aim to determine whether it will be possible to find adequate numbers of fresh dung-piles for monitoring dung-pile disappearance rates, because if dung-count based methods are used for the formal surveys it will be necessary to find a minimum of 120 <u>fresh</u> dung-piles in areas representative of the vegetation and terrain types in the site during 6 or more equally-spaced visits to the site prior to the formal survey (i.e. 20 fresh dung-piles per visit; see Chapter 5).

(2) If it is not possible to find adequate numbers of fresh dung-piles for monitoring decay rates or to achieve adequate encounter rates for dung-piles (of all ages) on the RSTs then it will <u>not be possible</u> to use line transect based dung counts for the formal survey and you will have to consider fecal DNA based capture–recapture methods, the design of which is guided by fecal concentration surveys (see # 5 in this sequence and Chapter 9). Typically a fecal concentration survey will be implemented once the data from an RST survey has been analysed (see # 4.k.ii in this sequence) but if adequate numbers of people and other resources are available, it is possible and desirable to conduct an RST survey and a fecal concentration survey simultaneously.

ii) If the previously collected data (referred to in 3a above) suggest that dung-pile encounter rates would be too low to facilitate line transect based dung counts for the formal survey phase, then the aim of the pilot phase survey should be to assess whether fecal DNA based capture–recapture survey methods will be feasible and so a fecal concentration survey will be needed (see # 5 in this sequence and Chapter 9). In these circumstances no RST survey is necessary.

b) You must also decide whether the aim of the pilot survey is just to collect sufficient data to allow an appropriate survey method and design to be selected for the formal survey phase or whether the aim is also to collect data on the distribution of elephants within the sites, the extent of human disturbance, evidence of poaching, and the like. If these additional aims are to be met, the pilot surveys will need to be more extensive, covering a greater area within each site, and will therefore require more people and/or take longer (and will therefore cost more).

   i) Despite this greater cost, a good case can be made for such extensive pilot surveys. Field data from several sites in Central Africa point to the utility of such surveys. For example, in Minkébé, all elephant carcasses discovered have come from surveys using a method called the 'travel recce' (see Annex 4) and in the Ndoki forest Blake (2002) explained the ecological basis of forest elephant distribution using similar methods. The value of these data on elephant distribution and human penetration/utilization of sites is enormous. However, such surveys are outside the scope of this document, which is concerned with using dung counts to estimate elephant population size. Please consult your SSO for further advice.

**4) Pilot survey option 1: evaluation of a site's potential suitability for line transect based dung surveys using recce-survey transects to determine dung-pile encounter rates**

a) A relatively quick and easy method called the recce-survey transect (RST; see Chapter 7) should be used to determine dung-pile encounter rates and areas (strata) of high and low elephant density based on these encounter rates:

   i) to conduct a RST a survey team should walk along the line of least resistance through the forest while attempting to follow a straight line as far as possible, and record all dung-piles found. Distance along RST routes should be measured using a topofil[1]. A record of vegetation types and human sign found during the

[1] A topofil is an instrument for precise distance measurement. It is essentially a small box containing a reel of cotton thread and a metering device that records how much thread has been pulled out of the box. You simply tie the thread to a fixed object at your starting point, zero your meter and begin walking. The thread pulls out as you walk turning the counter. The instrument is mounted to your belt or carried in your hand, so the thread always remains taut. When you reach your desired finishing point, you simply break the cotton thread. Photodegradable thread breaks down with sun exposure.

RST should be recorded using an appropriate standard protocol for your region. All dung-piles found along the RSTs should be classified into decay stages using the MIKE S System described in Chapter 4. Perpendicular distance to the dung-piles should not be measured, but surveyors should note whether the dung-piles were within 2 m (≤ 2 m) of the survey line (this will help facilitate comparisons between areas of very different vegetation density and thus visibility, by allowing analysts to restrict their analyses of encounter rates to those dung-piles found no ≤ 2 m from the line). Depending on terrain and vegetation type, it should be possible to cover 1–6 km per day but individual RSTs should be 1–2 km in length. A target RST length should be decided during the survey design stage (see e below).

b) Wildlife survey sites are often stratified to decrease variance in density estimates. Stratification will likely be essential in all MIKE sites. It is common to define strata based on expected animal density (e.g. high, medium, low). It may be possible, from existing data, to define strata for some MIKE sites before beginning fieldwork. For sites where this is possible, strata should be defined prior to the pilot survey and the data collected during the pilot survey should be used to refine the stratification prior to the formal survey.

c) If insufficient data exist to facilitate stratification prior to the pilot surveys, serious consideration should be given to stratifying by distance from areas of human activity and/or vegetation types for the pilot surveys [see for example Barnes et al. (1997b), White & Edwards (2000), and Buckland et al. (2001)]. Advice should be sought from your SSO and the MIKE statisticians.

d) As discussed in the previous section (# 3.b.i in this sequence), it is important to decide on the aim of the pilot survey: is it just to collect data that will allow an appropriate method to be selected for the formal population survey phase or is it to conduct a more extensive survey of the site that will itself provide useful data on elephant distribution, human use of the site, and possibly poaching? The proportion of the site covered and survey effort needed for the latter will be larger, and so one needs to make this decision before one can move on to the design phase.

e) If time permits, the automated survey design module of the software package DISTANCE 4.0 (Thomas et al. 2003) should be used to locate the RSTs. If time is pressing, a standard systematic survey design with a random start point should be used. Advice should be sought from your SSO and the MIKE TAG. (The automated survey design component of DISTANCE is discussed in more detail in Section 8.2.1)

f) Ideally RSTs should be arranged so that they are parallel to any major gradients of density, so that variation in encounter rate is maximized within RSTs and minimized between them. So, for example, if one suspects that density decreases with increasing distance from major rivers then the RSTs should be placed approximately perpendicular to those major rivers.

g) Survey teams should be provided with a list of locations for the start points of the RSTs. Locations should be uploaded into a GPS and used for navigating in the forest in conjunction with maps (and any aerial photographs or satellite images that are available).

h) It may be desirable to adopt an adaptive survey strategy—i.e. stopping the survey when it becomes clear that dung-pile encounter rates are suitable for dung count methods and high <u>and</u> low density strata can be clearly identified (please discuss this with your SSO). This will be not be possible, of course, if one has decided to use the pilot phase surveys to gather data on elephant carcasses, human use of MIKE sites, etc. (see # 3.b.i above).

i) You should aim to conduct both the pilot survey and the subsequent formal survey during the same time of year (or at least during the same season) in order to minimize the problems caused by seasonal elephant movements. For example, the geographical limits of high- and low-density strata may vary significantly between wet and dry seasons in some areas.

j) During the pilot survey phase, the surveyors should also aim to determine whether it would be possible to find adequate numbers of fresh dung-piles for monitoring dung-pile disappearance rates. [Note: if dung-count based methods are used for the formal surveys, it will be necessary to find a minimum of 120 fresh dung-piles in areas representative of the vegetation and terrain types in the site (so not all in one elephant 'hotspot' around a saltlick for example). These dung-piles will need to be found during 6 or more equally spaced visits to the site prior to the formal survey (i.e. 20 fresh dung-piles per visit; see Chapter 5).]

k) Once all the RSTs have been completed, the dung-pile encounter rates should be analysed as described in Chapter 2 to estimate the total line length that will be necessary to achieve dung-pile density estimates with CVs of 10% and 20–25%. You will also need to estimate the effort required to find 120 fresh dung-piles for dung-pile disappearance rate monitoring. These estimates should then be discussed with your SSO and the MIKE statisticians. Specifically, it will be necessary to (1) decide on an appropriate target CV for the formal survey and then decide whether the pilots survey data (the RST data) indicate that it will be feasible to achieve this target in a 3-month formal survey using line transects and (2) whether it is likely to be feasible to find adequate numbers of fresh dung-piles in areas representative of the vegetation and terrain types in the site:

   i) if the answer to both these questions is yes, you will need to begin planning the formal line transect based dung count survey (go to # 6 in this sequence);

   ii) if the answer to both these questions is no, you will need to consider whether fecal DNA based capture–recapture methods should be used (go to # 5 in this sequence). It may be possible to conduct the fecal concentration surveys described in # 5 in this sequence immediately after the RST surveys: there is no requirement to wait until the following year. Indeed it may be possible to conduct RST surveys and fecal concentration surveys simultaneously if adequate resources exist.

l) Write a detailed report on your RST based pilot survey and submit it with together with copies of all your data and the associated computer files to your National Officer and your SSO (Chapters 11 & 12).

**5) Pilot survey option 2: evaluation of a site's potential suitability for fecal DNA based capture–recapture population survey methods using fecal concentration surveys**

a) Successful use of capture–recapture based population survey methods relies on a survey design that maximizes capture probabilities [e.g. see Karanth & Nichols (2002)]. This means that surveyors should search for elephant dung-piles in places where they are likely to be found, not in randomly selected plots. The aim of the pilot phase of fieldwork should therefore be to assess whether 'fresh' and 'reasonably fresh' dung-piles can be found in adequate numbers if survey teams search in likely elephant 'hotspots'. This approach is here called a fecal concentration survey (FC survey). Once these data have been collected it may be possible to immediately begin implementing a formal capture–recapture survey (see Chapter 9).

   i) For the present purposes a 'fresh' dung-pile is defined as one that is likely to be less than 48 hours old (also see Section 5.2.2). A 'reasonably fresh' dung-pile is defined as one consists mostly of intact boli that are not obviously degraded (mouldy, infested with termites, etc.). Ideally these 'reasonably fresh' dung-piles should be no older than two weeks (Eggert et al. 2003), but we realize that assigning actual ages to dung-piles will not be possible.

b) Planners should aim to conduct both the pilot FC survey and the subsequent formal fecal DNA based capture–recapture surveys during the same time of year (or at least during the same season) in order to minimize the problems caused by seasonal elephant movements.

c) Local hunters, researchers, and others familiar with the sites should be asked to provide information about likely elephant 'hotspots' including salt licks, water holes, major elephant trails, roads, and areas of frequent human–elephant conflict (e.g. crop depredations by elephants).

d) This data-gathering phase should be followed by careful searches of these 'hotspots' and any other likely sites:

   i) the number of fresh and reasonably fresh dung-piles found at 'hotspots' should be recorded, and their locations recorded using GPS equipment. Any other fresh and reasonably fresh dung-piles found while working in the site (e.g. walking between 'hotspots') should also be recorded. All fresh and reasonably fresh dung-piles should also be classified using the system presented in Chapter 4;

   ii) the location of all fresh and reasonably fresh dung-piles found during the FC survey should be entered into a GIS database to facilitate analysis and survey planning.

e) Once the FC survey is complete you should prepare a report with maps of the site showing the numbers and locations of 'fresh' and 'reasonably fresh' dung-piles found along elephant trails, at salt licks, and other elephant 'hotspots' together with the dates when these dung-piles were found. These data should then be analysed with the assistance of your SSO and the MIKE statisticians to determine whether a formal fecal DNA based capture–recapture survey should be attempted in your site. Note that it should be possible to begin implementation of the formal capture–recapture survey more or less immediately after the FC survey. See Chapter 9 for the present field protocol for a fecal DNA based capture–recapture survey.

**6) Formal survey option 1: using line transects to estimate dung-pile density, and converting this estimate to elephant density using appropriate dung production rate data and dung-pile disappearance rate data collected at the site in the period before the line transect survey**

a) Use standard line transect methods to estimate dung-pile density (Chapter 8):

   i) the total length of line transect will be determined by the target coefficient of variation for the survey (which will be set by the MIKE statisticians; see sections 2.1.1 and 8.2.1). The number, length, and location of individual line transects will be determined using the automated survey design component of DISTANCE 4.0 (Thomas et al. 2003; Section 8.2.1).

ii) typically all the line transects will need to be completed within a 3-month period.

iii) all dung-piles found during the line transect surveys must be classified using the MIKE S system (Chapter 4).

iv) for all those dung-piles found ≤ 1 m from the transect line and having intact boli (see dung-pile classification section) the circumference of the 3 largest intact boli should be measured; if only 1 or 2 intact boli are present in a dung-pile they should still be measured (Chapter 10).

b) Use the retrospective approach to estimating dung-pile disappearance rates [*sensu* Laing et al. (2003)]. This means that you must conduct decay experiments prior to the survey, at the survey site (field methods are described in detail in Chapter 5, so only a brief summary is provided here):

i) if possible, use local knowledge or the results of previous studies in the site to estimate the time, *t*, it takes for elephant dung-piles to disappear. Begin monitoring dung-pile disappearance rates *t* months prior to the mid-point of the line transect survey, e.g. if a 3-month-long line transect survey were planned for June/July/August 2008 and *t* is 4 months, disappearance rate monitoring should be initiated in March 2008. However, if there are no data on dung-pile disappearance rates for the site, start monitoring dung-pile disappearance a minimum of 12 months prior to the mid-point of the line transect survey;

ii) plan for a minimum of 6 equally-spaced visits to the survey site, with the final visit timed to coincide with the midpoint of the line transect survey (see Chapter 5 for further explanation);

iii) during each visit, locate, classify, and mark a minimum of 20 fresh dung-piles (see Chapter 5 for guidance on how to identify fresh dung-piles);

iv) all fresh dung-piles included in the decay rate monitoring experiments must be classified using the MIKE S system (Chapter 4);

v) all fresh dung-piles located and included in the monitoring program should be identified using a unique reference number;

vi) the procedures for searching for fresh dung-piles should aim to ensure that representative samples of the survey site's major vegetation types, rainfall zones, and topography (slope) are obtained;

vii) since it is vital that all marked dung-piles can be re-located, dung-piles that were marked in previous visits should be checked during all subsequent visits to (a) ensure that the teams can relocate the dung-piles and (b) to check that the markers are still present (and to replace these if necessary);

viii) dung-piles should only be reclassified during the final visit (to avoid excessive handling of dung-piles, which may affect decay rates). The final visit should be timed so that it falls in the middle of the line transect survey period that will be used to calculate dung-pile density;

ix) if possible, the same people who will conduct the survey should be responsible for monitoring decay rates. This is to try and ensure consistency of classification between decay monitoring experiments and surveys;

x) decide which dung-pile stages (in the S system) will be treated as 'still present' and which will be treated as 'disappeared'. Typically dung-piles in stages S1, S2, and S3 will be treated as 'still present' and dung-piles in stages S4 and S5 will be treated as 'disappeared' (but see Section 4.3 for situations when another division may be appropriate);

xi) calculate dung disappearance rates (see Chapter 5; also see Laing et al. (2003) and seek advice from your SSO and the MIKE statisticians).

c) Decide whether you will be estimating defecation (= dung production) rate at your site:

i) if you will, begin the defecation rate monitoring work at the same time as the dung-pile decay rate monitoring work (see Chapter 6 for essential guidance about the methods you will need to use);

ii) if you will not be estimating defecation rate at your site, select an appropriate rate for your region (see Chapter 6 and Annex 2).

d) Once the line transect surveys and decay rate monitoring work (and defecation rate work if attempted) are complete, calculate dung-pile density from your line transect data using the program DISTANCE 4.0 [Thomas et al. (2003); see Chapter 8]. Make certain that you use the same division of dung-piles into 'still present' (typically those in stages S1, S2, and S3) and 'disappeared' (typically those in stages S4 and S5) that you used in the dung disappearance experiments (see # 6.b.x above).

e) When you are happy with your dung-pile density estimates use program DISTANCE 4.0 to convert your dung-pile densities into elephant densities (DISTANCE 4.0 allow you to include estimates of dung-pile decay and defecation rates together with their standard errors).

f) Plot a histogram showing the distribution of dung-pile sizes in your site (using the dung-pile circumference data collected during the line transect surveys). These dung-pile dimension data will help you, your SSO, and the MIKE TAG estimate changes in elephant population age-structure when your site is re-surveyed (Chapter 10).

g) Write a report and submit it with together with copies of all your data and the associated computer files to your National Officer and your SSO (Chapter 11).

**7) Formal survey option 2: using fecal DNA based capture–recapture survey methods to estimate elephant population size**

a) Use the method described in Chapter 9.

# 4. Dung-pile classification

## 4.1 The new standard MIKE dung-pile classification system (the S system)

Whenever we aim to estimate elephant density from estimates of dung-pile density it is necessary to calculate dung-pile decay rates. This is done by monitoring the decay of freshly dropped dung-piles until they disappear. Dung-count based surveys rely on the field-workers responsible for monitoring decay rates and those counting dung-piles along transects being able to consistently classify dung-piles into the appropriate classes. It is very important therefore that the system adopted is simple to use and robust. The S system, described below, which was developed by WCS researchers in Sumatra and the Lao PDR, is such a system, and it is the system that should be used for MIKE dung-count based survey work. For a discussion of the problems with previously used systems see Annex 1.

Surveyors at each MIKE site should provide feedback on the implementation of this system so as to facilitate modifications and improvements to the system if/as necessary. Feedback should be passed from the site level to the appropriate SSOs/Regional Representatives and the latter should pass all feedback received to the MIKE TAG.

| **The MIKE 'S system' for dung-pile classification** | |
|---|---|
| **Stage** | **Definition** |
| S1 | All boli are intact (see notes below) |
| S2 | One or more boli (but not all) are intact |
| S3 | No boli are intact, but coherent fragments remain (fibres are held together by fecal material, see notes below) |
| S4 | No boli are intact; only traces (e.g. plant fibres) remain; no coherent fragments are present (but fibres may be held together by mud, see notes below) |
| S5 (gone) | No fecal material (including plant fibres) is present |

**Notes**

A bolus is 'intact' if: (1) its shape and volume is plausibly the original shape and volume; and (2) it is coherent **and** can be handled without crumbling.

A 'coherent' fragment is defined as a fragment (consisting of plant fibres embedded in a matrix of other fecal material) that does not crumble/break-up when handled. Plant fibres held together by mud **do not** count as coherent fragments.

The fecal material must be handled before a dung-pile is classified:

When examining boli to determine whether they are coherent it may be necessary to break them open to see if they held together by mud or fecal material.

When examining fragments they should be passed from one hand to the other and rubbed gently between the fingers to determine whether the fibres are truly coherent or whether they separate easily, **but no attempt to pull them apart or crush them should be made**.

It is important to remember that dung-piles may not be in stage S1 when freshly dropped by elephants, they can be in stage S2 (or even stage S3).

It is recommended that all survey leaders produce a sheet of annotated drawings and/or photographs to help teams correctly identify 'intact' boli.

## 4.2 Using the S system

- The standard MIKE dung-pile classification system (the S system) is to be used for all MIKE dung-count based survey work.

- During field work dung-piles should be recorded as belonging to stage ‘S1’, ‘S2’, ‘S3’, ‘S4’, or ‘S5’ as appropriate; dung-piles should not be recorded as, say, ‘present’ if in classes S1 through S3 and ‘disappeared’ if in classes S4 or S5. This classification into ‘still present’ and ‘disappeared’ is done during the analysis phase (also see Section 4.3).

- When testing to see whether a bolus is still coherent, gently touch and rock it to see whether the whole bolus moves as one (it is still ‘coherent’) or whether the bolus is in fact already split into more than one fragment (it is no longer ‘coherent’).

- Look to see whether termites or ants have hollowed-out boli. Such hollow boli will crumble easily when examined but when examining such boli to determine if they are coherent it may be necessary to break them open to see if they held together by mud or fecal material.

- If the number of boli is unclear, note the range of possibilities. For example, write ‘5 to 7 boli’ or ‘at least 4 boli’.

- Often knowing the exact number of intact boli will not be important (see above for definition of ‘intact’). For example, if a dung-pile has 5 boli, of which 2 are definitely intact and another may be intact, do not waste your time trying to decide whether the third bolus is intact or not because the dung-pile will be in stage S2 regardless of whether 2 or 3 boli are intact.

- You must, however, take the time to examine the boli carefully if answering the question of how many intact boli remain will determine which stage the dung-pile is in. For example, if a dung-pile has 5 boli, of which 4 are definitely not intact and the fifth may be intact, then deciding whether that fifth bolus is really intact or not will determine whether the dung-pile is in stage S2 or S3. If it is impossible to be sure, give both possibilities and make a note of the reason(s) why you are unsure.

- You must also be careful when deciding how many dung-piles the boli you find come from. Sometimes you will find 2 or more dung-piles close together. In such cases you will need to look at the size and appearance (colour, shape) of the boli, as well as how degraded they are (e.g. whether they have fungus growing on them), and how far apart the boli are. These observations will help you decide which boli belong to which dung-pile and how many dung-piles are present. The number of boli should also be used as a guide: most dung-piles contain 3 to 8 boli, so if you find 15 boli it is very likely that they belong to at least 2 dung-piles. If it is impossible to be sure, give all possibilities and make a note of the reason(s) why you are unsure.

- Surveyors at each MIKE site should provide feedback on the implementation of this system so as to facilitate modifications and improvements to the system if/as necessary. Feedback should be passed from the site level to the appropriate SSOs/Regional Representatives and the latter should pass all feedback received to the MIKE TAG.

## 4.3 The need for a multi-stage classification system

Why have a multi-stage classification system? Clearly, the minimum requirement is a simple two-stage system ('dung-pile is still present' / 'dung-pile is deemed to have disappeared'). However, having several classes allows for greater flexibility. For example, consider a survey team that finds that a large proportion of the dung-piles they had monitored over the months before their survey are still in classes S1–S3 at the time of their survey. If the team were to calculate elephant density using an estimate of dung-pile density derived from dung-piles in classes S1–S3 then the estimate of elephant density would be biased. However, providing that the majority of monitored dung-piles had made the transition to stage S3 prior to the survey, an unbiased estimate of elephant density could be calculated from an estimate of dung-pile density derived from dung-piles in classes S1–S2. A simple 'present' / 'disappeared' system does not allow such flexibility.

An additional note of clarification may be helpful here: for the example discussed above, when using Excel and Genstat to calculate decay rates (see Section 5.2.5) all dung-piles in stages S1 and S2 would be considered 'still present' and given a code of 1 and all dung-piles in stages S3, S4, and S5 would be considered 'disappeared' and given a code of 0.

# 5. Monitoring dung-pile decay rates

## 5.1 Preamble

Dung surveys require data on the abundance of dung-piles, defecation (dung production) rates, and dung-pile decay rates (sometimes referred to as disappearance rates). The last of these is usually the most problematic, and is the subject of this section.

Please note that throughout this document, the term 'decay' not 'disappearance' will be used to refer to the disappearance of dung-piles irrespective of the means by which the process occurs. For example, dung-piles that have been washed away by water, destroyed as a result of trampling by animals, or broken-down (decayed) as a result of bacterial processes, are all considered to have 'decayed'.

The design of experiments to allow robust estimation of dung-pile decay rates has received surprisingly little attention. Many elephant surveyors have not assessed dung decay rate at their sites, instead they have used data from other sites often many hundreds of kilometres from where they were working (Hedges & Tyson 2002). This is not to criticize these surveyors, often they had no choice. Nevertheless, decay rates can be highly variable between sites. For example, the reciprocal of mean duration time, which is often used to calculate decay rates (Dawson 1990; Barnes & Barnes 1992), has been calculated from several studies in Africa and the results nicely illustrate the problem of between site variation. For northeastern Gabon, Barnes & Barnes obtained decay rates of 0.022–0.026, and for Lopé Reserve in central Gabon, White (1995) obtained a decay rate of 0.018. In nearby southwestern Cameroon, Nchanji & Plumptre (2001) obtained decay rates of 0.013 to 0.007, or 38.8% to 72.2% of the values from Gabon. Nchanji & Plumptre note that some of this variation may be due to differences in the researchers' determination of when dung-piles have disappeared, which can be rather subjective depending on the classification system used (see Chapter 4 and Annex 1), but this cannot account for all the difference.

White's study shows that the fruit content of the elephants' diet is likely to have a large effect on the mean duration of dung-piles. In addition, the work of White (1995), Barnes et al. (1997a), and Nchanji & Plumptre (2001) clearly show that climate, and especially rainfall, plays a major role in determining dung decay rates. Thus inter-site differences in rainfall regime and elephant diet (especially the fruit content of the diet), and probably vegetation type, prevent simple extrapolations between sites and seasons. This has major implications for dung-based elephant surveys and is a strong argument against the use of decay rates from other sites.

More fundamentally, in most studies to date, dung-piles have been monitored until they disappear, and in many cases monitoring has been initiated at the same time as the dung surveys themselves. This approach, termed the *prospective* method by Laing et al. (2003) can lead to significant biases (Hedges & Tyson 2002; Laing et al. 2003). Fortunately, an alternative approach, increasingly known as the *retrospective* approach, has been developed [Laing et al. (2003); also see Hiby & Lovell (1991), Marques et al. (2001), and Buckland et al. (2001:186–187)]. Retrospective estimates of dung decay require the surveyors to locate cohorts of fresh dung-piles by making a number of visits (≥ 6 visits) to the area prior to the survey. These marked dung-piles are then revisited to establish whether they are still present or have decayed at the time of the survey. Logistic regression techniques can be used to estimate probability of decay as a function of time, and possibly of other covariates, and the mean time to decay is estimated from this function (Buckland et al. 2001:186–187; Laing et al. 2003).

All MIKE dung surveys must use the retrospective method of estimating dung-pile decay rates [*sensu* Laing et al. (2003)]. This means that it is essential to conduct decay experiments prior to every survey, at every survey site. However in providing the following minimum standards and guidance for undertaking dung decay estimation, it should be recognized that there has been very little field experience with the retrospective method and so feedback is encouraged in order to improve the guidance provided here. Nevertheless, recent elephant survey work that has or is using the retrospective methods, demonstrates its' applicability.

## 5.2 Methods to be used

### 5.2.1 Design and timing of decay rate monitoring experiments

- All MIKE dung surveys must use the retrospective method of estimating dung-decay rates [*sensu* Laing et al. (2003)]. The prospective [*sensu* Laing et al. (2003)] and steady state approaches [*sensu* McClanahan (1986)] to incorporating decay rates into elephant density estimation must <u>not</u> be used for the MIKE programme.

- Use of the retrospective approach means that it is essential to start to conduct decay experiments <u>prior</u> to every survey, at <u>every</u> survey site.

- If possible, use local knowledge or the results of previous studies in the site to estimate the time, *t*, it takes for elephant dung-piles to completely disappear. Begin monitoring dung-pile decay rates *t* months prior to the mid-point of the line transect survey, e.g. if a 3-month-long line transect survey were planned for June/July/August 2008 and *t* is 4 months, decay rate monitoring should be initiated in March 2008. If there are no data on dung-pile decay rates for the site, start monitoring dung-pile decay a minimum of 12 months prior to the mid-point of the line transect survey.

- Plan for a minimum of 6 equally spaced visits to the survey area, with the final visit timed to coincide with the midpoint of the line transect survey. For example, if *t* is 4 months and the survey is planned for June/July/August 2008, the 6 equally spaced visits will need to be made at 20 day intervals and will take place in April, May, June and July 2008.

- At each visit, locate, classify, and mark a minimum of 20 fresh dung-piles (see below for guidance on how to identify fresh dung-piles). It should be noted that at present there is some uncertainty about the number of dung-piles that need to be monitored: 20 dung-piles per visit may be too many and 10 may be adequate. However, given this uncertainty the precautionary principle suggests aiming for a minimum of 20 per visit (or 120 for the whole study): survey work is expensive and so we do not want to discover that 60 is inadequate after the survey is completed.

- The procedures for searching for fresh dung-piles should aim to ensure that representative samples of the survey site's major vegetation types, rainfall zones, and topography (slope) are obtained. Ideally, this would involve a designed survey, for example one comprising several strip transects, randomly or systematically placed within the study area, to ensure that landscape/vegetation types ('habitat types' are sampled in proportion to their occurrence (Buckland et al. 2001; Laing et al. 2003). Dung-piles identified for monitoring should be left *in situ* (and should not be protected in any way, by for example the creation of fences around them).

- In practice, it may require searching for fresh dung-piles in three or four areas selected to encompass as many of the factors likely to affect dung decay rates as possible. Before adopting this latter approach it is essential to consult with your SSO.

- If the method for searching for fresh dung-piles in representative areas given immediately above is simply not feasible, consideration should be given to methods that rely on finding a concentration of elephants (and therefore fresh dung-piles) and establishing dung decay monitoring experiments by moving dung-piles to representative areas. Unfortunately this ‘find and move’ approach is problematic. For example, if dung decay plots are established by moving freshly dropped dung-piles to locations chosen to represent, say, different vegetation types, the decay rates in these plots may in fact not be truly representative of decay rates in those vegetation types. A further concern here is the density of dung-piles in the plot, for example artificially high densities of dung-piles may attract dung beetles and lead to higher than typical decay rates. Even if dung-piles are moved to random locations those locations may not be representative of areas where elephants defecate. Another issue is the loss of dung-piles to flooding: plots are unlikely to be established in areas close to rivers for example, but dung-piles will be dropped in such areas. Thus the use of plots or other ‘find and move’ approaches is likely to underestimate the decay rates of dung-piles. This is why for unbiased estimation, the ideal is to locate freshly dropped dung-piles by systematic searches of landscape/vegetation types (‘habitat types’) sampled in proportion to their occurrence, and then monitor the dung-piles *in situ*. However, we recognize that the ideal may not be obtainable at all sites. If ‘find and move’ approaches have to be used, advice must be obtained from MIKE SSOs/Regional Representatives and the MIKE TAG.

- Great care should be taken to avoid over-representation of dung-piles dropped at waterholes and saltlicks, or on logging roads or major elephant tracks. These dung-piles are likely to decay at unrepresentatively slow rates because of their exposure to sunlight, which dries them out (White 1995), or at unrepresentatively high rates because of the effects of trampling by animals (Hedges & Meijaard in prep.). The teams should therefore search off trails in the adjacent forest whenever they find evidence of fresh elephant presence.

### 5.2.2 Field methods for dung-pile decay rate experiments

- Search for and classify/mark fresh dung-piles only. Fresh should be taken as meaning dung-piles dropped within the previous 48-hours. It is important to remember that fresh dung-piles may not be intact; they can be in stage S2 (or even stage S3) when found. Fresh dung-piles are identified by their appearance. They will be moist throughout, making then dense (heavy). They will usually feel slimy to the touch. Flies will often be present and the dung-pile should smell of elephant dung, not fungus, or earth. Very fresh dung-piles are usually a lighter-brown colour than older ones. Secondary evidence of fresh dung is provided by the presence of obvious recent elephant footprints and possibly damage to vegetation (e.g. plants pushed-over or trampled/eaten).

- The recommended means of identifying ‘fresh’ dung-piles given above should be used in those areas where it is not possible to find sufficient dung-piles to facilitate a more experimental approach. However, if time, human resources, and dung-pile abundance permit, the criteria for identifying ‘fresh’ dung-piles should be studied; and if, for example, observations show that the criteria classify dung-piles as ‘fresh’ if they are up to four days old, fresh sign should be considered to be 2 days old (the average age of signs identified as fresh) for the purposes of analysis, as recommended by Laing et al. (2003).

- Dung-piles should not be fenced-off or otherwise protected from trampling, disturbance, etc. They should be left as they were found.

- Datasheets and field notebooks should be used to record decay rate data as described below (having a notebook in addition to a datasheet allows you to record additional information which will help you relocate the dung-piles; see box 5.1).

- The number of boli per marked dung-pile should be recorded.

- All fresh dung-piles located and included in the monitoring program should be identified using a unique reference number, which is recorded on the appropriate datasheet, in the team's field notebook, and on a marker (a metal stake) that is pushed into the ground next to the dung-pile. Indelible-ink pens or paint will be needed to write on these metal stakes. Bamboo or wooden stakes should be avoided if possible, as they tend to rot or be eaten by termites.

- The reference number should also be written in red paint on a nearby tree and the number of paces and compass bearing from the tree to the dung-pile recorded in the team's field notebook. Finally, the dung-pile should also be marked by tying orange flagging tape (marked with the reference number) to a suitable nearby branch, and recording in the field notebook the number of paces and compass bearing from the tape to the dung-pile. (This duplication of effort may seem like overkill but experienced dung surveyors know that metal stakes get kicked-out by elephants or covered by dung-piles, that ants cut flagging tape from trees, and that red paint fades and can be hard to see in the gloom of the forest. Furthermore, because only a relatively small number of dung-piles are monitored during these experiments a failure to relocate even a few dung-piles can have serious implications.)

- In addition to the location data described above, the GPS location of the dung-pile must be recorded on the datasheet.

- A general description of the location (e.g. 'approximately 2 km downstream of Ban Thalang, 200m west along major elephant trail, on the north bank') should be recorded in the team's field notebook.

- Locations of all marked dung-piles should be clearly recorded on datasheets so that the dung-piles can be easily found again. This should be tested to see whether the directions recorded (bearing and number of paces from recognizable landmarks or GPS points) are adequate.

- Monitoring teams must make a duplicate set of datasheets as a back up. One copy should be left at the base-camp.

**Box 5.1: Data to record when monitoring dung-pile decay rates**

**(a) Essential location data for monitored dung-piles**

| What to record: | Where to record it: |
|---|---|
| Reference number | Write it on a nearby tree (using red paint), on the orange flagging tape (using a permanent black marker pen), and on the datasheet (in black waterproof ink), as well as in the field notebook. |
| GPS location data (UTM data) | Write it on datasheet and in the field notebook. |
| Paces and compass bearing from tree with red painted reference number | Write it on datasheet and in the field notebook. |
| Paces and compass bearing from orange flagging tape | Write it on datasheet and in the field notebook. |
| A description of the location (to help you find the general area again) | Write it in the field notebook. |

**(b) Other data to record for each dung-pile**

In addition to the reference number and location data discussed above, the following data should be collected for each dung-pile:

- The date the dung-pile was found
- The number of boli in the dung-pile
- Whether the dung-pile was found on a trail or not
- Whether the dung-pile was moved (e.g. whether it was moved off a trail into the surrounding forest)
- The vegetation type
- Slope (degrees)
- Altitude (metres above sea level)

**See the example datasheet (at end of Chapter 5).**

## 5.2.3 Classification and reclassification of dung-piles during decay rate monitoring experiments

- The MIKE programme will use logistic regression methods to estimate the probability of dung-pile decay as a function of time (Laing et al. 2003). This method only require a single follow-up visit, timed to coincide with the mid-point of the line transect survey, to establish whether the dung-piles are still present or have disappeared.

- However, since it is vital that all marked dung-piles can be re-located, if time permits dung-piles that were marked in previous visits should be checked during all subsequent visits to (a) ensure that the teams can relocate the dung-piles and (b) to check that the metal stakes, red paint, and flagging tape are still present (and to replace these if necessary).

- Nevertheless, it is more important for the teams to search for additional fresh dung-piles during a site visit than it is for them to return to previously marked dung-piles. Priority should therefore be given to searching for new dung-piles.

- Dung-piles should only be reclassified during the final visit (to avoid excessive handling of dung-piles, which may affect decay rates). The final visit should be timed so that it falls in the middle of the line transect survey period that will be used to calculate dung-pile density.

- It is vitally important that the criteria for determining whether dung-piles have decayed used during the decay monitoring experiments are the same as those used in the surveys to estimate dung-pile density. In all cases the S system described in this document should be used (Chapter 4).

- If possible, the same people who will conduct the survey should be responsible for monitoring decay rates. This is to try and ensure consistency of classification between decay monitoring experiments and surveys. Where it is not possible to use the same people, regular checks of consistency between teams should be conducted.

- In any case, dung decay rate monitoring programs should be designed so that testing inter-observer consistency of dung-pile classification is possible, and such testing should be conducted during each visit.

## 5.2.4 Equipment needed for dung decay rate monitoring

### 5.2.4.1 Each dung decay monitoring team will require:

*8.3.1 Dung-pile monitoring equipment*

- Metal stakes (e.g. tent pegs) for marking dung-piles
- Hammer
- Flagging tape (for indicating dung-pile locations)
- Red paint and paint brushes
- Permanent marker pens (lots!)
- Two GPS units
- Two sighting compasses
- Datasheets and clipboards
- Waterproof notebooks
- Pencils and indelible pens
- Dung classification field reference sheet (illustrated with photos and diagrams of classified dung-piles)
- Vegetation classification field reference material (appropriate for site/region)
- Clinometer

*8.1.3 Camping equipment*

- Mosquito nets
- Hammocks (optional)
- Tents and/or tarpaulins
- Groundsheets
- Cooking paraphernalia and water bottles
- Rucksacks
- Torches and batteries
- First-aid kit

## 5.2.5 Analysis of decay rate data

The data required to estimate mean time to decay are, for each marked dung-pile, its age on the date of the last visit and its status, which is = 1 if not yet decayed (‘still present’) or = 0 if ‘disappeared’. Assume for now that no other covariates have been recorded.

Enter the data into an Excel worksheet in two columns headed DAYS for the age of the dung-piles in days, and STATE for the status, for example:

| DAYS | STATE |
|---|---|
| 50 | 0 |
| 50 | 0 |
| 50 | 1 |
| 50 | 0 |
| 50 | 0 |
| 42 | 1 |
| 42 | 0 |
| … | … |
| etc. | etc. |

The basic method of estimation is described by Laing et al. (2003). However, considerable simplifications to their calculations are possible. A Genstat program (Genstat version 7) has been prepared to produce the estimated mean decay time, its standard error, and coefficient of variation (CV). You can obtain the latest version from your SSO.

### Estimating decay rate using Excel and Genstat:

- Start Genstat and read in the data from the Excel spreadsheet prepared as above
- Select Open from the File menu and the select Files of type: Other Spreadsheet Files
- Open the Excel workbook and select the worksheet containing the data
- Click Next twice
- By moving columns with the -> and <- buttons, ensure that the Selected Columns are just DAYS and STATE
- Click Finish and then OK
- Next load the program in the file mean decay.gen
- Select Open… from the File menu and select Files of type: Genstat Files
- Open the file mean decay.gen
- Select the window with the mean decay.gen program file and run the program by clicking ctrl-W

The estimated mean decay time, its SE and CV should be at the bottom of the Genstat’s output window. The Excel file Dung decay example.xls contains some fictitious data. Before ‘going live’ with analysis of real data, it is recommended that you get some practice with this.

# ELEPHANT DUNG-PILE DECAY (DISAPPEARANCE) RATE MONITORING DATASHEET

Sheet number: Dates: Locations:
Observers / technicians responsible: Data entered to computer? (Y/N): Computer file name(s):

| Dung-pile ref. number | Date dung-pile found [dd/mm/yy] | Number of boli | Dung-pile moved? (yes/no) | Location [give UTM or lat/long coordinates] On trail? | Vegetation type, slope, altitude | Information to be recorded for each dung-pile during each trip: enter number of days since dung-pile was originally found, the date (dd/mm), whether it was found again during subsequent visits, and the stage it was in for the first and last visits | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Visit #1 | Visit #2 | Visit #3 | Visit #4 | Visit #5 | Visit #6 | Visit #7 | Visit #8 | n/a | n/a | n/a | n/a | n/a |
| EX1 (example) | 12/03/04 | 5 | No | 18534500 12040000 Not on trail | Scrub 10° 800m asl | S1 fresh 12/03 | found 31 days 12/04 | found 61 days 12/05 | not found 93 days 13/06 | found 121 days 11/07 | found 150 days 9/08 | found 181 days 9/09 | S5 211 days 9/10 | – | – | – | – | – |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |

In this example, visit #8 coincides with the midpoint of a 3-month line transect survey and is therefore the last visit.

# 6. Defecation rates

## 6.1 Background and justification for defecation rate data recommendations

To estimate elephant population density from dung-pile density requires knowledge of defecation rates (dung production rates) as well as dung decay rates. Defecation rate data for all elephant taxa, however, are scarce.

Obtaining defecation rate data from wild elephants, particularly in forests, is difficult and potentially dangerous. In theory, captive elephants can be used to produce the necessary data, but in practice, there are serious concerns about the influence of a typical captive elephant's diet on its defecation rate.

Studies of forest-dwelling elephants in Africa have found defecation rates between 16.2 and 19.77 per 24-hours, with no evidence of seasonal variation (Merz 1986; Tchamba 1992; Theuerkauf & Ellenberg 2000; Annex 2).

Encouragingly, the work of Tyson et al. (in review) suggests that for elephants in weakly seasonal environments in Asia, defecation rates are likely to fall within the same range as that found in African forest elephants. Tyson et al. used 10 tamed but wild-caught Asian elephants to determine daily (24-hour) defecation rates. Fieldwork was carried out in Way Kambas National Park in Sumatra (in Indonesia) during the 2000 dry season and the 2001 wet and dry seasons. Elephants were allowed to forage naturally in the forest during the day and were chained in areas of natural forage during the night. After eliminating incomplete data, arising from disturbances caused by flooding and wild elephant raids, Tyson et al. obtained 33 complete 24-hour periods for each of the 10 elephants in the first trial. The second and third trials produced data from 55 and 54 complete 24-hour periods, respectively. This study therefore has the largest sample size—by a large margin—of any defecation rate study in either Africa or Asia (Annex 2). Median defecation rate for the 10 elephants in each trial was 18 per 24 hrs; with an overall mean of 18.07 with 95% CI [17.93, 18.20] and a standard error of 0.0689. No seasonal effect on defecation rate was found (Tyson et al. in review).

Furthermore, the work of Vancuylenberg (1977) and Watve (1992), in south-eastern Sri Lanka and southern India respectively, also encourages the belief that defecation rates for wild Asian elephants are likely to be between 16 to 18 per 24-hours (Annex 2). Interestingly, Reilly (2002a), reported a figure of 17.93 per 24-hours for Asian elephants in Way Kambas National Park in Sumatra during the wet season of 1998, but lower defecation rates in the dry seasons of 1994 and 1997 (11.83 per 24-hours in 1994, 13.04 per 24-hours in 1997). However, both 1994 and 1997 were El Niño Southern Oscillation (ENSO) years, and her site in Sumatra experienced a severe drought and extensive forest fires in both years. Under these circumstances we would expect forage availability to be restricted with a concomitant reduction in the elephants' forage intake and defecation rates.

What do the results of these studies imply for dung-count based estimates of elephant population size? Captive elephants can be used to obtain the necessary data in some areas, provided that the captive elephants are allowed to forage freely in typical elephant habitat, as in the present study. These studies are expensive, however, and it seems unlikely that many further studies of defecation rate will be conducted in the near future. We need to ask, therefore, whether it would be appropriate to use the data from Sumatra and the Indian sites for other sites in Asia and the data from the African sites for other sites in Africa.

We see two approaches to this problem and these are described below.

- **For forests in weakly seasonal areas.** Assume that (a) defecation rates do not show significant seasonal variation in forests (Merz, 1986; Tchamba, 1992; Theuerkauf & Ellenberg, 2000; Tyson et al. in review), and (b) that a rate of 18 defecations per 24-hours is appropriate for forest sites in weakly-seasonal areas of Asia and Africa (see above).

- **For strongly seasonal areas and for forest areas where the assumptions made above are considered inappropriate.** There are no data from strongly seasonal areas of Southeast Asia, but such data do exist for southern India, and these data (together with those from Africa) suggest that defecation rates in these areas show major seasonal variation because of the large variations in the protein, fibre, and moisture content of elephant food stuffs (Guy 1975; Barnes 1982; Dawson 1990). For such seasonal areas, and for forest areas where the assumptions made above are considered inappropriate, we suggest that dung count data be corrected for dung-pile decay rate but not for defecation rate, and that the resulting index of population density be used to evaluate trends. For this approach to be appropriate, all subsequent dung surveys would have to be conducted at the same time of year as the first survey, and there should be no significant intra-seasonal variation in defecation rate. Providing these conditions are met the indices of population density produced may be treated as direct analogues of absolute population density (Hedges & Tyson 2002; Tyson et al. in review).

Even in the relatively non-seasonal equatorial regions, extreme climatic conditions, such as those caused by ENSO events, may have a pronounced effect on defecation rates of elephants in forests. It is recommended that surveyors of forest elephant populations who wish to calculate the number of elephants from dung surveys only count dung dropped during typical climatic conditions if they want to apply the 18 defecations per 24-hour rate recommended here.

## 6.2 Defecation rates to be used for MIKE surveys

- In areas where the climate does not show marked variations (e.g. pronounced wet and dry seasons) a mean rate of 18.07 defecations per 24 hours and standard error 0.0698 (Hedges et al. 2003; Tyson et al. in review; Annex 2) should be used until additional studies have been completed.

- In areas where the elephants' eat large amounts of fruit during certain periods of the year, dung count surveys should be conducted outside the period of fruit availability. This is because it is suspected that eating large quantities of fruit increases elephants' defecation rates.

- All repeat dung-based surveys in a given site should be conducted at the same time of year (i.e. during the same season) as the first dung-based survey.

## 6.3 The need for additional studies and recommended methods for such studies

- Additional studies should be conducted in both strongly seasonal environments and more constant ones. There are good opportunities for more work in both Southeast Asia and South Asia (tracking of captive elephants when they are foraging in the wild).

- For strongly seasonal environments, at least one forest site in Southeast Asia (Myanmar or Thailand) or one forest site in South Asia (India or Sri Lanka) should be selected for further defecation rate monitoring studies.

- At least one more site in a stable forest environment outside of Indonesia should be conducted to supplement that conducted by WCS in Sumatra (Tyson et al. 2003).

- At least one study in forest in Central Africa should be conducted.

- For all these sites the following methods should be used:

  - tame captive elephants, such as those held in timber camps, can be used for defecation rate studies, but it is important that the animals are allowed to feed on a natural diet by foraging freely in typical wild elephant habitat.

  - defecation rate data should not be collected for the first three days of any study in order to ensure all foodstuffs consumed prior to the beginning of the period of feeding on a natural diet have passed through the animals' digestive systems (Karesh pers. comm.).

  - monitoring should be conducted over continuous 24-hour periods to account for diurnal/nocturnal variation in defecation rates (Ananthasubramaniam 1992; Tyson et al. in review) and unexpected peaks in defecation.

  - extrapolation from short observation periods (< 1 week in length) may be unrepresentative and should be avoided.

  - data should be collected from both male and female elephants, and if possible from juvenile animals as well as sub-adults and adults (2 adults, 2 sub-adults, and 2 juveniles is the recommended minimum).

  - moving tame captive elephants into forest environments in order to study defecation rates is potentially dangerous to the health of wild elephants living in the forest, since diseases and parasites may be introduced to the wild population. Therefore, suitably qualified veterinarians should check the health of the captive animals before they are allowed to feed in areas with wild elephants.

  - tracking of wild elephants is not recommended, but there are situations where it is likely to be the only option (e.g. in African forests). Only experienced elephant trackers should attempt this hazardous task. Even with skilled field personnel, there is a risk of error if the team misses defecations produced by the target group, or include old dung piles or dung from non-target elephants.

  - the method of observing elephants at waterholes and saltlicks may produce biased data and should not be used [e.g. Watve (1992) found that the defecation rate at waterholes and saltlicks was 1.15/hour, while it was only 0.66/hour in the forest in Mudumalai Wildlife Sanctuary in southern India].

- For all studies, whether involving captive or wild elephants, it is essential to seek advice from people with experience of monitoring elephant defecation rates during the planning stage.

# 7. Estimating dung-pile encounter rates using recce-survey transects: field methods

## 7.1 Introduction

In places where there is little or no information about the elephant populations of the area to be surveyed it may be necessary for MIKE dung-count based surveys to be done in two stages (Chapter 3). The first stage is the pilot survey, which has the following aims:

1. to collect data on elephant distribution and abundance (by collecting data on dung-pile encounter rates). This will help you design an efficient line transect based survey for the second stage (the formal survey).
2. to allow the teams to become familiar with the survey site;
3. to allow the teams to become familiar with the equipment (GPSs, compasses, topofils, etc.) and with camping in the forest;
4. to assess any logistic problems, for example the feasibility of access to difficult areas.

The pilot survey uses relatively quick and easy methods to assess elephant distribution. The main method used is the recce-survey transect (RST). These RSTs involve small teams walking through the forest and counting all elephant dung-piles seen. The teams attempt to stay on a pre-determined compass bearing but they are allowed to make detours around obstacles as necessary. There is no requirement to maintain a dead straight line or to measure the perpendicular distance from the survey line to any dung-piles seen. RSTs are thus much quicker than formal line transects.

## 7.2 Recce-survey transect methods

### 7.2.1 General methods

- Each RST teams should be composed of a minimum of three people: (1) a cutter, who cuts a way through the forest as needed; (2) a compass person, who directs the cutter; and (3) a dung-pile spotter and data-recorder.
- The spotter/data-recorder carries a topofil to record the distance walked from the start point and a GPS.
- GPS data should be recorded at the beginning and end of every RST. In addition, GPS data should be recorded every 500 m along the RST.
- RST routes will be 1–2 km in length depending on the survey design adopted for the pilot survey (see Chapter 3).
- The speed at which the teams complete the RSTs will depend on terrain, the vegetation types encountered, and the amount of elephant dung found. However, as a guide, RSTs in forested areas should not be conducted faster than 1 km per hour. For grasslands, the maximum speed should be 45 minutes per 1 km. At speeds faster than these, it is likely that the teams will miss a significant number of dung-piles.

- Data collection on RSTs should be suspended during heavy rain, very overcast conditions, or other times of poor visibility. Furthermore, RST data should not be collected before 07:00h or after 16:30h due to poor visibility.

- Once an RST has been completed, the team may travel on to the next RST or back to the camp.

### 7.2.2 Cutting recce-survey transect lines

- The cutters should cut just the minimum needed to allow the team to walk through the forest. Do not make a path or trail. Cutting too much vegetation along the route is bad because:

    1. it damages the forest;
    2. it allows poachers easy access;
    3. it wastes time and energy;
    4. falling branches and leaves can cover dung-piles making them difficult to see.

### 7.2.3 Dealing with obstacles along recce-survey transect routes

- Remember, unlike for line transects, there is no need to maintain a dead straight line. The idea is to walk on a compass bearing making detours around obstacles so as to avoid wasting time and energy. However, RST teams should not deviate from the original compass bearing by more than 45° and should aim to return to the original line after any deviations.

- The following guidelines for dealing with obstacles should be used:

    - thickets, major treefalls, etc.: do not waste time chopping through these obstacles. Use the compass to find a landmark on the other side of the obstacle then walk around the obstacle to the landmark passing the topofil over or through the obstacle if possible. If it is not possible to pass the topofil over/through the obstacle, simply walk around the obstacle carrying the topofil. The small inaccuracies in RST length introduced by doing this are not important and should be ignored.

    - water bodies such as flooded grasslands that you can wade across: continue the RST as normal, but record the distance on the topofil at the point you begin wading and at the point where you stop wading. This is because we need to know that, for example, 300 m of the RST route was under water when calculating dung-pile encounter rates.

    - water bodies such as deep pools, lakes, etc. that you cannot wade: record the GPS location at the edge of the water, identify a landmark the other side of pool/lake, break the topofil thread, walk around the pool/lake to the landmark, record the GPS location at the landmark, estimate the distance across the water body that should have been walked, then continue as normal having re-tied the topofil thread.

    - major rivers, gorges, cliffs, etc. that you cannot cross: record distance and GPS location, stop recce-survey transect, return to camp.

### 7.2.4 Things to record along recce-survey transects

- Record all of the things in the list below, and make a note of the distance from the start point of the RST using a topofil. In addition, for those things indicated below, GPS locations should also be recorded:

| | **Record distance from start point using a topofil** | **Record GPS location** |
|---|---|---|
| All elephant dung-piles found (see below for further detail) | Yes | No |
| Any sightings of elephants | Yes | Yes |
| Any elephants heard | Yes | Yes |
| Any elephant carcasses found | Yes | Yes |
| All elephant trails that cross the recce-survey transect route | Yes | No |
| Any logging roads that cross the recce-survey transect route (the spotter/recorder should note whether elephant footprints are present) | Yes | No |
| Any crop fields or other agricultural activity encountered | Yes | Yes |
| Any other signs of human activity (e.g. snares, poachers' camps, etc.) | Yes | No |
| Any saltlicks | Yes | Yes |
| Any streams or small waterholes | Yes | No |
| Any ponds or lakes | Yes | Yes |
| Transitions between major vegetation types | Yes | No |

Why take GPS reading for some things and not others?

- Dung-piles: it is far too time-consuming to take GPS readings for every dung-pile and in any case unnecessary as the topofil indicates how far along the line any dung-pile was found and GPS fixes will not be used in any analyses;
- Animal trails or logging roads crossing RSTs: same as for dung-piles (too time-consuming, precise coordinates are not needed, and the information is available from topofil readings);
- Streams: as for dung-piles and animal trails;
- Transitions between major vegetation types: again the topofil reading provides the location data at an appropriate resolution; waiting for a GPS reading at every vegetation type transition will waste lots of time for no gain in useful data.

- When returning to camp after completing a RST all dung-piles seen should be counted and a note made of any elephants seen or heard.

### 7.2.5. Finding and recording elephant dung-piles along recce-survey transects

- For all elephant dung-piles found along the RSTs the distance (in metres) from the start of the recce-survey transect should be recorded. A topofil is used to measure these distances.

- All dung-piles seen while conducting RSTs should be classified into decay stages using the MIKE S system classes (Chapter 4).

- There is also no need to measure the distance from the line to the dung-pile or the size of the dung-pile. Remember, you are just collecting data on dung-pile encounter rates. However, you should note whether the dung-piles are ≤ 2 m from the RST line (this will help facilitate comparisons between areas of very different vegetation density and thus visibility, by allowing analysts to restrict their analyses of encounter rates to those dung-piles found no ≤ 2 m from the line).

- The team members should also examine the dung-piles to determine whether the boli present form one or more than one dung-pile. Use the number and size of the boli (especially their diameter), their colour and general appearance, and the distance between the boli to guide your decision (see the section on dung classification for further detail).

## 7.2.6 Data collection and management for recce-survey transect teams

- Record the RST data on approved datasheets. These datasheets should be kept in a folder in a watertight bag.

- When the teams return to the base-camp/office after each survey trip the team leaders must enter the data into the computer and photocopy the datasheets.

- The original datasheets should be filed in the appropriate office. Photocopies should be filed at another site.

- The format for RST datasheets is:

<table>
<tr><td colspan="2">Date (dd/mm/yyyy):</td><td colspan="2">Recce-survey transect number:</td></tr>
<tr><td colspan="4">General description of location:</td></tr>
<tr><td colspan="4">Start point (UTM):</td></tr>
<tr><td colspan="4">Finish point (UTM):</td></tr>
<tr><td colspan="2">Compass bearing:</td><td colspan="2">Distance at finish (m):</td></tr>
<tr><td colspan="2">Start time:</td><td colspan="2">Finish time:</td></tr>
<tr><td colspan="4">Team members' names:</td></tr>
<tr><td>Distance from start (m)</td><td colspan="2">Number of dung-piles<br>≤ 2 m from RST line?<br>Decay stage</td><td>Other notes</td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td colspan="4">Number of dung-piles found on return journey through forest:</td></tr>
</table>

Most of the datasheet should be self-explanatory. A couple of points of clarification are however included below:

1. the ‘Recce-survey transect number’ is that on the survey locations map and the GIS for the site;
2. for the ‘General description of location’ the team leader should write something like ‘approximately 2-km from Ban Thalang to Poong Ta-ee road, Nakai Plateau’;
3. the ‘Number of dung-piles’ will normally be 1, but in some cases 2 or more dung-piles will be found at the same location, in which case the appropriate number should be entered in this column (see example below). In some cases the number of dung piles will be unclear, in which case the recorder should enter ‘1 possibly 2 piles’ or whatever is appropriate (see the examples below);
4. the ‘Other notes’ column should be used for recording streams, saltlicks, elephant sightings, etc;
5. for further clarification see the example sheet.

### Typical example of recce-survey transect data entry

| | | |
|---|---|---|
| Date (dd/mm/yyyy): 09/12/2004 | Recce-survey transect number: Example 1 | |
| General description of location: 2 km from Ban Thalang along road to Poong Ta-ee, Nakai Plateau | | |
| Start point (UTM): 18534500, 12040000 | | |
| Finish point (UTM): 12345678, 12345678 | | |
| Compass bearing: 045° | Distance at finish (m): 3 km | |
| Start time: 0715h | Finish time: 1530h | |
| Team members' names: Sithisack, Kanya, Teu | | |
| Distance from start (m) | Number of dung-piles ≤ 2 m from RST line? Decay stage | Other notes |
| 0 | | Closed canopy forest |
| 126 | 1 (> 2m; S3) | |
| 145 | 1 possibly 2 (> 2 m; S2?) | 8 boli, 4 of which looked fresh and 4 old but all very close together and same size |
| 148 | | Stream |
| 345 | | Elephant footprints seen on animal trail |
| 456 | | Animal trail |
| 459 | | Transition from closed canopy forest to secondary scrub |
| 654 | 2 (≤ 2 m; S3) | |
| 789–1120 | | Waded across flooded grassland (789–1120 m) then re-entered closed canopy forest at 1120 m |
| 1123 | 1 (≤ 2 m; S2) | |
| 1345 | 1 (≤ 2 m; S2) | |
| 1489 | 1 (≤ 2 m; S3) | |
| 1491 | | Animal trail |
| 1656 | | Snare, broken by team |
| 1899 | 1 (> 2 m; S3) | |
| 1924 | | Transition from closed canopy forest to secondary scrub |
| 1972 | 2 (≤ 2 m; S3) | 12 boli close together, but obviously 2 different sizes (female + calf?) |
| 2001 | | Elephants heard, GPS location = 12345678, 12345678 |
| 2341 | | stream |
| 2366 | | Transition from secondary scrub to closed canopy forest |
| 2349 | | Saltlick, many animal footprints including elephant prints, GPS = 12345678, 12345678 |
| 2897 | | Animal trail |
| 2976 | 1 (≤ 2 m; S1) | |
| 3000 | | End of transect (still in closed canopy forest) |
| 14 elephant dung-piles were seen while walking back through from the end of RST to the campsite. | | |

## 7.2.7 Equipment needed for recce-survey transects

### 7.2.7.1 Each recce-survey transect (RST) team will require:

*Navigation and data collection*

- Maps (and if available satellite images and/or aerial photographs)
- Two sighting compasses
- Two suitable GPS units (e.g. Garmin GPS 72), plus copious batteries
- Two topofils (e.g. Hipchains) and adequate thread
- Clinometer
- Approved datasheets and folder
- Waterproof notebooks for additional data-recording
- Plastic ziplock bags to protect datasheets from water
- Water-tight bags
- Pencils and indelible pens
- Dung classification field reference sheet (illustrated with photos and diagrams)
- Recce-survey transect field methods reference sheet (e.g. the relevant sections from this document)
- Standard vegetation-type classification reference material (appropriate for site)
- Simple cheap digital camera for recording carcasses and other things of interest (optional)

*Cutting transects*

- Cutlasses, machetes, parang (or equivalent)
- Secateurs (optional)

*Camping equipment*

- Mosquito nets
- Hammocks (optional)
- Tents and/or tarpaulins
- Groundsheets
- Cooking paraphernalia
- Water bottles
- Rucksacks
- Torches and batteries

# 8. Estimating dung-pile density using line transects: survey design and field methods

## 8.1 Introduction

Line transect based methods for estimating the density of animals or their sign are well established (Burnham et al. 1980; Buckland et al. 2001, 2004). In line transect sampling, observers move along a straight line recording detected objects (such as dung-piles). However, unlike the case of strip (belt) transects where the observers have to count all objects within a strip of known width, in the case of line transects the observers record the distance from the line to each object detected. For a standard analysis, all objects on or near the line should be detected, but the method allows a proportion of objects within a distance *w* of the line to be missed. Therefore, a wider strip can be used than for strip transect sampling. For sparsely distributed objects, such as elephant dung-piles, the method is typically more efficient than strip transect sampling because sample size is larger for the same amount of effort. Estimation of density from line transect data is explained in great detail the standard texts cited above and is therefore not further described here.

## 8.2. Methods

### 8.2.1 Survey design

Good statistically defensible survey design is vital for the success of the MIKE programme. Designing wildlife surveys is a complex process and requires specialist knowledge. For these reasons it is essential that you seek advice from your SSO and the MIKE statisticians when designing a MIKE survey. **All survey designs <u>must</u> be approved by MIKE statisticians before fieldwork begins**.

#### 8.2.1.1 Number of line transects required

Using the method described in Section 2.1.1, one can estimate the total length of transect required for a given encounter rate and a desired precision. Using a value of 3 for the dispersion factor (= variance inflation factor), *b*, as suggested for planning purposes in Section 2.1.1, together with a target coefficient of variation (CV) of the estimated dung-pile density estimate of either 25% or 10% allows us to estimate total line length for a range of encounter rate values (Table 8.1). For example, for an expected elephant dung pile encounter rate of 1 dung-pile per kilometre, 300 km of line transects would be required to obtain an estimate of dung-pile density with a CV of 10 percent. See also Section 8.2.1.5 'Definition of sampling units'.

**Table 8.1: Total survey effort in kilometres of line required for line-transect surveys to achieve a desired coefficient of variation (CV) with different dung-pile encounter rates**

| CV | Encounter rate (dung-piles / km) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1.0** | **2.0** | **3.0** | **4.0** | **5.0** | **6.0** | **7.0** | **8.0** | **9.0** | **10.0** |
| **25%** | 48.0 km | 24.0 km | 16.0 km | 12.0 km | 9.6 km | 8.0 km | 6.9 km | 6.0 km | 5.3 km | 4.8 km |
| **10%** | 300.0 km | 150.0 km | 100.0 km | 75.0 km | 60.0 km | 50.0 km | 42.9 km | 37.5 km | 33.3 km | 30.0 km |

### 8.2.1.2 Stratification

You will need to subdivide your site into strata (areas) to either improve precision or to simplify the logistics of the survey. In the latter case, for example, the study area may be stratified according to ease of access and less effort may be allocated to hard to access strata. It is likely that this may lead to some loss in precision, but the logistics may enforce such stratification nonetheless. **Stratification by ease of access should only be adopted if approved by your SSO and the MIKE statisticians.**

If possible, you should stratify the site by expected elephant density (because such stratification will help improve the precision of your population estimates). This means that you should divide the site into two or three areas: low- and high-density strata; or low-, medium-, and high-density strata. The results of the pilot survey should allow you to define these strata (Chapter 3).

Stratification by distance from areas of human activity is sometimes a sensible alternative (particularly if one has few data on elephant distribution in advance of the survey) because elephant density may well vary with distance from human disturbance (Barnes et al. 1997b). Another useful alternative is stratification by habitat type as one might expect both elephant density and the probability of detection to change by habitat type. In addition, if you have been forced to adopt a 'find and move' approach to dung decay rate monitoring and have selected a number of different habitat types in which to search and locate dung-piles (Section 5.2.1) then it may be appropriate to stratify by habitat-type (but seek advice from your SSO and the MIKE statisticians).

However, stratification by habitat type is only possible if spatially explicit information on habitat is available (i.e. you have maps or satellite images showing habitat types) and the habitat types are not too fragmented and intertwined so as to make stratification by habitat type impossible at the design stage. In these situations, a possibility would be to use the record of habitat type changes along your line transects to stratify your survey: i.e. one would then have a measure of the amount of survey effort spent in each habitat type, which would allow post-stratification by habitat type during the analysis stage. Again, seek advice form your SSO and the MIKE statisticians.

### 8.2.1.3 Allocation of survey effort to strata

If you define strata using the expected density of elephants in order to improve precision, as described above, you should allocate your survey effort per strata (the number of line transects you plan to survey per strata) in proportion to the expected elephant density in each stratum (allocating more effort to strata with more elephants).

If you define strata based on other criteria (e.g. ease of access) and if nothing is known about elephant density in each of the strata, then effort should be allocated in proportion to stratum size.

### 8.2.1.4 Arrangement and spacing of line transects in a site

Each transect should be 1 km in length unless another line length has been recommended by the MIKE statisticians for your site. There is often a temptation to design a survey with a small number of long transects because that is more efficient from the logistic point of view. But from the statistical point of view (i.e. the power of the design to detect changes in elephant abundance), it is more efficient to have a large number of short transects.

Ideally to achieve greater precision one should orientate transect lines parallel to any gradients of density, so that any variation in encounter rate is maximized within transects and minimized between them. So, for example if one suspects that density decreases with increasing distance from a habitat feature such as a major river then transects would be placed approximately perpendicular to the river.

The computer program DISTANCE 4.0 (Thomas et al. 2003) has an automated survey design component and GIS capability and you should use DISTANCE to design your line transect surveys. In order to use the automated survey design features of the program, you will need to define your site in a spatially explicit manner by means of an ESRI ArcView shapefile.

The automated survey design component permits the selection of a design from among a number of different possibilities, and lets one explore the design's properties given the logistical constraints for the survey in question. A number of frequently used line transect designs, both systematic and non-systematic, have been implemented in DISTANCE 4.0.

The type of survey design generally considered for dung count based surveys in the MIKE sites is a 'systematic segmented line transect design' with a random start point. This design involves placing a systematic arrangement of track-lines across the study area and then locating line transects of specified length systematically along it to meet the desired total length requirements of the survey. The line transects should be short, and will normally be 1 km in length. See box 8.1 for an example.

Although this type of design provides transect segments that are occasionally less systematically placed than those given by 'systematic segmented grid sampling' designs, it tends to spread segments over a greater range of any potential density gradient. This provides for good spatial coverage of the site and is likely to yield a representative sample leading to a more precise estimate of dung density. The random start point used in the design permits a standard analysis using design-based estimators and analysis of this type of systematic design generally proceeds as if the position of each transect were randomly selected. Although theoretically this is an issue, in practice systematic spacing of transects provides better spatial coverage within the survey area, and therefore an improvement in density estimate compared to randomly placed transects.

### 8.2.1.5 Definition of sampling units

Correctly defining your sampling units is vital for the proper analysis of your line transect data. In the survey designs discussed above, either the individual line transects themselves or the set of line transects along a single trackline are taken to be the sampling unit depending on whether the line transects are judged to be spatially independent. Dependence between data collected along line transects is generally negatively correlated with distance separating these line transects. Thus the definition of the appropriate sampling unit will depend on the selected separation distance. The separation distance will in turn depend on the number of line transects needed to achieve the total line length, which in turn depends on the desired target coefficient of variation (CV) for your dung-pile density estimate (sections 2.1.1 and 8.2.1.1). The debate on what is and what is not independent when sampling elephant populations is complex—an elephant may move 25 km in a day (Blake 2002)—and currently unresolved.

To get a reliable estimate of variance in observed sample size at least 15–20 sampling units are needed per stratum.

**Box 8.1: Examples of automated line transect survey designs produced by program DISTANCE 4.0 (Thomas et al. 2003)**

The site in this example has two strata, namely a national park and an adjacent logging concession, and the latter is more heavily impacted by human activity. Transect lines are oriented in a northeast-southwest direction as this is suspected to coincide with the elephant density gradient in the area.

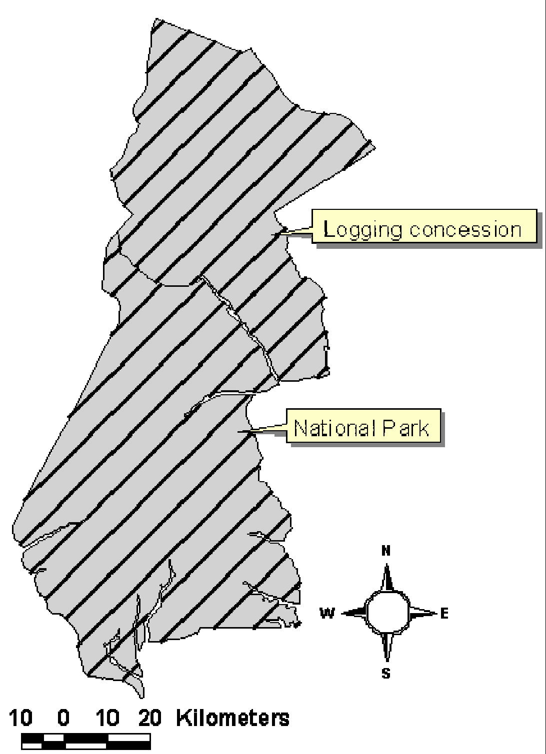
(a) A design suitable for direct sighting based surveys

If the site is covered in open habitat types and suitable for direct sighting based surveys of elephants either by means of aerial or terrestrial line transect surveys, then a design with systematic parallel line located with a random start in each stratum might be appropriate. Note that the spacing between sequential line transects is 6.5 km in the national park, but 6 km in the logging concession to ensure sufficient replication (15 lines in each stratum).

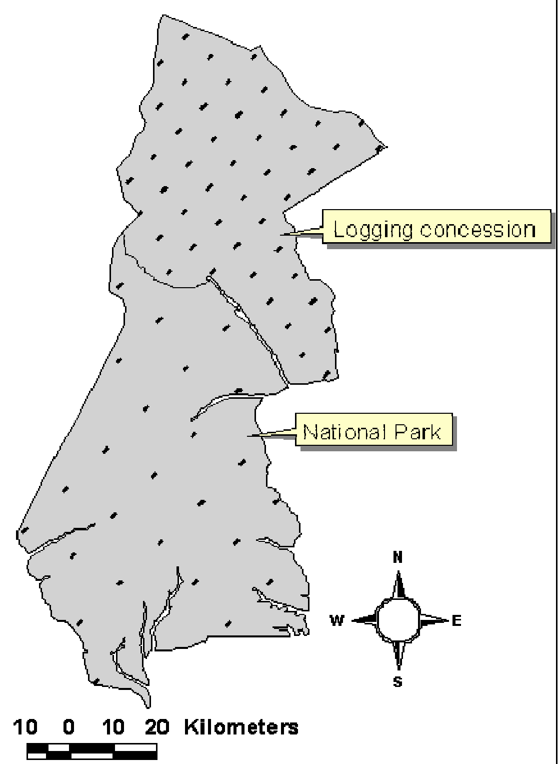
(b) A design suitable for dung-count based surveys

In the case of a site covered in closed habitat types such as forest, an indirect survey of elephant dung is currently the preferred survey option. Here a design comprising 1 km long line transects systematically spaced with a random start could be a good design option. In this example, the 25 and 47 transect lines have a systematic spacing of 12 km and 7 km in the national park and logging concession, respectively. Greater effort was allocated to the logging concession stratum because while expected elephant density was low, access was easy. Note that normally effort is allocated in proportion to expected elephant density (allocating more effort to strata with more elephants).

(a)




(b)



### 8.2.2 Survey design implementation problems related to map inaccuracies

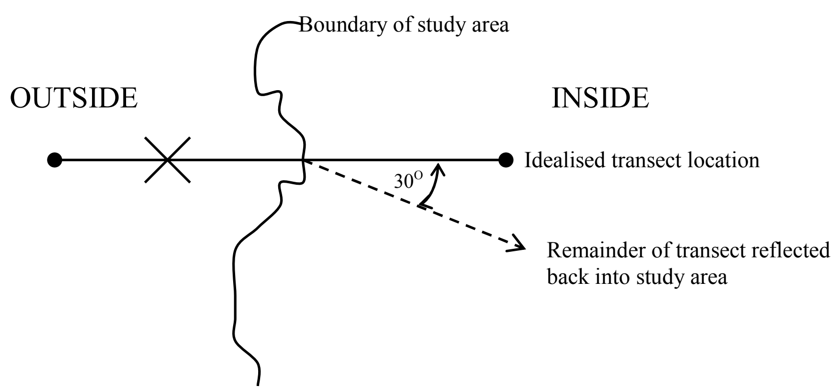
The best maps currently available for the Central African sub-region are of relatively poor resolution, and this is probably true for forest elephant range in much of West Africa and Southeast Asia. In some countries, paper maps typically have a scale of 1:200,000, which were generated from aerial photographs taken in the late 1950s. Satellite images (Spot, Landsat) are available for much of the region, and some of the sites. These too suffer from a lack of geo-referencing accuracy, and cloud cover often obscures large areas. These errors lead to a number of problems in survey design:

1. imperfect geo-referencing of paper and digital maps may be 'shifted' from the true position on the ground. In reality, then, survey locations will therefore not be where they are depicted to be on the maps;
2. imperfect knowledge of the terrain coupled with imperfect geo-referencing;
3. inaccurate information about land use including roads and human settlements.

The combination of 1 and 2 may lead to considerable problems for execution of ground surveys. Survey locations generated may, in reality; fall in swamps, on the other side of a large river, on the edge of a 75° rock-face, or even outside the study area. Most of these problems will not be encountered until the survey teams are on the ground and so a set of easy to follow and unambiguous protocols must be developed to account for these issues. Whatever is decided will bias the survey design by some unknown amount, but without perfectly geo-referenced maps that include all swamps, all inaccessible areas, and other relevant landuse types, these problems are unavoidable.  Some suggestions are given below.

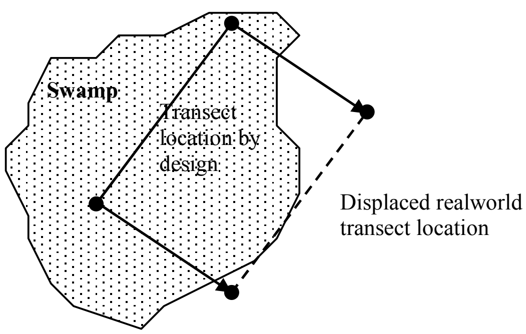
*a. Transect location is outside the study area*

If the start point of the transect is inside the study area but it crosses outside along its length (identified by a river marking the MIKE site border for instance, or a road marking the edge of a stratum), when the real-world 'edge' is reached the transect will be reflected back at a 30% angle.



*b. Transect location wholly outside study area or wholly within a swamp*

In these cases, the transect will be relocated to the closest estimated location within the study area or terra firma. This will be somewhat subjective because field teams will not have a systematic way to find these locations, however from maps and the lay of the land, they will have an idea of which direction the closest terra firma may be found.




*c. Transect goes over precipice or extreme hazard*

In this case, the transect should be suspended at the edge of the hazard noting the distance along the transect. Survey teams should navigate around the hazard and continue the transect as soon as conditions are suitable. GPS fixes will be taken at the end and beginning points which will allow an estimate of the total length of inaccessible area to be calculated at the end of the survey.

NOTE. Only when conditions become extremely dangerous should survey teams abandon a transect line. Elephants under heavy hunting pressure in hilly or mountainous terrain often seek refuge in inaccessible areas such as steep slopes. Therefore if these are systematically avoided, the abundance estimate will be negatively biased.

## 8.2.3 Field methods

### 8.2.3.1 Locating survey tracklines and line transect

- Survey teams will be provided with a database of GPS locations for both the start and end point of tracklines (the lines linking the line transect sections, see Section 8.2.1) and the line transects, as generated in Distance 4.0. Locations will be uploaded into an appropriate GPS (e.g. Garmin 72) and used for navigating in the forest in conjunction with site maps, aerial photographs, and satellite images.

- Each team should carry two GPS units, one for daily use, and one as a backup. Use long-life batteries; although expensive, they are more cost-efficient.

### 8.2.3.2 General methods

- Each line transect team should be composed of a minimum of 4 people: 1 cutter, who cuts a straight-line path through the forest; a compass person, who directs the cutter; a dung-pile spotter; and a data-recorder. Everybody should keep their eyes open for dung-piles and tell the data-recorder if they see any. [However, if you are combining dung-pile surveys with searches for other species of interest e.g. ape nests or terrestrial mammals, there should be a dedicated spotter for these other species who does not look for dung-piles.] These jobs can be rotated provided everybody knows how to use a sighting compass. Two cutters may be needed in very dense forest to prevent people from becoming exhausted.

- 1–2 field assistants who will help transport equipment and help with measurement taking, such as perpendicular distances may also be added to the team if necessary. During transect cutting and surveying the rest of the team (porters) should remain at the start point and follow on some time later so as not to get in the way of the survey team.

- The data-recorder carries a topofil to record the distance walked from the start point and a GPS.

- GPS data should be recorded at the beginning and end of every line transect. In addition, GPS data should be recorded every 500 m along the transect.

- Line transects will normally be 1 km in length although on occasion they may be longer depending on the survey design adopted (see Chapter 3 and Section 8.2.1).

- The speed at which the teams complete the transects will depend on terrain, the vegetation types encountered, and the amount of elephant dung found. However, as a guide, transects in forested areas should not be conducted faster than 1 km per hour. For grasslands, the maximum speed should be 45 minutes per 1 km. At speeds faster than these, it is likely that the teams will miss a significant number of dung-piles.

- Data collection on transects should be suspended during heavy rain, very overcast conditions, or other times of poor visibility. Furthermore, transect data should not be collected before 07:00h or after 16:30h due to poor visibility.

### 8.2.3.3 Cutting line transects

- Two people are needed to cut a transect, a cutter and compass person who directs the cutters. Following the methods described by White & Edwards (2000), the compass person should cut a stake, which when pushed into the ground is at eye level. The sighting compass is placed on the stake and oriented so that one can sight through it without touching it. The cutter then traces a path away from the compass person cutting the minimum amount of vegetation necessary to mark a path and allow the team to follow. The compass person must carefully monitor the cutter(s). Each time a cutter deviates from the path the compass person should immediately call out a correction (left or right). The compass person must be very strict, as cutters often tend to deviate along animal trails or around dense thickets: this will result in biased data. When it becomes difficult to see the cutter the compass person should tell them to stop and move forward to where they are waiting (they must not move in the meantime). **A well cut, straight transect is crucial for good data collection and to reduce biases.**

- It is important also to emphasize that the cutters should cut just the minimum needed to allow the team to walk through the forest. They should not make a path or trail. Cutting too much vegetation along the route is bad because:

    1. it damages the forest;

2. it allows poachers easy access;
3. it wastes time and energy;
4. falling branches and leaves can cover dung-piles making them difficult to see.

- Once the path is identified and the compass person has moved on to where the cutter is waiting, the rest of the team should move forward while looking carefully for dung-piles.
- The transects will form the basis of long term monitoring at each site and so their start point and compass bearing must be accurately recorded. GPS fixes must be taken at the start and end of every transect.

### 8.2.3.4 Dealing with obstacles along line transect routes

- Remember, unlike for recce-survey transects, it is essential to maintain a dead straight line. The following guidelines for dealing with obstacles should be used (also see Section 8.2.2):
    - thickets: cut through these obstacles (see below for dense bamboo thickets).
    - water bodies such as flooded grasslands that you can wade across: continue the transect as normal, but record the distance on the topofil at the point you begin wading and at the point where you stop wading. This is because we need to know that, for example, 300 m of the transect route was under water when calculating dung-pile encounter rates.
    - water bodies such as deep pools, lakes, etc. that you cannot wade: record the GPS location at the edge of the water, identify a landmark the other side of pool/lake, break the topofil thread, walk around the pool/lake to the landmark, record the GPS location at the landmark, estimate the distance across the water body that should have been walked, then continue as normal.
    - dense bamboo thickets that you cannot cut through: record the GPS location at the edge of the thicket, identify a landmark the other side of the thicket, break the topofil thread, walk around the thicket to the landmark, record the GPS location at the landmark, estimate the distance across the thicket that should have been walked, then continue as normal.
    - major rivers, gorges, cliffs, etc. that you cannot cross: record distance and GPS location, stop the transect and move on to the next transect (or return to camp depending on the time of day).

### 8.2.3.5 Things to record along line transects

- Record all of the things in the list below, and make a note of the distance from the start point of the transect using a topofil. In addition, for those things indicated below, GPS locations should also be recorded:

| | **Record distance from start point using a topofil** | **Record GPS location** |
|---|---|---|
| All elephant dung-piles found (see below for further detail) | Yes | No |
| Any sightings of elephants | Yes | Yes |
| Any elephants heard | Yes | Yes |
| Any elephant carcasses found | Yes | Yes |
| All elephant trails that cross the line transect route | Yes | No |
| Any logging roads that cross the line transect route | Yes | No |
| Any crop fields or other agricultural activity encountered | Yes | Yes |
| Any other signs of human activity (e.g. snares, poachers' camps, etc.) | Yes | No |
| Any saltlicks | Yes | Yes |
| Any streams or small waterholes | Yes | No |
| Any ponds or lakes | Yes | Yes |
| Transitions between major vegetation types | Yes | No |
| See Section 7.2.5 for an explanation of why some things require a GPS fix and others do not. | | |

### 8.2.3.6 Finding and recording elephant dung-pile data during line transect surveys

- All team members should look for dung-piles and draw the attention of the data-recorder to any dung-piles seen. [However, if you are combining dung-pile surveys with ape nest surveys there should be a dedicated nest spotter who does not look for dung-piles.]

- For all elephant dung-piles found along the transect the distance (in metres) from the start of the transect should be recorded. A topofil is used to measure these distances.

- The spotter and data recorder should examine the dung-piles found to determine whether the boli present form one or more than one dung-pile. Use the number and size of the boli (especially their diameter), their colour and general appearance, and the distance between the boli to guide your decision (see the section on dung classification for further detail).

- The perpendicular distance from the line transect's centre line to the centre of the dung-pile must be measured using a steel measuring tape:

    - following recommendations in White & Edwards (2000), first sight along the transect and determine where the centre line lies: this should be imagined as a very thin line indicating the exact centre of the cut path. Use the topofil thread that is being used to measure transect length to mark the centre line. A common mistake is to count all dung-piles which lie in the cut area as being on the transect line and recording a perpendicular distance of 0 cm. This is wrong and will seriously reduce the quality and utility of the data you collect;

- next, decide where the centre of the dung-pile lies. The easiest way to do this is to create the smallest possible square or rectangular box around the dung-pile, using straight canes or metal tapes, and then find the midpoint of the diagonal, X, which will also be the centre of the dung-pile (Figure 8.1). Be careful, elephants often defecate whilst walking and so dung boli may be spread over several metres (sometimes 10s of metres). You must look carefully at tracks, and boli size, age, and composition to help you determine which dung boli belong with which (i.e. form one defecation event);

- next, identify the point on the transect line from which the perpendicular distance should be measured. This can be done by using a compass set at 90° to the direction of travel and then moving until the dung-pile lies on this line;

- once you have located the two points between which the perpendicular distance should be taken, use a steel tape measure to measure it and record the distance *in centimetres* to the nearest centimetre.

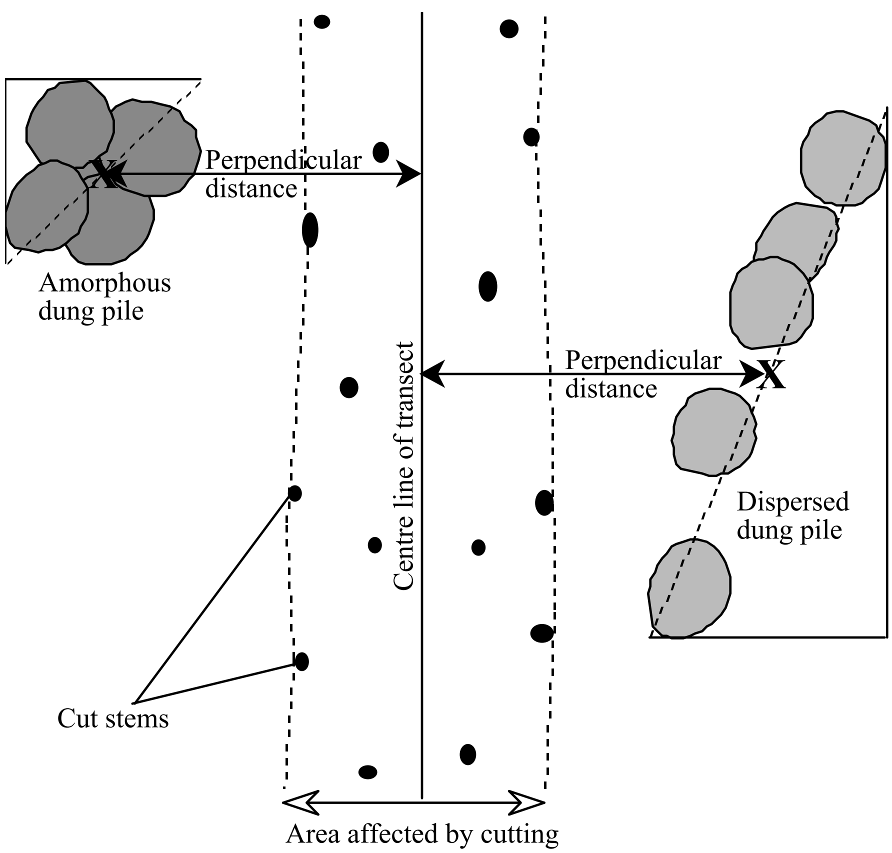



Figure 8.1: Measuring the perpendicular distance from the centre of a dung-pile to the centre line of a transect: X is the centre of the dung-pile from which the perpendicular distance to the transect's centre line should be recorded.

- Once the perpendicular distances have been recorded, for all those dung-piles found ≤ 1 m from the transect line and having intact boli (see dung-pile classification section) the circumference of the 3 largest intact boli should be measured; if only 1 or 2 intact boli are present in a dung-pile they should still be measured (see Chapter 10). It is important to measure boli after measuring and recording perpendicular distances, to do so before might result in erroneous perpendicular distances if the dung-piles were moved during classification.

- Then, the dung-piles should be classified into decay stages using the MIKE S system (Chapter 4). It is important to classify dung-piles after measuring and recording perpendicular distances and circumferences, to do so before might result in erroneous perpendicular distances (if the dung-piles were moved during classification) or difficulty in measuring circumferences (if boli were broken during classification).

#### 8.2.3.7 Data collection and management for line transect survey teams

- Record the line transect data on approved datasheets. Keep these datasheets in watertight bags. [Cybertrackers or some other form of electronic field data-logger may be used in the future, if approved by the TAG.]

- When the teams return to the base-camp/office after each survey trip the team leaders must enter the data into the computer and photocopy the datasheets.

- The original datasheets should be filed in the appropriate office. Photocopies should be filed at another site.

- The format for line transect datasheets is shown overleaf.

## Line transect datasheet showing an example of typical field data

<table>
<tr><td colspan="4">Date (dd/mm/yyyy): 09/12/2004</td><td colspan="2">Line transect number: Example 1</td></tr>
<tr><td colspan="6">General description of location: 2 km from Ban Thalang along road to Poong Ta-ee, Nakai Plateau</td></tr>
<tr><td colspan="6">Start point (UTM): 18534500, 12040000</td></tr>
<tr><td colspan="6">Finish point (UTM): 12345678, 12345678</td></tr>
<tr><td colspan="4">Compass bearing: 045°</td><td colspan="2">Distance at finish (m): 1 km</td></tr>
<tr><td colspan="4">Start time: 0725h</td><td colspan="2">Finish time: 1030h</td></tr>
<tr><td colspan="6">Team members’ names: Sithisack, Kanya, Teu</td></tr>
<tr><td rowspan="2">Distance from start (m)</td><td colspan="4">Dung-pile data</td><td rowspan="2">Other notes</td></tr>
<tr><td>Number of boli</td><td>Perpendicular distance (cm)</td><td>Decay Stage</td><td>Diameters (cm)</td></tr>
<tr><td>0</td><td></td><td></td><td></td><td></td><td>Closed canopy forest</td></tr>
<tr><td>26</td><td>6</td><td>348</td><td>S2</td><td>N/A</td><td></td></tr>
<tr><td>48</td><td></td><td></td><td></td><td></td><td>Stream</td></tr>
<tr><td>145</td><td>5</td><td>29</td><td>S1</td><td>42, 44, 44</td><td>No DNA sample taken; GPS location 87654321, 87654321</td></tr>
<tr><td>256</td><td></td><td></td><td></td><td></td><td>Animal trail</td></tr>
<tr><td>259</td><td></td><td></td><td></td><td></td><td>Transition from closed canopy forest to secondary scrub</td></tr>
<tr><td>265</td><td>6</td><td>79</td><td>S3</td><td>N/A</td><td></td></tr>
<tr><td>276</td><td>5</td><td>223</td><td>S2</td><td>N/A</td><td></td></tr>
<tr><td>335</td><td>4</td><td>65</td><td>S2</td><td>35, 36, –</td><td>Only 2 intact boli; No DNA sample taken; GPS location 87654321, 87654321</td></tr>
<tr><td>489</td><td>6</td><td>243</td><td>S2</td><td>N/A</td><td></td></tr>
<tr><td>491</td><td></td><td></td><td></td><td></td><td>Animal trail</td></tr>
<tr><td>656</td><td></td><td></td><td></td><td></td><td>2 snares, old, broken</td></tr>
<tr><td>899</td><td>5</td><td>3</td><td>S2</td><td>29, 31, 28</td><td>No DNA sample taken; GPS location 87654321, 87654321</td></tr>
<tr><td>924</td><td></td><td></td><td></td><td></td><td>Transition from secondary scrub to closed canopy forest</td></tr>
<tr><td>999</td><td></td><td></td><td></td><td></td><td>Very old elephant carcass found, photos # EX1, EX2, EX3; GPS location = 12345678, 12345678</td></tr>
<tr><td>1000</td><td></td><td></td><td></td><td></td><td>End of transect (still in closed canopy forest)</td></tr>
</table>

Most of the datasheet should be self-explanatory. A couple of points of clarification are however included below:

1. the ‘Line transect number’ is that on the survey locations map and the GIS for the site;
2. for the ‘General description of location’ the team leader should write something like ‘approximately 2-km from Ban Thalang to Poong Ta-ee road, Nakai Plateau’;
3. the ‘Other notes’ column should be used for recording transitions between vegetation types, elephant sightings, carcasses, etc.

### 8.2.4. Data analysis and reporting

- Once the line transect surveys and decay rate monitoring work (and defecation rate work if attempted) are complete, calculate dung-pile density from your line transect data using the program DISTANCE 4.0 [Thomas et al. (2003); see Buckland et al. (2001) for advice]. Make certain that you use the same division of dung-piles into 'still present' (typically those in stages S1, S2, and S3) and 'disappeared' (typically those in stages S4 and S5) that you used in the dung disappearance experiments.

- When you are happy with your dung-pile density estimates, use program DISTANCE 4.0 to convert your dung-pile densities into elephant densities (DISTANCE 4.0 allows you to include estimates of dung-pile decay and defecation rates together with their standard errors).

- Write a report and submit it with together with copies of all your data and the associated computer files to your National Officer and your SSO (Chapter 12).

### 8.2.5 Equipment needed for line transect surveys

#### Each line transect survey team will require:

*Navigation and data collection*

- Maps (and if available satellite images and/or aerial photographs)
- Two sighting compasses
- Two GPS units (e.g. Garmin GPS 72), plus copious batteries
- Two topofils (e.g. Hipchains) and adequate thread
- Two metal measuring tapes (5 metres)
- Two flexible plastic measuring tapes to record the circumferences of dung boli
- Clinometer
- Approved datasheets and folders
- Waterproof notebooks
- Plastic ziplock bags and water-tight bags to protect notebooks from water
- Pencils and indelible pens
- Dung classification field reference sheet (illustrated with photos and diagrams)
- Line transect field methods reference sheet (e.g. the relevant sections from this document)
- Standard vegetation-type classification reference material (appropriate for site)
- Simple cheap digital camera for recording carcasses and other things of interest (optional)

*Cutting transects*

- Cutlasses, machetes, parang (or equivalent)
- Secateurs (optional)
- Pole or stake that is at eye level when pushed into the ground and which is of large enough diameter to support a sighting compass (Section 8.2.3)

*Camping equipment*

- Mosquito nets
- Hammocks (optional)
- Tents and/or tarpaulins
- Groundsheets

- Cooking paraphernalia and water bottles
- Rucksacks
- Torches and batteries

# 9. Estimating elephant population densities using fecal DNA-based capture–recapture sampling

## 9.1 Introduction

Capture–recapture methods provide a means of estimating population size from data on the numbers of animals caught or sighted, and the pattern of recaptures and re-sightings of known individuals. Easy to understand introductions to capture–recapture methods are provided in the manuals by Wilson et al. (1996) and Karanth & Nichols (2002).

Although capture–recapture methods were originally developed for those situations where animals are actually caught and marked with tags, the underlying concepts are valid even when animals are not caught but are identified using natural markings such as the stripe patterns of Tigers. Recently, a lot of attention has been paid to identifying individuals from DNA material obtained from their hair or scats, and the use of such non-invasive genetic sampling for capture–recapture surveys has increased rapidly [for reviews see Mills et al. (2000), Waits (2004), and Lukacs & Burnham (2005); for an example of a fecal DNA based capture–recapture population estimate for a forest elephant population see Eggert et al. (2003)].

DNA-based capture–recapture studies typically follow the same basic principles. First, samples containing DNA are collected at several points in time. DNA is then extracted from the samples and amplified at several microsatellite loci. Other molecular markers, such as single nucleotide polymorphisms, may also be used. Matching genotypes are considered to have come from the same individual and are classified as recaptures. The data are then analysed in a capture–recapture framework (Lukacs & Burnham 2005).

Reducing genotypic error in capture–recapture studies is important for reducing overall bias in population estimates. To do this the researcher has to keep the following principles in mind during sampling design and while carrying out sample collection and laboratory protocols for obtaining genotypes.

- Design a sampling protocol that ensures a high capture probability for individuals within the population of interest. This means that surveyors should search for elephant dung-piles in places where they are likely to be found, not in randomly selected plots (this is clearly a very different approach to that used for the line transect based dung count surveys described earlier in this document and this difference will need to be emphasized during training of field teams).

- Ensure that sample collection protocols and laboratory protocols provide DNA samples of high quality where misidentification of genotypes is reduced. When in doubt about either dung or DNA samples, do not collect dung samples or extract DNA from dung; this can be achieved by deliberately culling doubtful samples from the sample set.

- Genotypic error is increased when the ratio of the genotypes observed once to the number of genotypes observed more than once in recaptures, is high. Therefore to maintain an acceptable ratio, during recaptures sampling should be intensive or there should be more recapture occasions.

The method for formal fecal DNA based capture–recapture surveys outlined below recognises these principles. However, it should be understood that the methods will be further refined as more experience is gathered using this survey approach. This method cannot therefore be considered as *the* standard.

## 9.2 Survey design and field methods

- The first step is to map the 'hotspots' identified during the fecal concentration survey of the site ('hotspots' are places such as saltlicks, waterholes, major elephant trail crossing points, crop depredation locations, etc. where 'fresh' and 'reasonably fresh' dung-piles can be found reliably; see section 3.2 # 5).

- Once the 'hotspot' map for the site is available you should begin to devise a sampling design (by experimenting on the map) using different choices of 'hotspots' (which will become sample collection locations) to optimise the spacing between the sample collection locations. The configuration of the sample collection locations will vary from site to site depending on local conditions, but the basic principle is to cover the site so that there are no 'holes' in the site where elephants could move without any chance of you collecting their dung. To put it another way, every elephant's home range should contain at least 2–3 sample collection locations.

- The distance between sample collection locations must be small if home ranges are expected to be small; if home ranges are large, the distance between sample collection locations can also be relatively large. For capture–recapture sampling of Tiger populations using camera traps, Karanth & Nichols (2002) suggest deploying camera traps (which can be thought of as sample collection sites) 5–10 km apart for Tigers with home ranges of 200–500 km$^2$; these broad guidelines are probably appropriate for forest elephants (indeed, they are likely conservative as many elephant's home ranges will be larger).

- If after experimenting with the 'hotspot' map there are obvious 'holes' in the distribution of your sampling effort over the site you must take steps to remedy this problem. One approach is to divide those parts of the site without adequate sample collection locations into 'blocks' that can be sampled in a single day. Generally such blocks will be of equal size, but if the terrain, for example, is much more difficult in some parts, then this should be taken into account when determining the size of the block.

- You are now ready to begin sample collection. The field teams should return to all the 'hotspots' that have been selected as sample collection locations and collect samples from as many 'fresh' and 'reasonably fresh' dung-piles as possible recording the GPS location for all sampled dung-piles (see below for definitions of 'fresh' and 'reasonably fresh' and for the sample collection protocol). If no fresh and reasonably fresh dung-piles are found at the 'hotspots' the teams should search along animal trails, especially fresh elephant trails, in the area surrounding the 'hotspot' (a broad guideline is to search as much of the area within a 2 km radius of the 'hotspot' as possible). It is advisable to search the area around the 'hotspot' and collect additional samples even if fresh dung-piles were sampled at the 'hotspot.

- For those parts of the site without 'hotspots', the blocks discussed above will need to be searched. The field teams should spend one day in each block, following elephant trails and collecting as much fresh dung as possible. Trails are used to help cover as much area as possible, but it is important to attempt to follow all fresh elephant trails encountered, and to collect samples from as many fresh dung piles as possible. It is also important to attempt to cover as much of the area in the block as possible, regardless of the density of the trails.

- All dung-piles from which you collect samples must be destroyed to avoid the possibility of re-sampling from the same dung-piles when you revisit sample collection locations in the subsequent rounds of the survey.

- You should aim to complete this 'first round' of sample collection as quickly as possible. As a guide, 'as quickly as possible' means completing the first round in no more than 14 days.

- Once the 'first round' of sample collection is complete you must plan the subsequent rounds. You need at least two rounds of sample collection but >2 rounds is better because you will be able to use more refined statistical models for your data analysis.

- On revisiting the sample collection locations (and the blocks without 'hotspots') it is very important to collect only fresh dung that you are confidant was not present during the first capture. It is therefore best to wait at least two weeks before revisiting a sample collection location ('hotspot') or block. But it is equally important to avoid waiting long enough so that the elephants have moved out of that area, so all sample collection rounds should be completed within the same season to minimize the risk of large scale movements of elephants confounding the results.

## 9.3 Collecting fecal DNA samples

- Only collect samples from 'fresh' or 'reasonably fresh' dung-piles.

- A 'fresh' dung-pile is defined as one that is less than 48 hours' old. Fresh should be taken as meaning dung-piles dropped within the previous 48-hours. It is important to remember that fresh dung-piles may not be intact; they can be in stage S2 (or even stage S3) when found. Fresh dung-piles are identified by their appearance. They will be moist throughout, making then dense (heavy). They will usually feel slimy to the touch. Flies will often be present and the dung-pile should smell of elephant dung, not fungus, or earth. Very fresh dung-piles are usually a lighter-brown colour than older ones. Secondary evidence of fresh dung is provided by the presence of obvious recent elephant footprints and possibly damage to vegetation (e.g. plants pushed-over or trampled/eaten).

- A 'reasonably fresh' dung-pile is defined as one consists mostly of intact boli that are not obviously degraded (mouldy, infested with termites, etc.). Ideally these 'reasonably fresh' dung-piles should be no older than two weeks. If it is possible to collect only from 'fresh' dung-piles, then do so and ignore 'reasonably fresh' dung-piles.

- Record on the datasheet whether the dung-pile was fresh or reasonably fresh.

- Wear latex gloves when collecting the samples. Do not allow your skin to touch the dung-pile or the outside of your gloves when putting them on.

- Only collect from one bolus per dung-pile (choosing the freshest one); this is to prevent errors cause by mistakenly thinking boli from two or more dung-piles are from one pile and thus possibly collecting fecal material from more than one elephant per sample.

- It is best to collect samples from the outside of the bolus if it is very fresh, but from the underside if the sample is not very fresh. Use a plastic fork to collect approximately 1/5 tube of dung (approximately 10 g, usually one or two small 'forkfuls'). Place the dung in the tube but do not pack it down.

- Do not use the same fork for collecting other samples. Throw it away! (In an environmentally acceptable manner.)

- Mark the outside of the tube and the cap with the sample number, using a permanent marker.

- Each sample you collect should be given a unique code number.

- After collecting the dung sample, measure the maximum circumference of three intact boli in the dung-pile using a plastic measuring tape, and enter these data on the approved datasheet (see appended example datasheet for further detail). If there are more than three intact boli present then the largest three should be measured. If only one or two intact boli are present in a dung-pile it (they) should (both) be measured. Boli may need to be inspected carefully to make sure the correct axis is measured, particularly if they have been distorted by trampling or impact with the ground.

- All dung-piles from which you collect samples must be destroyed to avoid the possibility of re-sampling from the same dung-piles when you revisit sample collection locations in the subsequent rounds of the survey.

- For each sample, enter the sample number, the GPS location, and the bolus circumference(s) on the datasheet along with any useful comments such as estimated group size and composition, presence of seeds, etc. Place the tube in a plastic Ziplock bag and write the sample number on the bag.

- When you return to camp in the evening, boil the fecal samples by placing the tubes in a pan of water for at least 15 minutes in the tube. (Loosen the tubes' lids but keep them on the tubes to prevent splash-contamination.) Then add approx. 10 ml. of the Queen's College buffer (just enough to cover the sample completely) and shake to make sure it is completely saturated. Do not fill the tube completely—the sample will expand as it absorbs the liquid. Return the tube to the correct Ziplock bag.

- Protect the samples from sunlight as UV light may damage the DNA. This means storing the tubes in a dark-coloured plastic box.

- The samples can be kept at room temperature, but if refrigeration is available it may extend the life of the sample.

- For long-term storage or shipping of samples, top-up the buffer if necessary, close the cap tightly, and wrap the cap and top of the tube in Parafilm.

- Note: Since it will be necessary to ask a Wildlife Department official to sign a certification that this boiling step was done (to allow import to the USA for analysis) it would be a good idea to show them once how it is done so they understand what they are signing. This step is important to avoid bringing live bacteria or viruses into the USA.

## 9.4 Data management for the fecal DNA collection teams

- Record the fecal DNA sample data on the appropriate datasheet (one is appended).

- Ziplock bags should be carried to protect the datasheets from water.

- When the team returns to the base camp/office after each collection trip the team leader must enter the data into the computer and photocopy the datasheets.

- The original datasheets should be filed in the appropriate national office. The photocopies should be sent to your SSO. New datasheets should be used for every survey trip.

## 9.5 Equipment needed

In addition to standard navigation and camping equipment (Annex 3), the field teams will need the following equipment:

- 30–50 ml polypropylene tubes with polypropylene caps
- Test-tube rack
- Saucepan that can hold test-tube rack when boiling samples
- Plastic forks
- Queen’s College buffer (20% DMSO, 0.25 M EDTA, 100 mM Tris, pH 7.5, saturated with NaCl)
- Parafilm
- Permanent marker pens
- Approved datasheets and folders
- Water-tight bags for storing datasheets and folders
- Latex gloves
- Ziplock bags

## 9.6 Datasheet for collecting fecal DNA samples

| DATE | SAMPLE # | VEG TYPE | GPS LONG | GPS LAT | DECAY STAGE | FRESH OR REASONABLY FRESH | CIRCUMFERENCES | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

# 10. Elephant age determination from dung

## 10.1 Preamble

It would add much value to dung surveys if in addition to producing estimates of population size they also produced information about population age structure, as this will help us understand population trends.

Three indirect methods for estimating elephant size or age from dung have been suggested: dung mass (Coe 1972), bolus circumference (Jachmann & Bell 1979, 1984; Tyson et al. 2002, in prep.), and bolus diameter (Morgan & Lee 2002; Reilly 2002b). All these studies used either directly measured captive elephants or shoulder height estimates obtained from photogrammetry to establish linear relationships between mean dung bolus diameter or circumference and elephant shoulder height.

Dung mass is impractical to measure during field surveys and the relationship between mass and elephant age demonstrated by Coe was derived from fresh dung, making Coe's method unsuitable for use during dung-count based surveys since the majority of dung-piles found will be many weeks or months old. Bolus circumference and diameter are, however, easy to measure during surveys, and neither diameter nor circumference change appreciably with time for those boli which remain intact (Reilly 2002b; Tyson et al. 2002, in prep.). Reilly (2002b) suggests that measurement of the greatest diameter is simpler and more precisely measured in the field. However, comparisons of bolus circumference and diameter showed that the coefficient of variation for circumference was always smaller than that for diameter (Tyson et al. 2002, in prep.).

It would appear therefore that potentially valuable data on population age structure can be collected relatively easily during dung surveys if dung dimensions are measured. However, a number of constraints need to be recognized:

1. while mean bolus circumference is a good predictor of shoulder height, repeated measurements of dung size from several elephants over three 2-month periods demonstrated that mean circumference (and diameter) of boli showed large variations in a given individual (Tyson et al. 2002, in prep.);
2. where the sex of an elephant that produced a dung pile is unknown, and where sexual dimorphism in the population is pronounced, there is a problem in assigning an age class from dung size. For example, a dung pile with mean bolus circumference of 45cm may be from a mature female or from a sub-adult male (but this can be overcome by collecting fecal DNA samples from the measured dung-piles; see Chapter 9);
3. small boli may be overlooked (or have higher decay rates) potentially leading to underestimation of the number of juveniles in the population (Jachmann & Bell 1984).
4. to reduce errors due to seasonal effects (e.g. dietary changes that might affect dung form), inter-year comparisons of age structures based on bolus size should only use data collected in the same season of each study year.

## 10.2 Methods to use

### 10.2.1 Collection of dung circumference data

- Measuring of dung boli circumference should be part of the routine procedure carried out when dung-piles are encountered during line transect surveys.

- For all those dung-piles found ≤ 1 m from the transect line and having intact boli (see dung-pile classification section) the circumference of the 3 largest intact boli should be measured. If only 1 or 2 intact boli are present in a dung-pile they should still be measured.

- The maximum circumference of each bolus should be measured to the nearest centimetre using a flexible plastic tape measure; boli may need to be inspected carefully to make sure the correct axis is measured, particularly if they have been distorted by trampling or impact with the ground (Photograph 9.1).

- If resources permit, fecal DNA samples should be collected from all measured dung-piles (see Chapter 9).

- The location of each dung-pile should be recorded using a GPS.

Photograph 9.1: Demonstration of how to measure dung-pile circumference. Gloves are being worn here because the fieldworker had been collecting fecal DNA specimens, they are not normally required! (Photo: © Ms Puntipa Pattanakeaw/WCS)

## 10.2.2 Recording dimension data

- Dung circumference data should be recorded along with the line transect data (using approved datasheets, see Section 8.2.3.7)

## 10.2.3 Presentation of dung bolus circumferences

- For each dung-pile measured, a mean circumference should be calculated.
- Data should be categorized by sex if fecal DNA samples were collected and the results of the analyses are available.
- All circumference data should be tabulated for the site as follows:

| **Site name: Way Kambas National Park, Sumatra, Indonesia**<br>**Site location (give GPS or lat/long data): lat 4°62'–5°26' S and 105°54'–105°90' E**<br>**Start date of all surveys included here (yyyy/mm/dd): 2006/06/01**<br>**End date of all surveys included here: (yyyy/mm/dd): 2006/09/01** | | | | | |
|---|---|---|---|---|---|
| **Dung-pile ID number** | **Line transect number** | **Location were found** | **Sex (if known)** | **Circumferences (cm)** | **Mean circumference (cm)** |
| EX1_1 | EX1 | Give GPS coordinates | Not known | 42, 44, 44 | 43.33 |
| EX1_2 | EX1 | Give GPS coordinates | Not known | 35, 36, – | 35.5 |
| EX1_3 | EX1 | Give GPS coordinates | Not known | 29, 31, 28 | 29.33 |
| Etc... | Etc… | Etc… | Etc… | Etc… | Etc… |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

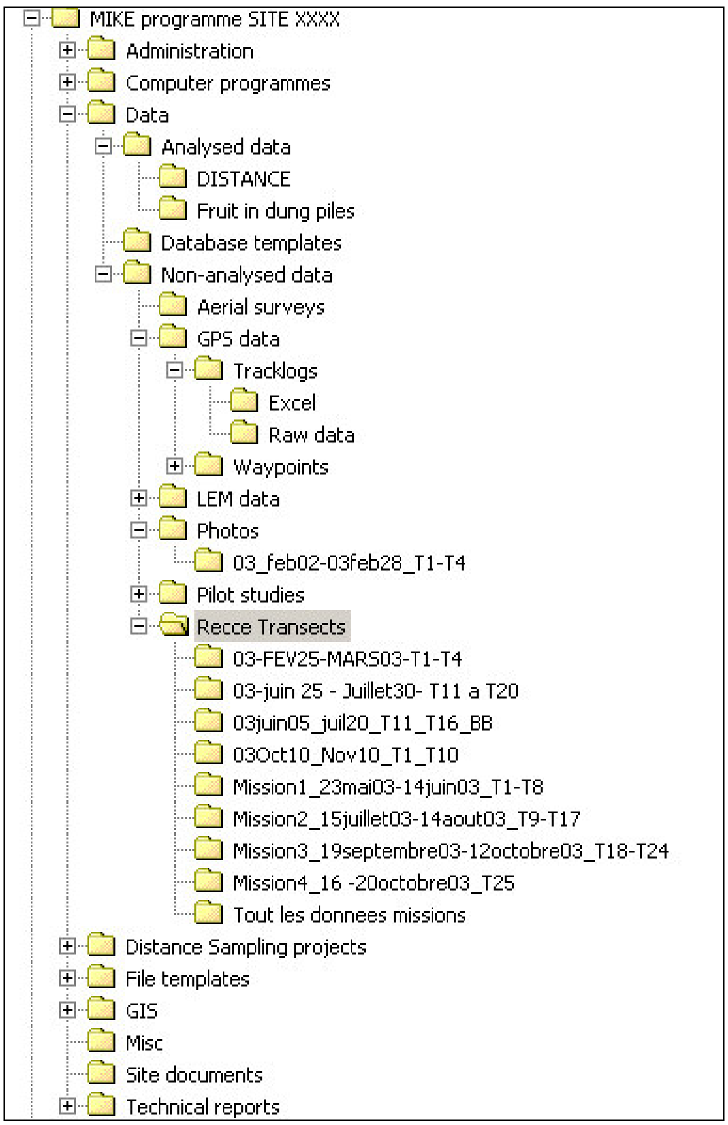
- Plot a histogram showing the distribution of dung-pile sizes in your site (using mean circumference data). If you have data on the sex of the animals responsible for the measured dung-piles plot 2 histograms, 1 for males, and 1 for females. These dung-pile dimension data will help you, your SSO, and the MIKE TAG estimate changes in elephant population age-structure when your site is re-surveyed.
- Include all these data and the histograms in your survey report (Chapter 12).

# 11. Data management at the site level

## 11.1 File management system

- All files generated under the MIKE programme must be accessible to a wide and potentially uninformed group of users. This requires a logical and simple file management system.

- Every computer used by MIKE at a site should have a directory specifically for MIKE material following the format illustrated below:




- Every file generated should find a suitable place in the file structure. There will clearly be a need to add sub-directories as files proliferate, but all directories should follow the same principles.

- Filenames should accurately describe the contents of the file. A file named 'Survey results.xls' is meaningless. That file will be lost within the MIKE system.

- All MIKE generated files should follow a clear and unambiguous naming system. This should follow the following pattern:

  Site name _typeofdata_startdate_enddate.xxx

- Dates should start with the year, month, and day (i.e. yyyymmdd)

- For example in the case of transect data:

  Minkebe_transectdata_20030725_20030921.xls

- Or for a progress report:

  Minkebe_progressreport_LEM_20030912.doc

## 11.2 Backing up data

### 11.2.1 Introduction

Survey notebooks, datasheets, and electronic data including computer files and GPS data are the product of weeks or months of hard physical toil. If they are lost the effort and money used to collect this will have been for nothing. This is not only embarrassing, it may have grave consequences for the MIKE programme, and for the future funding potential of important field operations. Yet the annals of field biology are replete with tales of biologists who have lost their original data through theft, fires, accident, or computer failure.

Data are at risk until copies have been made, distributed, and stored in at least two different physical locations.

### 11.2.2 General methods

- Make at least three photocopies of the original datasheets. These should be distributed as follows: one set to the MIKE site officer, which must flow through the MIKE data management process to the SSO. The second set should be given to the site management authority. The third set should be kept by the survey team leader until requested by MIKE. Even after they have been transcribed, data-sheets are still valuable for verification purposes.

- Do not keep the photocopy with the original: if the original is lost, then the copy will be lost too. Keep it in a separate building (in case of fire or theft).

- It is desirable that all notes and records on datasheets and in notebooks be transcribed into digital format but this is not always possible. Notes are often invaluable to understanding the background or context of numeric data, and they are frequently overlooked if not entered into the electronic database. Keywords may be used to help searches for important events qualitatively described in the notes section. All notes should be referenced by the date and time they were written.

- All computer files must be backed up. At the end of each day make a copy of each file that you have changed during the day. Use two USB external hard disk drives or flashcards to copy files, and either take the backup home or store it in a separate building. There should always be three copies of any file, one on the hard drive and two copies on external media.

- Every week all data should be backed up again either onto a CD or an external hard disk drive.

- Every month a complete copy of all MIKE files—data and otherwise—should be burned onto CDs and distributed as follows: 1 copy to the MIKE site officer, 1 copy to the site management authority, 1 copy to remain with the person who was responsible for data collection and transcription.

- When the editing is completed (e.g. all the data from a transect survey have been transcribed into an Access database file), a complete copy should be burnt onto CDs and distributed as follows: 1 copy to the MIKE site officer, 1 copy to the site management authority, 1 copy to remain with the person who was responsible for data collection and transcription.

# 12. Data Reporting

## 12.1. Writing survey reports

Each survey must be fully documented for posterity. Reports should follow standard scientific writing practices. The narrative report must give a full description of the survey and should contain the following elements:

**Background**

1) Location, dates, description of the area
2) Previous information (e.g. past surveys)
3) Objective
4) Design, stratification, sampling intensity

**Results**

5) Tables for each stratum showing observations of dung-piles and perpendicular distances for each recce-survey transect and line transect
6) Print-outs from DISTANCE 4.0
7) Calculations of elephant density
8) Any other important observations made on recce-survey transect and line transects (e.g. illegal activities, observations of elephants)

**Discussion**

9) Compare with previous surveys and comment on any problems that were encountered

**References**

10) Sources for pre-existing information about the area should be quoted
11) Sources of methodology/design unique to the survey should be quoted

**Appendices**

12) Details of methods
13) List of personnel
14) Dates of each trip into the forest
15) Map of survey zone showing strata and location of each transect
16) Copy of the original datasheets (the data should be copied onto a CD that should be included with the narrative report following the data management protocol)
17) List of the files and formats for the data on disc, and a brief description of each file

# Annex 1. Dung-pile classification systems: some comments on previously-used systems

The most commonly used system of classifying dung-piles, used in almost all dung-based elephant surveys to date is the A–E system of Barnes & Jensen (1987). An alternative system (relying partly on changes in dung odour) was used in the MIKE pilot project in Central Africa (White & Edwards 2000; Beyers et al. 2001). At least one other system has been employed: that of Wing & Buss (1970), which was subsequently modified by Wiles (1980).

**The Wing & Buss / Wiles system:**
The Wing & Buss / Wiles system is unsuitable for multi-team surveys such as those carried out by the MIKE Program. The main problems are the lack of definitions for key terms, and, more seriously, the ambiguous cut-off points between the classes, which rely on expert opinion and are therefore problematic for surveys involving large numbers of people (Hedges & Tyson 2002).

| **The Wing & Buss / Wiles system** | |
|---|---|
| Easily Recognized | Little noticeable deterioration. Boli remaining essentially intact and identification of dropping easy. |
| Recognizable | Extensive decomposition, erosion, settling, and rearrangement of fecal materials may have occurred, but sufficient concentration of materials remain to allow definite recognition by an experienced worker during a field count. |
| Barely Recognizable | Decomposition and removal of fecal material so extensive that only with care and examination of indirect evidence can the remaining materials be identified as components of an elephant dropping. May fail to be recognized by an experienced worker during a field count. |
| Not Recognizable (Gone) | The removal or decomposition of fecal material so complete that identification as an elephant dropping no longer possible. |

**The MIKE Central Africa Pilot Project / White & Edwards system:**
The system used for the MIKE Central Africa Pilot Project (White & Edwards 2000; Beyers et al. 2001) is also problematic—mainly because of the difficulty of deciding what constitutes ‘still smells of dung’ and applying it consistently, especially when many people are going to be using the system. A second, related, problem with this method stems from the stated need to break open dung-piles to determine whether they still smell of dung. This means that the dung-piles which are monitored over time to assess decay rates are likely to decay faster than the unmonitored dung-piles that the survey teams record along transects (since the monitored boli may be repeatedly broken open by the decay rate monitoring team). Thus, in addition to being difficult to apply consistently, the system can also introduce a systematic bias: i.e. decay rates of monitored dung-piles will be quicker than unmonitored ones (Hedges & Tyson 2002).

| **The MIKE Central Africa Pilot Project / White & Edwards system** | |
|---|---|
| Fresh | Sometimes still warm(!), with fatty acid sheen glistening on exterior and strong smell. |
| Recent | Odour present (break the boli), there may be flies, but the fatty acid sheen has disappeared. |
| Old | Overall form still present although boli may be partly or completely broken down into an amorphous mass, no odour. |
| Very Old | Flattened, dispersed, tending to disappear. |

**The A–E system of Barnes & Jensen:**
The A–E system requires the surveyor to classify dung-piles into five classes (A, B, C1, C2, D, E) based on their state of decomposition [see Barnes & Jensen (1987: 3–4) or Dawson & Dekker (1992: 25–28)]. Unfortunately, several problems exist with the system. Firstly, assigning dung-piles to classes can be fairly subjective, especially as definitions of key term such as 'intact' are not given. This can lead to both intra- and inter-study differences between surveyors' classification of dung-piles (Barnes 1996; Nchanji & Plumptre 2001; Hedges & Tyson 2002). Secondly, the classification of many dung-piles relies on assessing whether 'more than half the boli are still distinguishable as boli'. However, for this system to be applied unambiguously in the field one has to know how many boli there were in the first place—which is clearly impossible. And equally clearly, if one takes the definitions to refer to the actual number of boli still remaining in the field (rather than the number originally deposited) a dung-pile can 'undecay', e.g. from stage C2 to stage C1 (Hedges 1993; Hedges & Tyson 2002).

| **The A–E system of Barnes & Jensen** | |
|---|---|
| A | Boli intact, very fresh, moist, with odour. |
| B | Boli intact, fresh but dry, no odour. |
| C1 | Some of the boli have disintegrated, but more than half are still distinguishable as boli. |
| C2 | < 50% of the boli are distinguishable; the rest have disintegrated. |
| D | All boli completely disintegrated; dung-pile now forms an amorphous flat mass. |
| E | Decayed to the stage where it would be impossible to detect at 2 metres in the undergrowth; it would not be seen on a transect unless directly underfoot. |

The Barnes & Jensen A–E system can however be modified to make it suitable for use in MIKE surveys (Hedges & Tyson 2002). The essential modifications being: (1) providing a definition for what constitutes an 'intact' bolus, and (2) classifying dung-piles according to the proportion of the remaining boli that are still intact. These modifications are incorporated in the new MIKE dung-pile classification system (the S system) described in Chapter 4.

# Annex 2. Published defecation rates for Asian and African elephants

| Location | Season | Forest type | Method | No. of elephants / sample size | Defecation rate per 24-hours | CV (%) | Reference |
|---|---|---|---|---|---|---|---|
| **Asian Elephants** | | | | | | | |
| South-eastern Sri Lanka | ? | N/A | O/C | 37/129.2 elephant-hrs | 15.0 | 74.2 | Vancuylenberg (1977). |
| Parambikulam Wildlife Sanctuary, southern India | Post-monsoon | Moist-deciduous +wet evergreen | C | 4/288 elephant-hrs | 15.1 | 12.5 | Dawson (1990) |
| Parambikulam Wildlife Sanctuary, southern India | Early dry | Moist-deciduous +wet evergreen | C | 3/260 elephant-hrs | 13.2 | 15.3 | Dawson (1990) |
| Mudumalai Wildlife Sanctuary, southern India | Dry (mid) | Moist +dry deciduous | C | 7/492 elephant-hrs | 9.3 | 17.83 | Dawson (1990) |
| Mudumalai Wildlife Sanctuary, southern India | Early monsoon | Moist +dry deciduous | C | 6/156 elephant-hrs | 13.3 | 32.0 | Dawson (1990) |
| Mudumalai Wildlife Sanctuary, southern India | Monsoon | Moist +dry deciduous | C | 6/115.5 elephant-hrs | 14.6 | 13.9 | Dawson (1990) |
| Mudumalai Wildlife Sanctuary, southern India | Post-monsoon | Moist +dry deciduous | C | 7/148 elephant-hrs | 15.9 | 20.7 | Dawson (1990) |
| Mudumalai Wildlife Sanctuary, southern India | ? | Moist +dry deciduous | O? | ?/88hrs | 16.33 | ? | Watve (1992) |
| Way Kambas National Park, SE Sumatra, 1994 | Dry | Wet evergreen | C | 5/20 elephant-days | 11.83 | 10.99 | Reilly (2002a) |
| Way Kambas National Park, SE Sumatra, 1997 | Dry | Wet evergreen | C | 12/50 elephant-days | 13.04 | 15.84 | Reilly (2002a) |
| Way Kambas National Park, SE Sumatra, 1998 | Rainy | Wet evergreen | C | 4/28 elephant-days | 17.93 | 22.87 | Reilly (2002a) |
| Way Kambas National Park, SE Sumatra, 2000 & 2001 | Rainy & dry | Wet evergreen | C | 12/1420 elephant-days | 18.1 | 14.4 | Tyson et al. (in review) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **African Elephants** | | | | | | | |
| Kibale, Uganda | ? | Wet evergreen /rainforest | O | 132/400 elephant-hrs | 17.0 | 3.4 | Wing & Buss (1970) |
| Tsavo East National Park, Kenya | ? | Savanna / woodland | C | 4/308 elephant-hrs | 17.1 | 33.0 | Coe (1972) |
| Sengwa Wildlife Research Area, Rhodesia | Wet & dry | Savanna / woodland | T/O | 48/ ? | 14 males, 10 females | ? | Guy (1975) |
| Ruaha National Park, Tanzania | Dry | Savanna / woodland | O | ? | 9.6 | ? | Barnes (1982) |
| Ruaha National Park, Tanzania | Wet | Savanna / woodland | O | ? | 32 | ? | Barnes (1982) |
| Tai National Park, Ivory Coast | ? | Wet evergreen /rainforest | T | ? | 18.0 | 1.2 | Merz (1986) |
| Kasunga National Park, Malawi | Dry | Savanna / woodland | T | 147 elephant-hrs | 15.7 | ? | Jachmann & Bell (1984) |
| Nazinga Game Ranch, Burkina Faso | Dry | Savanna / woodland | T | ?/ 88.2 elephant-hrs in total for both seasons | 14.1 | ? | Jachmann (1991) |
| Nazinga Game Ranch, Burkina Faso | Wet | Savanna / woodland | T | | 27.2 | ? | Jachmann (1991) |
| Santchou Reserve, Cameroun | Wet & dry | Wet evergreen /rainforest | T | ?/3091 elephant-hrs | 19.77 | 4.2 | Tchamba (1992) |
| Parc National des Volcans, Rwanda | ? | Wet evergreen /rainforest | T | Small | 16.2 | 2.8 | Plumptre (2000) |
| Bossematié Forest Reserve, Ivory Coast | Dry | Wet evergreen /rainforest | T | 33/88.5 elephant-hrs | 16.6 | 106.6 | Theuerkauf & Ellenberg (2000) |
| Bossematié Forest Reserve, Ivory Coast | Wet | Wet evergreen /rainforest | T | 59/137.5 elephant -hrs | 18.1 | 79.6 | Theuerkauf & Ellenberg (2000) |

O = observation of wild elephants, C = observations on captive or tamed elephants, T = tracking wild elephants & counting dung piles, CV = coefficient of variation.

# Annex 3. Summary of equipment needs

## Each recce-survey transect (RST) team will require:

### Navigation and data collection

- Maps (and if available satellite images and/or aerial photographs)
- Two sighting compasses
- Two suitable GPS units (e.g. Garmin GPS 72), plus copious batteries
- Two topofils (e.g. Hipchains) and adequate thread
- Clinometer
- Approved datasheets and folders; waterproof notebooks
- Plastic ziplock bags to protect datasheets and notebooks from water
- Water-tight bags
- Pencils and indelible pens
- Dung classification field reference sheet (illustrated with photos and diagrams)
- Recce-survey transect field methods reference sheet (e.g. the relevant sections from this document)
- Standard vegetation-type classification reference material (appropriate for site/region)
- Simple cheap digital camera for recording carcasses and other things of interest (optional)

### Cutting transects

- Cutlasses, machetes, parang (or equivalent)
- Secateurs (optional)

### Camping equipment

- Mosquito nets
- Hammocks (optional)
- Tents and/or tarpaulins
- Groundsheets
- Cooking paraphernalia
- Water bottles
- Rucksacks
- Torches and batteries
- First-aid kit

## Each line transect survey team will require:

### Navigation and data collection

- Maps (and if available satellite images and/or aerial photographs)
- Two sighting compasses
- Two GPS units (e.g. Garmin GPS 72), plus copious batteries
- Two topofils (e.g. Hipchains) and adequate thread
- Two metal measuring tapes (5 metres)
- Two flexible plastic measuring tapes to record the circumferences of dung boli
- Clinometer
- Approved datasheets and folders; waterproof notebooks
- Plastic ziplock bags to protect notebooks and datasheets from water; water-tight bags
- Pencils and indelible pens
- Dung classification field reference sheet (illustrated with photos and diagrams)

- Line transect field methods reference sheet (e.g. the relevant sections from this document)
- Standard vegetation-type classification reference material (appropriate for site/region)
- Simple cheap digital camera for recording carcasses and other things of interest (optional)

### Cutting transects

- Cutlasses, machetes, parang (or equivalent)
- Secateurs (optional)
- Pole or stake that is at eye level when pushed into the ground and which is of large enough diameter to support a sighting compass (Section 8.2.3)

### Camping equipment

- As above

## Each dung decay monitoring team will require:

### Dung-pile monitoring equipment

- Metal stakes (e.g. tent pegs) for marking dung-piles
- Hammer
- Flagging tape (for indicating dung-pile locations)
- Red paint and paint brushes
- Permanent marker pens (lots!)
- Two GPS units
- Two sighting compasses
- Approved datasheets and folders
- Waterproof notebooks
- Water-tight bags for datasheets and folders
- Pencils and indelible pens
- Dung classification field reference sheet (illustrated with photos and diagrams of classified dung-piles)
- Vegetation classification field reference material (appropriate for site/region)
- Clinometer

### Camping equipment

- As above

## Each fecal concentration survey team will require:

### Navigation and data collection

- Maps (and if available satellite images and/or aerial photographs)
- Two sighting compasses
- Two suitable GPS units (e.g. Garmin GPS 72), plus copious batteries
- Two topofils (e.g. Hipchains) and adequate thread
- Clinometer
- Waterproof notebooks and datasheets
- Plastic ziplock bags to protect notebooks and datasheets from water
- Pencils and indelible pens
- Dung classification field reference sheet (illustrated with photos and diagrams)
- Fecal concentration survey field methods reference sheet (e.g. the relevant sections from this document)
- Standard vegetation-type classification reference material (appropriate for site/region)

- Simple cheap digital camera for recording carcasses and other things of interest (optional)

### Cutting transects
- Cutlasses, machetes, parang (or equivalent)
- Secateurs (optional)

### Sample collection equipment
- 30–50 ml polypropylene tubes with polypropylene caps
- Test-tube rack
- Saucepan that can hold test-tube rack when boiling samples
- Plastic forks
- Queen's College buffer (20% DMSO, 0.25 M EDTA, 100 mM Tris, pH 7.5, saturated with NaCl)
- Parafilm
- Permanent marker pens
- Latex gloves
- Ziplock bags

### Camping equipment
- As above

# Annex 4. Additional notes about ‘recce’ methods

The method of estimating dung-pile density included in these Standards is the line transect (Buckland et al. 2001). However, in recent years, a number of so-called ‘recce’ (reconnaissance) survey methods have been used in conjunction with line transects in an attempt to improve the precision of dung count based surveys. While this use of ‘recce’ methods to estimate elephant dung-pile density is not endorsed by the MIKE Technical Advisory Group (TAG) and is not therefore included in these Standards, for completeness a few additional notes about this method are included here.

One use of recce methods has involved teams walking along the path of least resistance through the forest and counting all dung-piles found, but not measuring perpendicular distances to these dung-piles. It has been shown that dung-pile encounter rates on such recce transects are strongly correlated with encounter rates on nearby line transects, which arguably allows recces to be used to estimate dung-pile density, providing the functional relationship between encounter rates on recces and line transects is derived from a subset of recces matched with (calibrated against) line transects. Once this relationship has been established, a combination of recces and line transects should, it is argued, provide a more precise estimate of dung-pile density than line transects alone, because recces require roughly three times less effort than line transects and thus more ground can be covered by a given number of surveyors (Walsh & White 1999; Walsh et al. 2001). These recce methods were developed by Richard Barnes, Jefferson Hall, Peter Walsh, Lee White, Steve Blake, Rene Beyers and others in Africa (e.g. Barnes 1989; Hall et al. 1998; McNeilage et al. 1998; Walsh & White 1999; Beyers et al. 2001; Blake 2002).

There has been considerable discussion of the relative merits of using such recce/transect combinations for forest elephant surveys (Walsh 1999; Walsh & White 1999; Walsh et al. 2001; Beyers et al. 2001; Hedges & Tyson 2002). However there is as yet no agreement about how—indeed whether—recce/transect combinations should be used in an attempt to improve the precision of dung count based surveys, and this approach is not endorsed by the MIKE TAG.

Another type of recce is the ‘travel recce’. ‘Travel recces’ are widely used in Central Africa to collect data whilst survey teams are walking from the end of one line transect to the beginning of the next. Typically they are used to collect data on dung-pile encounter rates, other elephant sign, carcasses, major habitat type changes, and human sign. The direction of travel on these ‘travel recces’ is very flexible (the teams can deviate to investigate clearings, waterholes, etc.) or follow human trails. These methods have proven very valuable for the collection of MIKE Law Enforcement Monitoring (LEM) data and for allowing teams to gain a relatively quick understanding of the major threats to elephant and other wildlife populations in an area. They are however not a means of estimating elephant density from dung counts, and ‘travel recces’ are therefore not included in these Standards. A good case can nevertheless be made for the wider adoption of these methods for MIKE sites and for the development of appropriate standards.

Neither of the above recce methods should be confused with the recce-survey transects (RSTs) described in this Standards document. RSTs are simply used to estimate dung-pile encounter rates (not densities) during pilot surveys (to aid the design of formal line transect based surveys) and this use is uncontroversial.

# References

Ananthasubramaniam, C.R. (1992) Some aspects of elephant nutrition. In: The Asian Elephant [Ed. Silas, E.G., Krishnan Nair, M. & Nirmalan, G.]. Kerala Agricultural University, Trichur, India.

Barnes, R.F.W. (1982) Elephant feeding behaviour in Ruaha National Park, Tanzania. African Journal of Ecology 20: 123–136.

Barnes, R.F.W. (1989) The Poor Man's Guide to Counting Elephants. Unpublished report.

Barnes, R.F.W. (1993) Indirect methods for counting elephants in forest. Pachyderm 16: 24–30.

Barnes, R.F.W. (1996) Estimating forest elephant abundance by dung counts. In: Studying Elephants [Ed. Kangwana, K.]. African Wildlife Foundation, Nairobi, Kenya.

Barnes, R.F.W. (2001) How reliable are dung counts for estimating elephant numbers? African Journal of Ecology 39: 1–9.

Barnes, R.F.W. (2002) The problem of precision and trend detection posed by small elephant populations in West Africa. African Journal of Ecology 40: 179–185.

Barnes, R.F.W., Asamoah-Boateng, B., Naada Majam, J., Agyei-Ohemeng, J. (1997a) Rainfall and the population dynamics of elephant dung-piles in the forests of southern Ghana. African Journal of Ecology 35: 39–52.

Barnes, R.F.W., Barnes, K.L. (1992) Estimating decay rates of elephant dung-piles in forest. African Journal of Ecology 30: 316–321.

Barnes, R.F.W., Beardsley, K., Michelmore, F., Barnes, K.L., Alers, M.P.T., Blom, A. (1997b) Estimating forest elephant numbers with dung counts and a geographic information system. Journal of Wildlife Management, 61: 1384–1393.

Barnes, R.F.W., Jensen, K.L. (1987) How to count elephants in forests. IUCN/SSC African Elephant and Rhino Specialist Group Technical Bulletin Number 1.

Beyers, R., Thomas, L., Hart, J., Buckland, S. (2001) Recommendations for Ground-based Survey Methods for Elephants in the Central African Forest Region. Monitoring the Illegal Killing of Elephants (MIKE) Central African Pilot Project, Technical Report No. 2, 21 August 2001.

Blake, S., (2002) The Ecology of Forest Elephant Distribution and its Implications for Conservation. Ph.D. dissertation, University of Edinburgh, UK.

Blake, S., Hedges, S. (2004) Sinking the Flagship: the Case of Forest Elephants in Asia and Africa. Conservation Biology 18: 1191–1202.

Blanc, J.J., Thouless, C.R., Hart, J.A., Dublin, H.T., Douglas-Hamilton, I., Craig, C.G., Barnes, R.F.W. (2003) African Elephant Status Report 2002: An Update from the African Elephant Database. IUCN/SSC African Elephant Specialist Group, Gland, Switzerland, and Cambridge, UK.

Blouch, R.A., Haryanto (1984) Elephants in southern Sumatra. IUCN/WWF Project 3033, Bogor, Indonesia.

Buckland, S.T., Andersen, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., Thomas, L. (2001) Introduction to Distance Sampling: Estimating abundance of biological populations. Oxford University Press, UK.

Buckland, S.T., Andersen, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., Thomas, L. (2004) Advanced Distance Sampling. Oxford University Press, UK.

Burnham, K.P., Andersen, D.R., Laake, J.L. (1980) Estimation of density from line transect sampling of biological populations. Wildlife Monographs 72: 1–202.

Campbell, D., Swanson, G.M., Sales, J. (2004). Comparing the precision and cost-effectiveness of fecal pellet group count methods. Journal of Applied Ecology 41: 1185–1196.

Coe, M.J. (1972). Defecation by African elephants (*Loxodonta africana africana* (Blumenbach)). East African Wildlife Journal 10: 165–174.

Dawson, S. (1990) A model to estimate the density of Asian elephants (*Elephas maximus*) in forest habitats. MSc thesis, University of Oxford, UK.

Dawson, S., Dekker, A.J.F.M. (1992) Counting Asian Elephants in Forests. RAPA Publication: 1992/11, FAO, Bangkok Thailand.

Duckworth, J.W., Hedges, S. (1998) Tracking Tigers: A review of the Status of Tiger, Asian Elephant, Gaur, and Banteng in Vietnam, Lao, Cambodia, and Yunnan (China), with Recommendations for Future Conservation Action. WWF Indochina Programme, Hanoi, Vietnam.

Eberhardt, L.L. (1978) Appraising variability in population studies. Journal of Wildlife Management 42: 207–238.

Eggert, L.S., Eggert, J.A., Woodruff, D.S. (2003) Estimating population sizes for elusive animals: the forest elephants of Kakum National Park, Ghana. Molecular Ecology 12: 1389–1402.

Guy, P.R. (1975) The daily food intake of the African elephant, *Loxodonta africana* Blumenbach, in Rhodesia. Arnoldia 7: 1–8.

Hall, J.S., White, L.J.T., Inogwabini, B.I., Ilambu, O., Morland, H.S., Williamson, E.A., Saltonstall, K., Walsh, P., Sikubabwo, C., Dumbo, B., Kaleme, P.K., Vedder, A., Freeman, K., 1998. A survey of Grauers gorillas (*Gorilla gorilla graueri*) and chimpanzees (*Pan troglodytes schweinfurthi*) in the Kahuzi Biega National Park lowland sector and adjacent forest in eastern Congo. International Journal of Primatology, 19: 207–235.

Hedges, S. (1993) Large mammal surveys in Baluran and Alas Purwo National Parks, East Java: problems and possible solutions. Interim Report to Dept. of Biology, University of Southampton, UK and Dept. of Terrestrial Ecology and Nature Conservation, Wageningen Agricultural University, The Netherlands.

Hedges, S., Johnson, A. (2004) Conservation of Asian Elephants on the Nakai Plateau, Khammouane Province, Lao PDR: Mid-term Performance Report, December 2004. A report to USFWS and WCS. Wildlife Conservation Society, Bronx, New York, USA.

Hedges, S., Meijaard, E. (in prep.) Fallacies from faeces, or how not to count ungulates.

Hedges, S. Tyson, M.J. (2002) Some thoughts on counting elephants in SE Asian forests, with particular reference to the CITES Monitoring the Illegal Killing of Elephants Program. Wildlife Conservation Society, New York, USA.

Hedges, S., Tyson, M.J., Sitompul, A.F., Kinnaird, M.F., Gunaryadi, D., Aslan (2005) Distribution, status, and conservation needs of Asian elephants (*Elephas maximus*) in Lampung Province, Sumatra, Indonesia. Biological Conservation 124: 35–48.

Hedges, S., Tyson, M.J., Sitompul, A.F., Kinnaird, M.F., O'Brien, T.G. (2003) WCS Sumatran Elephant Project: Final Report on Year 3 to USFWS/AsECF, 21 July 2003. Wildlife Conservation Society, New York, USA.

Hiby, L., Lovell, P. (1991) DUNGSURV – a Program for estimating elephant density from dung density without assuming steady state. In: Censusing Elephants in Forests: Proceedings of an International Workshop [Eds Ramakrishnan, U., Santosh, J. & Sukumar, R.]. Asian Elephant Conservation Centre, Bangalore, India.

Jachmann, H. (1991) Evaluation of four survey methods for estimating elephant densities. African Journal of Ecology 29: 188–195.

Jachmann, H. (2001) Estimating abundance of African wildlife: an aid to adaptive management. Kluwer, Boston.

Jachmann, H., Bell, R.H.V. (1984) The use of elephant droppings in assessing numbers, occupance, and age structure: a refinement of the method. African Journal of Ecology 22: 127–141.

Karanth, K.U., Nichols, J.D. (Eds) (2002) Monitoring tigers and their prey: A manual for researchers, managers and conservationists in tropical Asia. Centre for Wildlife Studies, Bangalore, India.

Laing, S.E., Buckland, S.T., Burn, R.W., Lambie, D., Amphlett, A. (2003) Dung and nest surveys: estimating decay rates. Journal of Applied Ecology 40: 1102–1111.

Lukacs, P.M., Burnham, K.P. (2005) Review of capture–recapture methods applicable to non-invasive genetic sampling. Molecular Ecology 14: 3909–3919.

Marques, F.F.C., Buckland, S.T., Goffin, D., Dixon, C.E., Borchers, D.L., Mayle, B.A., Peace, A.J. (2001) Estimating deer abundance from line transect surveys of dung: sika deer in southern Scotland. Journal of Applied Ecology 38: 349–363.

McClanahan, T.R. (1986) Quick population survey method using fecal droppings and a steady state assumption. African Journal of Ecology 24: 37–39.

McNeilage, A., Plumptre, A., Brock-Doyle, A., Vedder, A., 1998. Bwindi Impenetrable National Park, Uganda. Gorilla and large mammal census 1997. Working paper 14. Wildlife Conservation Society, New York, USA.

Merz, G. (1986) Counting elephants (*Loxodonta africana cyclotis*) in tropical rain forests with particular reference to the Tai National Park, Ivory Coast. African Journal of Ecology 24: 61–68.

Mills L.S., Citta J.J., Lair K.P., Schwartz M.K., Tallmon D.A. (2000) Estimating animal abundance using non-invasive DNA sampling: promise and pitfalls. Ecological Applications 10: 238–294.

Morgan, B.J., Lee, P.C. (2003) Forest elephant stature in the Reserve de Faune du Petit Loango, Gabon. Journal of Zoology 259: 337–344.

Nchanji, A.C., Plumptre, A.J. (2001) Seasonality in elephant dung decay and implications for censusing and population monitoring in southwestern Cameroon. African Journal of Ecology 39: 24–32.

Neff, D.J. (1968) A pellet group count technique for big game trend, census and distribution: a review. Journal of Wildlife Management 32: 597–614.

Plumptre, A.J. (2000). Monitoring mammal populations with line transect techniques in African forests. Journal of Applied Ecology 37: 356–368.

Putman, R.J. (1984) Fact from faeces. Mammal Review 14: 79–97.

Reilly, J. (2002a) The biology, ecology and conservation of the Sumatran elephant *Elephas maximus sumatranus* in Way Kambas National Park, Sumatra. PhD thesis, Manchester Metropolitan University, UK.

Reilly, J. (2002b) Growth in the Sumatran elephant (*Elephas maximus sumatranus*) and age estimation based on dung diameter. Journal of Zoology 258: 205–213.

Taylor, B.L., Gerrodette, T. (1993) The uses of statistical power in conservation biology: the vaquita and the northern spotted owl. Conservation Biology 7: 489–500.

Tchamba, M. (1992) Defecation by the African forest elephant (*Loxodonta africana cyclotis*) in the Santchou reserve, Cameroon. Mammalia 56: 155–159.

Theuerkauf, J., Ellenberg, H. (2000). Movements and defecation of forest elephants in the moist semi-deciduous Bossematié Forest Reserve, Ivory Coast. African Journal of Ecology 38: 258–261.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H. (2002) DISTANCE 4.0. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/.

Tyson, M.J., Hedges, S., Sitompul, A.F. (2002) WCS Sumatran Elephant Project: Six-month report: January–June 2002. Wildlife Conservation Society, Bogor, Indonesia.

Tyson, M.J., Hedges, S., Sitompul, A.F., Sukatmoko, Gunaryadi, D. (in review) Defecation rates of Asian Elephants in Sumatra, and implications for elephant surveys in Southeast Asia. Journal of Wildlife Management.

Tyson, M.J., Hedges, S., Sitompul, A.F., Sukatmoko, Gunaryadi, D. (in prep.) Elephant age determination from dung dimensions. To be submitted to Journal of Wildlife Management.

Vancuylenberg, B.W.B. (1977) Feeding behaviour of the Asiatic elephant in southeast Sri Lanka in relation to conservation. Biological Conservation 12: 33–54.

Waits L.P. (2004) Using non-invasive genetic sampling to detect and estimate abundance of rare wildlife species. In: Sampling Rare or Elusive Species: Concepts, Designs, and Techniques for Estimating Population Parameters [Ed. Thompson W.L.], pp. 211–228. Island Press, Washington, D.C., USA.

Walsh, P.D. (1999) Some Thoughts on a Statistical Framework for Monitoring Forest Elephants in Central Africa. Wildlife Conservation Society, New York, USA.

Walsh, P.D., White, L.J.T. (1999) What It Will Take to Monitor Forest Elephant Populations. Conservation Biology 13: 1194–1202.

Walsh, P.D., White, L.J.T, Mbina, C., Idiata, D., Mihindou, Y., Maisels, F., Thibault, M. (2001) Estimates of forest elephant abundance: projecting the relationship between precision and effort. Journal of Applied Ecology 38: 217–228.

Watve, M. (1992) Ecology of host-parasite interactions in a wild mammalian host community in Mudumalai, southern India. PhD thesis, Indian Institute of Science, Bangalore, India.

White, L.J.T. (1995) Factors affecting the duration of elephant dung-piles in rain forest in the Lopé Reserve, Gabon. African Journal of Ecology 33: 142–150.

White, L., Edwards, A. [editors] (2000) Conservation research in the African rain forests: a technical handbook. Wildlife Conservation Society, New York, USA.

Wiles, G.J. (1980) Faeces deterioration rates of four wild ungulates in Thailand. Natural History Bulletin of the Siam Society 28: 121–134.

Wilson, D.E., Cole, F.R., Nichols, J.D., Rudran, R., Foster, M.S. [Eds] (1996) Measuring and Monitoring Biological Diversity: Standard Methods for Mammals. Smithsonian Institution Press, Washington, USA and London, UK.

Wing, L.D., Buss, I.O. (1970) Elephants and Forests. Wildlife Monographs no.19.

WWF (2002) Saving a Future for Asia's Wild Rhinos & Elephants. WWF's Asian Rhino and Elephant Action Strategy. WWF-International, Gland, Switzerland.