The the following text is the summary section of: 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, Sumatran Elephant Project, Bogor, Indonesia.

Summary

Over the last few months there have been several discussions about the methods that should be adopted for the MIKE Program in SE Asia. We have therefore committed some thoughts about counting elephants to paper, in particular the use of dung surveys, camera-traps, and the potential utility of carcass surveys. Some of these points were made in Duckworth & Hedges (1998) and in a document one of us (SH) prepared for the October 1999 SE Asian MIKE Program planning workshop in Bangkok, both of which drew on the results of dung survey work conducted by SH, MT, Erik Meijaard, Christel Mols, and Sonja van Zanten on Java and Borneo over the 1991–1999 period; other points draw on the elephant survey work we have been conducting in southern Sumatra since January 2000.

Dung-count surveys to assess elephant population size and trend

- Dung-count based methods are well established for surveying forest elephant populations, so the basic methods are not described. We concentrate instead on those aspects which we think require further attention by those planning the proposed MIKE SE Asia Program: (1) classification of dung-piles into recognizable stages, (2) dung decay rate, (3) defecation rate, (4) the 'steady state' approach, (5) estimating the number of dung-piles per unit area, (6) evaluation of the accuracy of dung counts, (7) ageing elephants from their dung, and (8) the problems posed by small populations.

Classification of dung-piles into recognizable stages

- For dung decay to be monitored accurately, and for the decay rate data to be of use for converting estimates of dung density into elephant density we need to be able to assign dung-piles into classes based on their state of decay, and to do this consistently. Several classification systems exist: we review the problems with these systems and suggest some possible improvements. Harmonization of methods between Asia and Africa would be desirable before the start of any training or survey work under the MIKE Program in SE Asia.

Dung decay rates

- Dung decay rates can be highly variable between sites. Between-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.

- This suggests to us that decay rates should be monitored at all sites where dung-based survey methods are used to monitor elephant populations. We recognize this will be time-consuming, but given the high profile and controversial nature of the MIKE Program we believe it is essential.

- Within site dung decay rates are also highly variable, both within and between months. This suggests that several cohorts of dung-piles should be monitored per month, every month, in order to obtain a representative sample of variation in decay rates. Furthermore, wherever

possible, the decay monitoring work should aim to cover as many of the major vegetation types as possible within the survey site. A minimum of 50 fresh dung-piles should be located per major vegetation type per month.

- Rainfall should be recorded at the site if possible, otherwise rainfall data should be obtained from the nearest meteorological station. Data on habitat characters and microclimate should be recorded during decay rate monitoring experiments if time permits, as this will help us gain a better understanding of the processes affecting decay rates.

- This need for site-specific decay rates, and the likely high variability of decay rates within and between months and vegetation types has obvious implications for the selection of MIKE sites. Large numbers of dung-piles will be needed, so sites with large elephant populations—or sites where dung-piles can be readily found because the distribution of the elephants is relatively predictable—are likely to be preferable. An alternative may be to use sites close to places holding captive elephants such as elephant training centres and use dung from these elephants to monitor decay rates, but there are concerns about the effects of a captive-type diet on elephant dung consistency and thus decay rate. This could be overcome by using elephants from the centres but allowing them to forage naturally. For areas where a regular supply of fresh dung-piles will be difficult to achieve, the use of non-dung-count based survey methods is likely to be preferable. (See too the discussions about the 'steady state' approach and the problems of small populations.)

- It has been suggested that dung decay rates may be less variable while dung-piles are fresh, and so it may be advantageous to count only those dung-piles which are in the early stages of decay. However, restricting dung counts to recently dropped dung-piles would make the survey results more sensitive to the effects of immigration and emigration. In addition, the number of recent dung-piles found during surveys may well be prohibitively small, requiring too high a survey effort to achieve adequate precision.

- An alternative to using only recent dung-piles (e.g. classes A to B) may be to restrict analyses to dung-piles in intermediate stages (e.g. A–C1 or A–C2). A dynamic modelling approach using data from a pilot survey could be used to determine which decay stages should be included in analyses to minimize variance in decay rates while maintaining adequate sample size. This trade-off requires further attention.

- Although plots are easier to monitor than scattered dung-piles, there are problems with moving fresh dung-piles to form plots (the plots may be unrepresentative of areas where dung-piles are dropped, artificially high dung-pile densities on plots may increase decay rates by attracting dung beetles, etc.) The ideal is to locate freshly dropped dung-piles and monitor them *in situ*, but we recognize that the ideal may not be obtainable at all sites.

- 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.

Elephant defecation rates

- We have just completed a major study of defecation rates for Sumatra Elephants (*Elephas maximus*) with funding from WCS, USFWS/AsECF, and WWF. The results were rather encouraging since the mean defecation rate obtained, 18.15±2.53 defecations per 24-hour period with 95% CI [18.02, 18.29], is similar to rates obtained in other studies of forest-dwelling elephants, both in Asia and Africa (Tables 2 & 3). The overall median defecation

rate for the three study periods was 18 defecations in 24 hours. Small differences in the defecation rates of elephants, attributable to the vegetation type in which they foraged during the day, were found. The effect of foraging environment was however small, a difference of one defecation in 24 hours. The ranking of the defecation rates in three vegetation types (swamp grass, scrub, and forest) was not consistent between study periods and there was no significant effect when the data were combined across the three study periods. There are, however, reasons to expect that defecation rates are likely to be significantly lower in El Niño years in areas where this phenomenon leads to serious droughts.

- Defecation rate studies are expensive (our study cost about US$21,000): it seems unlikely therefore that any further studies of defecation rate will be conducted during the first phase of the MIKE Program in SE Asia (2003–2004?). So we need to ask whether it would be appropriate to use our data from Sumatra for other sites in SE Asia. We see two approaches to this problem:

    - We could assume that (a) defecation rates do not show significant seasonal variation in forests and (b) that our Sumatran data are typical for forest elephants (as suggested above). Thus a rate of 18 defecations per 24-hours would be used to convert dung count data to elephant densities for all forest sites in SE Asia. Data on elephant defecation rates currently being conducted by the Smithsonian Institution in Myanmar should help us assess whether making such assumptions would be warranted.

    - For non-forest areas, and for forest areas if the assumptions made above are judged to be inappropriate, we suggest that dung-count data are 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 can be treated as direct analogues of population density.

- If further defecation rate studies are planned, a number of points should be borne in mind. These concern the use of tame elephants (health issues, whether the tame elephants' diets are representative of those of wild elephants, etc.); likely differences between defecation rates at waterholes/clearings and forest areas; the need to allow for differences between day- and night-time defecation rates and diurnal peaks in defecation rates; differences between age/sex classes, etc. (see pp. 19–20).

The 'steady state' approach

- We review the problems of estimating elephant population density using the 'steady state' approach [i.e. calculating elephant density based on the assumption that defecation and decay rates are constant and so dung-pile density will remain constant once the system is in equilibrium, see McClanahan (1986) and Barnes & Jensen (1987), also see pp. 20–26]. From the studies reviewed (including our work in East Java and southern Sumatra), it is clear the limitations of the method are increasingly recognized, and there are now a number of alternatives. These include: repeat counts, the DUNGSURV model (Hiby & Lovell 1991), iterative approaches such as that developed by Plumptre & Harris (1995), and rainfall models of the kind developed by Barnes *et al*. (1997) and Barnes & Dunn (2002). We briefly review the pros and cons of these methods.

- Since we know that the steady state approach is problematic—i.e. many if not most systems are unlikely to be in a steady state for much of the time if at all—we believe it would be very unwise to adopt a steady state approach for the MIKE Program. (Or, to be more precise, the steady state approach should only be used if it demonstrably holds for the survey site and period.) The precautionary principle suggests that the most robust survey methods should be adopted, not least because the MIKE Program has attracted a lot of controversy.

- We suggest that this means dung-count based elephant surveys should only be conducted in sites where it is possible to find enough fresh elephant dung to facilitate the on-site monitoring of decay rates. Furthermore, we recommend the adoption of a protocol that would facilitate the use of more than one alternative to the steady state approach. We believe the most suitable protocol would be one that allowed for the development of site-specific rainfall models and the use of the DUNGSURV or iterative models.

- One of the most significant implications for the MIKE Program in SE Asia is that dung-piles will need to be monitored for a minimum of 6 and ideally >12 months before dung-count surveys start.

- If the protocol we recommend is adopted, cohorts of dung-piles would need to be established in every month of the year for at least one year (ideally starting one year before the surveys begin), and rainfall monitored continuously throughout the period. Preliminary inspection of four large data sets for elephant dung-pile decay rates in Africa and Asia (i.e. those of White 1995, Barnes *et al*. 1997, Nchanji & Plumptre 2001, and our data from southern Sumatra) suggests that in order to achieve mean monthly decay rates with confidence intervals between 10% and 25% of the mean, 50 to 100 dung-piles should be monitored per month. Note, however, that this assumes that the vegetation types are relatively homogenous across the site, if substantial areas of open grassland exist in addition to forest, dung-piles will need to be monitored in both vegetation types and if necessary separate rainfall models produced.

- What about small elephant populations where it is difficult to find fresh dung? Essentially the answer to this question is: use other methods, not dung counts. A similar conclusion was reached by Barnes (2002) from his analysis of the likely precision of dung counts and the expected power of dung-based monitoring programs when elephant population size is low (see pp. 33–35).

Estimating the density of dung-piles per unit area

- The combined line transect / recce transect approach of Walsh & White (1999) has now been widely adopted for elephant surveys in forests, including those conducted as part of the MIKE Program. Previously, there was some debate about the most appropriate survey design to use when employing line and recce transect methods. In particular, whether a purposive design is appropriate (Walsh 1999; Burn & Underwood no date; Hedges, Tyson, & Sitompul 2000; also see Appendix 2). This debate appears to have been resolved, and the consensus seems to be that a line and recce transect combination should be used in a non-purposive design, at least for the MIKE Program (e.g. Buckland 2000; Thomas *et al*. 2001; MIKE SE Asia proposal to USFWS/AsECF, 15 June 2002).

- Our data show that non-purposive recces are quicker than line transects by a factor of between 1.5 and 3 depending on terrain and dung-pile density. In addition, recces only require three people, while line transects require five or six. Thus recces are likely to be substantially more efficient than line transects even when a non-purposive stratified random

sampling design is used. The actual increase in efficiency will depend on terrain, accessibility, and dung-pile density.

- Despite the general agreement about the utility of recce transects, a number of issues still require attention. For example, the methods used to calibrate recce transects against line transects have differed between studies. Harmonization of methods between Asia and Africa would be desirable before the start of any training or survey work for the MIKE Program in SE Asia.

- Another issue concerns the power of line and recce transect surveys to detect changes in population size, particularly when elephant populations are small. Precision can be improved by re-surveying transects in subsequent years (Plumptre 2000; Beyers *et al*. 2001; also see pg. 27). It is not possible to re-survey recce transects with anything like the same precision. The significance of this requires further attention, but we suggest two possible approaches, which may warrant further consideration.

- Our data show that over time survey teams tend to increase their recce-walking speed. The number of dung-piles found on recces relative to the number found on paired line transects also declines over time. Common sense suggests that this is a causal relationship, and re-training results in slower recce-walking speeds and greater parity between dung-pile encounter rates on recces and paired transects. Thus, one of the lessons from our evaluation of the recce method is the need for regular re-training of recce teams involved in large multi-team survey projects such as MIKE. Another might be the adoption of area-specific speed limits for recces.

- Particular care needs to be taken when the boli from one defecation 'event' are spread over several tens of meters, and when more than one elephant has defecated in the same place. Surveyors need to be trained to use the appearance of dung boli (colour, size, apparent age, composition, etc.) to distinguish 'events' and thus determine appropriate perpendicular distances. Our experiences on Sumatra, Borneo, and Java suggest that regular quality-checking and re-training are likely to be necessary.

- Generally, line transects are preferable to strip transects for dung surveys because dung-pile visibility declines rapidly with distance from the observer, thus many dung-piles are likely to be missed unless the strip transects are rather narrow in which case the density estimates will have wide confidence intervals. However, in areas of tall grass and other concealing vegetation where dung-pile visibility is very low, actively searching for dung-piles in strip transects might be preferable if large numbers of dung-piles are likely to be missed along line transects. If strip transects are used either as a stand-alone survey method or in combination with recce transects, it will be necessary to demonstrate that all dung-piles within the strip transects are found by the surveyors. Because of concerns about dung-pile visibility in areas of tall *Imperata* grassland in our Way Kambas National Park study site in southern Sumatra, strip transects (3 m wide) were created by searching for dung-piles 1.5 m either side of our line transects. These data are currently being analysed.

- We evaluated adaptive plot methods during the first year of our elephant survey work in southern Sumatra. At the end of the method evaluation phase in 2000, we concluded that adaptive cluster plots presented too many logistical problems, and so we decided not to adopt this method for subsequent survey work in Sumatra. Furthermore, Buckland (2000) argues that the efficiency of adaptive sampling is only appreciably higher than for conventional random or stratified random sampling if the distribution of objects is very clustered, and as he notes—and our work shows—this is when the logistical difficulties of adaptive sampling are greatest. In light of these problems, there would seem to be no

advantage to allocating further effort to evaluating adaptive sampling for dung-count based surveys of elephants as part of the MIKE Program in SE Asia.

Evaluation of dung-based survey methods

- A few studies that have attempted to test the accuracy and precision of dung counts for elephants and their results were encouraging (Jachmann & Bell 1984; Dawson 1990; Jachmann 1991; Plumptre & Harris 1995; Varman, Ramakrishnan, & Sukumar 1995; also see Barnes 2001). However, given the high profile of the MIKE Program, it might be a good idea to conduct further evaluations of the accuracy and precision of dung survey methods as a MIKE project, i.e. conducting dung counts in areas where the size of the elephant population is known as a result of total counts or reliable estimates based on aerial surveys or DNA-based methods, particularly if new approaches to deriving elephant density from dung-pile density are to be developed and tested.

Ageing elephants from their dung

- Our ability to monitor trends in forest-dwelling elephant populations would be much improved if we could determine population age-structure as well as population size from dung surveys. The work of Jachmann & Bell (1984) and Reilly (2002) has shown that the circumference and diameter of dung boli are potentially useful predictors of elephant age. We re-examined the possibility of ageing elephants from dung dimensions during our work in southern Sumatra. Data analysis is ongoing, but preliminary results indicate that the measurement of dung dimensions during surveys will allow surveyors to monitor changes in the age-structure of wild elephant populations as suggested by the earlier studies.

- It is clear, however, that there are a number of potential problems with the method. One concern is the possibility that dung dimensions change as the dung decays, although our work and that of Reilly (2002) suggest that this is not in fact a significant problem.

- Another issue is the relationship between elephant size and age. For example, the elephants we used to establish the relationship between dung dimensions and elephant size are of unknown age, and while we could use data from, say, India to assign ages to the size classes, there are reasons to believe Sumatran Elephants are smaller than those in South Asia. Nevertheless, changes in the size-structure of elephant populations are likely to be a good indicator of major changes in the age-structure of those populations.

- Another problem concerns the use of captive elephants to derive curves relating elephant size or age to dung dimensions; this can be overcome by selecting appropriate animals (see pg. 31).

- More seriously, dung-piles from very young elephants are likely to be under-represented during transect surveys. We suggest that a possible approach to this problem would be to include dung circumference in the ancillary data collected during line-transect surveys, and stratify the data accordingly to allow the estimation of density estimates per dung-pile size class (and thus elephant size- or age-class). Clearly, this would increase the time required per transect, but the additional data on population age- or size-structure might justify the extra effort. We feel this issue requires further attention, especially in light of the relatively low power of either sighting- or dung-based counts to detect changes in elephant population size for small populations, and the concomitant need to pay more attention to changes in age-structure (Plumptre 2000; Barnes 2002, also see pp. 33–35).

- A further problem is caused by the fact that the curves relating dropping dimensions to elephant size age may differ for the two sexes (Jachmann & Bell 1984; Reilly 2002; Tyson, Hedges, & Sitompul 2002b, in prep.). In Jachmann & Bell's study of African Elephants the

curves are different above 15 years of age: this means that for boli-size classes equivalent to this age and older the defecations will have been produced by male and females of different ages, each sex being represented in proportion to the sex ratio of the age classes concerned. This problem is easy to deal with if the sex ratio of the population being studied is known, as it was in Jachmann & Bell's study site, but obviously for most forest sites it will not be known. However, Reilly (2002) found no significant difference between the diameter of dung boli from males and females of the same age class of Sumatran Elephant. Her results are encouraging, since they suggest that the relatively low level of sexual dimorphism shown by *Elephas maximus* compared to *Loxodonta africana* will facilitate the use of dung-size ageing techniques in the former species in areas where sex ratios are unknown.

- A related issue is the problem potentially introduced by age- and/or sex-specific differences in defecation rates. We are currently analysing the data from our WKNP study site to assess the likely significance of this problem.

- Providing the problems discussed above can be resolved, dung-based ageing methods promise to become useful additions to the elephant surveyor's tool kit. If further development work suggests the method should be adopted for regular monitoring of forest elephant populations, for example as part of the MIKE Program, the following points should be borne in mind:

    - Dung circumference appears to be a better predictor of elephant size than dung diameter. Circumference is easier and quicker to measure accurately in the field than dung diameter.

    - If possible, curves relating dung dimensions to elephant age or size should be developed for the region where the surveys will be conducted. Data presented in Jachmann & Bell (1984) illustrate the considerable variation in dropping size from different populations (see pg. 32).

The problem of small populations

- The precision of both aerial sample surveys and dung counts is inversely proportional to elephant abundance. This means that the power of a monitoring program such as MIKE to detect changes in elephant abundance declines as population size declines. Unfortunately, this problem becomes disproportionately more severe as population size drops to a few hundred animals (Barnes 2002). Barnes argues that as most West African elephant populations are already small, it is unlikely that the biennial surveys of the kind planned under the MIKE Program would detect declines in population size until the populations are well on the way to extinction. These conclusions have obvious relevance to the MIKE Program, and not just for West Africa. Elephant populations in SE Asia are in many cases likely to be smaller than those in West Africa (Duckworth & Hedges 1998).

- Barnes (2002) argues that it would make more sense to allocate most effort to monitoring elephant mortality (from carcass density and changes in population sex- and age-structure), law enforcement, and indices of illegal activities including trade in ivory and other elephant products. However he argues that determining sex- and age-structure is likely to be as difficult as detecting trends in numbers, and the estimates of these parameters are unlikely to be either accurate or precise. This may well prove to be the case, but we suggest that further thought needs to be given to the utility of combining dung-counts to estimate population size with dung-measuring to estimate age-structure. The power of such combined surveys to detect population trends (and their likely causes), especially when combined with carcass surveys and indices of illegal activities, may be superior to dung-

counts alone, and could facilitate the inclusion of smaller elephant populations in the monitoring program than would a solely dung-count based survey strategy.

- It would also seem desirable to extend the very useful analysis of Barnes (2002) in order to provide more detailed guidelines about the minimum size of elephant populations which should be included in the MIKE Program. It is also unclear (to us at least!) whether Barnes allowed for the improved resolution which results from re-using the same transect routes in subsequent years (e.g. Plumptre 2000; Beyers *et al*. 2001; also see pg. 27). Precision can also be improved through spatial modelling (Beyers & Hart 2001; Thomas & Buckland 2001; Thomas *et al*. 2001).

- Nonetheless, it is clear that monitoring elephant population trends in SE Asian will prove a major challenge, and further development of methods suitable for small populations should be an explicit goal of the MIKE Program in SE Asia. We suggest a number of methods which may warrant further investigation (see pp. 34–35).

Camera-trap surveys as an alternative to dung counts

- In recent years, the use of camera-trap derived photograph accumulation rates as indices of population size for cryptic large mammals has received a fair amount of attention. However, to date very few studies have attempted to evaluate whether camera-trap data can in fact be profitably calibrated using independently derived estimates of population density. We therefore assessed whether photograph accumulation rate was a good predictor of elephant density as derived from dung surveys.

- Analyses are ongoing, nevertheless it is clear that photograph accumulation rate is a poor predictor of dung-pile abundance, and thus we assume of elephant density.

- Results to date suggest that there may be a threshold density below which camera-trapping may not be a useful survey method for forest elephants. This threshold density would appear to be between 66 and 14 elephants/100 km^2; indeed below this threshold camera-traps may be unable even to reliably confirm the presence of elephants, at least with the camera density and placement used in our study.

- While the initial results of our work in Sumatra are not especially encouraging, they do suggest how camera-trapping methods could be developed to improve their utility for elephants—ideas that could be evaluated as part of the MIKE Program.

- Perhaps the most important issues requiring further attention are the questions of camera density and placement. Our results suggest that the elephants were spending a lot of time outside the trapping blocks (i.e. that their home ranges were large relative to the trapping blocks). Possible solutions that might warrant investigation as part of the MIKE Program include: (1) increasing the length of the camera-trapping periods (perhaps leaving the cameras in the field for 60 days instead of the 30 days we used, however this could lead to an increase in the number of unusable films or camera malfunctions due to prolonged exposure to high humidity levels); (2) increasing the number of camera-traps used per trapping period (we used 20 camera-traps, 30–40 would probably be a better number); and (3) changing the shape of the trapping blocks (we used strips 2 km x 10 km, a broader grid would probably be more appropriate).

Carcass surveys in forests

- In the early discussions and meetings about MIKE in SE Asia, concerns were expressed about the efficiency of searching for carcasses in forested areas because detection distances are often less than 50 meters. These concerns have presumably been resolved for the MIKE Program in Africa, since carcass data are being collected as part of the Law Enforcement Monitoring component. However, some government officials in Asia as well as others interested in MIKE appear to remain unconvinced about the value of carcass searches under SE Asian conditions.

- So, would it be worth investing effort in carcass surveys as part of the MIKE SE Asia Program? Based on many years' experience in East Java and southern Sumatra we would suggest that the answer is yes, certainly in the protected areas of Indonesia, and possibly in other parts of Asia too. For example, in Bukit Barisan Selatan National Park (3568 km^2), which is one of our study areas in southern Sumatra and a potential MIKE site, our teams and the Rhino Protection Unit (RPU) and Tiger Protection Unit (TPU) teams found evidence of at least 17 elephants which had been killed between 1 January 2000 and 1 November 2002. Of these 17 animals, one is thought to have died as a result of human–elephant conflict (it was caught in a coffee plantation but died shortly afterwards), but most of the other 16 are thought to have been killed by poachers. It is important to note that this number of elephant carcasses was found without dedicated carcass searches.

- These data suggest that it would be worth having teams of park rangers or other MIKE survey teams conduct systematic searches for carcasses (working in collaboration with existing RPU or TPU teams in Sumatra). These searches would probably best be conducted as more or less straight recces, crossing the PAs and employing a systematic survey design. They could be conducted in addition to or as a replacement for the existing scheme which involves RPU and TPU patrols following forest tracks.