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The journal is intended as a medium of communication on issues that concern the management and conservation of Asian elephants (*Elephas maximus*) both in the wild and in captivity. It is a means by which members of the AsESG and others can communicate their experiences, ideas and perceptions freely, so that the conservation of Asian elephants can benefit. All articles published in *Gajah* reflect the individual views of the authors and not necessarily that of the editorial board or the AsESG.

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Editorial Note

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Cover: Wild bull elephants on the Hardwar - Bijnor National Highway which passes through the Shyampur Forest (Hardwar Forest division, Uttarakhand, India)
Photo by Ritesh Joshi

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Editorial

Prithiviraj Fernando (Member Editorial Board)

"How many wild elephants are there globally, in a particular region, country, or location?" is the universal question we are asked as conservationists, scientists, managers or simply people interested in elephants. Unfortunately, as Asian elephants live in low visibility habitats and are secretive and largely nocturnal, the answer to this question has been very elusive.

A variety of methods have been developed for counting elephants, such as direct aerial, vehicle, foot and waterhole counts of elephants; indirect estimates based on sign, dung and footprints; and individual identification based on genetics or photography and mark-capture or rarefaction curves. They range from the quick and dirty to highly technical. Obviously, ones with error estimates are preferable to those that only provide a number with no indication of how far or close to the truth that number is. Methods that estimate densities require a leap of faith in extrapolation to area extent, to arrive at the all important 'number'. The proliferation of techniques is good evidence that there is not a single method that is easily applied, accurate and precise.

Given the difficulties in estimating it, why do we need to know the 'number'? At a global-scale, perhaps to assess conservation status. The 'number' may help non-technical people relate to the threat to the species. If the global population of Asian elephants is 40,000 and that of African elephants is ten times that, the Asian is obviously more 'endangered'. Are 'guesstimates' based on impressions of people who are in the field adequate for this purpose? If our estimate is 40,000 but there were actually 20,000 or 80,000 elephants does it matter? Would the species conservation status change significantly?

Does it have a bearing on resource allocation? Does the estimate of ten times less Asian than African elephants mean that Asian elephants get a greater share of global conservation funds? Consider the rhinos. Global population estimates for each species are around 11,000 white; 3000 black; 1500 Indian; 200 Sumatran and 50 Javan. Does the allocation of global conservation funding have any relation to the respective numbers? Or if we take subspecies; 4 northern vs 11,000 southern white; 2 Vietnamese vs 50 Indonesian Javan rhinos. Did the provision or lack of resources play a role in the demise of those subspecies? Did the 'number' not help?

Perhaps the 'number' is important to monitor the success or lack of it of global conservation efforts? Published estimates for global numbers of Asian elephants since 1978 have ranged from 28,000-42,000 (Olivier 1978), 23,000-41,000 (Shoshani & Eisenberg 1982), 34,470-53,710 (Santiapillai & Jackson 1990) to 41,410-52,345 (Sukumar 2003). What do these numbers mean? Has the population over this 25 year period gone up, down, remained static or can we not say?

What about at the level of a country? Does it even make sense to state a 'number' of elephants where countries share borders and elephants range across them? Is it any better for island populations? Country estimates for Sri Lanka have ranged from 1500 (Norris 1959), 1600-2200 (McKay 1973) 2000-4000 (Olivier 1978), 5000 (Hoffmann 1978), 2700-3200 (Santiapillai & Jackson 1990), 1967 (Hendavitharana *et al.* 1994). Estimates for Sabah (Borneo) have ranged from 2000 (H. Keith 1949), 500-5000 (Banks 1949), 500-2000 (Davies & Payne 1982) to 1100-1600 (WWF-AREAS 2006). Again what do these numbers mean? Do they reflect real ups and downs? Did elephants in Sri Lanka actually increase from 1500 in 1951 to 5000 in 1978 and decrease to 1967 in 1994? Considering such estimates as real numbers could pose a very real danger to elephant conservation, as it can give completely erroneous impressions of success or failure of conservation efforts.

Could we use the 'number' to plan conservation strategies? Can we determine a-priori how many elephants we want to have in a country - perhaps through Population Viability Analysis? An effective population of 50 may have an extinction probability of 0% over 100 years, which changes to certainty of extinction over 500 or 1000 years. If we want to account for genetic viability of populations, the number could be 5000 or 10,000. As the paper by Sitompul *et al.* in this issue states, the actual demographic parameters on which PVAs are based are not available even for well studied populations like Way Kambas. Even if we can come up with a desired number what then? Let's say we decide that a particular country should have 5000 elephants. Let's also assume that we can count accurately to the last elephant. We do the count and find that there are 20,103 elephants. Do we cull 15,103 because we only want 5000? Or let's say we find there are only 467. What are we going to do to increase it to 5000? Can we force them to breed more?

At the third level, we may want to know how many elephants there are in a particular location. Here again, does it make sense to talk of the number in a park if the home ranges of elephants are not restricted to the park? Maybe we want to know the number in a location because it is going to be developed or there is very high human-elephant conflict, and the elephants have to be removed. We want to decide whether to remove them by driving, capture-translocation, domestication or culling. Then we need to know how many elephants we are dealing with, because it will determine the method and logistics. However, even to get at the correct number of elephants in a circumscribed area is no easy task. In Sri Lanka, the estimated number of elephants for the Walawe Left Bank drive area of about 500 km^2 was 116. When the drive was done in 2006, 200+ elephants were driven into the Lunugamvehera National Park and probably over 300 elephants still remain in the drive area.

So overall, the 'number' is probably impossible to get at for global, regional and country-wide scales, and its relevance to actual conservation is questionable. It is probably of value at local scales, for planning and monitoring the impact of management activities, which however, needs accuracy and precision. Unfortunately, the quick and dirty methods are neither accurate nor precise, so we have to rely on the more technical methods. These require a high degree of training, skill, expertise, funds, time and dedication.

What then of global, regional and country-wide scales? Is there any other way of assessing conservation status? What about the IUCN criteria of 'extent of occurrence' and 'area of occupancy'? Would these provide a better, more objective way of assessing and monitoring conservation status? Asian elephants have and continue to lose a significant extent of range, which can be objectively estimated at global, regional and country-wide scales. Would that then not provide hard data that is accurate, precise and easily collected over large areas, allowing better assessment and monitoring? These are issues we need to ponder as members of the AsESG.

'Elephant wall' at 'Yatala Seya' a 2300 year old stupa in Tissamaharama, Sri Lanka
Photo by Prithiviraj Fernando

Notes from the Co-chairs IUCN/SSC Asian Elephant Specialist Group

Simon Hedges and Ajay Desai

Following on from the 'Note from the Co-chairs' in the last issue of Gajah, in which we wrote that a likely group project would be the creation of an Asian Elephant Database (AsED) similar to the African Elephant Database (AED), I am pleased to tell you that – after a lengthy process – the Asian Elephant Specialist Group (AsESG) and the African Elephant Specialist Group (AfESG) have been awarded a grant by the USFWS to develop a Asian Elephant Database as part of a Global Elephant Database. This database concept received range state government support at the 'Asian Elephant Range States' Meeting and such a database is long overdue for Asian elephants. The AsESG's Database Working Group (DWG) has started a review of data coding systems for the Asian Elephant Database. Once the DWG has reached some preliminary conclusions, we will seek inputs from the wider AsESG. The next step will be to hold a meeting of the Data Working Groups of the AsESG and AfESG in the second half of this year to discuss development of the new databases.

The other AsESG Task Forces have also been active. For example, the Wild Elephant and Elephant Habitat Management Task Force is discussing if/how Asian elephants can be incorporated into the "endangered species value" measure in "High Conservation Value Forest" assessments; and the Captive Elephant Management Task Force has been drafting possible AsESG position statements on registration of captive Asian elephants and the rational and sustainable use of captive Asian elephants. Once these within-task force discussions are further advanced, the task forces will share their drafts with the wider AsESG for comments and further inputs.

The Human–Elephant Conflict Task Force (HECTF) has begun organizing an HEC 'retreat'. This retreat will serve to gather together those Asian elephant conservationists who are currently working on HEC mitigation projects and allow them to produce a report reviewing all the HEC mitigation techniques that have been developed and applied over the years in the Asian elephant range countries. The HECTF has submitted a proposal to the USFWS, and we hope that this retreat will be held in Sumatra late this year or early next year.

We thank all those AsESG members who have volunteered their time and efforts for these endeavours.

Ajay and I have begun the process of organizing a Strategic Conservation Planning Workshop for Asian Elephants, which will be held in Cambodia in October 2008 with support from the USFWS, WCS, and WWF. This strategic planning workshop was requested by range state delegates at the range states' meeting in Malaysia and will be similar – but not identical – to the Regional Strategic Planning Workshops for Central African Elephants and West African Elephants (which lead to regional strategies and national action plans for elephants in those parts of Africa). More details about this workshop will follow soon.

Finally, earlier this year, Ajay and I attended the first-ever IUCN/SSC Specialist Group Chairs' Meeting in the UAE. The meeting was a great success and provided an opportunity for presentations and discussions on the work of the IUCN/SSC's Species Conservation Planning Task Force, which aims to improve the effectiveness of the action planning process. Please note that the executive summary and meeting report of the Specialist Group Chair's meeting in UAE is available on the meeting website at: http://cms.iucn.org/about/work/programmes/species/about_ssc/ssc_chairs_meeting/index.cfm.

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The Design of Crop-Raiding Studies

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Introduction

The conflict between people and elephants continues as farms expand into elephant habitats. As soil fertility falls, more land per capita will be needed, and so the rate of habitat loss will accelerate. Government policy in most countries is to conserve elephants, but farmers must feed their families. More studies of crop-raiding problems are needed, for two reasons.

First, general principles must be clarified. A risk factor is a variable that increases the probability that a farm will be raided by elephants. Some variables always increase the risk that farms will be damaged, whatever vegetation zone you are working in. These are universal risk factors. For example, maize and the number of crops grown on a farm attract elephants in both savannah and forest in West Africa (Barnes *et al.* 2005; Danquah *et al.* 2006, Drabo Adama, pers. comm.).

Second, some risk factors are site-specific, perhaps certain crops grown only locally. In some places elephants eat crops that are ignored by elephants elsewhere. The wildlife manager needs to identify both universal and site-specific risk factors so that he can advise farmers how to minimize crop losses.

If we identify a particular crop as a risk factor, the farmer cannot just stop growing it. His family must eat. But on the other hand, that crop might increase the chance of losing all or part of his farm. He must balance the cost of modifying his behaviour against the risk of crop losses to elephants. The most objective way is to develop multivariate models that describe the probability in terms of several risk factors (Barnes *et al.* 2005). Then one can show the farmer that modifying one variable will reduce his risk by *x* %, and modifying a second will reduce risk by *y* %. Modifying both together will reduce his risk by *z* %. Then the farmer is free to make his own decisions.

The design of a crop-raiding survey is important because it determines the accuracy of the estimates and the validity of predictions. The design will also determine the cost of the fieldwork. The purpose of this note is to bring the choices to the attention of field workers. Here I present three designs, one that looks forward in time, one that assesses the situation now, and a third that looks back into the past.

Designs for crop raiding studies

Cohort study

A cohort study defines a sample of farms (a cohort) and follows it into the future. The ideal cohort will consist of farms randomly selected from the population of farms at risk in your study area. The beginning of the year or the start of the crop-growing season (i.e. planting) is the best time to enrol the participant farms. The hypothesized independent variables (X_1, X_2, X_3 …X_n) are measured on each farm (Table 1). Each farm is observed during the growing season and all raids by elephants (Y) are recorded.

The logistics of monitoring many farms scattered through the bush, especially if there are few roads, complicate this type of study, and could even render it impossible. Therefore a compromise is random cluster sampling: first, randomly select groups of farms. Then monitor the farms, or a random sample of farms, within each group.

This is the most expensive design described here, because you must have a large sample in order to ensure enough statistical power in your analyses. But it is also the design most likely to produce a

Table 1. Data that should be collected for each farm.

Distance to the boundary of the protected area or edge of forest
Distance to the nearest village
Distance to the nearest road
Distance to the next farm (the "nearest neighbour" distance)
Size of the farm
Number of types of food crops (e.g. rice, maize, tomatoes, etc.)
Number of types of perennial crops or tree crops (e.g. citrus, palm oil, etc.)
Area covered by each crop
Other measures of crop abundance (e.g. numbers of maize heads, palm trees, etc.)

large amount of information. This was the design we used around the Kakum Conservation Area in southern Ghana (Barnes *et al*. 2005).

This design will work best where crop-raiding is common. It should not be applied where few farms are damaged. For example, imagine a situation where you followed 100 farms but only 5 were raided. Except for calculating the percentage of farms that were raided, you would not gain much useful information for the effort expended.

There is a variation on this design: grouped cohort study. Imagine that you hypothesize that a particular crop, e.g. sorghum, is the principal risk factor in your study area. You can identify a sample of farms with sorghum and a sample without sorghum and follow these cohorts into the future. Here you have grouped farms by risk factor. This variant is also useful when you suspect that an uncommon risk factor - perhaps an unusual crop type - is particularly attractive to elephants.

Cross-sectional study

A cross-sectional study takes a snapshot of the population of farms at one point in time. One selects a random sample of farms and then records the number of raids (Y). At the same time one records the information on the variables that one expects to be important (X_1, X_2, X_3 …X_n ; Table 1). Thus, in contrast to the other two designs described here, the data on elephant raids (Y) is collected simultaneously - or at least in the same month - with that on the farm variables (X_1, X_2, X_3 …X_n).

For best results, choose the month when you expect the most raids. For example, you might decide to take your snapshot in August. Ideally, you would choose one particular day, perhaps the 15th August, for the snapshot. But it is more practical to choose the whole month of August. For the independent variables (X_1, X_2, X_3 …X_n), you must ensure that you record their values as they stand on 15th August. In fact, on any given farm most of the variables of interest (Table 1) will not change during the month. For each farm you record the number of raids (Y) that occur only during the month of August.

This is the cheapest type of design. It is also the quickest. It will reveal major trends, but is less likely to provide the insights that would come from a cohort study. It is most suitable for students who want to study crop-raiding in a particular area but have limited time and resources. It may also be useful as a pilot study when you are starting out in a new area. The results will generate hypotheses that you can test later with a more rigorous design.

Case-control

In contrast to the designs described above, the case-control is a retrospective design: it looks back into the past. In this type of design you start with farms that have been raided. These are 'cases'. You can include all damaged farms in your study area as cases. But it may be more practical for you to take just a sample of them.

Then you select, at random from the same area, farms that have not been touched by elephants. These are the 'controls' that will be compared to the cases. The controls must come from the same population of farms from which the elephants selected the cases. They must represent the same period - the same months or the same growing season - as the cases. If you have *n* cases, then you need at least *n* controls. However, 4*n* controls will give optimum precision (Young 2005).

You will set up your hypotheses, and establish a data collection protocol, before selecting the cases and controls. Once they are selected, you will look back at each farm to collect the necessary data. You should undertake this study at the end of the crop-growing season, because then you will know which farms were damaged and which were not. You will probably look backwards to the beginning of the crop-growing season if you are dealing with subsistence crops. If you are looking at perennial crops, for example citrus or oil palm, you might look one year into the past, or maybe even two years. But the further back you go, the greater the risk of inaccurate information on the variables that interest you.

Note the difference between case-control and grouped cohort studies. In the grouped cohort study you identify farms by risk factor and follow them forward, into the future, to record whether or not they were damaged by elephants. Thus you look forward from risks to consequences (Young 2005). With the case-control you identify farms that have already been damaged, and you look backwards, into the past, to compare them with farms that were not damaged. In other words, you look back from consequences to potential causes (Young 2005).

This is a design that has been developed in medical research, particularly for the study of diseases that are infrequent, like cancer. It does not seem to be used much in ecology, but it has several advantages. For example, it is a cost-effective design in an ecosystem where only a handful of farms suffer from elephants. Imagine a study site with 1000 farms of which 20 are raided in 2007. If you applied a cohort design and followed a random sample of 100 farms, you would probably get only two afflicted farms in your sample. That would give little useful data. But if you adopted a case-control design you could take all 20 raided farms as your cases, and then select another 80 farms as your controls. Thus you would have 100 farms in your study but obtain more useful data than if you had planned a cohort study.

Note that you can also use this design where crop-raiding is common. It is particularly useful, whether crop-raiding is uncommon or frequent, for testing a hypothesis that has emerged from previous work.

A disadvantage of this design is its susceptibility to selection bias. You must be rigorous in randomly selecting your cases from the damaged farms in your area. Of course this bias will not be an issue if you take all the damaged farms as cases. Another disadvantage is that you cannot calculate the percentage of farms in your study area that are raided. Thus you cannot make year-to-year comparisons about the trend in crop-raiding.

Data to be collected

Table 1 lists the data that must be collected, whatever design you select. This is not an exhaustive list: you might suspect that some other variable, specific to your particular study site, attracts elephants.

If you hope to make comparisons between years for one study area, or to make comparisons between study areas, then monthly rainfall should be recorded. Rainfall influences crop growth and therefore the risk of elephant raids (Barnes *et al*. 2007).

A subsequent paper will describe methods for the analysis of these data. Do not forget to make backup copies of all field data sheets. If you type the data into a computer, then make a backup of the data files as well.

Discussion

Get to know the study area well before deciding upon the design. Walk through it, examine all the crops and talk to farmers. Decide upon definitions: what is a village and what is only a hamlet? What is a road, compared to a track or path?

When funds are limited there is the temptation to limit your studies only to those farms that have been damaged. But the farms that were not raided are as important as those that were raided. One must compare the farms that elephants selected against those that they did not find attractive. That will enable a proper evaluation of the risk factors. Furthermore, estimating the frequency of raided and undamaged farms will enable you to calculate the percentage of farms damaged. You can do this with both the cohort and the cross-sectional designs, but not with case-control studies. The percentage of farms that are damaged is an important indicator of the severity of the problem. If your management recommendations are effective, then surveys in the future will show that the percentage has declined.

With the case-control design you select farms that have been raided and those that have not. In other words, your dependent variable is binary: yes or no. The other two designs will also give you binary data: raided farms and intact farms. But amongst the raided farms there will be those that have been damaged once, twice, thrice or several times. Instead of evaluating factors that determine whether or not a farm will be raided, better use will be made of your hard-won data from cohort and cross-sectional designs if you relate the number of raids to the hypothesized risk factors. Again, the relative frequencies of farms that have been raided multiple times will enable future surveys to show whether your management policy is successful.

The type of design you select depends upon the resources available and the exact questions you are asking. When time is limited, then the choice of design is between cross-sectional and case-control studies. When both time and resources are limited, than choose the cross-sectional. If only a few farms are damaged, then the case-control is the only practical option. If your coffers are overflowing, then the cohort design is the one to use.

We must never forget that people are suffering while we fiddle with our calculators. We must adopt the most time-efficient strategy to minimise crop losses. If you have only one year for a study of crop-raiding, then here is an efficient strategy. During the growing season do a cross-sectional study, with a large sample, perhaps 50 farms. That will give an estimate of the percentage of farms suffering crop-raiding. Analysis of those data will generate hypotheses. At the end of the growing season, when you know which farms have been raided and which are intact, do a case-control study that looks back to the beginning of the growing season. That will enable you to test hypotheses from the cross-sectional study.

If you have two years for a crop-raiding project, then do a cross-sectional study in the first year. That will give you the information to decide upon the sample size for a cohort study that will start at the beginning of the second year.

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Review of Tuberculosis in Captive Elephants and Implications for Wild Populations

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Historical perspective

Tuberculosis (TB) is an ancient disease of animals and humans. Clinical signs, characteristic of TB were described in Asian elephants by Ayurvedic physicians over 2000 years ago (Iyer 1937; McGaughey 1961). TB has been reported in captive elephants worldwide (Narayanan 1925; Bopayya 1928; Seneviratna *et al.* 1966; Pinto *et al.* 1973; Chandrasekharan *et al.* 1995; Mikota *et al.* 2000, 2001; Ratanakorn 2001; Gavier-Wieden *et al.* 2002; Chakraborty 2003; Rahman 2003; and others).

Elephant TB surveillance began in the U.S. in 1997. Between 1996 and 2007 at least 40 elephants representing over 12% of the Asian elephants in the United States have been diagnosed with culture positive TB, primarily *Mycobacterium tuberculosis,* the human form. This figure is significant considering the low prevalence of human TB in the U.S. (< 4 persons / 100,000) compared to Asia (Table 1). Seven elephant TB cases have been reported in Europe (Lewerin *et al.* 2005; Moller *et al.* 2005, 2006).

Intermingling of captive elephants with wild elephants, domestic livestock, and humans is common in many Asian range countries. The potential for TB transmission exists when wild bulls breed captive cows, when grazing land is shared with livestock, or when captive elephants are exposed to infected humans (Mikota *et al.* 2006a, 2006b).

Table 1. Estimated prevalence of human TB in the USA and selected Asian elephant range countries for the year 2006 (WHO 2008).

Country	Prevalence/100,000
USA	5
India	299
Indonesia	253
Myanmar	169
Nepal	244
Sri Lanka	80
Thailand	197

TB is a global epidemic for humans and an estimated 1.7 million people died of TB in 2006 (WHO 2008). The World Health Organization (WHO) states that early diagnosis and treatment is the best way to control TB, thus reducing the impact on infected individuals and their ability to transmit the disease.

TB lessons from Africa and mastodons

African buffalo have been under surveillance for TB (caused by *M. bovis*) since 1990. In a 15-year period, TB spread to infect all but the most northern herds, spilled over to 10 other mammalian species and is now found in several adjacent game reserves. Mortalities due to advanced TB occur at an annual rate of 11% (Michel *et al.* 2006). A decrease in overall body condition has been correlated with increased TB prevalence (Caron *et al.* 2003). Due to the chronic nature of TB, the long-term impact on this species has yet to be determined.

M. tuberculosis has recently been introduced into free-ranging banded mongooses (*Mungos mungo*) in Botswana and suricates (*Suricata suricatta*) in South Africa, suggesting that free-ranging African elephants, as well as Asian, may also be at risk for infection with human TB (Alexander *et al.* 2002).

Pathognomonic tuberculous lesions were identified in 59 of 113 mastodon (*Mammut americanum)* skeletons (52%) implicating pandemic TB as one of several probable factors contributing to mastodon extinction (Rothschild *et al.* 2006).

Causative agent

TB is caused by a bacterium in the genus *Mycobacterium*. Mycobacteria infect a broad range of species (Montali *et al.* 2001). *Mycobacterium tuberculosis* (*M. tb*) is the predominant disease-causing agent in elephants in North America and Europe, although cases due to the bovine form (*M. bovis*) have occurred. *Mycobacterium avium* (bird form) and saprophytic non-tuberculous mycobacteria (NTM) are commonly isolated from elephant trunk wash samples (Payeur *et al.* 2002). Only *M. szulgai*, an unusual NTM has been associated with disease in elephants (Lacasse *et al.* 2007).

Both African and Asian elephants are susceptible to TB although the disease appears to be more common in Asian elephants. This may reflect the closer association between Asian elephants and humans rather than a species predisposition.

Transmission and pathogenesis

Transmission of TB occurs primarily via the respiratory route. Feces, urine, genital discharges, milk, and feed or water may contain contaminated droplets. In elephants, *M. tb* has been isolated from respiratory secretions, trunk washes, feces, and vaginal discharges.

TB exposure may result in various outcomes, listed in Table 2. Latent TB infection (LTB) is the absence of clinical disease and no evidence of active shedding of live organisms. In LTB, the bacteria are sequestered in lung granulomas that may reactivate at a later date. Individuals with LTB are a reservoir for future active cases. Although only 5-10% of latently infected humans with normal immune status will develop active TB during their lifetime (CDC 2007) the identification and treatment of those at high activation risk remains an effective means of control (Nuermberger *et al.* 2004). It is unknown whether LTB occurs in elephants.

Clinical signs

TB in elephants cannot be diagnosed only on the basis of clinical signs which may be absent until the disease is quite advanced. Seemingly healthy elephants may harbor and transmit TB to other elephants and humans. In 24 culture-confirmed TB cases (17 in the US and 7 in Europe) only three elephants showed signs before diagnosis (Konstantin Lyashchenko, pers. comm.). Clinical signs, when present, may include weight loss, weakness, coughing or difficulty breathing. Many other diseases may cause similar signs. Respiratory discharges from the trunk are occasionally noted. Exercise intolerance may be seen in working elephants. Elephants that show antemortem wasting may have disseminated disease on necropsy.

Guidelines for the control of TB in elephants

The guidelines for the control of tuberculosis in elephants, which specify criteria for diagnosis, surveillance, and treatment were instituted in the U.S. in 1997. The guidelines are revised as new information becomes available. The 2008 Guidelines will become official pending approval (in October 2008) by the board of directors of the United States Animal Health Association (USAHA) the current overseeing body. The 2008 draft guidelines are posted on the USAHA web site (www.usaha.org/committees/tb/DraftTBGuidelines.pdf).

Diagnosis

The diagnosis of TB in elephants has been problematic. Radiography is not feasible and

Table 2. Possible scenarios following exposure to TB.

Scenario	Outcome
1	All bacteria are killed and no disease results
2	Bacteria multiply and clinical disease results (primary TB)
3	Infection and eradication
4	Bacteria become dormant and never cause disease (LTB)
5	Dormant organisms reactivate and cause active disease (often associated with immune suppression or concurrent disease)

many techniques commonly used in humans (sputum examination and culture, intradermal tuberculin testing) are unreliable in elephants. The ElephantTB STAT-PAK® Assay (Chembio Diagnostic Systems Inc., Medford, NY; www.chembio.com), a serological test licensed in August 2007 in the U.S. opens the door to testing in range countries.

ElephantTB STAT-PAK® Assay and Multi-Antigen Print Immunoassay (MAPIA)™

The STAT-PAK® Assay is a qualitative, immunochromatographic screening test for the detection of antibodies to *M. tuberculosis* and *M. bovis* in serum, plasma, or whole blood (Lyashchenko *et al.* 2006). The Assay uses a unique cocktail of recombinant *M. tuberculosis* proteins bound to a membrane solid phase. Blue latex particles conjugated with protein are used as the detection system. A drop of test sample and three drops of diluent are applied to the test well and flow through the membrane strip. If antibodies are present, the test line will appear blue (Fig. 1).

The MAPIA™ is a confirmatory test (Lyashchenko *et al.* 2000, 2006). Elephant serum samples are incubated with a MAPIA strip and antigen-bound antibodies are visualized using a specific IgG-binding enzyme conjugate and corresponding substrate. The MAPIA is a laboratory test that is currently available only in the U.S through Chembio Diagnostic Systems.

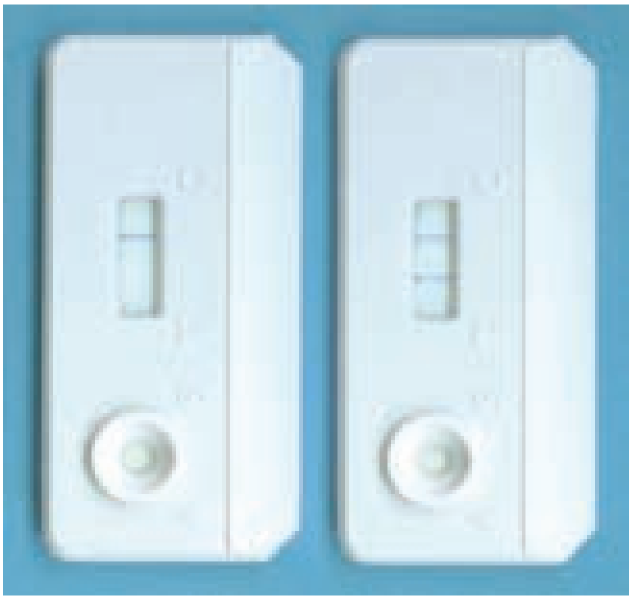

Figure 1. ElephantTB STAT-PAK® Assay. Left: non-reactive test; right: reactive test.

To date 99 Asian and 72 African elephants in Europe, Australia, South Africa, and the U.S. have been tested using the ElephantTB STAT-PAK® Assay and MAPIA including 23 elephants with culture-confirmed TB. Preliminary data has demonstrated 100% sensitivity and 97% specificity for STAT-PAK® Assay and 100% sensitivity and 100% specificity for the MAPIA using culture as the reference standard.

If the STAT-PAK® Assay is used as a screening test and the MAPIA™ is sequentially applied as a confirmatory assay, the accuracy of this testing algorithm is 100%. Seroconversion on the STAT-PAK® Assay and MAPIA™ has been noted in several elephants months to years prior to a positive culture (Lyashchenko *et al.* 2006).

An important advantage of serodiagnosis compared to trunk wash culture is that, once established, the antibody response remains sustained whereas culture may be intermittently positive or negative in infected elephants. A decline in specific antibodies to certain antigens in MAPIA has been observed suggesting a possible method to monitor response to therapy (Lyashchenko *et al.* 2006).

Although the STAT-PAK® Assay is new, retrospective studies (looking at banked serum from confirmed cases) have shown the test to be an accurate and early TB predictor, often preceding culture detection by months to years. This presents an opportunity to segregate infected elephants and initiate treatment before shedding and transmission to other elephants or people.

Commercial distribution of Chembio's ElephantTB STAT-PAK® Assay in the U.S. is currently restricted to the National Veterinary Services Laboratories (NVSL) and the test performed by NVSL personnel. The STAT-PAK was developed as a point-of care test, however, and is available internationally. Contact Chembio Diagnostic Systems, Inc. for further information (www.chembio.com).

Culture

Samples for culture are obtained using a trunk wash technique. Sterile saline is instilled and the trunk is elevated then lowered into a zippered plastic bag or other clean collection device. Ideally the elephant is trained to forcibly exhale so that the sample is from the lower respiratory tract. The sample is transferred to a secure screw-top tube and submitted to a certified TB laboratory. Three samples are collected on separate days. The Guidelines include a description of the procedure. A modified procedure using a tray has been developed in Asia for trunk-phobic elephants (Abraham & Davis 2008).

Although isolation of the organism is the "gold standard" to diagnose TB, culture has inherent limitations as a primary diagnostic technique: 1) Failure to isolate the organism does not rule out infection as characteristic intermittent shedding provides a potential for false-negative results. 2) Sample quality from the trunk wash method is variable and contamination is common. 3) Reporting time is slow, typically eight weeks. Infected elephants that are shedding while culture results are pending pose a risk to other elephants and humans. 4) Culture (requiring three samples per elephant) may not be practical or affordable to screen large numbers of elephants in Asia.

In Sweden, only six of 174 trunk wash samples were culture positive pre-mortem from five elephants confirmed TB positive (by culture) postmortem. All five elephants tested positive by the STAT-PAK® Assay (Moller *et al.* 2006).

Adequate laboratory support for culture may not be available in range countries. Techniques that have evolved in U.S. labs to address the issue of contamination may not be readily adopted in labs that have human TB diagnosis and control as their primary mission. These modified techniques developed by the National Veterinary Services Laboratories (Ames, Iowa, USA) are included in the guidelines.

Despite limitations, culture is an important diagnostic technique. Speciation (to differentiate *M. tuberculosis* and *M. bovis*) may be pertinent to management strategies. Drug sensitivity testing is important if treatment is planned.

Other tests

Intradermal tuberculin test: The intradermal tuberculin test correlates poorly with culture results and is not reliable in elephants (Mikota *et al.* 2001; Lewerin *et al.* 2005).

Acid-fast stain (AFS): A positive AFS is suggestive of TB but not definitive. AFS has low sensitivity (50% in humans) and is non-specific, particularly in geographic areas where NTM are commonly isolated (Dalovisio *et al.* 1996). AFS has not been widely used to detect TB in elephants.

Nucleic acid amplification techniques: The Gen-Probe Amplified Mycobacterium tuberculosis Direct Test (MTD; Gen-Probe, San Diego, California, 92121) detects RNA from live or dead TB organisms. In the U.S. the MTD is approved for the diagnosis of TB in humans but only in conjunction with culture. The MTD is quick (2.5 to 3.5 hours) and can detect low numbers of organisms. The MTD has been used in a limited number of elephant studies (Payeur *et al.* 2002).

Enzyme Linked Immunosorbent assay (ELISA): The ELISA measures antibodies against specific antigens. One ELISA study demonstrated an estimated sensitivity of 100% and specificity of 100%, on 47 elephants (7 culture positive) (Larsen *et al.* 2000). The ELISA is not available commercially.

Restriction fragment length polymorphism (RFLP): Commonly called DNA finger-printing, RFLP can identify different mycobacterial strains. Six *M. tb* strains were identified from six U.S. herds (Mikota *et al.* 2001) and five elephants and one giraffe were infected by four different *M. tb* strains in Europe (Lewerin *et al.* 2005).

Postmortem examination

Deceased elephants should undergo a complete postmortem examination. A number of guidelines are available for this purpose:

1) Techniques and Procedures for Post-mortem of Elephants (2003) Cheeran, J.V. and Nair, N.D. Project Elephant, Ministry of Environment & Forests, Government of India, New Delhi.

2) Elephant Necropsy Protocol of the American Zoo and Aquarium Association Elephant Species Survival Plan (www.elephantcare.org/protodoc_files/new%2006/ElephNecropsy2004_2005_final_version.pdf)

3) A guide to post-mortem procedure and a review of pathological processes identified in the elephant by D.F. Keet & R.G. Bengis (www.elephantcare.org/protodoc_files/afrnecro.pdf)

Pathologic changes in TB infected elephants are found primarily in the lungs and thoracic lymph nodes, although extrapulmonary or disseminated TB may involve the liver, kidney, spleen, adrenals, or genitourinary tract. Pulmonary lesions may be focal or widespread, depending on the disease stage. In advanced cases, extensive caseocalcareous and cavitating lesions may be seen throughout the lungs often associated with large pulmonary abscesses colonized by secondary bacteria (Mikota *et al.* 2000). Enlargement of bronchial and thoracic lymph nodes is common.

Respiratory protective equipment should be available during all elephant necropsy procedures. To protect against TB, properly fitted, disposable, particulate filter respirators that are rated to protect against TB or positive air pressure respirators (PAPRs) should be used. Ordinary surgical masks do not protect against TB. PAPRs are expensive cumbersome to wear and may not be practical during the monsoon in Asia.

Approaching the thorax through the diaphragm will minimize exposure to TB (Montali 2006).

Treatment

Elephant treatment guidelines in the U.S. have evolved from protocols known to cure TB in humans. Pharmacokinetic studies have been conducted in elephants for isoniazid (Maslow *et al.* 2005), ethambutol (Maslow *et al.* 2005), pyrazinamide (Zhu 2005), and rifampin (Maslow *et al.* 2005). The duration of treatment is 12 months. Three drugs are administered for two months followed by two drugs for 10 months using a combination of isoniazid (INH), pyrazinamide (PZA), rifampin (RIF), and ethambutol (ETH). Streptomycin has not been used in the U.S. Pyrazinamide is not effective against *M. bovis.*

Veterinarians seeking to treat elephants for TB should consult current Guidelines (www.usaha.org/committees/tb/DraftTBGuidelines.pdf) and experienced colleagues.

In the case of multi-drug resistant TB (MDR-TB), defined as resistance to both INH and RIF, second-line drugs such as amikacin, ciprofloxacin, levofloxacin and others may be needed. The increased risks to staff must be considered before initiating treatment for MDR-TB.

TB drugs may be given by direct oral or rectal administration. Adequate drug levels cannot be achieved if drugs are mixed with food offered free-choice. Some drugs are bitter and elephants will refuse them. Elephants can be trained to accept a bite block and medications delivered via a large animal dose syringe. Most elephants can also be readily trained to accept rectal administration; adequate blood levels can be achieved for INH and PZA (but not RIF) by this route. Treatment is challenging and elephants, like humans, may experience side effects (Dumonceaux & Mikota 2006). Therapeutic drug monitoring (Peloquin 2002) is recommended for elephants receiving anti-TB drugs but may not be available in all countries.

TB drugs are expensive and the cost to treat one elephant for a year in the U.S. may exceed US$ 50,000. The availability of cost effective drugs in Asia will make it possible to treat an elephant for under US$ 2000.

Zoonotic considerations and personnel health and safety

Several reports discuss the zoonotic aspects of elephant TB (Maslow 1997; Ryan 1997; Michalak *et al.* 1998; Davis 2001; Montali *et al.* 2001; Oh *et al.* 2002). Because *M. tb* is primarily a human pathogen, exposure to infected humans is the most likely source of infection for elephants and other humans.

Infected elephants pose the greatest risk to mahouts who live in close daily association. The extent of risk to humans (or elephants) in other situations such as religious events or large festivals has not been studied. According to the U.S. Center for Disease Control (CDC 2008): "To become infected, a person usually has to spend a relatively long time in a closed environment where the air was contaminated by a person with untreated tuberculosis who was coughing and who had numerous *M. tuberculosis* organisms (or tubercle bacilli) in secretions…" Note however, that the World Health Organization (WHO 2007) says: "…When infectious people cough, sneeze, talk or spit, they propel TB germs, known as bacilli, into the air. A person needs only to inhale a small number of these to be infected…."

After the diagnosis of TB in one U.S. herd, 11 of 22 handlers had positive intradermal test results and one handler had active TB with the same RFLP pattern as the infected elephant (Michalak *et al.* 1998). This is the only published case of active human TB associated with elephant contact to date.

Annual TB testing is advisable for personnel working with elephants. Consultation with local health authorities is advisable and facilities should develop protocols to protect staff.

Management of TB in elephants in range countries

The varying elephant keeping systems and differing cultural attitudes pose challenges for elephant TB control in Asia. Consideration must be given to national and international laws, local resources, and tourism. Managing TB in government versus privately owned elephants may require different strategies.

Permanent segregation, treatment, and euthanasia are the three basic methods to control TB. Permanent segregation may be the best options for old elephants in which infections may be long-standing and cure unlikely. Treatment is difficult and better methods to confirm cure are needed. The MAPIA™ changes in response to treatment but this test is only available in the U.S. A negative culture series is supportive but limited by the factors mentioned above. Euthanasia may not be acceptable or legal in some areas or it may be mandated in others as was done by the government in Sweden.

Preliminary algorithms for managing various scenarios and for addressing human health concerns are presented in Figures 2-5. Figure 2 is a simplistic flow chart of possible options for culture positive elephants. Segregation is a logical first step. A permanent quarantine facility with protective barriers to prevent the intermingling of wild elephants may be possible in some areas. Detailed protocols for the protection of human health are essential. Euthanasia is undesirable but perhaps should be considered in cases of MDR-TB given the difficulty of treatment and increased risk to humans.

Figure 3 depicts the more challenging management of culture-negative / serologically positive elephants. Prophylactic treatment is an option - again depending on the number of cases and available funds. Age and exposure history are considerations. Monitoring for active disease is also another option. Protocols will need to be established to determine the frequency of culture and continued research on other ways to detect shedding is encouraged. The current lack of a fast and accurate method to determine shedding is a major drawback.

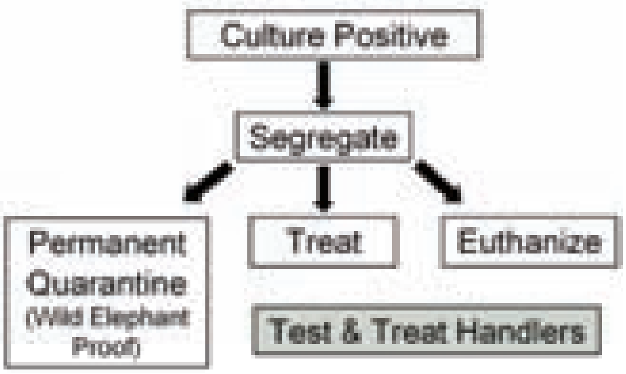

Figure 2. Options for culture positive elephants.

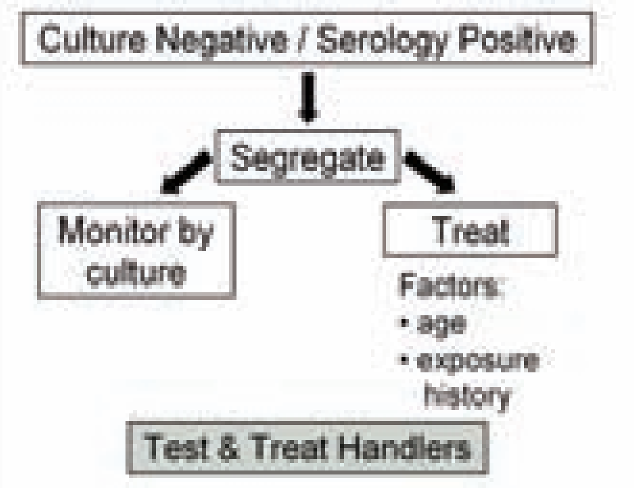

Figure 3. Options for culture negative / serology positive elephants.

Elephants that are serologically and culture negative but have had known exposure should be placed on an enhanced surveillance schedule because we do not yet know the time interval from infection to serological conversion (Fig. 4).

Figure 5 describes a protocol to address the TB health status of mahouts and other staff. This is a critical component of the overall strategy. Collaboration with public health agencies that already have TB screening programs will be helpful. All mahouts should be tested to initiate the program. Elephants cared for by infected mahouts should undergo increased monitoring.

Treatment considerations

It is unknown whether elephants develop latent TB. Of the 2 billion humans estimated to be infected with TB worldwide, 4-10% will develop active

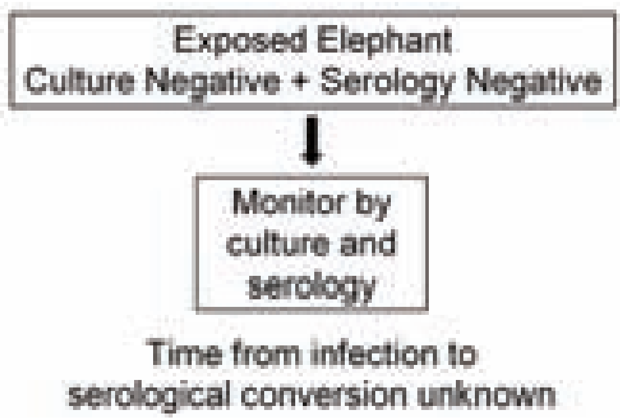

Figure 4. Options for exposed elephants that are culture and serology negative.

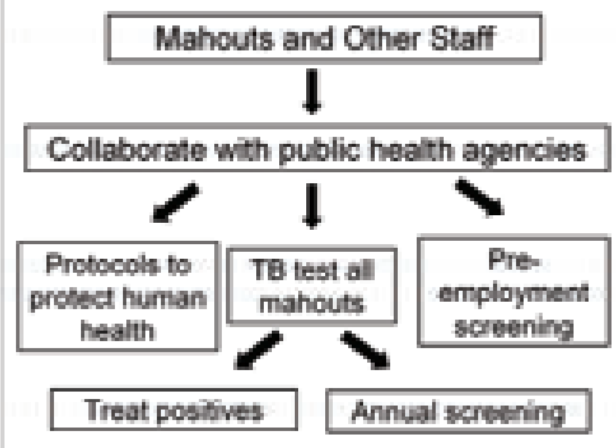

Figure 5. Care and treatment of staff.

disease (defined as TB infection with actively reproducing organisms); the other 90-96% will remain latent (the TB organisms are walled-off and sequestered in the body). However, latent TB can become active at any time, particularly if there is stress from other diseases or old age.

There are two approaches to consider to control TB in elephants:

1) Approach the problem aggressively and treat all serologically positive elephants even if they are culture negative.

Advantages:

- infected elephants may be treated before there is shedding and transmissibility to other elephants
- aggressively controlling TB among captive elephants may avert the introduction of TB into wild populations

Disadvantages:

- if elephants do develop latent disease, some elephants may be treated unnecessarily
- the lack of culture data precludes basing treatment on drug sensitivity testing and multi-drug resistant strains may be overlooked. There are, however, only a limited number of drugs to choose from, careful monitoring of treatment could help prevent creating resistance, and treatment of MDR TB (if present) may not be feasible anyway (cost prohibitive)
- the drugs are strong and some elephants will get sick during treatment (though no elephants have died during treatment)
- a positive culture is necessary for epidemiology studies (*M. tb* vs. *M. bovis*)

2) Wait until elephants are culture positive before initiating treatment.
Advantages:
- only elephants confirmed to be infected will be treated
- drug sensitivity information will be available

Disadvantages:
- infected elephants may transmit TB or succumb to infection prior to detection by culture
- the disease may become further advanced before detection, perhaps compromising the chances of successful treatment
- adequate laboratory support for culture may not be available
- infected elephants that go undiagnosed may develop exercise intolerance or other signs and be unable to work
- wild populations may be at increased risk if controlling TB among captive elephants is delayed

The majority of elephants that have died with TB in the U.S. have had advanced disease and were a source of infection for other elephants and humans. Despite 10 years of surveillance by culture, new cases are still being found. Perhaps if the STAT-PAK® Assay had been available earlier and had formed the basis of prompt treatment, we would have broken the cycle of infectious TB before now.

Deciding to treat serologically positive elephants might be a bold but necessary move if we are to control TB in elephants. In the early 1980's TB was thought to be under control in the U.S. and surveillance programs weakened. This led to a resurgence of TB between 1985 and 1992. Today we face forms of TB that cannot be treated because of inadequate global control programs.

TB and wild elephants

What are the risks that TB will infect wild populations or that it may already be there? Could TB become as devastating a problem for elephants as it is for humans? The risks are greater in regions where captive and wild elephants intermingle during grazing or breeding - India, Nepal and Myanmar for example. Communal grazing areas shared by elephants and domestic cattle pose an additional risk. Further studies of both captive and wild elephants are needed.

Management strategies are currently under development in Nepal that may serve as a model for other countries. A range country meeting (sponsored by WWF-Nepal and Elephant Care International) is tentatively planned for 2009 to share information and develop regional strategies.

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For a comprehensive list of references on elephant TB see: www.elephantcare.org/TBrefs.htm

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Herd near Kaudulla National Park, Sri Lanka (May 2008)
Photo by Jennifer Pastorini

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A Study on the Seed Dispersal Capability of Asian Elephants in the Northwestern Region of Sri Lanka

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Introduction

Herbivores are shown to be involved in seed dispersal of many plant species. Thus they will have an impact on habitat quality and maintenance. Elephants are megaherbivores that consume a large amount of plant matter including fruiting bodies. Further, they have large home ranges and therefore can disperse seeds over long distances. Many studies have demonstrated that African elephants play a major role in dispersal of seeds of a number of plant species (Short 1981; Keon 1983; Lieberman *et al*. 1987; Dudley 1999; Cochrane 2003). Further, Cochrane (2003) has demonstrated that seed dispersal of *Balanites wilsoniana* is dependent on African elephants. In contrast to African elephants very few studies have been done on the seed dispersal capability of Asian elephants (Vinod & Cheeran 2000; Kitamura *et al.* 2007).

In Sri Lanka, even though there are several studies on the feeding behavior of Asian elephants (Mueller-Dombois 1972; McKay 1973; Vancuylenberg 1977; Ishwaran 1983), studies on seed dispersal by elephants are lacking, except for one study on the effect of changes in gut passage time due to seasonal differences in diet and its impact on seed dispersal distance (Campos-Arceiz *et al.* 2007). The aim of this investigation was to identify the seeds that are dispersed by Asian elephants and to determine the germination potential of these seeds under different conditions to determine the role of Asian elephants on dispersal of seeds of the dominant plant species identified in the area.

Materials and methods

Study area

The study area is located in the northwestern region of Sri Lanka encompassing the Mahaweli system H and adjoining areas. The study area is demarcated by the towns of Puttalam in the East, Mahawa in the South, Habarana in the West, and Anuradhapura in the North. The extent of the study area is approximately 3000 km^2 and includes 15 administrative divisions.

Identification of plant seeds in elephant dung

A total of 145 dung piles from different parts of the study area were examined. From each dung pile examined, two boli were placed in a tray and separated by hand. All the intact seeds or seed fragments present were removed and placed in a sample vial. These seeds were identified subsequently by comparing it with the reference collection of plant seeds constructed from both cultivated and non-cultivated plant species found in the area.

Determination of germination potential in situ

If seeds were found during macroscopic analysis of two boli from a dung pile, some of the remaining dung boli were left in the same location, marked and observed until the boli decayed completely. In order to determine the effect of shade, dung piles were selected from shaded habitats as well as open habitats and the experiment was carried out both during the dry season and wet season. Therefore, in situ germination potential was investigated under four conditions, namely wet open (n=50), wet shade (n=80), dry open (n=52) and dry shade (n=75).

Determination of germination potential ex situ

If seeds were found during macroscopic analysis of the two boli from a dung pile, a dung bolus was removed and placed in a green house. First, the affect of disintegration on germination of seeds was tested with 10 replicates for each treatment. Second, all six conditions were tested under green house conditions, namely shade vs. open, broken vs. intact boli, with watering vs. without watering, resulting in eight experimental combinations. Five replicates were assigned to each combination. In both the experiments dung boli were assigned randomly to each experimental condition.

Determination of germination potential of seeds removed from dung

Elephant dung contains large amounts of undigested material, which may interfere with the germination of the seeds. Therefore to determine the germination potential of seeds in the absence of dung, seeds removed from elephant dung were placed in plastic cups containing soil that had been exposed to steam for 30 min. Then the plastic cup was placed in a green house and watered daily for 14 days. Seeds of 10 plant species (*Tamarindus indica, Drypetes gardneri, Bauhinia racemosa*, *Panicum maximum, Clitoria ternatea*, *Elusine coracana*, *Cucurbita maxima, Oryza sativa, Cucumis melo* and *Capsicum annum*) were selected for this study based on the density of seeds present in elephant dung, habit of the plant and occurrence (cultivated vs. natural). A total of 10 seeds were tested from each plant species selected.

Relative abundance of indigenous plants

In order to determine whether elephants play a major role in dispersal of dominant plant species found in the natural habitats of the study area, the relative abundance of plant species present in the area was determined. A total of 111 transects, each 1 km x 5 m, were carried out in different regions of the study area. The relative abundance of a given plant species was determined based on the number of transects in which the plant was recorded relative to the total number of transects carried out.

Results

Out of the 145 dung piles examined 107 (74%) contained seeds of one or more plant species. A total of 188 seed groups were recovered from these 107 dung piles. Majority of the seeds

Table 1. List of non-cultivated plant species whose seeds were observed in elephant dung (n=145).

Family	Scientific name	Vernacular name	Habit*	RA**	# dung piles
Euphorbiaceae	*Drypetes gardneri*	Eta wira	T	0	6
Fabaceae	*Aeschynomene indica*	Diya siyambala	H	17	1
	Alysicarpus vaginalis	Aswenna	H	0	1
	Atylosia scarabaeoides	Wal kollu	C	0	3
	Bauhinia racemosa	Maila	T	81	3
	Cassia tora	Peti tora	S	66	6
	Clitoria ternatea	Katarodu	C	23	1
	Indigofera tinctoria	Nil awari	H	0	5
	Mimosa pudica	Nidikumba	H	78	6
	Tamarindus indica	Siyambala	T	41	22
Hernandiaceae	*Hernandia nymphaeifolia*	Palatu	T	0	1
Myrtaceae	*Syzygium gardneri*	Damba	T	0	1
Nymphaeaceae	*Nymphaea nouchali*	Manel	H	3	1
	Nymphaea pubescens	Olu	H	35	9
Passifloraceae	*Passiflora fitida*	Dal batu	C	49	2
Poaceae	*Cymbopogon nardus*	Heen pengiri	H	13	1
	Eleusine indica	Bela-tana	H	0	5
	Panicum curviflorum	Meneri-thana	H	0	1
	Panicum maximum	Guinea tana	H	51	12
	Pennisetum spicatum	Bajiri	H	0	8

* T = tree, H = herb, C = climber, S = shrub
** RA = relative abundance of each species calculated based on % occurrence in 111 transects

Table 2. List of cultivated plant species whose seeds were observed in elephant dung (n=145).

Family	Scientific name	Vernacular name	Habit*	# dung piles
Anacardiaceae	*Mangifera indica*	Amba	T	2
Cucurbitaceae	*Benincasa hispida*	Alu puhul	C	2
	Cucumis melo	Kekiri	C	11
	Cucurbita maxima	Wattaka	C	3
	Lagenaria siceraria	Diya labu	C	1
Fabaceae	*Arachis hypogaea*	Rata kadju	H	1
	Vigna unguiculata	Cowpea	C	2
	Vigna marina	Me karal	C	1
Poaceae	*Eleusine coracana*	Kurahan	H	16
	Oryza sativa	Wee	H	16
	Panicum miliaceum	Meneri	H	1
	Zea mays	Bada iringu	H	4
Solanaceae	*Capsicum annum*	Miris	H	10
	Solanum melongena	Ela batu	H	1

* T = tree, C = climber, H = herb

tend to pass through the gut undamaged except for large seeds which showed signs of damage. Out of these, 22 seed groups (12%) could not be identified. Of the remaining 166 seed groups 95 (50%) belonged to non cultivated plant species (Table 1) while the remaining 71 (38%) belonged to cultivated varieties (Table 2). The 22 unidentified seed groups were represented by 10 species of plants. The 95 seed groups of non cultivated plants were represented by 20 species of plants while the 71 seed groups from cultivated plants were represented by 14 species.

Majority of the seeds (55%) of non cultivated plants were from herbaceous plant species followed by trees (25%), climbers (15%), and shrubs (5%). In the case of cultivated plant species once again the majority of the seeds belonged to herbaceous plants (50%) followed by climbers (42%) and trees (8%). Seeds belonging to only three dominant plant species (*Bauhinia racemosa*, *Cassia tora* and *Panicum maximum*) of the open scrub/ grass mosaic occupied by these elephants were found in their dung.

In situ germination trial no seed germination was observed in the 127 dung boli tested during the dry season. However, during the wet season seed germination was observed in 23% of the dung boli tested (Table 3). Further, germination was found to be higher (40%) in dung boli left in the open area (Fig. 1) compared to the dung boli left in the shade (13%).

The impact of disintegration of the dung bolus on seed germination potential was tested under green house conditions which indicated that germination potential increases (Table 4) when the dung bolus is broken (70%) compared to intact dung boli (20%).

When all three conditions were tested under green house conditions seed germination was observed in watered dung piles irrespective of whether the dung was kept in shade or open areas. No major difference was observed between broken and intact boli when water is present. However, in the trials without water overall germination rate was only 5% compared to 35% overall germination rate observed in the with water trials.

Out of the 10 plant species tested for the germination potential of seeds removed from the elephant dung, seeds belonging to seven plant species showed germination. Highest germination ability was shown by *Cucurbita maxima* (70%) followed by *Oryza sativa* (60%),

Table 3. Comparison of the in situ germination potential of seeds in intact dung boli kept in open and shaded areas during wet and dry season.

Treatment		n	# dung boli
dry season	shade	75	no germination
	open	52	no germination
wet season	shade	80	10
	open	50	20

Clitoria ternatea (30%) and *Eleusine coracana* (30%), *Cucumis melo* (20%), *Capsicum annum* (20%), *Panicum maximum* (10%), *Bauhinia racemosa* (10%). Seeds of *Drypetes gardneri* and *Tamarindus indica* did not germinate at all.

The major habitat type seen in the study area can be defined as open scrub which is evident in the composition of the dominant plant species observed in the area (Table 5). The plant assemblage was dominated by shrub species (44%) followed by trees (28%) which forms an open canopy and herbaceous plants (20%) makes up the lower layer. Few species of climbers (10%) were observed associated with the tall trees.

Discussion

Approximately 75% of the dung piles examined in this study contained seeds belonging to one or more plant species. Altogether seeds belonging to 44 species of plants were discovered in elephant dung. Out of these, 14 species can be classified as cultivated plants. This may have resulted due to raiding of crops or stored grain. However, our observations indicate that elephants do graze in fallow chenas (slash-and-burn agriculture fields) where a substantial number of plants with fruiting bodies remain even after the farmer has abandoned the chena. Therefore, presence of seeds of cultivated plant varieties cannot be ascribed to crop raiding alone.

Majority, of the seeds that belonged to non-cultivated plant species were of herbaceous plants. Seeds belonging to only four tree species were found in elephant dung during this study. Of these four species, seeds of *Tamarindus indica* made up nearly 25% of all the identifiable seeds of non-cultivated species. However, subsequent germination studies indicate that these seeds do not germinate readily even after removal from the dung. Perhaps, the period of observation (14 days) may have not been long enough for germination to take place as some plant seeds take a longer period for germination.

Seeds belonging to only three dominant plant species (*Bauhinia racemosa*, *Cassia tora* and *Panicum maximum*) of the open scrub/ grass mosaic occupied by these elephants were found in their dung. The other plant species whose seeds were present in elephant dung were relatively rare. Therefore, it can be concluded that elephants do not play a major role in seed dispersal of the dominant plant species in the scrub/grass mosaic habitat occupied by them. Further, germination study also supports this hypothesis as the seeds that readily germinate in elephant dung were non-recalcitrant seeds that belonged mostly to herbaceous species. However, the habitat occupied by the elephants in this study is a scrub/grass mosaic, which can be defined as an early seral stage resulting due to high human activity. Therefore, care should be taken when extrapolating these results to elephants inhabiting climax vegetation. A similar study focusing on elephants inhabiting natural

Table 4. A comparison of the germination potential of seeds in dung boli tested under various conditions in a green house.

Treatment			n	# boli	# plants
Broken			10	7	10
Intact			10	2	4
Shade	water	broken	5	2	4
		intact	5	2	3
	no water	broken	5	1	1
		intact	5		
Sun	water	broken	5	1	1
		intact	5	2	5
	no water	broken	5		
		intact	5		

Figure 1. Germination of *Cucurbita maxima* seed in a disintegrated elephant dung pile deposited in an open area during the rainy season.

Table 5. Dominant plant species (recorded in 50% or more of the 111 transects) in the study area.

Classification	Scientific name	Common name	Habit*	Total	%
Fabaceae	*Cassia fistula*	Ehela	T	55	50
Poaceae	*Panicum maximum*	Rata tana	S	57	51
Asteraceae	*Vernonia zeylanica*		H	58	52
Asteraceae	*Xanthium indicum*	Urukossa	S	58	52
Typhaceae	*Typha angustifolia*	Hambupan	S	59	53
Sapindaceae	*Lepisanthes tetraphylla*	Dambu	T	60	54
Amaranthaceae	*Achyranthes aspera*	Gas karal heba	H	61	55
Amaranthaceae	*Aerva lanata*	Polpala	H	61	55
Ulmaceae	*Holoptelea intergrifolia*	Godakirilla	T	64	58
Asteraceae	*Vernonia cinerea*		H	65	59
Fabaceae	*Pongamia pinnata*	Karanda	T	65	59
Sapindaceae	*Schleichera oleosa*	Koon	T	65	59
Convolvulaceae	*Ipomoea obscura*	Tel kola	C	67	60
Fabaceae	*Derris scandens*	Kala wel	C	69	62
Malvaceae	*Hibiscus vitifolius*	Maha epala	S	70	63
Malvaceae	*Sida acuta*	Gas bavila	S	71	64
Rubiaceae	*Mitragyna tubulosa*	Helamba	T	71	64
Fabaceae	*Cassia occidentalis*	Peni thora	S	72	65
Fabaceae	*Cassia tora*	Pethi thora	S	73	66
Fabaceae	*Dichrostachys cinerea*	Andara	S	74	67
Verbenaceae	*Lantana camara*	Gandapana	S	74	67
Asclepiadaceae	*Calotropis gigantea*	Wara	S	75	68
Moraceae	*Streblus asper*		T	75	68
Combretaceae	*Terminalia arjuna*	Kumbuk	T	76	68
Myrtaceae	*Syzygium cumini*	Madan	T	76	68
Fabaceae	*Tephrosia purpurea*	Pila	H	78	70
Malvaceae	*Abutilon indicum*		S	81	73
Asteraceae	*Mikania cordata*	Wathu palu	C	86	77
Euphorbiaceae	*Croton laccifer*	Keppetiya	S	86	77
Euphorbiaceae	*Phyllanthus reticulatus*	Kaila	S	86	77
Fabaceae	*Mimosa pudica*	Nidi kumba	H	87	78
Rhamnaceae	*Ziziphus oenoplia*	Heen-eraminiya	S	87	78
Tiliaceae	*Grewia orientalis*	Keliya	S	87	78
Cyperaceae	*Cyperus spp.*	Pan	H	88	79
Cyperaceae	*Fimbristylis spp.*	Pan	H	90	81
Fabaceae	*Bauhinia racemosa*	Maila	T	90	81
Meliaceae	*Azadirachta indica*	Kohomba	T	98	88
Asteraceae	*Eupatorium odoratum*	Podi-singho maran	S	100	90
Euphorbiaceae	*Flueggea leucopyrus*	Katupila	S	101	91

* T = tree, H = herb, C = climber, S = shrub

vegetation is needed before a final conclusion can be arrived at, regarding the role of Asian elephants as a seed dispersal agent.

Most of the seeds present in the dung are capable of germination. Yet only few seeds germinated under natural conditions. Presence of water is the main factor that determines the seed germination in elephant dung. Seeds present in the dung deposited during the rainy season germinated readily while no seed germination was observed in the dung piles deposited during the dry season. However, seeds present in the dung deposited in the dry season may remain dormant till the next rainy season before they begin to germinate. This hypothesis could not be tested during this study as all the dung piles deposited during the dry season decayed completely before the onset of the rainy season. Further, dung piles left in open areas showed a high germination rate compared to dung piles left in the shade. A similar situation is reported by Cochrane (2003) for *Balanites wilsoniana*.

Disintegration of dung piles also resulted in a higher rate of germination compared to intact dung boli. Disintegration of dung piles in nature is determined by number of factors such as rain and animal assemblage in the area as some animals such as jungle fowl, and mongooses tend to break up the dung piles in search of food. Some of these animals in turn may feed on the seeds present in elephant dung and act as secondary dispersal agents. During the rainy season dung piles tend to disintegrate rapidly which could have also contributed to the increased rate of germination observed during the rainy season.

Conclusion

Fruiting bodies appear to be a major component of elephants diet as approximately 75% of the dung piles observed during this study contained seeds belonging to one or more species. Most of the seeds present in the dung are capable of germination. Yet only few seeds germinated under natural conditions. Germination of seeds in the elephant dung is governed by a number of factors such as availability of water, amount of shade and presence or absence of agents that can disintegrate elephant dung. Based on the composition of plant species whose seeds were found in elephant dung and germination rate of these seeds it can be concluded that elephants do not play a major role in dispersal of seeds of the dominant plant species of the scrub/ grass mosaic occupied by them.

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A Geo-Spatial Assessment of Habitat Loss of Asian Elephants in Golaghat District of Assam

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Introduction

The state of Assam is regarded as one of the strongholds of Asian elephant conservation (Stracey 1963; Santiapillai & Jackson 1990; Choudhury 1999; Bist 2002), with about 5,200 elephants as assessed in 2005 by the Assam Forest Department. In comparison, the total Indian elephant population numbers about 26,400. The forest areas of Golaghat and Karbi Anglong districts are one of the richest forest covers with outstanding biodiversity values. The forest areas of Golaghat and adjoining areas of the Karbi Anglong districts are represented by the Nambor-Doigrung Wildlife Sanctuary (120 km^2), Garampani Wildlife Sanctuary (6 km^2) and Nambor Wildlife Sanctuary (37 km^2). These sanctuaries are also part of the Kaziranga-Karbi Anglong Elephant Reserve, declared on 17 April 2003, with an estimated area of 3,270 km^2.

The forest areas of Golaghat district play a major role in the conservation of elephants in the Kaziranga-Karbi Anglong Landscape. Massive shrinkage and fragmentation of natural habitat due to illegal human settlement, and opening up for tea industry are major anthropogenic disturbances that have contributed enormously towards the total destruction of elephant habitats in Golaghat district. Moreover, the killing of wild elephants for ivory and meat has led to a decline in elephant populations in these areas since 1980 (Lahiri Choudhury 1980). Growing animosity between humans and elephants has increased tremendously resulting in massive human-elephant conflict that has shattered the age-old co-existence of humans and elephants (Talukdar *et al.* 2006).

In view of the increased human-elephant conflict, we undertook a study on the loss of forest cover since 1974, in the Golaghat district in Assam, excluding the Kaziranga National Park (430 km^2). The study was based on satellite images of the areas in 1974, 1991 and 2004, and intense ground assessment of the current forest cover, to find out the relationship between habitat loss of elephants and subsequent increases in human-elephant conflict in Golaghat district. We used remote sensing and GIS technologies for analyzing and estimating loss of Asian elephant habitat due to deforestation and encroachment in the moist deciduous and semi-evergreen forests.

Methods

Study area

We selected eight Reserve Forests of Golaghat district of Assam (Fig. 1, Table 1). The study area is about 942 km^2 of the 3,588 km^2 total area of Golaghat district. We excluded the area of Kaziranga National Park (380 km^2) and the Panbari RF (12 km^2) area because these areas are properly protected and there is no massive forest degradation noticed in these areas in the recent past. The latitudinal and longitudinal extension of our study area is from 25°45' to 26°30'N latitude and 93°45' to 94°05'E longitude. The average annual rainfall is between 2,000-2,300 mm, and average temperature in the winter season is 8°C which rises to 37°C in summer. Relative humidity varies from 60% in March to 95% in July. These

Table 1. Reserve forests (RF) of the study area.

#	Name	Area [km^2]
1	Doyang RF	252.93
2	Nambor South RF	236.86
3	Diphu RF	165.25
4	Rengma	150.90
5	Nambor North RF	93.15
6	Disma RF	20.15
7	Lower Doiugurung RF	13.54
8	Upper Doigurung RF	9.30

Figure 1. Location map of the study area in Gree.

reserve forests were once ideal habitat for Asian elephants (Choudhury 1999).

Data set used

For this study the primary data used were serial satellite images, Survey of India (SOI) topography maps, ground control points (GCPs) and other spatial data that includes forest boundary maps available with state forest department and also sketch maps of forest areas available with the State Revenue Department. The satellite images used in this study are Landsat MSS imagery of 1974, Landsat TM imagery of 1991 and IRS 1D LISS III imagery of 2004 (Table 2). The Survey of India topography maps no. 83F/6, 83F/10, 83F/13, 83F/14, 83F/15, 83F/16, 83G/13, 83J/2, 83J/3 and 83J/4 (1:50,000) and 83F, 83J, and 83F (1:250,000) were used for geo-referencing of satellite images. In addition, a base map and the vector layers i.e. district boundary, forest boundary and drainage available within the study area were prepared.

Methodology

Landsat MSS, Landsat Thematic Mapper and IRS 1D LISS-III digital data pertaining to 1974, 1991 and 2004 were used to assess the forest cover changes within the eight Reserve Forests of Golaghat district of Assam. Survey of India (SOI) topographical maps at 1:50,000 and 1:250,000 scale and Forest Survey of India (FSI) reports for Assam were also consulted and used as collateral data. Ground truthing was done from October 2005 to September 2006. Landsat MSS, Landsat-TM scene and IRS 1D LISS-III were radiometrically corrected using the dark pixel subtraction technique (Kushwaha & Hazarika 2004). They were then geo-referenced with Survey of India topographical maps using the Polyconic projection system. The Polyconic

Table 2. Satellite data used for the study.

Data type	Path/row	Date
Landsat MSS	144,145-42	26.1.1974
Landsat TM	134,135-43	28.1.1991
IRS 1D LISS III	112,113-53	22.12.2004

projection system was used because the Survey of India topographical maps were based on that projection. As the Golaghat district does not come under a single scene of the satellite images, we constructed a mosaic using the relevant satellite scenes. We took well-identified ground control points (GCP) with the help of a Garmin 72 GPS receiver to rectify the satellite images. Sub-pixel image to map registration accuracy was achieved through repeated attempts. The district image was extracted by superimposing the vector layer of the district boundary of Golaghat district. Similarly the forest area of Golaghat district since 1974 was extracted by superimposing the forest boundary vectorised from Survey of India (SOI) topographical sheets. The three period images were then visually interpreted on-screen using supervised classification, using green, red and near infrared band combination. Training sites were made by demarcating a polygon for the known cover types that were later applied to the entire image. A classification scheme was developed using maximum likelihood algorithm and the overall number of classes in each case was kept constant. The visually interpreted images were superimposed to detect changes from one period to the other. All operations were carried out using ERDAS IMAGINE 9.0 version software.

Results and discussion

Assessment of habitat loss

The Golaghat district of Assam was once famous for its thick forest cover and also as a prime habitat of the endangered Asian elephant (Choudhury 1999). The oldest reserve forest of Assam exists in the Golaghat district. In 1872, the Nambor Reserve Forest was declared with an area of 875.5 km^2. In 1965, for better management, a part of Nambor Reserve Forest was declared as Nambor South Reserve Forest with an area of 199.57 km^2. In 2003, the Upper and Lower Doigrung Reserve Forests along with an additional area of 120 km^2 were included to form the Nambor-Doigrung Wildlife Sanctuary. A large portion of forest cover of Golaghat district has been encroached and deforested. The forest cover change in Golaghat district is summarized in Table 3.

The Nambor-Doigurung Wildlife Sanctuary faces large-scale encroachments, which have occurred from 1980 onwards. As a result, the total forest cover area of Nambor-Doigurung Wildlife Sanctuary has been reduced from 120 km^2 to 54.08 km^2 (55%). The balance 66 km^2 area has been encroached by human populations. Figure 2 shows the encroachment of forest cover in Nambor-Doigurung Wildlife Sanctuary. The same scenario is seen in Diphu RF, Rengma RF, Doyang RF, and Nambor South RF of Golaghat district. These areas were once some of the best elephant habitats in South Asia (Choudhury 1999). Reserve forests like Doyang, Rengma, Diphu, and Nambor South, have been totally encroached during 1974-2004 and currently only 3.38% of forest cover exists in Doyang RF, 4.86% in Rengma RF, 1.97% in Diphu RF and 0.07% in Nambor South RF. One can see these areas are now full of villages, small tea gardens, agricultural practices, shops, etc.

Out of 1,037.94 km^2 of Reserve Forest in Golaghat forest division, only 167.94 km^2 (16.18%) now remains undisturbed. Figure 3 shows the current status of forest cover in the Golaghat District.

Table 3. Forest cover change in the study area.

Forest	Forest cover [km^2]			Change [%]	
	1974	1991	2004	1974-1991	1991-2004
Doyang RF	93.35	4.21	3.16	-95.45	-24.94
Rengma RF	123.63	17.52	6.02	-85.31	-65.64
Nambor South RF	199.57	0.15	0.15	-99.92	0
Diphu RF	118.12	7.74	2.33	-93.45	-70.02
Disma RF	0.02	0.47	0.22	+2250.00	-53.19
Nambor North RF	67	50.51	30.19	-24.61	-40.23
Upper Doigurung RF	8.62	7.71	6.67	-10.55	-13.49
Lower Doigurung RF	13.07	11.49	10.93	-12.09	-4.87

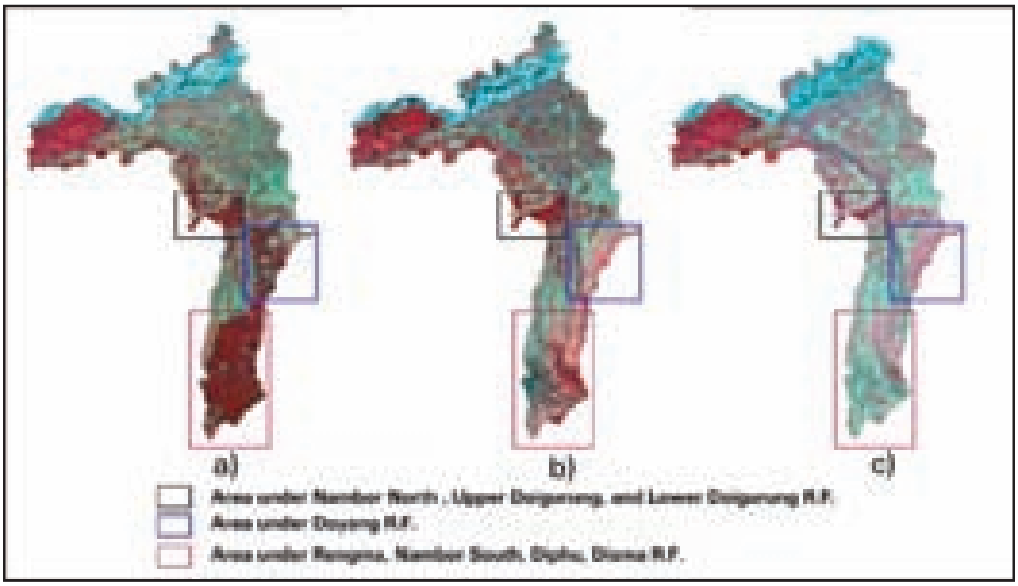

Figure 2. False colour images of Golaghat district pertaining to periods a) 1974, b) 1991 and c) 2004. Red colour indicates the forest cover.

The change in land use in Golaghat district is evident between 1974 to 1991 and 1991 to 2004 (Fig. 4 and Table 4). The forest cover in the southern part of Golaghat district is completely gone, leading to intense human-elephant conflict in the district.

Causes of forest loss

The main causes of elephant habitat loss in Golaghat district are:

- Land use change from forest to agricultural land and tea gardens.
- Encroachment by human populations from nearby villages.
- Use of wood as a source of heat and energy.
- Illegal cutting and felling of trees for business purposes.

Human-elephant conflict

The Asian elephant is considered one of the most significant cultural symbols of the people of Asia, and also stands for the need to safeguard sufficient natural forest areas. However the species is endangered due to a number of conservation issues. Growing human populations, demand for cultivable lands and alteration of forest habitat to human habitation and cropland result in serious human-elephant conflict in Assam (Srivastava *et al*. 2002; Talukdar & Barman 2003). The forest cover in northeastern India is disappearing at an alarming rate. More than 500 km^2 of forests are being destroyed annually (Choudhury 1999). This has resulted in increase of human-elephant conflict to alarming proportions in Assam in general, and in the Golaghat district of Assam in particular, in recent times (Talukdar & Barman 2004). During harvesting season, wild elephants

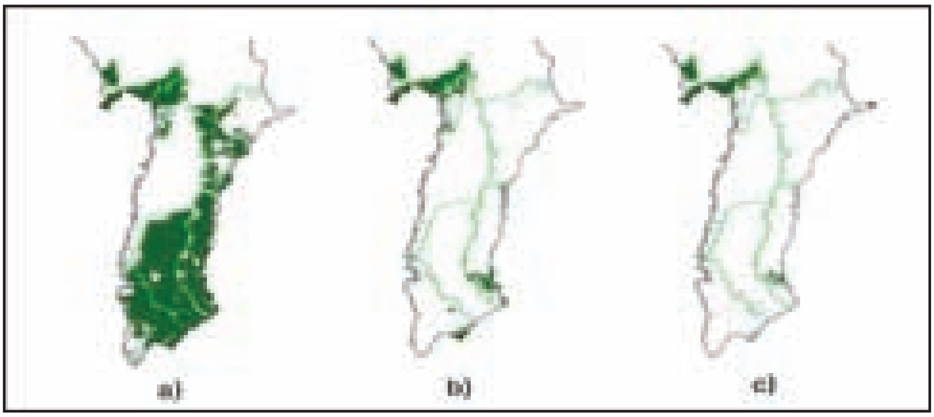

Figure 3. Forest cover change in the study area. Forest cover in 1974 (a), 1991 (b) and 2004 (c).

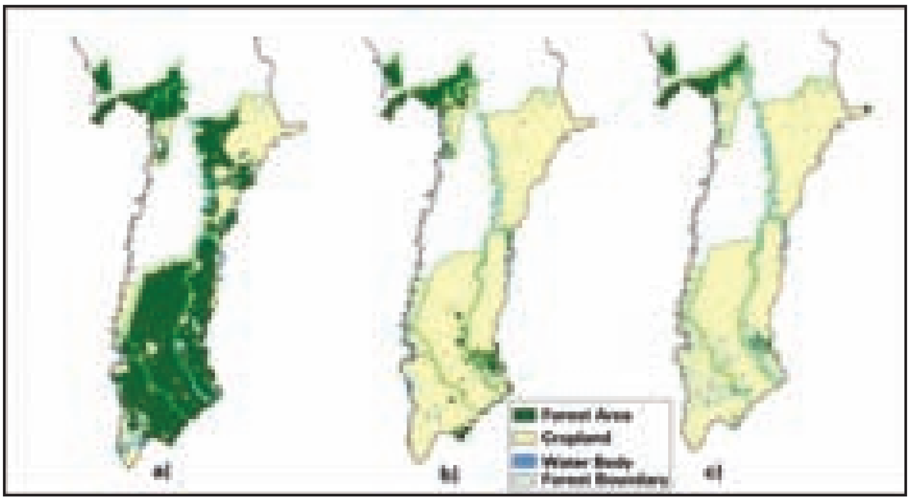

Figure 4. Land use in the study area in 1974 (a), 1991 (b) and 2004 (c).

come out of the existing forest area to nearby villages in search of food and increase the levels of depredation in crop fields giving rise to serious human-elephant conflict situations. The economy of the district as a whole is mainly agro-based, wherein the people basically cultivate paddy as their main livelihood. On the other hand paddy attracts elephants, which ultimately creates loss of farmers' annual food and income. This leads to human-elephant conflict, which results in the loss of human and elephant lives. The large-scale loss of crops and an increase in the numbers of human casualties by wild elephants has disturbed the age-old peaceful bond of co-habitation between humans and elephants, resulting in humans killing elephants in vengeance. The number of human casualties by wild elephants, and the number of elephant deaths as a result of human-elephant conflict in Golaghat district is shown in the following graph (Fig. 5).

Conclusion

In recent years, development activities such as establishment of the Numalighar Refinery in the Telgaram area, widening of the national highway, and increasing tea estates and encroachments has led to fragmentation of elephant habitats. Further, extraction of stones from forests of Behora, Mikirchang, Bogidola and Lakowa area has minimized the free ranging movement of elephants in Golaghat district, leading to a chaotic situation. The present status of elephants in Golaghat is in complete contrast to the past.

The only solution to minimize elephant habitat loss and human elephant conflict is the restoration of key forest cover and elephant corridors. All encroachers should be evicted from the areas with immediate effect as per the existing Forest Conservation Act of 1980, and a rehabilitation plan needs to be prepared for the encroachers. Stringent measures should be adopted to check any further deforestation in the existing forest cover of the Golaghat district. The entire area should be regularly monitored using remote sensing to detect the loss of elephant habitat due to human activities or any natural disaster. The need of the hour is to initiate a concerted approach by involving all the relevant stakeholders and work collectively to ensure that tangible results could be achieved in the field of elephant conservation through community participation and better forest-public relationship. Restoration of forest cover seems to be the only permanent solution for the burgeoning problem. However, in the short run, as immediate measures, crop guarding, chasing wild elephants by using domesticated

Table 4. Land use change in the study area.

Class Name	Area [km^2]			Net change [km^2]		Change [%]	
	1974	1991	2004	1974-1991	1991-2004	1974-1991	1991-2004
Forest	623.38	99.8	59.67	-523.58	-40.13	-83.99	-40.21
Cropland	282.18	805.76	839.8	523.58	34.04	185.55	4.22
Water body	36.52	36.52	42.62	0	6.1	0	16.70

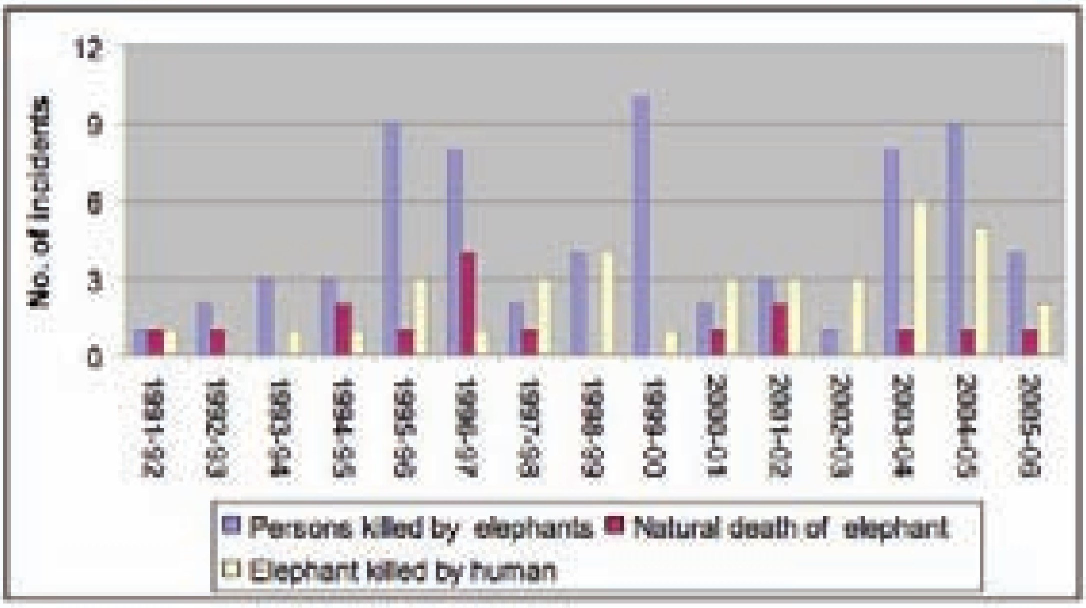

Figure 5. Intensity of human-elephant conflict in Golaghat district.

elephants and the use of fire torches would be helpful. The primary stakeholders need to be provided with alternative livelihood generating options so that they could tolerate the possible damage caused by wild herds, at least in the short term. The general public needs to extend their full support to such collective initiatives and play an active part to minimize human-elephant conflict in the area through restoration of forests as far as feasible.

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Modelling Impacts of Poaching on the Sumatran Elephant Population in Way Kambas National Park, Sumatra, Indonesia

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Introduction

Poaching has been known to have a large impact on elephant populations in both Africa (e.g. Douglas-Hamilton 1987; Poole & Thomsen 1989) and Asia (Sukumar 1989; Sukumar *et al.* 1998). There are fears that poaching of Asian elephants has increased since CITES approved an experimental one-off sale of ivory from Botswana, Namibia, and Zimbabwe to Japan in July 1999, following compliance with a number of agreed conditions. Another one-off sale from South Africa, Namibia, and Botswana was approved in 2002 but that sale has not yet taken place (CITES 2000; Milliken 2004). In Sumatra, during the 1980s and 1990s, poaching was not considered a major threat to elephants (Blouch & Haryanto 1984; Blouch & Simbolon 1985; Santiapillai & Jackson 1990); however it is feared that poaching activity has increased since year 2000 (Sitompul *et al*. 2002; Hedges *et al*. 2005). While poaching activity is predicted to continue increasing, accurate data on poaching is very difficult to obtain. Furthermore, there have been no field studies in Sumatra identifying the impact of poaching on elephant abundance and population trends.

Population modelling has been widely used in wildlife ecology studies for many terrestrial large mammals (e.g. Belovsky 1987; Berger 1990; Rothley *et al*. 2005). Incorporating modelling approaches as part of adaptive management strategies, allows managers to develop more effective conservation strategies (Cromsigt *et al*. 2002) while reducing the uncertainty about how the system responds to management actions (Williams *et al*. 2002). Furthermore, modelling allows managers to make an empirical assessment of the species of interest and identify and implement the management strategies that are most likely to increase the probability of a species persisting over a given time period. However, developing detailed and accurate population models for many species requires extensive historical baseline data (i.e., population size, age structure, sex-ratio, fecundity rate, and natural survival and mortality rates). In Sumatra, reliable baseline data for Sumatran elephant is uncommon; however the results of a couple of studies (Riley 2002; Hedges *et al*. 2005) provide reliable data for the elephant population in Way Kambas National Park. We believe that modelling of elephant populations and poaching threats will help managers identify key parameters to monitor, and strategies to adopt, in order to minimize extinction threats for Sumatran elephants.

In this paper, we estimate the potential impact of poaching on the elephant population in Way Kambas National Park (WKNP) using a stochastic population model. We projected the population trend under three different poaching scenarios: no poaching, low poaching, and high poaching. For each model, we predicted the population's age distribution, growth rate, and trends in abundance estimates over 50 years. Finally, we calculated the extinction probability for each scenario and conducted sensitivity analyses to identify the parameter that had the largest effect on the model's estimates.

Methods

Study area

Field data used in the model were collected in Way Kambas National Park (WKNP), Sumatra, Indonesia. WKNP is located in eastern part of Lampung Province in south-eastern Sumatra (4°62'–5°26' S and 105°54'–105°90' E), and is 1235 km^2 in area The entire park is < 50 m above sea level and annual rainfall is 2000–3000 mm. Vegetation types are typical tropical lowland and swamp forest. Most of the park was logged in the 1960s and 1970s, so most of the forested area in the park is relatively degraded. Nonetheless, the park has still been categorized as the second highest priority for Sumatran elephant conservation (Santiapillai & Jackson 1990). The park boundary is approximately 227 km long and 65% (148 km) of it is bordered by 34 villages. The elephant population in the park was estimated to be 180 (95% CI = [144, 225]) in 2002 (Hedges *et al*. 2005). The government of Indonesia established an Elephant Training Centre (ETC) in the south-eastern area of the park in the early 1980s; the purpose of this ETC was to house "problem elephants" captured as a result of human–elephant conflict and habitat conversion in WKNP and other parts of Lampung Province (Hedges *et al*. 2005). The "problem elephants" were then tamed and trained at the ETC for tourism purposes. The ETC in WKNP is the largest such centre in Sumatra and during 2000–2002 was known to contain about 100 elephants (authors' pers. obs.).

Methods

We developed a stage-based stochastic population model to determine the impact of poaching in the park based on known rates of illegal killing of elephants in WKNP (Sitompul *et al*. 2002). Population trajectories and maximum population size under different scenarios were predicted for elephants in WKNP using a Leslie matrix projection model (Leslie 1945, 1948). The model consisted of four different life-history stages: calf, juvenile, subadult, and adult and operated on an annual time step basis (Fig. 1). The calf stage included any elephant <1 year old, juveniles included ages 1–5 years, subadult elephants included individuals >5–15 years old, and adults included individuals >15 years old (Sukumar 1989). Each simulation began by assigning individuals to one of the four life history stages: calves were 8.04% of the population, juveniles were 28.57%, subadults 50%, and adults 13.39%, based on the demographic configuration of the elephant population in WKNP in Reilly (2002). The number of calves produced each time step was a function of the number of adults and subadults and fecundity. Stage-specific maximum annual fecundity rate was assumed to be constant over time and estimated to be 0.225 for both subadult and adult elephants, and was based on long-term studies of Asian elephants in other regions (Sukumar 1989). Stage-specific natural survival rate was assumed to be similar to Asian elephants in India and averaged 0.85 for the calf, 0.96 for the juvenile, 0.98 for the subadult, and 0.85 for the adult life history stages. We incorporated stochasticity into the model by randomly generating annual survival rates from a beta distribution with the mean specified above and a standard deviation that was 10% of the mean.

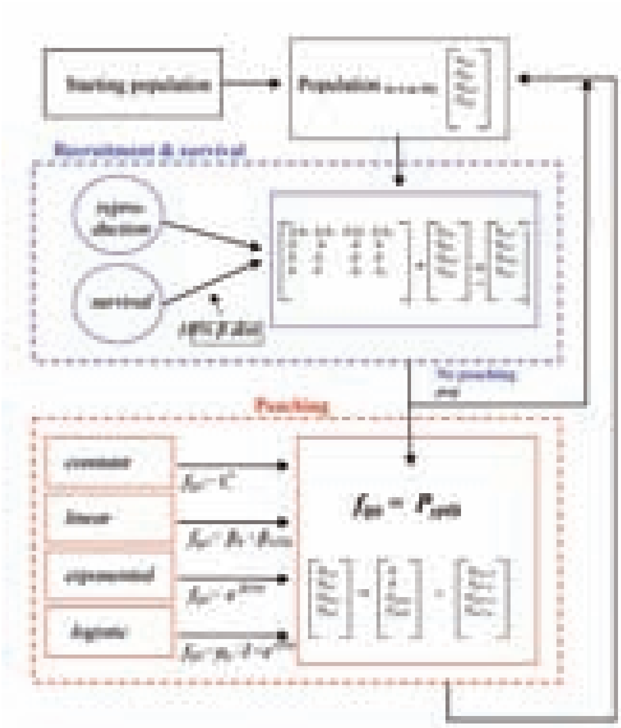

Figure 1. Model flow for population estimation and demographics as a function of recruitment, survival and poaching for elephants projected for 50 years in Way Kambas National Park.

For each simulation scenario, we ran 1000 replicate simulations for a 50 year time period, and observed the final population structure at year 50. Mean and 95% confidence interval (95% CI) of population size, population structure, and population growth rate (λ) were calculated. In addition, a quasi-extinction coefficient (*EC*) was estimated as the proportion of the 1000 replicate simulations that resulted in extinction before 50 years.

We evaluated the effect of poaching on elephant populations using three different scenarios. The first scenario, which we called the control, assumed that the elephant population in the park was fully protected, resulting in no anthropogenic removal of elephants (no poaching and elephant capture due to conflict with human). The second scenario assumed poaching occurred at a low rate defined as the mean number of elephants known to have been removed from the population per year due to poaching over the years 2000–2004. The number of elephants poached in the park was estimated from the total number of carcasses with signs of poaching activity found in the park in the 2000–2002 period (n=8 elephants) plus 8 elephants that had been found killed by poachers in the 2003–2004 period (Sitompul *et al*. 2002; Hedges *et al*. 2005; WCS unpub. data). We assumed only sub-adult and adult elephants were poached. The third scenario assumed that high poaching would occur in the park based on continued human population growth and land use trends in Lampung Province. High poaching was defined as a 2x increase on the previously defined low poaching rate described above. Because the relationship between poaching and population size is unknown, we modelled poaching rates as a function of population size using four alternative functions: (1) poaching was constant over time; (2) poaching was a negative linear function of population size; (3) poaching was an exponential decay function of population size; and (4) poaching was a logistic function of population size. For the high poaching rate scenario, poaching functions were kept the same as in the low poaching rate scenario. For each poaching function, the number of sub-adult and adult elephants poached from the park was randomly assigned using a Poisson distribution and the scenario-specific rate. Thus, the rate of poaching per year, in the model, was assumed to be additive to the stage-specific natural mortality. We did not include sex-specific differences in poaching rate because there was no information on such sex-specific differences for WKNP. There is evidence that adult female elephants are also poached in Sumatra and their toenails, genitalia, and other body parts are collected for use in traditional medicines (Sitompul *et al*. 2002).

Several other assumptions were required in constructing the models. Natural mortality rates used were derived from data on Indian elephants, which might be different than Sumatran elephants. However, it is unlikely that they would be substantially different because elephants in India and Sumatra have similar life histories. Furthermore, we did not include a carrying capacity function because the carrying capacity of the study area is not well studied (but is thought to be much higher than the present population size) and because our primary concern was preventing declining populations and local extinction, the effect of density-dependent factors as the population approached carrying capacity was considered unimportant. However, model scenarios projecting increases in population will need refinement and some measure of carrying capacity should be included as those data become available. Finally, potential genetic problems associated with small isolated elephant populations (e.g. inbreeding depression) were not included in our model.

Sensitivity analyses

The purpose of the sensitivity analyses was to determine the relative influence of each parameter and alternative poaching model on model estimates (Williams *et al.* 2002). Relative sensitivity of model estimates can be evaluated by varying model input parameters over a specified range and examining the change in model outputs. For this study, we evaluated the relative sensitivity of the year 50 model estimates to each parameter by calculating a Sensitivity Index (SI) using regression analysis to calculate the slope and uncertainty of each poaching function and then multiplying the slope and uncertainty of the parameter to calculate the SI following the methods of Wiegand *et al*. (1998). We evaluated the sensitivity of reproductive parameters of sub-adult and adult elephants by varying the reproductive rates from 0.19 to 0.25, with 0.01 increments. We also evaluated model sensitivity to the survival rate parameter for the calf to juvenile transition and the sub-adult to adult transition by varying the survival parameter for each life history stage from 0.75 to 0.90, with 0.05 increments. To understand the sensitivity of the population model to the alternative poaching functions, we varied poaching rate from the low poaching scenario's 50% to 200% of the estimate values in 10% increments. The results of these sensitivity analyses for the high poaching rate scenario will be identical to the low poaching rate scenario since the difference between the low and high poaching rate scenarios is simply the magnitude of the poaching rate. All simulation modelling and sensitivity analyses were conducted using SAS (SAS version 8.2).

Results

Projection of the WKNP elephant population over a 50-year period showed the population increasing from 180 elephants to 594 elephants (95% CI = [570, 618]) if we assumed that poaching stopped. The extinction coefficient for the control population was 0.0 and population growth rate (λ) was 1.02 (0.0001 SE). Under the low poaching rate scenarios we also showed that the elephant population would increase (Fig. 2). The linear poaching function produced an elephant population in year 50 of 422 (95% CI = [403, 441]). The extinction coefficient using the linear function was also 0.0 and λ was 1.02 (0.0002 SE). If poaching in the park behaves as an exponential extinction function, the elephant population in year 50 was estimated to be 325 (95% CI = [308, 342]). The extinction coefficient for this function was 0.009 and λ was 1.01 (0.0002 SE). The constant and logistic poaching functions in the model produced estimates of elephant population size of 253 (95% CI = [235, 271]) and 263 (95% CI = [245, 281]), respectively. The extinction coefficient with constant poaching was 0.099, and logistic poaching resulted in an estimate of 0.086. The population growth rate with constant poaching was 1.0 (0.0005 SE) and λ with logistic poaching was 1.0 (0.0005 SE; Table 1). The age distribution after 50 years for the control and low poaching rate scenarios changed slightly from one dominated by sub-adults towards one more dominated by adults (Fig. 3).

Population models with high poaching rate scenarios showed a different trend to the low poaching rate scenarios over the 50-year period. In the high poaching rate scenarios, only linear and exponential decay poaching patterns showed that the elephant population in WKNP would increase over the 50 years (Fig. 4). Population size in year 50 for the linear and exponential decay poaching functions was estimated to be 274 (95% CI = [263, 285]) and 217 (95% CI = [211, 226]), respectively. The extinction coefficient for the linear and exponential poaching functions was 0.0 and λ was 1.0 (0.0002 SE). For the exponential decay poaching function, the extinction coefficient was 0.01 and λ was 1.0 (0.0003, SE). In contrast, the constant poaching and logistic poaching functions in the high poaching scenarios showed that elephant population in WKNP would decline dramatically (Fig. 4). Final population size in year 50 for the constant and logistic poaching functions was 41 (95% CI = [33, 49]) and 37 (95% CI = [30, 44]), respectively. The extinction coefficient for constant poaching was 0.75 and for logistic poaching it was 0.76. The population growth rate was 0.97 (0.008 SE) for constant poaching and 0.97 (0.009 SE) for logistic poaching (Table 1). The age distribution in the high poaching rate scenarios showed similar patterns to the low poaching scenarios, with more adult individuals found at the end of each simulation (Fig. 5).

Sensitivity analyses

Sensitivity analyses for each natural parameter revealed high levels of variation in the model. The result of the sensitivity analyses for the sub-adult and adult reproductive parameters showed that small changes in the adult reproductive parameter caused large changes in the final population size. For example, an increase of 6% in the adult reproduction rate could cause a 76.01% change in final population size. In contrast, a 6% change in

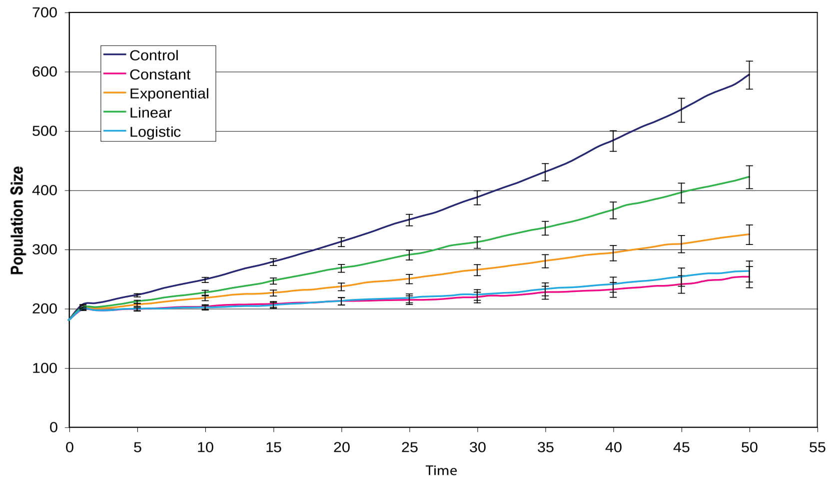

Figure 2. Simulated population trends of Asian elephants for 50 years under control and low poaching scenarios in Way Kambas National Park,. Density dependent effects using low poaching level scenarios were developed (constant, exponential, linear and logistic).

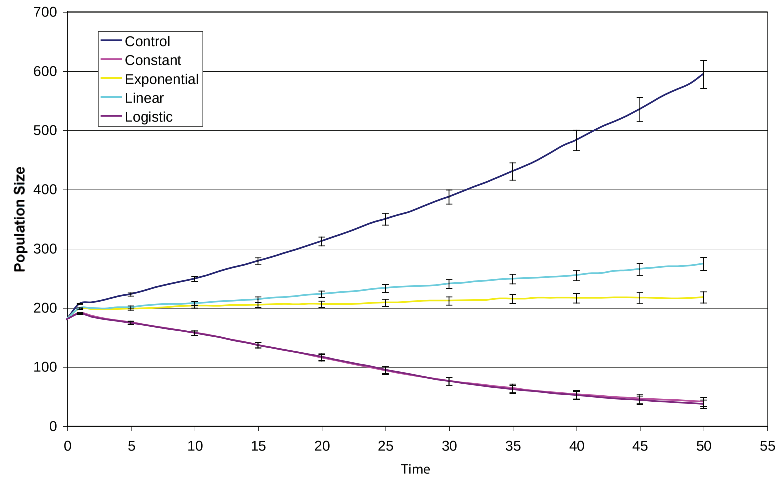

Figure 4. Simulated population trends over 50 years period under control and high poaching scenarios in Way Kambas National Park. Density dependent effects using high poaching level scenarios were developed (constant, exponential, linear and logistic).

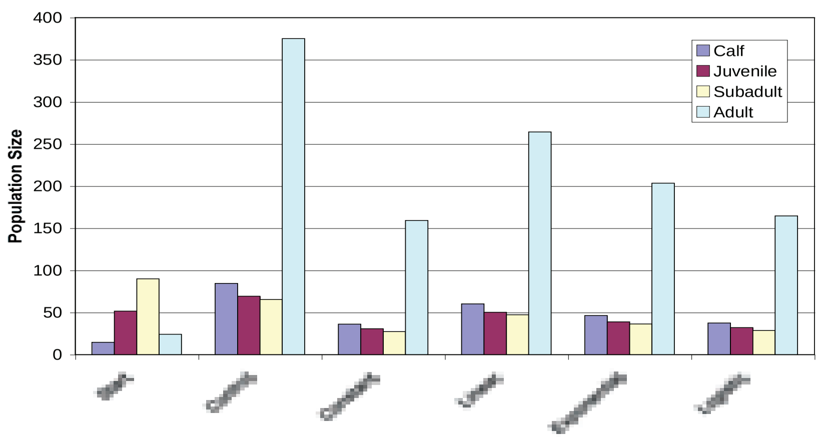

Figure 3. Projection of the age structure of the elephant population in Way Kambas National Park after 50 years of simulation, presented in the current population (start) and in control and low poaching scenarios.

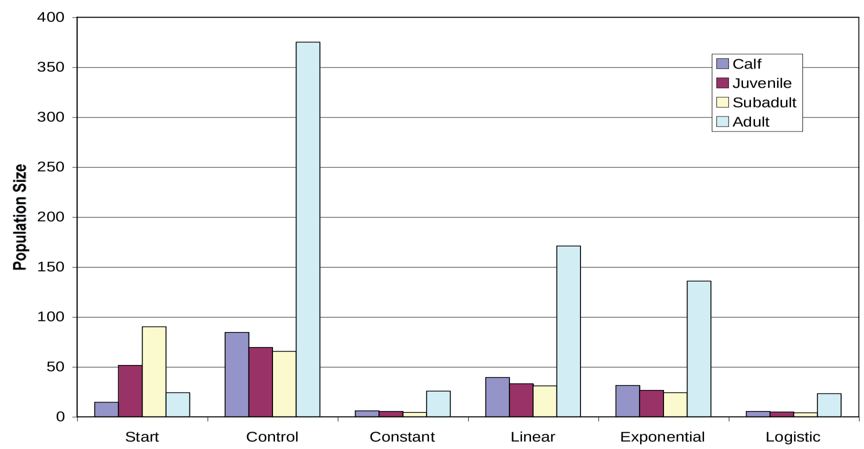

Figure 5. Projection of the age structure of the elephant population in Way Kambas after 50 years of simulation, presented in the current population (start) and in control and high poaching scenarios.

sub-adult reproduction rate only caused a 26.84% change in final population size (Fig. 6). For the survival parameter, sensitivity analyses showed that juvenile survival and young survival rates had relatively similar impact on the final population size. An increase of 5% in survival of young and juvenile elephants independently caused a change of 29.25% and 29.87% in final population size, respectively (Fig. 7). However, the adult survival parameter had a far more sensitive effect on the final population size compared to the sub-adult survival parameter. Changing the adult survival parameter 5% could cause an 86.54% change in final population size. In contrast, a 5% change in the sub-adult parameter only caused a 37.46% change in final population size (Fig. 8).

Sensitivity analysis for the four poaching function parameters showed clear differences in model sensitivity (Fig. 9, Table 2). The logistic poaching function appeared to have the greatest influence, which is shown by it having the lowest index (SI = -2.626) followed by the constant poaching function (SI = - 0.013). The linear, constant, and exponential poaching functions appeared to have relatively similar sensitivity in the model (Fig. 9). The level of uncertainty of poaching parameter in the model showed that the exponential parameter had the lowest uncertainty compared to the other three poaching parameters (Table 2).

Discussion

Our model clearly demonstrates that in the control (no poaching) scenarios the elephant population in the park will increase over time. Furthermore, the low poaching rate scenarios also show the elephant population increasing. These results imply that the low poaching rates observed in the past did not have a serious negative impact on the elephant population in the park. The population growth rate in the low poaching rate scenarios remained about 1.0 or above and extinction encounter rate after 1000 simulations was less than 0.1. However, if we doubled the poaching rate from the minimum known rate observed in 2000–2002, as in the high poaching scenarios, we found that the population could decline dramatically for the logistic poaching and constant poaching functions, with the extinction coefficients for both functions increasing significantly up to about 75%. For both the constant and logistic poaching functions, the magnitude of poaching pushed the population into negative growth rates. In contrast, the linear and exponential poaching functions did not differ much from the lower poaching scenarios. In this situation, poaching (linear and exponential functions) seemed to have little effect on the population even though the magnitude of the poaching increased two fold from the low poaching scenarios. It is clear from these results that further study of the WKNP population, and other Asian elephant populations, is necessary in order to decide which poaching function best describes reality and therefore allow us to better model population trajectories under different scenarios.

The age distribution in the model showed that the proportional representation of the different age stages in the population shifted towards the adult age stage for the low and high poaching rate scenarios. The overall pattern of age distribution for both poaching scenarios was the same, with

Table 1. Summary of model result representing final population size; population growth rate and extinction encounter using all possible scenarios in the model. *f* = poaching function of population size. N_{50}= population at year 50; λ = population growth ate; EC= Extinction Coefficient.

Scenarios	*f*	N_{50}	95%CL	λ	95%CL	EC
Control		594	23.59	1.02	0.0002	0
Low-poaching	constant	253	17.87	1.01	0.001	0.099
	linear	422	19.03	1.02	0.0004	0
	exponential	325	16.63	1.01	0.0006	0.009
	logistic	263	17.80	1.00	0.0009	0.086
High-poaching	constant	41	7.86	0.97	0.016	0.75
	linear	274	11.08	1.00	0.0005	0
	exponential	217	9.40	1.00	0.0007	0.01
	logistic	37	7.09	0.97	0.018	0.76

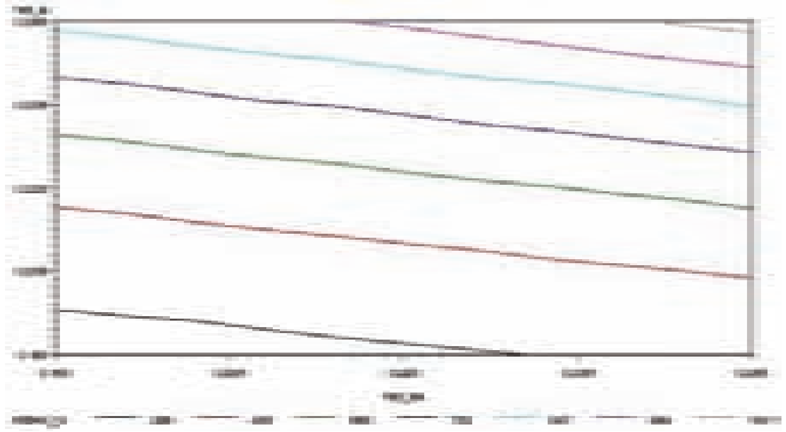

Figure 6. Response on predicted elephant population size in 50 years simulation for various combinations of adult reproduction rate (y-axis) and sub adult reproduction rate (x-axis). Line in different color represents elephant population size for specific adult and sub adult reproduction rate.

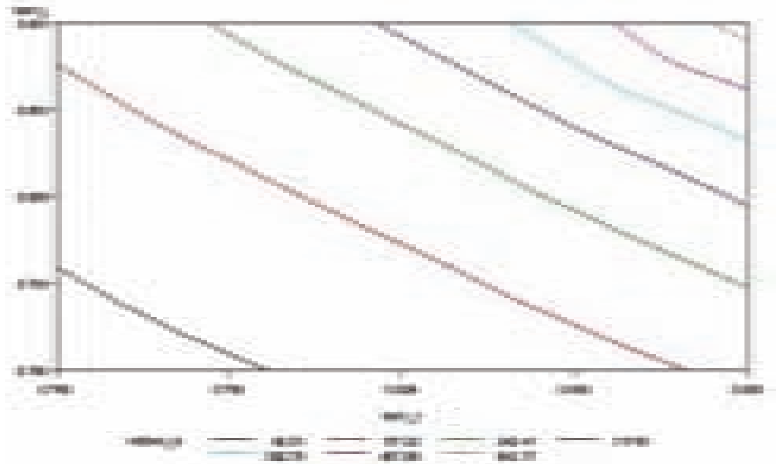

Figure 7. Response on predicted elephant population size in 50 years simulation for various combinations of juvenile survival rate (y-axis) and calf survival rate (x-axis). Line in different color represents elephant population size for specific juvenile and calf survival rate.

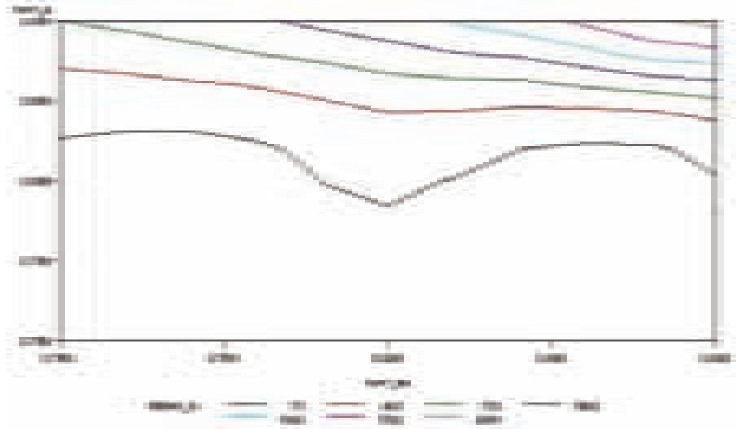

Figure 8. Response on predicted elephant population size in 50 years simulation for various combinations of adult survival rate (y-axis) and sub adult survival rate (x-axis). Line in different colour represents elephant population size for specific adult and subadult survival.

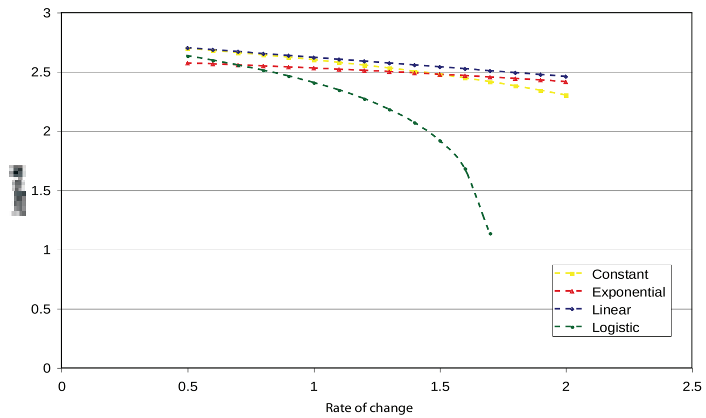

Figure 9. Response of population size in 50 years simulation to the rate of change on the poaching function parameter performed in the model. Different colour line represents different poaching function in the model.

Table 2. Sensitivity analysis of the poaching parameter. Poaching was specified as function of population size. β_0= parameter value; $\alpha(\beta,\beta_0)$= slope; $\Delta(\beta)$= approximate uncertainty in the parameter; $SI(\beta,\beta_0)$= sensitivity index of parameter β within point β_0.

Poaching	β_0	$\alpha(\beta,\beta_0)$	$\Delta(\beta)$	$SI(\beta,\beta_0)$
Constant	2.848	-0.258	0.049	-0.013
Exponent.	2.630	-0.105	0.012	-0.001
Linear	2.780	-0.161	0.000	0.000
Logistic	4.050	-1.802	1.457	-2.626

the highest proportion of the population formed by the adult stage followed by the calf, juvenile, and sub-adult stages. If we examine the relationship between population growth and age structure after simulation, we find that for the low poaching rate scenarios the population is predicted to grow after 50 years. A similar pattern was also found for the exponential and linear poaching functions in the high poaching rate scenario. If the population is growing, that means the population growth rate is equal to or more than one. In this situation we would expect the age distribution at the end of simulation year to be dominated by the younger age classes. However, our models did not predict this, suggesting that improved survival of sub-adult and adult elephants in the population over a relatively short projection period (50 years) relative to an elephant's lifespan provided our populations with much greater numbers of older individuals. As a result, there was not enough new recruitment to shift the age distribution towards the younger age classes.

Sensitivity analyses

Our sensitivity analyses showed that variation in reproduction parameters for adults had the greatest impact on model variability. Relatively small changes in adult reproduction rate could cause a significant impact on final population size. Therefore, reproduction rate of adult elephants needs to be determined accurately if models such as ours are to be useful management tools and to allow the demographic condition of populations of interest to be assessed. If we assumed reproduction rate in the population to be deterministic, and compared the sensitivity of the survival rate, we found the model was more sensitive to the adult survival parameter compared to the subadult survival parameter. Sukumar (1989) suggested that among adult elephants, female survival rate had a more significant effect on the population than did male survival rate. His study suggested that if adult male elephants have low survival, the population could still grow if female survival rate was high. Similar results have also been demonstrated for other long-lived species such as grizzly bears in Yellowstone National Park (Eberhardt *et al*. 1994).

Sensitivity analyses for the poaching parameter revealed a clear sensitivity to poaching function in the model and this was reflected in the sensitivity index value for the parameter. Sensitivity analyses showed the logistic poaching function was the most sensitive poaching function. This is most likely because the number of elephants poached per year was maintained at the maximum level and at the same time randomization was incorporated into the function. Clear differences can be found if we compare the sensitivity of the logistic to the constant poaching function: the constant poaching function tended to be less sensitive, even though the number of elephants poached per year was maintained at the maximum level, presumably because no randomization was incorporated into this poaching function.

Management implications

Our model suggests that the elephant population in WKNP will not decline over the next 50 years provided poaching rates remain at the low level observed in 2000–2002. While this result is encouraging, there is a possibility that the 2000–2002 poaching rate data used in this study underestimated real poaching rates in the park at that time because they were based on the number of elephant remains found without dedicated carcass searches. There is, therefore, a possibility that the number of elephants killed because of poaching was higher than our estimate, and our models suggest this if this were so the increased poaching could push the population toward negative growth. Moreover, even if the 2000–2002 data were representative of actual poaching rates at that time an evidence-based adaptive management approach to protecting the park's elephants would require monitoring of poaching rates to determine, for example, whether law enforcement targets were being achieved. Therefore a poaching monitoring program (e.g. systematic carcasses searching) should be established as a priority for management of the park's elephant population. This could perhaps involve the use of detection dogs (sniffer dogs) to improve carcass detection efficiency, as elephant carcasses are surprisingly difficult to find in forested environments. In addition to improving detection rates, the limited number of arrests in relation to elephant poaching and the existence of local ivory markets clearly also need to be addressed (Hedges *et al*. 2005). Interestingly, reducing poaching could also reduce human–elephant conflict around WKNP because research in Africa has shown that poachers hunting elephants in forests can drive them into closer proximity to surrounding farmland thus increasing crop depredation rates (e.g. Nchanji 2005).

Finally, this model did not incorporate habitat degradation or destruction in and around the park. However, illegal killing of elephants and other wildlife is known to be correlated with road building, agricultural encroachment, and other forms of habitat degradation and destruction that facilitate human access into wildlife-inhabited areas (Duckworth & Hedges 1998), and so elephant population management in WKNP and elsewhere on Sumatra should also focus on reducing habitat destruction, especially encroachments into elephant habitat.

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Nutritional Evaluation of Forage Preferred by Wild Elephants in the Rani Range Forest, Assam, India

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Introduction

Elephants are generalist feeders, consuming a large number of plant species. Numerous studies on feeding habits of African and Asian elephants have shown that proportions of various plant categories in the diet vary widely from one region to another (Sukumar 1985). Grasses, shrubs, tree leaves, aquatic plants and occasionally fruits make up the components of their diet.

Assam in India is home to about 5,300 wild Asian elephants (*Elephas maximus*), which are threatened globally. With continuous loss of habitat, qualitatively as well as quantitatively, elephants are forced to extend their range and raid crops to meet their energy requirements. Although large populations of elephants are found in the northeast regions of India and particularly in Assam, little effort has been made to study their feeding habits. Therefore, obtaining baseline data on elephant feeding habits was considered essential (Fig. 1).

The study of nutritional composition of forage consumed by *E. maximus* can present insights into the physiology of the species as well as help us in assessing its habitat and formulating habitat management plans.

Methods

The study was conducted in the Rani Range, Kamrup district, Assam. The Rani Range Forest is located around 91˚37'S and 91˚43'E. It has an annual rainfall of about 6.6 mm. The atmospheric temperature varies from 10.8˚ C to 31.8˚ C in extreme winter and summer respectively. The study area comprises of a forested area of 160 km^2, spread over the Rani Range Forest, Kamrup, India, and is divided into three Reserve Forests, namely, the Rani Reserve Forest, the Jarasal Reserve Forest and the Kwasing Reserve Forest. The physical aspect of the area was the prevalence of plateaus and hills that rarely exceed 1,000 meters in elevation. The basic vegetation type found in the area was tropical moist mixed deciduous forest. Degraded and scrub type vegetation was found scattered over the area. According to the elephant census report for the year 2002, the population of wild elephants in the study area was 79, although the estimated approximate population was around 150.

Direct observation of elephants was done visually, with or without binoculars. Forage consumed by elephants was identified based on observation of elephant feeding in selected zones representing broad habitat categories. Plant species eaten by each visible member in a herd were recorded at 5-minute intervals through the scan sampling method (Altmann 1974). In some places where sufficient direct observation was not possible, indirect observation was made by following an

Figure 1. Feeding male.

Table 1. Proximate analysis of grasses, plants and tree leaves preferably eaten by elephants in Rani Range Forest, Assam, India (% on DM basis).

Local name	Botanical name	C. P.	E. E.	C. F.	N.F.E.	Total ash
Uluban	*Imperata cylindrica*	5.23	3.24	32.20	50.58	8.45
Dal	*Hymenachne amplexicalnis*	9.4	2.34	22.10	54.08	12.2
Nal	*Arundo donax linn*	7.90	1.88	33.45	58.30	14.05
Kayaban	*Cyperus rotundus*	7.9	2.88	26.6	48.8	14.0
Arali	*Leersia hexandra*	13.15	3.87	22.02	46.45	15.08
Aruna	*Setaria palmifolia*	14.02	3.84	19.03	52.89	10.25
Kuchi	*Thysanolaena maxima* Roxb	15.30	3.81	23.58	47.68	9.6
Heleshi	*Enhydra fluctuans*	9.08	4.4	32.3	38.6	15.4
Mikania	*Mikania scandens* Wild	19.10	4.35	17.20	46.83	12.95
Dimaru	*Fics glomerata*	13.55	2.93	21.13	46.50	15.80
Sarua	*Streblus asper lour*	17.30	3.70	24.72	37.64	16.64
Neem	*Azadirachta indica*	18.30	3.89	16.80	51.05	9.85
Tara	*Costas speciosus*	11.24	4.87	28.5	47.76	7.57
Kanchan	*Bauhinia tomentosa*	13.67	3.9	25.25	43.20	13.9
Sisso	*Dalbergia sisso*	10.2	2.7	28.10	47.4	11.4
Bamboo	*Dendracalamus strictus*	15.2	1.3	26.10	42.60	14.8
Sal	*Shoea robusta*	9.4	2.8	26.88	56.25	4.5
Kadam	*Anthrocephatus*	8.80	3.68	13.20	62.33	11.9
Kalgus	*Musa* spp.	13.8	6.5	28.24	39.15	12.3
Kathal	*Artocarpus heterophyllus*	11.3	3.10	18.9	56.17	10.5

elephant track as far as possible and the types of grasses or plants consumed identified. The botanical names of grasses and plants were identified with the help of a taxonomist.

Results

The food selected by elephants in the Rani Range forest consisted of grasses, shrubs, tree leaves, bark, aquatic plants and sometimes fruits. During the study period, it was observed that elephants fed on about 20 species of grasses, plants and trees (Table 1). Grass constituted by far the most predominant component of the diet (Fig. 2).

Proximate analysis of the plants eaten by elephants in Rani Range forest carried out on percent dry matter basis, contained an average 11.8% crude protein, 2.85% ether extract, 23.95% crude fibre, 48.25% Nitrogen Free Extract (NFE) and 11.55% total ash (Table 1). In the study area, the highest percentage of crude protein was found in Mikania *Mikania scandens* (19.10%), ether extract in Kalgus *Musa* spp (6.5%), crude fibre in Nal *Arundo donax linn* (33.45%), NFE in Kadam *Anthrocephatus* (62.33%) and total ash in sarua *Streblus asper lour* (16.64%).

Discussion

The food resources crucial to elephants in natural condition were studied in the Rani Range forest. It was clear from the study that the food items of *E. maximus* consist of grasses shrubs, tree leaves, bark, aquatic plants and sometimes fruit. The major grasses were *Imperata cylindrica*, *Leersia hexandra*, etc. and the plants or tree leaves were *Ficus glomerata*, *Mossa* spp, etc. Similar findings were also reported by Sivaganesan and Johnsingh (1995) who found that grass formed the major portion of elephant diet in the Mudumalai

Figure 2. Feeding male.

Wildlife Sanctuary. The most important species were *Themeda* spp and *Apluda mutica*. The species variation of the grasses eaten can be attributed to the different geographical location of the study area. McKay (1973), Moss (1988), Sivaganesan and Kumar (1995) and Mercy (2002) also reported similar observations.

The study helped us in knowing the food preference of elephants in the area (Fig. 3) and thus would contribute to management plans of the forest department and formulate actions to safeguard the habitat in the long run.

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Figure 3. Herd and males feeding in the high grass.

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Elephant Cognition: A Review of Recent Experiments

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One of the greatest remaining biological mysteries, says Marian Dawkins, is "what goes on inside non-human minds" (1993). Indeed, the question whether some animals, at least, think, it could be argued, has fundamental implications to our world view and to the way we interact with animals at homes, farms, parks, zoos, and elsewhere.

This brief review focuses on the question whether elephants—one contender for high intelligence in animals—can act thoughtfully. For the purposes of the present discussion, we shall arbitrarily narrow down the meaning of thinking to just one aspect: the ability to plan future actions in one's head, before embarking on any specific course of action.

Discrimination experiments

Most of the evidence in this section is based on the pioneering work of Rensch (1957) and Altevogt (1990) with a single young Asian female at the Münster Zoo, and on our own work with 22 Asians at the Detroit Zoological Institute and Burma. In Burma, elephants first learned to remove a lid from a bucket, or to displace a box covering a hole in the ground, in order to obtain a desirable food item (Nissani *et al*. 2005; Nissani 2006). This was followed by either a black/white discrimination task, a large/small transposition task, or the placement of either box or lid on the ground so that they no longer obstructed access to the food, and then observing the elephant's reaction. For the most part, these experiments followed Fabre's (1915) and Thorndike's (1911) protocols of distinguishing trial-and-error learning from thoughtful behavior.

Laborious, gradual, process of learning

Thorndike, (1911, p. 73) argued that his cats and dogs escaped puzzle boxes through a mindless process of trial and error. Because understanding something as simple as pulling a loop to open a door must occur rapidly or not at all, it should have induced, at some point during the repeated introductions of his animals into the box, a sudden reduction in escape time. The actual, gradual, slope of the time-curve that he did observe suggested to him that his subjects failed to understand the cause-effect relationships between their actions and escape.

Like Thorndike's cats and dogs, all 13 Burmese elephants that mastered our black/white or large/small discrimination tasks did so gradually, with the number of correct responses rising by fits and starts, over several sessions, from chance level to near-perfect performance (Fig. 1).

The same logic applies to the pre-training of the elephants in our discrimination experiments, which involved learning to remove a lid from a bucket or to displace a box to uncover a hole in the ground. Here too, one never sees sudden improvements. On average, the 20 elephants taking part in these experiments required 3.4 sessions to learn the task, imperceptibly nearing the experimenter's goal.

In comparison to some other animals, elephants' performance is unremarkable

Rensch and Altevogt's young Asian elephant needed 330 trials, over a period of several days, to consistently choose the reinforced response in her first discrimination task (Rensch 1957). In an experiment which employed another sense modality, an 8-year-old took 7.5 months to distinguish 12 tones (Reinert, cited in Altevogt 1990, p. 474).

Likewise, the 13 elephants in our sample, which acquired our easier black/white or large/small visual discrimination tasks (mean age=13.2

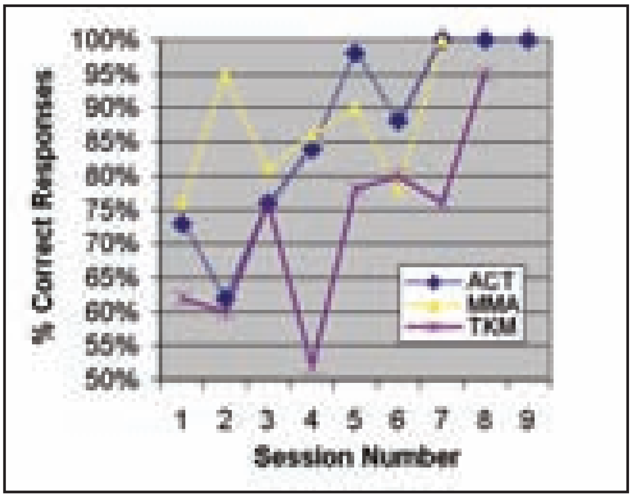

Figure 1. Learning curves for three representative elephants (ACT, MMA, TKM) in a white+/black- visual discrimination task.

years) did so in an average of 3 sessions and 154 trials (see also the section on short-term memory, below).

Additionally, the remaining 7 Burmese elephants (mean age=29.3 years) failed to reach criterion in an average of 6.6 sessions and 332 trials, suggesting that some elephants may be either unable to acquire simple visual discriminations or that they require an inordinate number of trials to do so.

An acquired behavioral sequence persists after it no longer serves a purpose

Thorndike (1911) reported that once an animal learned to escape from a puzzle box by performing a certain action (e.g. pulling a loop), on subsequent introductions to the box, and after the action no longer served a purpose (e.g., the cover of the box had been removed), the animal continued to perform that action. He argued that this supported the notion that the animal solved the task mechanically, without understanding the causal link between action and consequence.

Similarly, four logging elephants were trained to remove food from a coverless bucket by inserting their trunk into the bucket (Nissani 2006). They were next trained to remove a lid from the top of that bucket to obtain food. Once this behavioral sequence was established, the lid was placed alongside the bucket so that it no longer obstructed access to the food. If the elephants understood the nature of the task, they might be expected to ignore the side lid in the first few trials and retrieve the reward directly, as they used to do before the lid was introduced. On the other hand, if they did not understand what they were doing, in the first few trials they might continue to remove the lid before inserting their trunk into the coverless bucket and retrieving the food. Observations accorded entirely with the mindless learning hypothesis: in the first 5 critical trials, when the lid was placed alongside the bucket and no longer obstructed access to the reward, each elephant continued to remove the lid before retrieving the reward. A number of variations on this basic design involving 11 additional elephants, and numerous controls, amply confirmed this conclusion. It appears probable, therefore, that when acquiring the obstacle-removal task, elephants respond to the temporal contiguity of the two events, not to their causal relationship.

Long-term memory

Learning to discriminate between 20 pairs of symbols, a young elephant is said to have performed superbly on a test that combined all 20. The test lasted several hours, yet her performance actually improved toward the end. A year later, her scores ranged from 63 to 100 percent (Rensch 1957). After a break of more than 32 years, when she was about 40, the elephant remembered the experimental situation and sequence, but could no longer reliably choose the 20 correct symbols (Altevogt 1990).

Likewise, one of three elephants that learned a simple discrimination task remembered it eight years later (reported in Stevens 1978). More convincingly, the single elephant that learned to distinguish 12 pure tones was able to distinguish 11 sounds after 19 weeks and 9 sounds after an additional interval of 1.5 years (Reinert, cited in Altevogt 1990).

Short-term memory

Four circus elephants had to choose one of five identical boxes in which a morsel of food was placed before their eyes, yielding a 76% correct response rate as the baseline. In delayed response experiments, the best performing animal scored at chance level after a 15-second delay. When the choice was limited to one of three identical boards, chance level was reached after a 45-second delay (Grzimek 1944).

Our investigations of short-term memory of Burmese logging elephants yielded similar results. Two experimenters stood 1 m apart, facing the elephant at a 45° angle to its right and left, each holding a bucket. To help the elephant remember, the buckets differed in size and brightness. In each trial, a third experimenter, standing at a distance of some 2 m from the bucket-holders and directly facing the elephant, tossed a 2-4 cm piece of sugarcane into one of the buckets (for visual details see Nissani & Hoefler-Nissani 2004). At pre-training 1, the two buckets rested on the ground. At pre-training 2, the buckets were placed on the ground right after the sugarcane loudly hit the bottom of one of the buckets, in full sight of the elephant, who now had to choose the correct bucket in order to secure the food reward. After the elephant mastered this second pre-training task, in experimental trials, following the toss and sugarcane entry into one bucket, the bucket holders placed the buckets behind their backs, hidden from the elephant, and kept them there for a specified period of time. Both holders then simultaneously placed the buckets on the ground in front of them, within easy reach of the trunk. Various control measures were employed to rule out reliance on experimenter bias, smells, sights, or sounds, in choosing the bucket. Interobserver reliability was measured by comparing the written records of one experimenter to a video record maintained by another.

Of the six elephants taking part in this experiment, one did not meet predetermined criteria for the absence of experimenter bias, and two others failed to reach pre-training criterion (in 8 and 18 sessions, respectively). The other three elephants reached that criterion by the 3rd or 4th session and their performance in experimental sessions improved over time. In their last session, when the buckets were lowered to the ground after a 4 seconds delay, the three elephants retrieved food from the correct bucket in 80-100% of the trials. When the duration of the waiting interval was increased to 6 seconds and was accompanied by an interference (walking towards the elephant and giving it a piece of sugarcane), the percentage of correct responses declined to 60%-67%. When the duration or level of difficulty of the task were raised, subjects' performance declined still further.

We may note in passing that the two experiments described in this section strikingly differ from short-term tests with human beings. Tests with humans are designed (by using nonsense syllables, for instance) to prevent the formation of mnemonic rules. In the few cases where subjects manage to develop such rules, extraordinary feats of memory are observed. By contrast, the two elephant protocols above made no effort to forestall the formation of mnemonic rules; had these same protocols been applied to human subjects, many such subjects might have developed such rules as "move forward the front leg on the side of the appropriate bucket and, once the bucket is lowered, select the bucket nearer this leg."

Williams (1950) says: "I don't believe that an 'elephant never forgets,' but I should scarcely be surprised if he tied a knot in his trunk to remember something, if he wanted to." Our elephants appeared to enjoy the activities and the unusual treats they were receiving, and one might expect that Grzimek's elephants did too, but not one of the nine seemed capable of maximizing food intake by developing a simple memory-enhancing strategy. If elephants think, either they think at a lower level than this, or their thinking is qualitatively different from ours.

Mirror self-referential behavior

A 1989 traditional mark test of two Asian elephants failed to elicit self-referential response to experimentally-induced visible alterations in their body image. Because this failure could potentially be ascribed to the poor vision of elephants (Povinelli 1989), another study (Fig. 2) of two captive Asian elephants at the Detroit Zoological Institute bypassed the traditional

Figure 2. Wanda, formerly of the Detroit Zoological Institute, scrutinizing a mirror, pre-training stage.

painted mark test, relying instead on the elephants' response to a more visually conspicuous object (a white turkey feather taped to their forehead). Despite the alternative design, neither subject engaged in mirror self-referential behavior (Nissani & Hoefler-Nissani 2006). However, another Asian elephant did pass the mark test (Simonet 2000; Simonet *et al.* 2000) and, more recently, Plotnik *et al*. (2006) reported that one of three Asian females at the Bronx Zoo passed the mark test as well.

We do not yet know whether mirror self-referential behavior implies a self-concept. Likewise, we cannot yet be sure whether elephants are capable of self-referential behavior. In chimpanzees, where such behavior has been repeatedly observed (Swartz & Evans 1991; Anderson 1996), not all individuals show this capacity, so the conflicting results described here could be ascribed to the fact that such behavior is only manifested by some individuals of a species but not by others.

Applying the bird string-drawing paradigm to elephants

In 1956, Thorpe commented: "The ability to pull up food which is suspended by a thread, the pulled in loop being held by the foot while the bird reaches with its beak for the next pull, is doubtfully inborn and it has been subject to many experiments. The act appears at first sight to be a real and sudden solution of the problem from the start, and thus to qualify for inclusion under "insight learning" (Thorpe 1956, p. 333). Successful performance in this task has been documented in well over ten bird species.

By using a retractable (bungee) cord, we were able to apply the string-drawing paradigm to the two elephants of the Detroit Zoological Institute (Nissani 2004). Both mastered the problem, but, although insight could not be ruled out, our observations were more consistent with a trial-and-error acquisition of the task. The two elephants acquired the behavior gradually, by fits and starts, and seemed unable to transfer their skill across a change in physical stimuli (Mackintosh *et al.* 1985), e.g., successfully retrieving the reward when the string was tied to a pole on the elephant's side of the cord (Nissani 2004).

To cast additional light on this application of the string-drawing paradigm to elephants, we presented seven Burmese elephants with a retractable cord. Here, elephants were first presented with a tamarind or salt-laced 80 cm simple, non-retractable rope to whose end a 20-30 cm piece of sugarcane was loosely attached (pre-training 1). Next (pre-training 2), a longer simple rope was used. Next (pre-training 3), the retractable cord later employed in the experiment itself was used, but without being tied at its end to a heavy log, so that, in this third pre-training phase, the cord functioned as a simple rope. The experiment itself involved tying the retractable cord to a heavy log a few meters away from the elephant, so that the sugarcane tied close to the cord's end could only be retrieved by repeated, coordinated, action of the trunk and another body part.

At the end of pre-training, which lasted 1-3 sessions, all elephants were able to effortlessly pull a long rope, in a series of 4-7 pulls, to obtain a piece of sugarcane tied to its end.

All seven logging elephants fully mastered the string-drawing sequence within 1-3 experimental sessions. In all cases of retractable rope pulling, the sequence involved pulling by the trunk, and then securing the rope by either foot or mouth. After 2-6 coordinated pulls, while still holding the rope with either mouth or foot, the elephants disengaged the sugarcane from the rope while still using mouth or forefoot as an anchor, and then consumed the sugarcane. All elephants seemed to be flexible about the use of anchor, interchangeably using mouth, foreleg, or both.

To test the transferability of this skill, two of these elephants were taken to a bridge. After a few trials of simple rope pulling, a long simple rope with a heavy rock and a piece of sugarcane at one end was tied by its other end to a rail and then thrown over the bridge. One elephant secured the rope immediately, in 5 coordinated trunk/mouth draws. The second elephant, in her first trial, used forelegs and mouth as anchors, as she did in the earlier retractable cord variation, but close to the end of the first trial, wrapped the cord around her trunk. On the second and subsequent trials, she only wrapped the rope around her trunk until both the sugarcane and the accompanying heavy rock landed on the bridge.

It remains to be seen whether something like retractable rope pulling takes place naturally in the wild. For instance, do elephants take a branch down with their trunk, keep it in place with their foot, and munch on the leaves? On a visit to a remote logging camp in the forest, I did see behavior equivalent to wrapping a rope around the trunk. One logging elephant grabbed the end of a long (at least 5 m) creeping edible vine wrapped around a tall tree, a vine which looked like a thin rope, disengaged it from the tree by wrapping it around its trunk 4-5 times, and consumed it.

To sum up this series of string-drawing experiments in elephants, we can say that all nine Asian elephants we tested in Michigan and Burma mastered this task. We cannot however decide whether the awkwardness they showed on mastering the task was traceable to the novelty of the stimuli that surrounded this task or to a lack of understanding of its nature. Likewise, one elephant failed a simple transferability test (Nissani 2004) while two others passed the bridge transferability test. It is possible, but not yet proven, that elephants perform actions akin to pulling/anchoring in the wild, and that the conceptual aspects of the task presented no novelty for them. More ingenious experimental designs than the ones presented here are needed before we can prove or disprove the existence of insight in the string-drawing paradigm in either birds or elephants.

Competitive food procurement

At an earlier experiment at the Detroit Zoological Institute (Nissani 2004), we observed two elephants immediately securing objects from one of the two openings of an inflexible tube, 5 cm in diameter, following the placement of a small food item in that tube. They expertly placed their trunk tightly over one of the tube's openings and either sucked the object toward them and ate it, or blew it out and retrieved it when it fell to the ground. We next applied their proficiency in this task to a competitive food procurement task.

When singly confronted with the tube, both elephants either sucked or blew, suggesting a random retrieving strategy. However, when both elephants were placed in a competitive situation in which sucking would have landed the bagel fragment or sugar cube in one's mouth, while blowing would end it on the ground near its companion, from the very start both elephants almost always sucked the morsel, a reward-maximizing behavior consistent with the view that they understood the situation. Many additional variations of this setup (Nissani 2004) showed that both elephants were capable of adjusting their behavior to answer the logical demands of the task.

We have since subjected these intriguing results to two additional test implications. Upon first being presented with the tube, the two Detroit elephants were immediately able to expertly obtain the food, thus raising the possibility that this was a variation of a familiar task, which they were trained to perform earlier in life. To throw some light on this possibility, we have tested the ability of two Burmese females, 16 and 17 years of age, to retrieve food from an identical tube. They both tried repeatedly, in two daily sessions lasting more than one hour each, to obtain the food, by wrapping their trunk around the length of the tube, tilting the tube, or using force. Their failure to apply either sucking or blowing is consistent with (but does not prove) the notion that, prior to our experiments with the two Detroit elephants, they had been trained in a similar task.

We also subjected the two Detroit elephants to a transferability test (Fig. 3). We used a shorter and wider inflexible PVC pipe, 45 cm in length and 15 cm in diameter. Both elephants could comfortably insert their trunk all the way through this pipe. The pipe itself was kept 1 m horizontally above ground, tied securely to a heavy stool. We placed about a third of a bagel inside the tube, and, to forestall its suction inside the tube, wedged it between two snugly-fitting round pieces of wood.

Owing to their poor visual acuity, both elephants could not see the food once it dropped to the ground, and had to grope for it with their trunk. To overcome this problem, a big pan was placed on the ground at the end of each tube, so that the elephants only had to search for the food inside the pan.

We now placed our two elephants in a competitive situation conceptually similar to the one they faced earlier in the sucking and blowing task. If they understood the requirements of the task, they might be expected to enter the tube on their partner's side and push the food towards themselves. If they did not understand, the pushing direction, in the first few trials at least, should remain random.

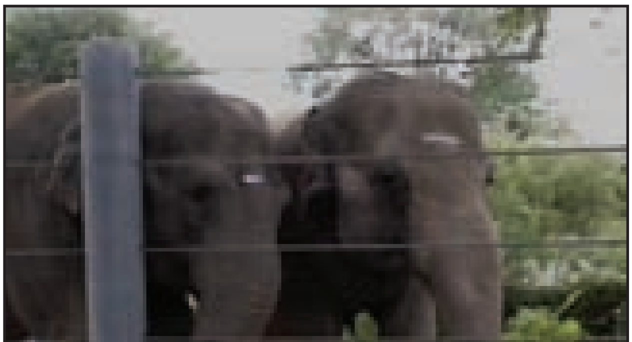

Figure 3. Competitive procurement transferability test, Detroit Zoological Institute

The data from Wanda are subject to two reservations. First, she was standing close to the dominant Winky, and her behavioral options were therefore constrained. Second, owing to earlier injuries, she was unable to perform certain actions with her trunk.

In the first competitive session, the more dominant Winky pushed the bagel towards Wanda on the first 6 trials; Wanda then consumed the bagel, leading Winky to twice raise her trunk in a threatening gesture. Then, on the 7th trial, Winky pushed the bagel towards herself and ate it. On the last trial, she pushed it again towards Wanda, and Wanda consumed it. Wanda pushed the bagel only once, towards Winky, who consumed it.

The second session consisted of 33 consecutive trials, of which 30 yielded clear results. The session and the entire experiment had to discontinue after trial 33 owing to the increasing intensity of Winky's agonistic behavior towards Wanda. In these 30 trials, Wanda pushed the bagel towards herself and received the reward in 5 trials. She pushed the bagel towards Winky, failing to get the reward, in 12 trials. Winky pushed the bagel towards herself and ate it in 7 trials. She pushed it towards Wanda in 6 trials, failing to get it in 3, and getting it in 3 (by retrieving it from Wanda's pan).

On one trial in that last session, each elephant simultaneously pushed from her side at the same time, each counterproductively struggling against the other (the intelligent thing to do would have been to let the other push the reward towards oneself, waiting for it to be dropped on one's side, and then picking it up quickly).

This informal, preliminary, investigation suggests that the two elephants did not understand the nature of this competitive task. Since this task was conceptually similar to the sucking and blowing competitive task described earlier, their failure casts doubts on our earlier insight interpretation of that task.

Do elephants know that people see? (The Povinelli Paradigm)

In a series of experiments, six young chimpanzees faced one trainer who could see them and one who could not (Povinelli & Eddy 1996). Startlingly, in the first few trials, in all but one variation, the apes consistently performed at chance level. For instance, they were as likely to beg food from a trainer with a bucket fully covering her head as from a trainer with a bucket over her shoulder.

A preliminary application of Povinelli's protocol to the two elephants of the Detroit Zoological Institute (Fig. 4), and a more complete experiment with six chimpanzees of that Institute, attempted to address methodological limitations of Povinelli et al.'s work (for a discussion, see Nissani 2004). In these experiments, both species performed significantly above chance in some conditions (Nissani 2004).

Extensive additional experiments with 14 logging elephants in two geographically isolated logging camps in Burma (complete descriptions will be published elsewhere and can, as well, be accessed at www.is.wayne.edu/mnissani/ElephantCorner/do elephants know that people see.htm) resorted to numerous controls and variations. These experiments lent support to previous studies of chimpanzees and elephants. Here too elephants performed well in the three background conditions and in some experimental conditions. They performed at about chance level in other conditions, even though these conditions were conceptually similar to the others and did not require greater visual acuity.

Figure 4. Buckets condition, elephant is seen begging from a person who cannot see the begging posture.

The statistically significant performance in some conditions can perhaps be best viewed as the formation, over a lifetime, of weak associations between human faces and rewards. Hence, although the overall results do not rule out thinking and a theory of mind, to this writer they appear more compatible with the notion that elephants do not know that people see, and, more generally, that elephants lack a theory of mind.

Retrieving distant objects with a stick

The spontaneous retrieval with a stick of otherwise inaccessible objects is sometimes cited as an example of insight, although this action could also arise by pure trial and error learning. Beck (1986) placed a food tray out of reach of captive hamadryas baboons, and an L-shaped rod within reach. After 11 hours, one youngster accidentally flipped the rod over the tray and, upon retrieving the rod, brought the tray within reach. Gradually and haphazardly, he learned to use it to retrieve food.

Leaving aside, however, the question of interpreting retrieval behavior, it is of interest to review the available literature. Hobhouse (1915, p. 277) reported that a single captive elephant never learned to use a stick to get a biscuit. Time after time she "would pull the stick in to her, getting the bun if it happened to be placed exactly right, and missing it if it was possible to do so. When she missed it, she got excessively annoyed with the stick, and would try to break it by stamping on it, or throw it away into her cage." Similar negative observations were made by Rensch and Altevogt (1954) and by Benjamin L. Hart, Lynette A. Hart and Noa Pinter-Wollman (pers. comm.). On six separate days, we have likewise failed to observe this behavior in the two Asian elephants of the Detroit Zoological Institute, even after repeatedly demonstrating to them the manipulation of food with a stick.

The one positive report known to me (Chadwick 1992) gives no details, and it is not clear whether, in this case, the behavior was directly made by the author, nor whether it could be attributed to training.

Looking back: Do elephants think?

Despite a century of intense scientific work, we still do not know if some animals, besides ourselves, think. In particular, the emerging psychological literature is more compatible with the view that elephants do not think. Elephants learn unfamiliar tasks in a mechanical, gradual fashion, with no clear evidence of comprehension. They require many trials to acquire a task, and, when the nature of the task is slightly changed (e.g., placing the lid alongside the bucket), they continue to act mechanically, suggesting that they do not understand the setup any better than Fabre's digging wasps or Thorndike's cats. Extensive efforts to come up with unequivocal demonstrations of insightful behavior or of theory of mind in this species are inconclusive (cf. Jayewardene 1994). On a few occasions, when seemingly insightful behavior is subject to transferability tests, the elephants fail to pass the new tests. Although uncertainties remain, two of nine elephants are perhaps capable of self-referential behavior in front of a mirror, but the meaning of such behavior remains unclear. Moreover, it is hard to believe that a minority of elephants are capable of self-recognition, while the majority is not. In short-term memory experiments, elephants never devise a rule of thumb to improve their performance.

Day *et al.* (2001) argue that "the evidence of high cognitive abilities in cetaceans does not stand up to close scrutiny under the standards established by laboratory researchers. This is likely to lead to a sterile debate between laboratory and field researchers unless fresh ways of taking the debate forward are found." Needless to say, this review discloses an almost identical dichotomy in our perceptions of elephants, a dichotomy, which likewise requires fresh ways of thinking. Until such new trails are blazed, we may perhaps conclude with the following statement: while our own extensive series of controlled experiments with elephants do not rule out the widespread view that elephants think, they appear more compatible with the view that they do not.

Acknowledgements

The Detroit Zoological Institute, Myanmar Department of Forestry, the Myanma Timber Enterprise, former Ambassador U Linn Myaing, made our elephant research possible. My wife Donna shared with me her love for elephants and the joys and liverbreaks of fieldwork. My heartfelt thanks to Dr. Wan Htun, U Tin Lay, and U Kyaw Kyaw, for guidance, guardianship, friendship, and competent assistance; may the needless clouds that have been darkening every aspect of their lives for decades disperse soon.

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Gajah 28 (2008) 53-54

Revised Trunk Wash Collection Procedure for Captive Elephants in a Range Country Setting

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In elephants, trunk washes are taken to diagnose tuberculosis and culturing the trunk wash is essential for proper treatment protocols based on drug sensitivity tests. Guidelines for the control of tuberculosis in elephants by the United States' National Tuberculosis Working Group for Zoo and Wildlife Species describe the procedure for trunk wash collection. According to the described procedure, 60 ml sterile 0.9% saline solution is instilled into the trunk of an elephant using a sterile syringe. After lifting the trunk as high as possible and then lowering, the wash is collected in a plastic bag placed on the tip of the trunk.

The procedure requires elephants to allow their keepers to restrain and manipulate the tip of the trunk. During field trials in southern India, it was observed that this imposed a limitation on the use of the technique. Unlike captive elephants maintained in zoos and circuses in non-range countries, which are trained to 'perform', most captive elephants in range countries are trained and conditioned only for 'work'. Majority of such elephants are 'trunk-phobic' and any handling or manipulation of the trunk led to struggle, and often resulted in contaminated collections.

To overcome this difficulty a revised method was developed by trial and error to collect trunk washes from 'trunk-phobic' elephants without touching the trunk. The hot and humid climate in southern India, which results in copious discharge from the trunk even with slight exercise, helped the revised procedure. The revised trunk wash collection procedure as described below gave good collections with minimal training and behavioral conditioning from 'trunk-phobic' elephants without manipulating the trunk. Compared to the collections done by the procedure using a plastic bag and trunk manipulation, contamination observed during culture for isolation and identification of mycobacteria was also found to be much less by the revised procedure.

Step 1: After a short period of exercise, the keeper commands the tusker to 'tie its trunk' on to the tusk so that the elephant rests the trunk on the tusk (Fig. 1). Tuskers performed the 'trunk-tie' without inhibition since almost all of them are trained for this practice, especially for the safety of mahouts. In case of a makhna (male elephant without tusks) and female elephants, the 'trunk-tie' is performed on a long pole (Fig. 2). The 'trunk-tied' elephant then stands in the sun for 10-15 minutes while the discharge accumulates in the trunk. Makhna and female elephants

Figure 1. 'Trunk-tie' by tusker.

Figure 2. 'Trunk tie' for makhna or female.

were made to walk for 10-15 minutes holding the pole, as when standing in one place they refused to hold the pole continuously. The quantity of discharge was less when the elephants stood or walked in shade.

Figure 3. Adding the saline into the tray with 'trunk tied' elephant in the sun in the background.

Step 2: 30 ml 0.9% saline is taken in a sterile plastic tray (Fig. 3), the tray placed on the ground beneath the trunk, and the keeper commands the elephant to 'drink' from the tray. When the elephant lowers the trunk into the tray the accumulated discharge drains directly into the tray on its own (Fig. 4). The command to drink is normally used with all elephants and is sufficient to make the elephant extend its trunk into the tray. When the trunk is extended to the tray, the keeper prevents the elephant from aspirating the fluid in the tray. The usual quantity of discharge collected by this revised procedure during the hot part of the day was about 15-20 ml.

Step 3: Discharge is mixed with saline by tilting motions of the tray. Collection is poured into a 50 ml sterile screw-capped tube and dispatched to the laboratory in cold chain.

Figure 4. Placing the tray on the ground and the elephant extending the trunk to the tray allowing the accumulated discharge to drain in to the tray.

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Recent Publications on Asian Elephants

Compiled by Jennifer Pastorini

Anthropologisches Institut, Universität Zürich, Zürich, Switzerland and
Centre for Conservation and Research, Rajagiriya, Sri Lanka

H. Aupperle, A. Reischauer, F. Bach, T. Hildebrandt, F. Göritz, K. Jäger, R. Scheller, H.-J. Klaue & H.-A. Schoon

Chronic endometritis in an Asian elephant (*Elephas maximus*)

Journal of Zoo and Wildlife Medicine 39 (2008) 107–110

Abstract. A 48-yr-old female Asian elephant with a history of pododermatitis developed recurrent hematuria beginning in 2002. Transrectal ultrasonography and endoscopic examination in 2004 identified the uterus as the source of hematuria and excluded hemorrhagic cystitis. Treatment with Desloreline implants, antibiotics, and homeopathic drugs led to an improved general condition of the elephant. In July 2005, the elephant was suddenly found dead. During necropsy, the severely enlarged uterus contained about 250 L of purulent fluid, and histopathology revealed ulcerative suppurative endometritis with high numbers of *Streptococcus equi* ssp. *zooepidemicus* and *Escherichia coli* identified on aerobic culture. Additional findings at necropsy included: multifocal severe pododermatitis, uterine leiomyoma, and numerous large calcified areas of abdominal fat necrosis. Microbiologic culture of the pododermatitis lesion revealed the presence of *Streptococcus agalactiae*, *Streptococcus equi* ssp. *zooepidemicus*, *Staphylococcus* sp., *Corynebacterium* sp., and *Entercoccus* sp. © 2008 American Association of Zoo Veterinarians.

B. Drews, R. Hermes, F. Göritz, C. Gray, J. Kurz, I. Lueders & T.B. Hildebrandt

Early embryo development in the elephant assessed by serial ultrasound examinations

Theriogenology 69 (2008) 1120–1128

Abstract. The elephant has an extraordinary long pregnancy, lasting 21 months. However, knowledge on embryo development is limited. To date, only single morphological observations of elephant embryo development associated with placentation are available, all lacking correlation to gestational age. The present study describes morphological characteristics of early embryo development in the elephant with exact biometric staging. Six pregnancies in five Asian and one African elephants with known conception dates were followed by 2D and 3D ultrasound, covering the embryonic period from ovulation to day 116 post-ovulation. The embryonic vesicle was earliest observed was on day 50 p.o. The proper embryo was not detected until day 62 p.o. Embryonic heartbeat was first observed on day 71 p.o. The allantois, which became visible as a single sacculation on day 71 p.o. was subdivided in four compartments on day 76 p.o. By day 95 p.o., head, rump, front and hind legs were clearly distinguished. Between days 95 and 103 p.o. the choriovitelline placenta was replaced by the chorioallantoic placenta. A physiological midgut herniation was transiently present between days 95 and 116 p.o. On the basis of the late appearance of the embryonic vesicle, delayed implantation in the elephant is discussed. The study provides a coherent description of elephant embryonic development, formation of the extraembryonic organs and their role in placenta formation, all of which are of interest for both comparative evolutionary studies and the improvement of assisted reproduction techniques. © 2008 Elsevier Inc. Reprinted with permission from Elsevier.

P. Fernando, E.D. Wikramanayake, H.K. Janaka, L.K.A. Jayasinghe, M. Gunawardena, S.W. Kotagama, D. Weerakoon & J. Pastorini

Ranging behavior of the Asian elephant in Sri Lanka

Mammalian Biology 73 (2008) 2-13

Abstract. We studied the ranging patterns of 10 elephants in and around the Yala protected area complex, southern Sri Lanka, using VHF radio telemetry. All tracked elephants displayed similar

ranging patterns. The observed home ranges were small (mean = 115.2±64.0 km^2) relative to reported home ranges in India, possibly in response to high habitat productivity and abundant perennial water sources. Elephants showed high fidelity to their ranges. Home ranges had relatively large core areas, suggesting intensive use of habitat. No geographically distinct seasonal ranges or migratory behavior was observed. Home range overlap was high, and territoriality was absent. Male musth ranges were considerably larger than non-musth ranges and may signify mate searching. Most elephants ranged both in and outside protected areas, suggesting that resources outside protected areas were important for their survival. Thus, translocating and restricting elephants to protected areas will be detrimental to their survival, as it limits resource access. The ranging patterns of Asian elephants suggest that conservation of the species requires their management both in and outside protected areas. © 2007 Deutsche Gesellschaft für Säugetierkunde.

B.L. Hart, L.A. Hart & N. Pinter-Wollman
Large brains and cognition: Where do elephants fit in?
Neuroscience & Biobehavioral Reviews 32 (2008) 86-98
Abstract. Among terrestrial mammals, elephants share the unique status, along with humans and great apes, of having large brains, being longlived and having offspring that require long periods of dependency. Elephants have the largest brains of all terrestrial mammals, including the greatest volume of cerebral cortex. In contrast to what one might expect from such a large-brained species, the performance of elephants in cognitive feats, such as tool use, visual discrimination learning and tests of ‘‘insight’’ behavior, is unimpressive in comparison to the performance by chimpanzees and, of course, humans. Where elephants do seem to excel is in long-term, extensive spatial-temporal and social memory. In addition, elephants appear to be somewhat unique among non-human species in their reactions to disabled and deceased conspecifics, exhibiting behaviors that are mindful of ‘‘theory-of-mind’’ phenomena. Information gleaned from studies on the neural cytoarchitecture of large brains reveals that the neurons of the cerebral cortex of elephants are much less densely populated than in large-brained primates. The interactions between cortical neurons would appear to be more global and less compartmentalized into local areas, and cortical information processing slower, than in great apes and humans. Although focused neural cytoarchitecture studies on the elephant are needed, this comparative perspective on the cortical neural cytoarchitecture appears to relate to differences in behavior between elephants and their primate counterparts. © 2007 Elsevier Ltd. Reprinted with permission from Elsevier.

N. Irie-Sugimoto, T. Kobayashi, T. Sato & T. Hasegawa
Evidence of means–end behavior in Asian elephants (*Elephas maximus*)
Animal Cognition 11 (2008) 359–365
Abstract The present study explores to what extent Asian elephants show “means–end” behavior. We used captive Asian elephants (*N* = 2) to conduct four variations of the Piagetian “support” problem, which involves a goal object that is out of reach, but rests on a support within reach. In the first condition, elephants were simultaneously presented with two identical trays serving as the “support”, with the bait on one tray and the other tray left empty. In the next two conditions, the bait was placed on one tray, while additional bait was placed beside the other tray. In the last condition, both trays contained bait, but one of the trays had a small gap which prevented the elephants from reaching the reward. Subjects were required to choose and pull either tray with their trunk and to obtain the bait (i.e. goal). Results showed that one elephant performed all of the support problems significantly above chance after several sessions, suggesting that the elephant was capable of understanding that pulling the tray was the “means” for achieving the “end” of obtaining the bait. This study showed that elephants show means–end behavior when subjected to a Piagetian “support” task, and indicates that such goal-directed behavior occurs in species other than primates. © 2007 The Authors.

C. Kongrit, C. Siripunkaw, W.Y. Brockelman, V. Akkarapatumwong, T.F. Wright & L.S. Eggert
Isolation and characterization of dinucleotide

microsatellite loci in the Asian elephant (*Elephas maximus*)

Molecular Ecology Resources 8 (2008) 175–177

Abstract. The endangered Asian elephant is found today primarily in protected areas. We characterized 18 dinucleotide microsatellite loci in this species. Allelic diversity ranged from three to eight per locus, and observed heterozygosity ranged from 0.200 to 0.842 in a wild population. All loci were in Hardy–Weinberg equilibrium, but linkage disequilibrium was detected between two loci in the wild, but not in the zoo elephants. These loci will be useful for the population-level studies of this species. © 2007 Blackwell Publishing Ltd.

P. Leimgruber, B. Senior, Uga, Myint Aung, M.A. Songer, T. Mueller, C. Wemmer & J.D. Ballou

Modeling population viability of captive elephants in Myanmar (Burma): implications for wild populations

Animal Conservation 11 (2008) 198–205

Abstract. Captive Asian elephants *Elephas maximus*, used as work animals, constitute up to 22–30% of remaining Asian elephants. Myanmar has the largest captive population worldwide (~6000), maintained at this level for over a century. We used published demographic data to assess the viability of this captive population. We tested how this population can be self-sustained, how many elephants must be supplemented from the wild to maintain it, and what consequences live capture may have for Myanmar's wild population. Our results demonstrate that the current captive population is not self-sustaining because mortality is too high and birth rates are too low. Our models also suggest ~100 elephants year^{-1} have been captured in the wild to supplement the captive population. Such supplementation cannot be supported by a wild population of fewer than 4000 elephants. Given the most recent expert estimate of ~2000 wild elephants remaining in Myanmar, a harvest of 100 elephants year^{-1} could result in extinction of the wild population in 31 years. Continued live capture threatens the survival of wild and captive populations and must stop. In addition, captive breeding should be increased. These measures are essential to slow the decline and extinction of all of Myanmar's elephants. © 2008 The Zoological Society of London. Reprinted with permission from Blackwell Publishing.

L. Lin, L. Zhang, L. Feng, X. Guo, J. Zhao & J. Dao

A preliminary study on designing ecological corridors in Xishuangbanna National Nature Reserve with 3S techniques

Frontiers of Biology in China 3 (2008) 101–105

Abstract. This paper is based on the fieldwork in Xishuangbanna Natioanl Nature Reserve in Yunnan Province of China. GPS data of Asian elephants were collected and analyzed with the remote sensing satellite photos of the region to estimate the landform physiognomy of different colors. We also analyzed a series of ecological factors including altitude, landform, relief, villages and roads which affected the distribution and movement of Asian elephants. The results suggested the possibility of designing and establishing corridors in Xishuangbanna National Nature Reserve to protect the population of wild elephants in the region. © 2008 Higher Education Press and Springer-Verlag. With kind permission from Springer Science and Business Media.

C.E. Miller, C. Basu, G. Fritsch, T. Hildebrandt & J.R. Hutchinson

Ontogenetic scaling of foot musculoskeletal anatomy in elephants

Journal of the Royal Society Interface 5 (2008) 465-475

Abstract. This study quantifies the shape change in elephant manus and pes anatomy with increasing body mass, using computed tomographic scanning. Most manus and pes bones, and manus tendons, maintain their shape, or become more gracile, through ontogeny. Contrary to this, tendons of the pes become significantly more robust, suggesting functional adaptation to increasingly high loads. Ankle tendon cross-sectional area (CSA) scales the highest in the long digital extensor, proportional to body mass$^{1.08\pm0.21}$, significantly greater than the highest-scaling wrist tendon (extensor carpi ulnaris, body mass$^{0.69\pm0.09}$). These patterns of shape change relate to the marked anatomical differences between the pillar-like manus and tripod-like pes, consistent with differences in fore- and hindlimb locomotor function. The

cartilaginous predigits (prepollux and prehallux) of the manus and pes also become relatively more robust through ontogeny, and their pattern of shape change does not resemble that seen in any of the 10 metacarpals and metatarsals. Their CSAs scale above isometry proportional to body $mass^{0.73\pm0.09}$ and body $mass^{0.82\pm0.07}$ respectively. We infer a supportive function for these structures, preventing collapse of the foot pad during locomotion. © 2007 The Royal Society.

A. Moss, D. Francis & M. Esson

The relationship between viewing area size and visitor behavior in an immersive Asian elephant exhibit

Visitor Studies 11 (2008) 26-40

Abstract. Immersive exhibits are increasingly popular in zoos, being seen as benefiting both animals and visitors. Multiple, discreet viewing areas are one of the key features of immersive zoo exhibits. Small, discreet viewing areas afford the visitor a very personal and intimate experience and may promote an affiliative response between the visitor and the animals on display, thus enhancing the immersive experience. This investigation sought to determine the effect of these viewing areas on visitor behavior, particularly in exhibits where the same animals could be viewed from different-sized viewing areas. This study in the Elephants of the Asian Forest exhibit at Chester Zoo, used unobtrusive visitor tracking to investigate how visitors behave at the exhibit's different-sized viewing areas. The results show that visitors are much more likely to stop, and stay for longer, at the largest viewing areas. Furthermore, there appears to be a proportional increase in visitor interest with increasing viewing area size. These findings have implications for zoo exhibit designers, particularly on the order in which viewing areas should be positioned. © 2008 Visitor Studies Association.

C.A. Oliveira, E.C.G. Felippe & M.O.M. Chelini

Serum cortisol and progestin concentrations in pregnant and non-pregnant Asian elephants (*Elephas maximus*)

Research in Veterinary Science 84 (2008) 361–363

Abstract. Blood samples were collected during the estrous cycle (n = 3), throughout gestation (n = 3), and during the periparturient period (n = 11) to assess serum concentrations of cortisol in pregnant and non-pregnant Asian elephants whose reproductive status was being monitored by serum progestin determination. While serum cortisol concentrations remained constant throughout gestation, progestin concentrations decreased significantly ($p < 0.05$) in the second half of pregnancy, declining to undetectable levels by 3 days before calving. During the non-luteal phase of the estrous cycle serum progestins varied from undetectable levels to 100 pg/ml (53 ± 10.7 pg/ml) then increased steadily during the luteal phase (322 ± 207.5 pg/ml). There were no significant differences between serum cortisol concentrations during the luteal and those of the non-luteal phase ($p > 0.05$). The mean cortisol concentration during the estrous cycle was about twice that during pregnancy ($p > 0.05$). No substantial changes in maternal cortisol were found during the course of pregnancy or the periparturient period. © 2007 Elsevier Ltd. Reprinted with permission from Elsevier.

N.M.B. Pradhan, P. Wegge, S.R. Moe & A.K. Shrestha

Feeding ecology of two endangered sympatric megaherbivores: Asian elephant *Elephas maximus* and greater one-horned rhinoceros *Rhinoceros unicornis* in lowland Nepal

Wildlife Biology 14 (2008) 147-154

Abstract. We studied the diets of low-density but increasing populations of sympatric Asian elephants *Elephas maximus* and greater one-horned rhinoceros *Rhinoceros unicornis* in the Bardia National Park in lowland Nepal. A microhistological technique based on faecal material was used to estimate the seasonal diet composition of the two megaherbivores. Rhinos ate more grass than browse in all seasons, and their grass/browse ratio was significantly higher than that of elephants. Both species ate more browse in the dry season, with bark constituting an estimated 73% of the elephant diet in the cool part of that season. Diet overlap was high in the resource-rich monsoon season and lower in the resource-poor dry season, indicating partitioning of food between the two species in the period of resource limitation. Both species consumed

large amounts of the floodplain grass *Saccharum spontaneum*, particularly during the monsoon season. As the numbers of both species increase, intraspecific and interspecific competition for *S. spontaneum* in the limited floodplains is likely to occur. Owing to their higher grass diet and more restricted all-year home ranges within the floodplain habitat complex, rhinos are then expected to be affected more than elephants. © 2008 Wildlife Biology.

A. Ramanathan & A. Mallapur

A visual health assessment of captive Asian elephants (*Elephas maximus*) housed in India

Journal of Zoo and Wildlife Medicine 39 (2008) 148–154

Abstract. A visual health assessment and survey questionnaire was conducted on 81 Asian elephants (*Elephas maximus*) housed in 10 animal facilities throughout India between November 2004 and February 2005. The survey questionnaire consisted of 10 questions that evaluated the health of the elephants, and they were completed after visually assessing each individual elephant. The information collected was ranked on a scale that was used to statistically compare the health among the study subjects. This study documented that 43.21% of the captive elephants surveyed exhibited hyperkeratosis. A significant proportion of the elephants owned by tourist camps had poor skin condition when compared with elephants from zoos and at a forest camp. Similarly, captive-born individuals were found to have better skin condition than animals that were caught from the wild. Sixty (74.1%) of the captive elephants that were observed during this study had fissures in their footpads, 20% of which were severe. The prevalence of foot fissures was significantly higher in females. A greater proportion of elephants owned by tourist camps displayed vertical and horizontal toenail cracks in comparison with the forest camp and zoo elephants. It was noted that 76.9% of the wounded animals and 80% of those having abscesses were housed at temples and tourist camps. Also, approximately 8.5% of the captive elephant population observed during this study had eye-related problems, and they were all housed at temples and tourist camps. In conclusion, it was evident that elephants housed at temples or tourist camps exhibited poor skin condition with wounds and abscesses. These findings suggest that the overall condition of the elephants housed at tourist camps was poor compared with elephants housed at zoos and at the forest camp. © 2008 American Association of Zoo Veterinarians.

L. Ren & J.R. Hutchinson

The three-dimensional locomotor dynamics of African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants reveal a smooth gait transition at moderate speed

Journal of the Royal Society Interface 5 (2008) 195-211

Abstract. We examined whether elephants shift to using bouncing (i.e. running) mechanics at any speed. To do this, we measured the three-dimensional centre of mass (CM) motions and torso rotations of African and Asian elephants using a novel multisensor method. Hundreds of continuous stride cycles were recorded in the field. African and Asian elephants moved very similarly. Near the mechanically and metabolically optimal speed (a Froude number (Fr) of 0.09), an inverted pendulum mechanism predominated. With increasing speed, the locomotor dynamics quickly but continuously became less like vaulting and more like bouncing. Our mechanical energy analysis of the CM suggests that at a surprisingly slow speed (approx. 2.2 ms^{-1}, Fr 0.25), the hindlimbs exhibited bouncing, not vaulting, mechanics during weight support. We infer that a gait transition happens at this relatively slow speed: elephants begin using their compliant hindlimbs like pogo sticks to some extent to drive the body, bouncing over their relatively stiff, vaulting forelimbs. Hence, they are not as rigid limbed as typically characterized for graviportal animals, and use regular walking as well as at least one form of running gait. © 2007 The Royal Society.

C. Thitaram, J.L. Brown, P. Pongsopawijit, S. Chansitthiwet, W. Wongkalasin, P. Daram, R. Roongsri , A. Kalmapijit, S. Mahasawangkul, S. Rojansthien, B. Colenbrander, G.C. van der Weijden & F.J.C.M. van Eerdenburg

Seasonal effects on the endocrine pattern of semi-captive female Asian elephants (*Elephas*

maximus): Timing of the anovulatory luteinizing hormone surge determines the length of the estrous cycle
Theriogenology 69 (2008) 237–244

Abstract. Better breeding strategies for captive Asian elephants in range countries are needed to increase populations; this requires a thorough understanding of their reproductive physiology and factors affecting ovarian activity. Weekly blood samples were collected for 3.9 years from 22 semi-captive female Asian elephants in Thai elephant camps to characterize LH and progestin patterns throughout the estrous cycle. The duration of the estrous cycle was 14.6 ± 0.2 weeks (mean ± S.E.M.; n = 71), with follicular and luteal phases of 6.1 ± 0.2 and 8.5 ± 0.2 weeks, respectively. Season had no significant effect on the overall length of the estrous cycle. However, follicular and luteal phase lengths varied among seasons and were negatively correlated (r = –0.658; P < 0.01). During the follicular phase, the interval between the decrease in progestin concentrations to baseline and the anovulatory LH (anLH) surge varied in duration (average 25.9 ± 2.0 days, range 7–41, n = 23), and was longer in the rainy season (33.4 ± 1.8 days, n = 10) than in both the winter (22.2 ± 4.5 days, n = 5; P < 0.05) and summer (18.9 ± 2.6 days, n = 8; P < 0.05). By contrast, the interval between the anLH and ovulatory LH (ovLH) surge was more consistent (19.0 ± 0.1 days, range 18–20, n = 14). Thus, seasonal variation in estrous cycle characteristics were mediated by endocrine events during the early follicular phase, specifically related to timing of the anLH surge. Overall reproductive hormone patterns in Thai camp elephants were not markedly different from those in western zoos. However, this study was the first to more closely examine how timing of the LH surges impacted estrous cycle length in Asian elephants. These findings, and the ability to monitor reproductive hormones in range countries (and potentially in the field), should improve breeding management of captive and semi-wild elephants.

N. Thongtip, J. Saikhun, S. Mahasawangkul, K. Kornkaewrat, P. Pongsopavijitr, N. Songsasen & A. Pinyopummin
Potential factors affecting semen quality in the Asian elephant (*Elephas maximus*)
Reproductive Biology and Endocrinology 6 (2008) 9.

Abstract. Background: One of the major obstacles in using artificial insemination to manage genetics of elephant population in captivity is the large variations in semen quality among ejaculates within the same and among individuals. The objectives of this study were to determine the influences of (1) age (2) seasonality (3) and circulating testosterone (SrTest), triiodothyronine (SrT3) and tetraiodothyronine (SrT4), as well as seminal (4) testosterone (SpTest), zinc (SpZn) and protein (SpTP) on semen quality in the Asian elephant. Methods: Analyses, including motility, viability and morphology were performed in semen samples collected twice monthly from 13 elephant bulls (age range, 10-to 72-years) by manual stimulation between July 2004 and June 2005. Serum samples obtained monthly were assessed for SrTest, SrT3, SrT4, and seminal plasma samples were evaluated for, SpTest, SpZn and SpTP. Results: The highest semen quality was observed at age 23 to 43 years. Percentages of progressive motility and viable sperm were lowest at age 51 to 70 years (P < 0.05); on the other hand, sperm concentration was lowest at age 10 to 19 years (P < 0.05). Percentage of sperm with normal morphology was highest at age 23 to 43 years. The levels of SrT3, SrTest, SpTest and SpZn were lowest at age 51 to 70 years, whereas SrT4 was lowest at age 23 to 43 years. Seasonality significantly affected semen characteristics in which percentage of viable sperm and cell concentration were highest during rainy season and lowest during summer months (P < 0.05). However, percentage of sperm with normal morphology was highest in summer and lowest in rainy season (P < 0.05). Seasonality significantly influenced SrTest with elevated concentrations observed in rainy season and winter (P < 0.05). Conclusion: This study indicates that age and seasonality had influence on semen characteristics in the Asian elephant. The knowledge obtained in this study will improve our understanding of the reproductive biology of this species.

J.H. van der Kolk, J.P.T.M. van Leeuwen, A.J.M. van den Belt, R.H.N. van Schaik & W. Schaftenaar

Subclinical hypocalcaemia in captive Asian elephants (*Elephas maximus*)

Veterinary Record 162 (2008) 475-479

Abstract. The hypothesis that hypocalcaemia may play a role in dystocia in captive Asian elephants (*Elephas maximus*) was investigated. The objectives of the study were to measure the total calcium concentration in elephant plasma; assess the changes in parameters of calcium metabolism during a feeding trial; investigate a possible relationship between calcium metabolism and dystocia; and assess bone mineralisation in captive Asian elephants in vivo. The following parameters were measured: total and ionised calcium, inorganic phosphorous and magnesium, the fractional excretions of these minerals, intact parathyroid hormone, 25-OH-D3 and 1,25-OH-D3. Radiographs were taken from tail vertebrae for assessment of bone mineralisation. The mean (sd) heparinised plasma total calcium concentration was 2.7 (0.33) mmol/l (n=43) ranging from 0.84 to 3.08 mmol/l in 11 Asian elephants. There was no significant correlation between plasma total calcium concentration and age. Following feeding of a calcium rich ration to four captive Asian elephant cows, plasma total and ionised calcium peaked at 3.6 (0.24) mmol/l (range 3.4 to 3.9 mmol/l) and 1·25 (0.07) mmol/l (range 1.17 to 1.32 mmol/l), respectively. Plasma ionised calcium concentrations around parturition in four Asian elephant cows ranged from 0.37 to 1.1 mmol/l only. The present study indicates that captive Asian elephants might be hypocalcaemic, and that, in captive Asian elephants, the normal plasma concentration of total calcium should actually be around 3.6 mmol/l and normal plasma concentration of ionised calcium around 1.25 mmol/l. Given the fact that elephants absorb dietary calcium mainly from the intestine, it could be concluded that elephants should be fed calcium-rich diets at all times, and particularly around parturition. In addition, normal values for ionised calcium in captive Asian elephants should be reassessed. © 2008 British Veterinary Association.

S. Varma

Spatial distribution of Asian elephant (*Elephas maximus*) and its habitat usage pattern in Kalakad–Mundanthurai Tiger Reserve, Western Ghats, southern India

Current Science 94 (2008) 501-506

Abstract. The study demonstrates the value of short term, but rapid surveys in understanding the spatial pattern of distribution of the Asian elephant (*Elephas maximus*) and its habitat usage pattern in the Kalakad–Mundanthurai Tiger Reserve, Western Ghats, southern India. Results indicated that the elephants use the habitat uniformly throughout the reserve, since encounter rates of elephant dung piles were found to be similar for most of the routes surveyed. However, data on fresh dung piles, indicative of presence of elephants at any given point of time and space, pointed to a clumped distribution. With respect to habitat use, 60% of elephant signs were recorded in the evergreen forests, 13% in grasslands and 12% in evergreen and reed belts. However, a comparison of dung density indicates a significant difference ($P < 0.0000$) across the habitats and the elephant densities appear to be more in the grasslands. The elevation of the reserve ranged from 40 to 1867 m; however, presence of elephants was limited to altitudes ranging from 300 to 1300 m, out of which 90% was restricted to altitudes ranging between 600 and 1200 m. © 2008 Current Science.

S. Varma, N.X. Dang, T. Van Thanh & R. Sukumar

The Asian elephants *Elephas maximus* of Cat Tien National Park, Vietnam: status and conservation of a vanishing population

Oryx 42 (2008) 92–99

Abstract. This study updates the status and conservation of the Endangered Asian elephant *Elephas maximus* in Cat Tien National Park, Vietnam. Line transect indirect surveys, block surveys for elephant signs, village surveys of elephant-human conflict incidents, guard-post surveys for records of sightings, and surveys of elephant food plants were undertaken during the dry and wet seasons of 2001. A minimum of 11 elephants and a maximum of 15-17 elephants was estimated for *c*. 500 km^2 of the Park and its vicinity. The elephants are largely confined to the southern boundary of the Park and make extensive use of the adjoining La Nga State Forest Enterprises.

During the dry season the elephants depend on at least 26 species of wild and cultivated plants, chiefly the fruits of cashew. Most of the villages surveyed reported some elephant-human conflict. Two adult male elephants seem to cover a large area to raid crops, whereas the family groups restrict themselves to a few villages; overall, the conflict is not serious. Since 2001 there have been no reports of any deaths or births of elephants in the Park. We make recommendations for habitat protection and management, increasing the viability of the small population, reducing elephant-human conflicts, and improving the chances of survival of the declining elephants of this Park. The Government has now approved an Action Plan for Urgent Conservation Areas in Vietnam that calls for the establishment of three elephant conservation areas in the country, including Cat Tien National Park.

E.B. Wiedner, C. Gray, P. Rich, G.L. Jacobson, R. Isaza, D. Schmitt & W.A. Lindsay

Nonsurgical repair of an umbilical hernia in two Asian elephant calves (*Elephas maximus*)

Journal of Zoo and Wildlife Medicine 39 (2008) 248–251

Abstract. Umbilical hernias were diagnosed in two captive-born, female Asian elephant (*Elephas maximus*) calves several weeks after birth. Daily manual reduction of the hernias for 5 wk in the first case and for 5 mo in the second resulted in complete closure of the defects. Nonsurgical repair of uncomplicated, fully reducible umbilical hernias in Asian elephants can be an alternative to surgery.

L. Yon, J. Chen, P. Moran & B. Lasley

An analysis of the androgens of musth in the Asian bull elephant (*Elephas maximus*)

General and Comparative Endocrinology 155 (2008) 109–115

Abstract. During musth in bull elephants, the androgens testosterone (T), dihydrotestosterone (DHT), and androstenedione all increase significantly. Given the unusual endocrine physiology that has been discovered in female elephants, it is also possible that bull elephants produce some unusual androgens. A cell-based androgen receptor assay was used to explore this possibility using two different methods. The first method compared the level of T measured by radioimmunoassay (RIA) with the level of androgen receptor (AR) activity measured in the serum of eight bull elephants during musth and non-musth periods. A ratio was calculated for T/AR activity for non-musth and musth, to determine if there was a change in the ratio between these two states. The second method used HPLC to separate two pooled serum samples (one non-musth and one musth) into fractions using a protocol which separates known androgens into specific, previously identified fractions. Each fraction was then tested with the AR assay to determine the androgenicity of any compounds present. This was done to determine if there were any fractions which had androgenic activity but did not contain any previously identified androgens. Results from the first analysis indicated no change in the T/AR ratio between non-musth and musth states. Clearly whatever active androgens are present during musth, they increase proportionately with T. Findings from the second analysis suggested that the only bioactive androgen present in the serum of non-musth Asian bulls is a low level of T. During musth, the only bioactive androgens detected were T and DHT; of these, T was by far the predominant active androgen present. Taken together, these two analyses suggest that T is by far the predominant active androgen present during musth in Asian bull elephants, and that no previously unidentified bioactive androgen is present.

If you need additional information on any of the articles in the above section, please feel free to contact me. If you are aware of a new publication on Asian elephants (in 2008), let us know the reference and we will consider its inclusion in the next *Gajah*.

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Book Review

"Tranquil Footsteps" by Srilal Miththapala

Reviewed by Namali Premawardhana

It is quite a feat to get inside an elephant's mind, to discover without interaction with the imposing and intimidating animal, the trials and tribulations it faces in daily life; its wants and needs. "Tranquil Footsteps" is one man's effort to help us achieve that. Through his book, which follows one herd of elephants living within the sanctuary of the Uda Walawe National Park, Srilal Miththapala not only affords the reader valuable and interesting information about this most majestic member of the animal kingdom, but also gives him insight into the creature's mind and heart.

The story is told through the eyes of the matriarch of this aprticular herd of elephants. We follow her, together with her family, through the drought, pain and death into monsoons, growth and life. During this journey, many times does one find oneself stopping suddenly to realise the important, yet almost forgotten fact that these are elephants the author writes of. He manages, deftly to portray the different members of the herd with their different characteristics in such a familiar manner, that quite often they seem to be human.

In rare moments of inspiration the narration puts the reader right in the elephant's skin (four feet, trunk and all!) clearly exemplifying the author's connection with, and love for, these majestic creatures. Yet sometimes the writer seems to be disconnected from the speaker (obviously as one is a she-elephant and the other is a he-man) and the transition between the engaged narration and the disengaged narration as seen in the transition between fact and fiction is not always smooth.

The book is a great balance of fact and fiction, but the two aspects don't always gel together. Added to this is the fact that some explanations tend to be repeated. But as it promises, the book DOES "appeal to a wide range of readers". On the one hand, the lifestyle, social patterns and peculiar habits of elephants are described from the basics to a degree of detail, which would thrill an average wild-life fan. On the other, a smattering of beautiful thoughts and expressions, combined with a moving, although at times disjointed storyline holds the general reader until the end.

Srilal Miththapala is a "serious wild-life and nature enthusiast", a scientist, hotelier and engineer. The man in the book is definitely the nature-man though sometimes it's difficult to say whether it is the "fan" or the "scientist". Both these sides of the author are seen clearly in the book, yet the last and most beautiful episode in the book shows an even deeper side to him.

In the fleeting moment of friendship and real communication between the youngest elephant in the herd and two young children visiting the park, Srilal Miththapala comes out as a friend, a sort of goodwill ambassador or peacemaker between elephants and man. He manages to convey a deeper message than what amazing creatures the elephants are: that they are simply living beings that crave the same things we do: love and protection.

Tranquil Footsteps
Srilal Miththapala (2008)
Stamford Lake
145 pages, ISBN 978-955-1131-87-8

News Briefs

Compiled by the Editor

News Briefs

1. HC admits PIL on man-elephant conflict (India)

Assam Tribune
February 22, 2008

The Gauhati High Court today admitted a public interest litigation (PIL) on protection and conservation of wild elephants arising out of frequent human-elephant conflicts and for protection of human life and property from elephant depredations in the State.

The Division Bench of Chief Justice Jasti Chelameswar and Justice Hrishikesh Roy, while admitting the petition (WP-C – PIL No 06 of 2008) issued notices to the respondents who include State's Forest Commissioner and Secretary, State's Principal Chief Conservator of Forests (Wildlife)—who is also the Chief Wildlife Warden of the State, Assam Union Environment and Forest Secretary, Director General of the Union Department of Environment and Forest,. The court also fixed April 7 next as the next date for the case.

In his petition, noted elephant handler and owner Bijoyananda Chowdhury said interalia on behalf of the public charitable trust Human Elephant Learning Programme (HELP) that due to the apathy of the State Forest Department there had been a gradual aggravation of the natural habitat of the wild elephants. This has resulted in frequent human-elephant conflicts. The herds of wild elephants are frequently intruding into the human habitations causing massive damages to property and incidents of killing human beings are also taking place frequently in the State.

The damages so caused frequently lead to fierce retaliation through poisoning the wild elephants by the affected people. Though such incidents are on the rise, the State authorities concerned are not taking any substantial step to stop the recurrence of such incidents, said Chowdhury, a founder executive member of the charitable trust.

Though the Government of India has issued circulars to the states and Union Territories suggesting, interalia, the minimum compensations to the victims of wild animal attacks and accordingly, a number of States and Union territories had implemented such guidelines. The Government of India had instructed all the State Governments and Union Territory authorities to raise the amount of compensation to the kin of those killed by wild animals to Rs 1 lakh per person way back in 1999, Chowdhury said.

However, Assam is far from implementing such guidelines and this particularly has impaired the wild elephant conservation in the State. This is despite the fact that Assam accounts for more than fifty per cent of the total elephant population of the country, Chowdhury said.

He said that while Assam Government is paying compensation at the rate of Rs 40,000 to the kin of each of those killed by wild elephants, Andhra Pradesh Government is paying Rs 1 lakh since 2003. The Government of this South Indian state has now proposed to raise the compensation amount to Rs 2.5 lakh per person. The Maharastra Government is paying Rs 2 lakh to the kin of each of those killed by wild animals, while the Governments of the Tamil Nadu, Karnataka and Meghalaya are also paying compensation at the rate of Rs 1 lakh per person in such cases, Chowdhury claimed. Chowdhury himself pleaded his case in the court today.

2. Myanmar's wild elephants helping cut down their forest habitat

Agence France Presse
February 18, 2008

Elephants in Myanmar have long been invaluable labourers in the country's timber industry, nimbly finding their way through forests and dragging heavy fallen trees to rivers for shipping. But as Myanmar's ruling junta expands logging in the country's teak forests, more wild elephants are being captured and trained for clear-cutting operations that destroy the very habitats in which they roamed freely, activists and industry insiders say.

"On account of the loss and fragmentation of their habitats, the size of the wild elephant population has declined," said Uga, chairman of local environmental group Biodiversity and Nature Conservation Association. "To obtain elephant power for logging, wild elephants are being captured and recruited," said Uga, who uses only one name.

Employing elephants is normally more environmentally friendly than using heavy machinery, which requires roads cut into forests, which cause more damage than elephants would. About 4,500 elephants are believed to be working in the logging industry, including 2,500 owned by the state-run Myanmar Timber Enterprise (MTE), Uga said.

As logging operations have dramatically expanded, especially in remote regions of northern Myanmar near the Chinese border, some companies are turning to private entrepreneurs to capture and train elephants, business owners said. One owner of domesticated elephants in Taungoo, about 150 miles (240 kilometres) north of Myanmar's commercial capital Yangon, said that 100 elephants had left in June to work on a timber operation in Sagaing province, hundreds of miles to the north.

Speaking on condition of anonymity, he said the elephants had been loaded into trucks to work for a company making veneers and plywood for export. He had one elephant in the group, which he said was taken on a three-year rental agreement to clear cut forests to make way for new towns in so-called replacement areas, where villagers are being relocated to make way for the Tamanthi hydropower project.

The dam on the Chindwin river, in a remote corner of northwestern Myanmar, will provide electricity mainly for export to neighbouring India. Ethnic minority groups in the region estimate that at least 35 villages will need to be relocated.

Officially, the MTE uses a selective felling system for its logging and employs elephants to drag the logs to the nearest waterways for transport. Under that system, only the most mature trees are logged, leaving younger ones to keep growing in a cycle meant to last 25-30 years. But the government has openly started clear-cutting forests as it embarks on the Tamanthi project and other dams around the country, with neighbours China and Thailand financing much of the construction.

One retired MTE official told AFP that orders to follow selective felling guidelines were often ignored. "Deforestation would not be occurring if we used the selective-felling system, adhering to the forestry law," he said on condition of anonymity. "But the advice of experts is ignored... by orders from the government."

According to the most recent estimates, some 1.5 million cubic metres (53 million cubic feet) of timber worth 350 million dollars was exported from Myanmar to China in 2005, most of it illegal, according to Britain-based forestry watchdog Global Witness. That was a 12 percent gain over the year before, and roughly double the amount exported in 2000, the group said.

Much of the logging takes place in remote areas of the country where it's impossible for outside experts to assess the extent of the environmental damage, but activists have long warned of the devastating consequences. "This is a particularly destructive approach to logging that causes huge environmental damage," said Mike Davis of Global Witness. For the elephants working in logging, the clear cutting means they are assisting in the destruction of their own habitat, Uga said. "Wild elephants are running out of pasture in the forests," he said. "Elephant conservation is important. We should follow forestry law to protect wild elephants as well as to protect the forest".

3. Thailand a key player in illegal wildlife trade

Apinya Wipatayotin, Bangkok Post
March 1, 2008

Thailand is a key player in the wild elephant trade, with the country being used as a transit point for jumbos from neighbouring countries on their way to foreign zoos, according to a report from the Thai Wildlife Protection Network.

Nikom Puttha, the network coordinator who commissioned the report on the wildlife situation in Thailand in 2007, said wild elephant calves from Burma are transported to Thailand via five border districts - Mae Sariang, Mae La Noi and Sop Moei districts in Mae Hong Son and Umphang and Phop Phra in Tak. It is estimated that at least 50 elephants are being smuggled from Burma to Thailand each year. The smugglers then apply for registration documents from authorities to certify they are captive elephants. The documents enable wildlife traders to legally move their animals to elephant shelters where they are trained for three years before being sent to foreign zoos.

‘’We have found that 70% of them will be trained at shelters in the northeastern provinces, such as Surin and Chaiyaphum, while 30% of them will be sent to elephant shelters in the North,’’ said Mr Nikom. Twenty per cent of the smuggled elephants die during transportation, the study has found. Mr Nikom urged the government to strengthen law enforcement to prevent the illegal trade of wild elephants and other wild animals.

Soraida Salwala, Secretary-General of Friends of the Asian Elephant, said the elephant export business grew rapidly after the controversial export of nine elephants to Australian zoos in 2006. The exports, she said, had set the precedence that wild animal exports for ‘’research and study’’ purposes under government-to-government contracts are acceptable. She added that Thailand exported four elephants to Germany, five to China and 11 to Malaysia last year.

Wildlife activists recently stopped the transportation of 30 elephants to China via Laos. ‘’And as far as we know, China has ordered some 300 elephants from Thailand to entertain visitors at the Olympic Games.

The newly-released report also found that the country is still a regional hub for the illegal wildlife trade, which mostly takes place in Bangkok, Chon Buri, Chiang Mai, Surat Thani and Tak provinces, where the major markets are. The five most-wanted wild animals are wild birds, turtles, pangolin, the slow loris and the tiger. The top destinations for the wildlife trade are China, Hong Kong, Taiwan, Japan and some EU countries. The wildlife trade is valued at about one billion baht a year, making it the third most profitable illegal business after drug and arms trafficking.

4. Rumble, rumble. Who’s there?

Science NOW Daily News
May 31, 2007

Elephants know the difference between good vibrations and bad, according to new research into the big animals’ low, rumbling alarm calls. They pay attention to seismic waves made by elephants they know and ignore those of strangers.

Behavioral ecologist Caitlin O’Connell-Rodwell of Stanford University in Palo Alto, California, discovered in 2004 that African elephants communicate with each other from kilometers away through ground vibrations. Although they make the calls with their trunks, the sounds also travel several kilometers along the surface of the ground, about as far as airborne sounds. O’Connell-Rodwell witnessed groups of Namibian elephants stopping in their tracks, leaning forward onto their toes, and pressing their trunks to the ground. The animals often adopted this listening posture before the arrival of another group of elephants. O’Connell-Rodwell recorded various elephant calls and found that wild elephants responded to ground vibrations alone. Researchers aren’t sure how elephants detect the waves, but they have vibration-sensitive cells in their feet and trunks.

In the new study, O’Connell-Rodwell asked whether the elephants can tell who is making the alarm calls. So the team recorded alarm calls made by elephants encountering lions in Kenya and Namibia. Then they converted the sounds into seismic waves and played them back to Namibian elephants visiting a water hole. The elephants responded to the Namibian vibrations by freezing, huddling, and leaving the area sooner. The elephants appeared to detect the Kenyan calls--they sometimes paused and looked more alert, for instance--but did not react dramatically. The Namibian elephants also ignored control recordings of synthesized sounds that had similar frequency and duration. The research is slated to appear in the August Journal of the Acoustical Society of America.

The scientists don't know why elephants respond differently to the alarm calls, but O'Connell-Rodwell suspects it is not due to dialect differences. The calls from the two countries are similar in frequency and duration. More likely, she says, is that the elephants trust the calls from animals they know but not those of strangers.

Behavioral ecologist Jan Randall of San Francisco State University in California, who studies kangaroo rats that use foot drumming vibrations to communicate, agrees that the elephants may be gauging the trustworthiness of the calls and heeding only the ones from reliable sources. That might help them avoid expending unnecessary energy responding to bogus calls. But alarm calls are hard to capture in the wild, and the researchers need to test more samples, Randall says. "It's an exciting result and it's really suggestive, but it needs some of the follow-up work to really pin it down."

5. Suspected viral infection kills elephants in Kerala (India)

Times of India
April 28, 2008

A suspected case of viral disease has resulted in the death of two wild elephants in the Wayanad district in Kerala in the last one month. The latest incident was reported from Chithalayam forest range in the district on Saturday. The Chithalayam forest range, 50 km from the district headquarters Kalpetta, borders the Bandipur sanctuary in Karnataka.

"A nine-month-old calf was found in the forest in a very weak condition Friday. The elephant herd was seen trying to help the calf stand upright. Though we tried to help the calf, the herd did not allow us to approach. The next day the calf died," forest range officer T. Pradeep said.

"We did not find any external injuries like snake bite on the carcass," he said. A month earlier a nine-year-old elephant was found dead in the same forest range. According to officials, elephants get stressed and become susceptible to diseases during summer when water and fodder are in short supply. Veterinary experts who examined the carcasses suspect that the deaths were caused by viral infection." There are similarities in both cases. It is a haemorrhagic disease. We are yet to confirm the cause of death. The body parts have been sent for examination.

6. Mob sets 'killer' elephant on fire (India)

Times of India
June 20, 2008

People of a town in Orissa's Keonjhar district executed a barbaric revenge on an elephant that had killed eight people over the last two years.

On Tuesday evening, when the elephant raided the area for fruits, a mob doused it with petrol and set it on fire. Its entire body in flames, the elephant ran wildly in all directions looking for water. But the mob beat drums and threw firecrackers to block its escape routes. Blinded with pain and disoriented, it would crash to its knees, struggle to its feet and run around again.

The elephant was on the verge of collapse when a downpour put out the flames. He was last seen on Wednesday, severely burnt but walking on NH-215. Forest officials said they have no information about the condition of the elephant. "We have no information about this incident. I will definitely start an inquiry," assistant conservator of forests Bimalendu Acharya said.

7. Extinct Javan elephants may have been found again - in Borneo

WWF Press Release
April 17, 2008

The Borneo pygmy elephant may not be native to Borneo after all. Instead, the population could be the last survivors of the Javan elephant race – accidentally saved from extinction by the Sultan of Sulu centuries ago, a new publication suggests.

The origins of the pygmy elephants, found in a range extending from the north-east into the Heart of Borneo, have long been shrouded in mystery. Their looks and behaviour differ from other Asian elephants and scientists have questioned why they never dispersed to other parts of the island. But a new paper published today supports a long-held local belief that the elephants were brought to Borneo centuries ago by the Sultan of Sulu, now in the Philippines, and later abandoned in the jungle. The Sulu elephants, in turn, are thought to have originated in Java.

Javan elephants became extinct some time in the period after Europeans arrived in South-East Asia. Elephants on Sulu, never considered native to the island, were hunted out in the 1800s. "Elephants were shipped from place to place across Asia many hundreds of years ago, usually as gifts between rulers," said Mr Shim Phyau Soon, a retired Malaysian forester whose ideas on the origins of the elephants partly inspired the current research. "It's exciting to consider that the forest-dwelling Borneo elephants may be the last vestiges of a subspecies that went extinct on its native Java Island, in Indonesia, centuries ago."

If the Borneo pygmy elephants are in fact elephants from Java, an island more than 1200 km (800 miles) south of their current range, it could be the first known elephant translocation in history that has survived to modern times, providing scientists with critical data from a centuries-long experiment.

Scientists solved part of the mystery in 2003, when DNA testing by Columbia University and WWF ruled out the possibility that the Borneo elephants were from Sumatra or mainland Asia, where the other Asian subspecies are found, leaving either Borneo or Java as the most probable source.

The new paper, "Origins of the Elephants Elephas Maximus L. of Borneo," published in this month's Sarawak Museum Journal shows that there is no archaeological evidence of a long-term elephant presence on Borneo. "Just one fertile female and one fertile male elephant, if left undisturbed in enough good habitat, could in theory end up as a population of 2000 elephants within less than 300 years," said Junaidi Payne of WWF, one of the paper's co-authors. "And that may be what happened in practice here."

There are perhaps just 1000 of the elephants in the wild, mostly in the Malaysian state of Sabah. WWF satellite tracking has shown they prefer the same lowland habitat that is being increasingly cleared for timber rubber and palm oil plantations. Their possible origins in Java make them even more a conservation priority.

"If they came from Java, this fascinating story demonstrates the value of efforts to save even small populations of certain species, often thought to be doomed," said Dr Christy Williams, coordinator of WWF's Asian elephant and rhino programme. "It gives us the courage to propose such undertakings with the small remaining populations of critically endangered Sumatran rhinos and Javan rhinos, by translocating a few to better habitats to increase their numbers. It has worked for Africa's southern white rhinos and Indian rhinos, and now we have seen it may have worked for the Javan elephant, too."

Appreciation

Professor Jeheskel "Hezy" Shoshani (1943 - 2008)

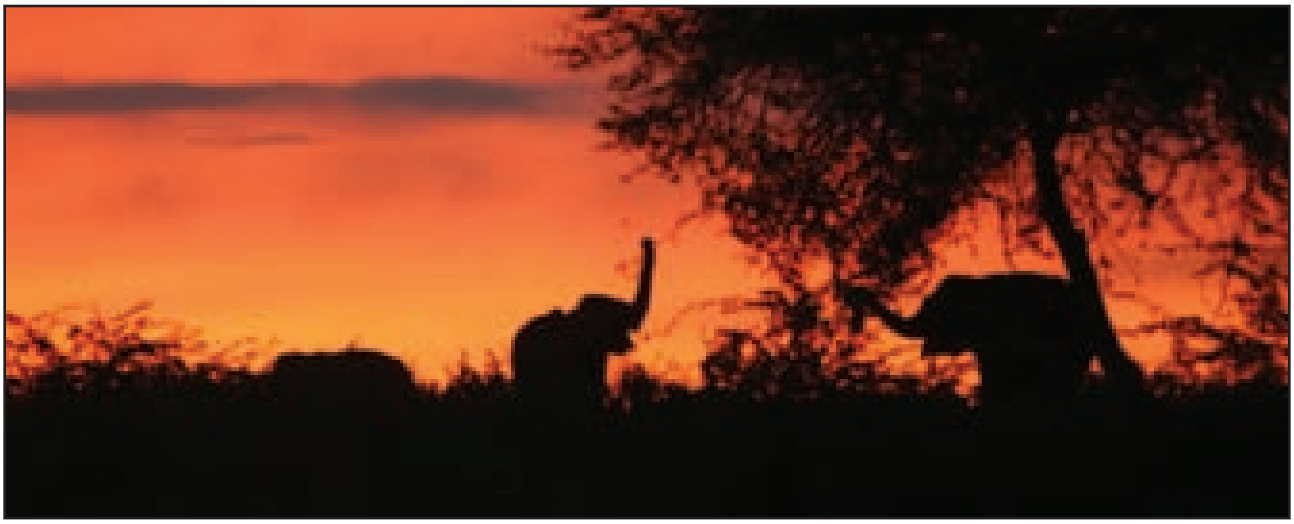
By Simon Hedges

On May 20th, 2008, an explosion in a public minibus in Addis Ababa (Ethiopia) seriously injured Professor Jeheskel "Hezy" Shoshani, 65, and he died later in hospital. A US citizen, Hezy, who was born in Tel Aviv, had been teaching in Addis Ababa for the previous year and a half as well as conducting elephant research in Ethiopia. Before that he spent eight years studying elephants in Eritrea. Throughout this period he also worked tirelessly to safeguard the region's elephants.

Hezy was an internationally renowned elephant expert and one of the world's most passionate protectors of elephants. He was also a much loved mentor to many students in Eritrea and elsewhere.

Hezy became interested in elephants after reading "Burma Boy" by Willis Lindquist. His primary research was on the evolutionary biology of the Proboscidea, especially their anatomy and physiology and how to apply this knowledge to our understanding of elephant behaviour and ecology. His identification of faunal remains found in excavations in Eritrea dating to 800–350 BCE were a major contribution to the prehistory of the Horn of Africa. Hezy published about 200 scientific and popular articles and was the editor of two books on elephants and their relatives: a popular book, "Elephants: Majestic Creatures of the Wild" (2000, Checkmark Books, New York, USA) and a technical volume (with Pascal Tassy), "The Proboscidea: Evolution and Palaeoecology of Elephants and Their Relatives" (1996, Oxford University Press, UK). Prior to his positions in northeast Africa, Hezy taught at Wayne State University in the USA for approximately 25 years. In 1977, he established the Elephant Research Foundation (an international non-profit organization) and was the editor of its publication, "Elephant".

Hezy's great friend Ian Redmond had the following message: "There is nothing I can say to soften the blow of such terrible news – we will all carry memories of Hezy's infectious laugh, thirst for knowledge, and love of life." I only had the pleasure of meeting Hezy once, at last year's CITES Conference in The Hague, although we had corresponded over the years, but like everyone who ever met him I was struck by his sense of humour, his energy, and his dedication to elephant conservation. His untimely death is a great loss for all of us – and for elephants.



Elephants at sunset in southern Sri Lanka (May 2008)
Photo by Prithiviraj Fernando

Instructions for Contributors

Gajah welcomes articles on all aspects of Asian elephants, of interest to those involved in conservation, management and research on Asian elephants and the general public. Articles may include but are not limited to research findings, opinions, commentaries, anecdotal accounts and book reviews. Readers are encouraged to submit comments, opinions and criticisms of articles published in *Gajah*. Such correspondence should be a maximum of 300 words, and will be edited and published at the discretion of the editorial board.

Manuscripts should be in British English and double-spaced on A4 paper. An article may have a maximum of 5000 words.

Tables and figures should be kept to a minimum. Each needs to be on a separate page at the end of the manuscript. Legends should be typed separately (not incorporated into the figure). Use of black and white figures is encouraged to facilitate reproduction. Refer to figures and tables in the text as (Fig. X) and (Table X). Include tables and line drawings in the MS WORD document you submit. Photographs, maps etc. should be submitted as extra files in JPEG or TIFF format.

References should be indicated in the text by the surnames(s) of the author(s) with the year of publication as in the example below:

(Baskaran & Desai 1996; Rajapaksha *et al.* 2004)

If the name forms part of the text, it may be cited as in the following example:

Sukumar (1989) demonstrated that...

Avoid if possible, citing references which are hard to access (e.g. reports, unpublished theses). Format citations in the 'References' section as in the following examples, writing out journal titles in full.

Baskaran, N. & Desai, A.A. (1996) Ranging behavior of the Asian elephant (*Elephas maximus*) in the Nilgiri biosphere reserve, South India. *Gajah* **15:** 41-57.

Olivier, R.C.D. (1978) *On the Ecology of the Asian Elephant*. Ph.D. thesis, University of Cambridge, Cambridge, UK.

Rajapaksha, R.C., Mendis, G.U.S.P. & Wijesinghe, C.G. (2004) Management of Pinnawela elephants in musth period. In: *Endangered Elephants, Past Present and Future*. Jayewardene, J. (ed.) Biodiversity & Elephant Conservation Trust, Colombo, Sri Lanka. pp 182-183.

Sukumar, R. (1989) *The Asian Elephant: Ecology and Management*. Cambridge University Press, Cambridge, UK.

Manuscripts should be submitted by e-mail to the editor <romalijj@eureka.lk>. If unable to do so, a hard copy can be sent to: Jayantha Jayewardene, 615/32 Rajagiriya Gardens, Nawala Road, Rajagiriya, Sri Lanka.

Deadline for submission of manuscripts for the next issue of Gajah is 30st September 2008.

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