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GAJAH is the official journal of the Asian Elephant Specialist Group (AsESG) of the Species Survival Commission (SSC) of the World Conservation Union (IUCN). The journal is intended as a medium for communication by members of the AsESG of important issues that concern the conservation and management of the Asian Elephant (*Elephas maximus*) both in the wild and in captivity. **GAJAH** welcomes communications and research papers on all aspects of the Asian elephant. **GAJAH** is aimed at professionals, biologists and academics carrying out research on Asian elephant, government and non-government organizations involved in its conservation, and interested members of the general public. All articles published in **GAJAH** are deemed to reflect the individual views of the authors and not the official points of view, either of the Asian Elephant Specialist Group (AsESG) or the Species Survival Commission (SSC). **GAJAH** is a non-profit publication that is supported by financial assistance from the U.S. Fish and Wildlife Service.

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Comment

Counting elephants in the wild

People in general are curious to know just how many elephants there are in an area. They are obsessed with numbers. Laymen often make the mistake of assuming that since elephants are so huge that it would be relatively easy to count them accurately in the field. Sometimes the less somebody knows about a subject, the easier they find a solution to it. Unfortunately, it is more difficult to count elephants in a forest than fish in a pond. As Cynthia Moss (1988) who has studied elephants in the wild in East Africa for more than two decades points out, it is precisely because they are so large that we can miss those animals that are either hidden behind the bulk of some huge ones or enclosed within a herd. Even in the grasslands of Sri Lanka where elephants are easily observed, sometimes one has to count a small herd of elephants several times before the exact number of animals can be determined.

To a fishery biologist, the number of fish of a particular species in a pond is important, as it constitutes a biological unit. But for an ecologist studying elephants, the size of an elephant population has very little biological significance, as the population cannot be circumscribed in the absence of clear boundaries. As Graeme Caughley (1977) argues, "density rather than size provides the biologically real measure of abundance", and "the majority of ecological problems can be tackled with the help of density, absolute estimates of density being unnecessary luxuries". Numbers do not represent much more than informed guesses. A population of 100 elephants in a particular area today would be of little significance if its habitat is to be converted to a sugarcane plantation or a housing estate in a few years' time.

Ideally, the collection of data on elephant numbers should be left to the management authority using qualified and experienced staff and standardized methods. In Sri Lanka, given the plethora of 'experts', elephant data are collected by a multiplicity of agencies and individuals using a variety of methods. Elephants are usually counted either from the air or from the ground. Ground surveys involve total counts by recognition and registration of individuals, or more commonly, dung counts. In Africa, where the bush elephant (*Loxodonta a. africana*) can be spotted easily as it moves across open savanna grasslands, the quickest technique for its census is the aerial survey conducted from fixed-wing aircraft or helicopter. Even aerial surveys are subject to considerable bias, and hence spot surveys on foot should be carried out in selected areas to establish 'ground truth' (Said *et al.*, 1995). But in Sri Lanka where the dense and tangled nature of the vegetation in the low country dry zone makes it difficult to observe elephants, aerial surveys are useless.

Estimating elephant numbers is not only difficult but expensive as well. The first attempt to estimate the number of elephants in Africa was made by Iain Douglas-Hamilton in the 1970s, who arrived at an estimate of at least 1,300,000 animals. By 1987 the number of elephants in Africa was estimated to have declined to 750,000, and the African elephant was therefore placed on Appendix I of the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1989. Today only about 600,000 animals are estimated to be present in Africa. Much of the information on elephant numbers in Africa and Asia is pure guesswork. Given the uncertainty, in Africa elephant numbers are assigned to four groups, **Definite, Probable, Possible** and **Speculative** (Said *et al.*, 1995). Thus the lack of accuracy of the number of elephants in the wild is not something unique to Asia.

The Asian Elephant Specialist Group (AsESG) of IUCN's Species Survival Commission (SSC), puts the number of wild elephants in Sri Lanka as anything between 3,000 and 4,000. It would not be possible to come out with an accurate estimate for the total number of elephants in the wild in Sri Lanka given that much of the north and east of the island could not be surveyed, because of two decades of war. The last survey of wild elephants in Sri Lanka was carried out by the Department of Wildlife Conservation in June 1993. Although the survey revealed that at least there were a minimum of about 2,000 elephants in the so called "safe areas" (Northwest, Mahaweli, Central, Eastern and Southern regions), the objective was not to estimate the number of elephants, instead it was designed to determine the structure and composition of the various groups of elephants that were encountered. The study provided information on the age and sex ratios, proportion of calves and percentage of tuskers in the populations.

All the gains in agriculture, literacy, healthcare in Sri Lanka are being undercut by one basic fact: the island's human population has increased from 3.6 million (or 55 people per sq.km) in 1900 to more than 19 (or 290 people per sq.km) in 2003. The trend in natural forest cover runs counter to the human population growth. As the forester R.W. Szechowycz (1956) pointed out almost 50 years ago, "Ceylon (as Sri Lanka was then known) from a point of view of forestry is analogous to a crowd of people moving happily around a floating ice which melts quickly till finally nothing stands under their feet". With an estimated forest cover of less than 23%, we are rapidly heading towards this situation. With the conversion of forest to other land uses, the elephant is running out of space in Sri Lanka. Most of the protected areas inhabited by elephants are small, less than 1,000 sq. km in size; nevertheless elephants, especially the bulls, may range over hundreds of square kilometers. The land/man ratio has declined from 2.7 ha in 1871 to less than 0.35 ha in 2000. The factors adverse to the survival of the elephant outside the protected areas stem not only from sheer growth in human population but also from the demands of the urban rich for goods of the kind that contribute to the degradation of elephant habitat. Their sheer size and gargantuan appetite mean that elephants and people cannot live together where agriculture is

the dominant form of land use, unless the damage they cause to farmers can be compensated. There are no easy solutions for resolving the human-elephant conflict in Sri Lanka. Much will depend on how rural people, gripped in the poverty vortex associated with poor soil and unreliable rainfall, perceive the worth of the elephant. To stop the wanton killing of elephants requires changing the perceptions of the farmers who suffer constant depredations from the animals. The capture of some elephants as a short-term solution was recommended long ago by Mr. Christy Wickremasinghe (retired Divisional Game Ranger of DWC) in 1964. The Ex-President of the Wildlife and Nature Protection Society, Mr. Thilo Hoffmann too recognized the need to capture, over a few decades, as many as 1,000 elephants from areas outside the protected reserves. Unfortunately, their recommendations fell on deaf ears. Many are now convinced that the only way man and elephant can exist successfully in the same environment is through finding ways to use the elephant as a sustainable economic resource. In the final assessment, it is understanding rather than sentimentality that will do most for the conservation of the elephant.

Charles Santiapillai
Department of Zoology
University of Peradeniya
Sri Lanka
E-mail: csanti@slt.lk

S. Wijeyamohan
Department of Biological Science
Faculty of Applied Science
Vavuniya Campus of the University of Jaffna
Kurumankadu, Vavuniya
Sri Lanka
E-mail: abhirhamy@hotmail.com

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A herd of elephants in Minneriya National Park, Sri Lanka. (photo: S. Wijeyamohan)

Guest Editorial

The meeting of the Asian Elephant Specialist Group (AsESG) at Phnom Penh, Cambodia, in May 2002 took stock of the status of elephant population and the conservation issues in the course of revising the Action Plan of 1990. The issues have largely remained as before – loss and fragmentation of habitat and escalating elephant-human conflict, in addition to poaching and a crisis with captive animals. We now have a much better appreciation of the magnitude of poaching for ivory and other products. The programme of Monitoring the Illegal Killing of Elephants (MIKE) under the auspices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), already operating in Africa, is now beginning in Southeast Asia and South Asia. A task force of the AsESG has also been working on a framework for the welfare and management of elephants in captivity.

The meeting brought in newer information of the status of elephant populations. With a few exceptions the news is grim – the Asian elephant is in dire straits in the Indo-China region, continues to be captured in significant numbers in Sumatra, and seems destined to lose habitat rapidly in Borneo. Even in India where the elephant is still holding its ground in terms of population numbers or even increasing in size, a combination of factors including escalating elephant-human conflict (in the east-central region), the selective poaching of tusked males (mainly in the south but also elsewhere), and deforestation (in the northeast) poses a threat.

The most exciting new information on the Asian elephant is undoubtedly the molecular genetic structure of the species emerging from the work of one of our members, Dr. Prithiviraj Fernando, working on populations across the range of the species outside India, and of Ms T.N.C. Vidya working primarily on the Indian populations. This work has been carried out using a non-invasive technique of extracting tiny amounts of genetic material (DNA) from the dung of wild elephants. Work on mitochondrial DNA (inherited maternally) and the nuclear DNA is underway. The results, some of which were recently presented at a symposium of the Society for Conservation Biology (held at Canterbury, U.K. in July 2002), promises to take our understanding of the phylogeography of *Elephas maximus* to a new level. This has important implications for conservation strategies of the species.

Sri Lanka has high genetic diversity among its elephant populations going by the amazing number (more than 15) of "mitochondrial haplotypes" seen across the island country. In contrast, the large elephant populations of southern India are low in mitochondrial genetic variation. The Indo-China region, whose elephants are in a precarious state, also seems to have high genetic variation in some of its small populations. There is however no case for treating the Sri Lankan elephants as a distinct sub-species because many of the haplotypes here are shared with populations on the Asian mainland. On the other hand, the Sumatran elephant, along with those of peninsular Malaysia, does show a certain distinctness. Another interesting result has been from the island of Borneo (the origin of the elephants here has been a matter of speculation). Preliminary work on the elephants of Borneo indicates a unique mitochondrial haplotype not found anywhere else in Asia.

The genetic information on Asian elephants will give us an additional criterion, as important as population or habitat size, for recasting the framework under which conservation strategies and priorities are worked out. The implementation of conservation strategies and plans is however a more complex affair that is linked to the rapidly changing social, economic and political landscape of the elephant range states across Asia.

Raman Sukumar
Chair, Asian Elephant Specialist Group
Centre for Ecological Sciences
Indian Institute of Science
Bangalore 560 012
India

A young tusker from Sri Lanka
(Photo:courtesy: Dr. H. I. E. Katugaha)

Secondary sexual characteristics in relation to the health status of male Asian elephants in Nagarahole National Park, southern India

Cheryl D. Nath

Abstract This paper presents the results of a six-month study on the relationship between exaggerated secondary sexual characteristics and health status in male Asian elephants. The aim of the study was to find out if tusk length and musth intensity serve as honest signals of genetic quality that might enable female elephants to distinguish between potential mates, as suggested by the sexual selection theories of Zahavi (1975) and Hamilton & Zuk (1982). For this purpose, the intensity of musth and the tusk length of 30 individually identified wild male elephants in the Nagarhole National Park, Southern India, were examined in relation to two health status indicators: external body condition and intestinal helminth parasite load. The study produced some interesting results. Individuals exhibiting signs of early musth had significantly better body conditions and lower parasite loads than individuals exhibiting no signs of musth. However, longer tusks were not significantly related to better health indicators in the sample population. Dominance behaviours recorded in dyadic interactions among male elephants indicated that dominance was associated with musth, height of the animal and tusk length in a high percentage of interactions. These results indicate that musth has the potential to be considered an honest signal of good health in male elephants, and hence female elephants might use this information when choosing mates. Since the period of research was short and the sample sizes of identified males might be considered small, these findings need corroboration by further investigations in this and other populations of wild Asian elephants. The study does provide a good basis for future investigations of musth as a signal of genetic quality and as an honest signal of handicap to female elephants and to humans trying to conserve the genetic fitness of this species in the long run.

Keywords musth, elephants, sexual selection, behaviour, parasite load, Nagarahole National Park.

Introduction

The development and expression of secondary sexual characteristics to apparently maladaptive extremes is an interesting and highly discussed phenomenon (Mayr, 1972; Kirkpatrick, 1982; Maynard Smith, 1991). Examples of exaggerated development of secondary sexual traits, which occur commonly in male animals (Kirkpatrick & Ryan, 1991) include the long tail plumes of birds, bright colours of butterfly wings and large, elaborate antlers of deer. Such exaggerated development has been attributed to consistent and heritable choice of these extreme characters by females (Fisher, 1930), and to the use of extreme phenotypic characters as signals of genetic quality by males (Zahavi, 1975, 1987; Hamilton & Zuk, 1982). Extremely developed secondary sexual traits in males have good potential to serve as signals of quality to females due to their higher intrasexual variances within populations, in comparison to other traits (Moller, 1994). This large range of variance exhibited by secondary sexual character traits (sometimes referred to as male ornamentation or sexual signals) may provide the basis for discriminatory choice of males by females.

Consistent selection of mates by females, on the basis of sexual signals, is a critical aspect required for exaggerated male signals to develop over evolutionary time (Darwin, 1871). Several theories have been advanced to explain the basis of consistent female choice of exaggerated and apparently maladaptive male characteristics. Fisher (1930) proposed that females might initially prefer a particular trait that reflects some aspect of male genetic quality. Subsequently the preference for this trait that is inherited by succeeding generations of females would cause the "runaway" development of the trait in succeeding generations of males who inherit that signal characteristic from their reproductively successful fathers.

An alternative to Fisher's 'Runaway Hypothesis' was provided by Zahavi's (1975) 'Handicap Principle', according to which females who always choose mates based on a signal that provides current information about male quality would always benefit from better genes for their offspring. Hence, males that signal their quality are more likely to be chosen than males that do not signal their quality. Further, only honest signals that consistently and objectively represent differential qualities of different males can serve as effective sexual signals, ensuring that signalling and signal-based choice do not lead to selection of poor quality males (Zahavi, 1987, 1991, 1993). In animals that do not exhibit paternal care of offspring, such as elephants, choice of good quality males to sire their offspring may be critical for females, who may rely heavily on honest signals of quality by males. Improved female discriminatory ability is constantly demanded and would benefit from increasingly finer resolution between competing male signals. Simultaneously, competing males across populations and successive generations would benefit from marginal increases in the magnitude of their signals (within biological limits), given female fidelity to those particular signals across populations and generations. The

Cheryl D. Nath
Centre for Ecological Sciences
Indian Institute of Science,
Bangalore – 560 012, India
E-mail: cnath@ces.iisc.ernet.in

large range of signal variance between competing males might then produce some males that have developed the traits to such an extreme that their own survival is compromised by those highly developed traits. They thus become handicapped, although not severely compromised in terms of their survival prospects, by their signalling traits (Zahavi, 1977). A crucial argument of this theory is that only those males of exceptionally good genetic quality would be capable of producing and sustaining this handicap signal, while it would be extremely deleterious or lethal for an individual of poor genetic quality to produce or maintain the same signal. However, given consistent female preference for males exhibiting comparatively "better" signals, overdeveloped secondary sexual characters may ultimately confer a selective reproductive advantage that offsets the survival disadvantage in those males.

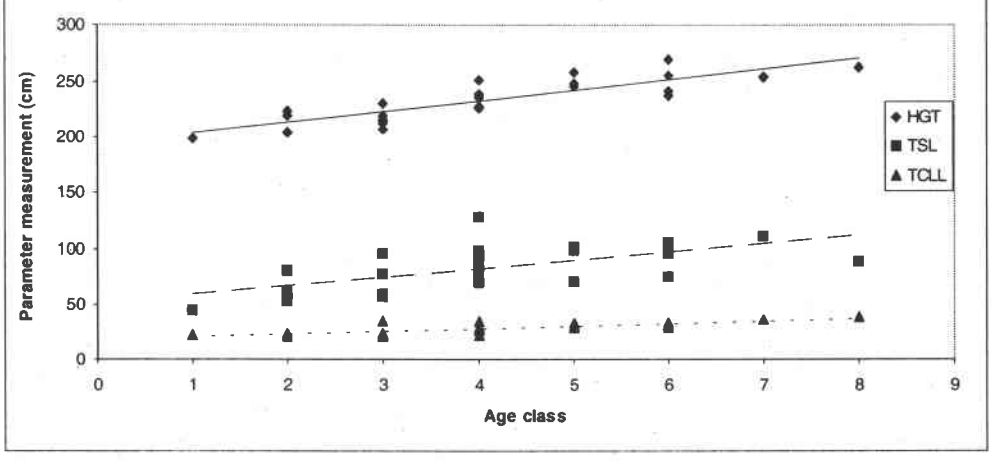
A similar theory put forward by Hamilton & Zuk (1982) argued that bright plumage in male birds might signal their genetic ability to resist chronic parasite infestations. Only very healthy birds would be able to invest in and maintain bright plumage, while weak and parasitized birds would have relatively dull plumage.

Among elephants, we can expect the evolution of discriminatory choice of males by females due to the higher Investment in reproductive and parental effort by females (Poole, 1989b). On the other hand, males need to convey information about their genetic fitness effectively due to the high variance in reproductive success between individual males. The reason for high variance in male reproductive success may be the polygynous nature of elephant societies, which often results in a high proportion of all matings in a season or year being carried out by a few dominant ('high quality') individuals (Poole, 1989a; 1989b; Poole & Moss, 1981). This may favour the development of sexual signals that effectively convey the message of good quality genes in dominant males. In addition, the lack of synchrony in fertile or rut periods of male and female elephants results in severe competition around the few widely dispersed fertile females at any given time. Male elephants may experience musth (heightened sexual activity period) for varying lengths of time during any season in a year (Poole, 1987; 1989a), just as females appear to come into oestrus once every 16 weeks (Hess *et al.,* 1983; Poole, 1989b). As a result, efforts are spent on signalling to and searching for mates (Poole & Moss, 1989). Signals that improve the likelihood of bringing together potential mates would tend to be selected over time (Rasmussen *et al.*, 1986; Poole, 1989b; Rasmussen, 1999).

The use of secondary sexual characters as honest signals of quality by male elephants was first investigated by Watve & Sukumar (1997), in their study of tusked male Asian elephants of Mudumalai Wildlife Sanctuary in southern India. Their study showed that the magnitude of positive deviation in tusk length from a standardised tusk length curve was significantly negatively correlated with intestinal helminth parasite load. Thus male elephants with relatively longer tusks apparently had relatively smaller intestinal helminth parasite loads. It was suggested that tusk length might serve as an honest signal of quality, within the framework of Hamilton & Zuk's (1982) theory of heritable true fitness. Since very long or crossed tusks may impose a heavy burden or hinder trunk movements when feeding, it was further suggested that longer tusks were also potential candidates in support of the Handicap Principle (Zahavi, 1975).

In addition to tusk length, in this study the phenomenon of musth was also considered as a potential sexual signal by male elephants. Musth in male elephants is a secondary sexual characteristic that aids in reproduction and dominance (Eisenberg *et al.*, 1971; Eisenberg & Lockhart, 1972; Poole, 1987). Among captive elephants in India, musth was found to be expressed more fully by male elephants in good health when compared with males in poor or debilitated condition (Chandrasekharan *et al.*, 1992). Testosterone levels in the body are elevated to around five times their usual levels (Poole *et al.*, 1984; Rasmussen *et al.,* 1996). This would serve to reduce the animal's immunity substantially, as elevated testosterone levels have been associated with reduced immunocompetence (Folstad & Karter, 1992). In addition, male African elephants in musth are known to greatly reduce the proportion of time spent on feeding, which could lead to a loss of body condition during this period (Poole, 1989a). Furthermore, the greater

Fig. 1. Variation of height (HGT), tusk length (TSL) and tusk circumference at level of tusk lip (TCLL) of identified male elephants. Age classes: 1= 10-15yrs, 2= 15-20yrs, 3= 20-25yrs, 4= 25-30yrs, 5= 30-35yrs, 6= 35-40yrs, 7= 40-45yrs, 8= 45-50yrs.



the length of time spent in musth, the higher are the costs in terms of total body condition loss. In some cases, considerable loss of water, often a critical resource for elephants, results from the practice of dribbling urine continuously while moving, during the period of musth (Poole & Moss, 1989; Chandrasekharan *et al.*, 1992). Urine dribbling is thought to warn other males as well as to alert oestrus females who come across the urine path, of the presence of a musth (and hence more dominant) bull in the area (Poole, 1989a; 1989b). Musth is thus a particularly complex and highly developed secondary sexual character in male elephants, whose high physiological cost makes it a potential sexual signal.

This paper reports on a study of musth and tusk length of individually identified male Asian elephants, in relation to their health status. As both these characters have aspects that can be considered maladaptive if excessively developed, the study investigated their potential to serve as signals of individual genetic quality and as handicap signals to facilitate female choice. The main aim of this study was to test the relationship between the secondary sexual character traits, musth and tusk length, and two chosen indicators of genotypic quality in wild male elephants. The indicators of genotypic quality (as expressed by the current health status) chosen for this purpose were overall external physical (body) condition and internal helminth parasite burden (parasite load or parasite density). A subjective composite score called the "Body Condition Index" (BCI) and the objectively quantified helminth parasite propagule density (referred to as "parasite load") per individual were used as indicators of health. Increasing values of both scores were associated with declining health (i.e. declining external body condition or increasing parasite load) in the animals studied.

The following *a priori* assumptions were made, on the basis of published information, in order to take up the study:
1. The selected secondary sexual traits are heritable. Support for the assumption that secondary sexual characters are heritable comes from studies on antlers in male deer, a secondary sexual character that is believed by many to play an important role in mate selection by female deer. Goss (1983) mentions the importance of inheritance and hormonal regulation in shaping antler morphology, while experiments performed by Harmel (1983) on white-tailed deer showed that although diet and nutrition may influence antler growth, genetics are of overriding importance in determining antler presence, length and quality. Further, another study by Scribner & Smith (1990) suggested that genetic heterozygosity might influence antler growth and size.

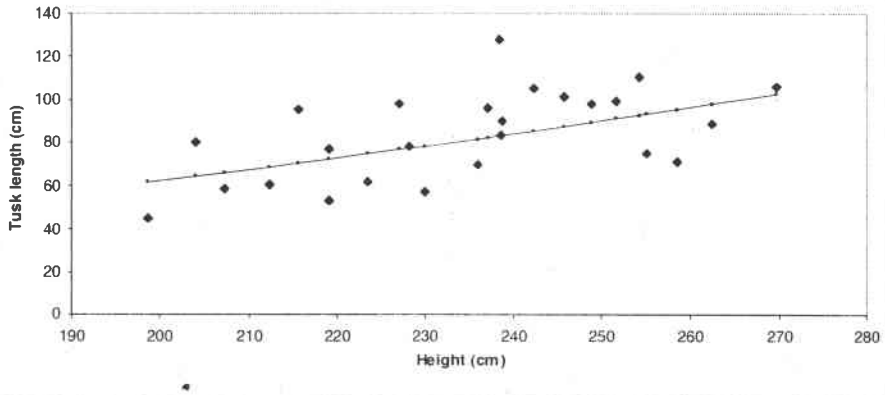
2. Female elephants in oestrus are selective in allowing male elephants to mate with them. This assumption of female choice of their mates is supported by long term studies of female African elephant behaviour (Moss, 1988; Poole, 1989b) and anecdotal evidence on captive and wild female Asian elephants (de Launey, 1938; Stracey, 1963; Krishnan, 1972).

3. Mate choice by females is based mainly on the genetic quality of males, which is indicated by the degree of exaggeration of selected sexual signals. Although this assumption is difficult to verify in the field, mathematical models of sexual selection (Kirkpatrick, 1982; Grafen, 1990) have shown that heritable characteristics of males, if consistently selected by females over several generations, can become stabilised in those populations.

Hypotheses were developed in the following manner for testing in the field:

Musth and relatively long tusks are signals of good health: If musth is a true signal of good quality, we would expect body condition to be very good before (or just before) an individual is able to attain and advertise a state of musth. Hence, assuming that musth intensity across individuals reflects comparable states of health and body condition, individuals exhibiting early stages of musth would be expected to have better health indicator values than other individuals. Further, we could also reasonably expect that the body condition of an individual would show a declining trend as musth intensity increases, if musth is truly a handicap to the individual. The durations of single episodes of musth show high variability across individuals. Reports range from a few days to several months of sustained musth for different animals (Toke Gale, 1974; Poole, 1987; 1989a; Chandrasekharan *et al*, 1992). Poole (1989a) found that most males suffered increased weight loss as their duration of musth increased. Thus, the high

Fig. 2. Measured tusk lengths versus heights of identified male elephants, with fitted quadratic curve. Best fit (r = 0.764) is shown by the line below and given by the equation :
Tusk length = -0.732 + (0.114 * Height) + (0.001 * Height^2)



variation associated with this trait may be linked to individual abilities to overcome the physiological costs associated with sustaining musth over long time periods. With regard to tusks, as shown by Watve & Sukumar (1997), tusk length was expected to be significantly negatively correlated with intestinal helminth parasite loads and with body condition. Using subjective scores for musth intensity (Musth Composite Index or MCI) and external body condition (BCI), and objective assessments of helminth propagule densities per individual, the following hypotheses were tested:

1. Individuals in early musth or with relatively long tusks were expected to have better health indicator values than individuals which did not attain musth or which had relatively short tusks, respectively.

2. Health indicators for individuals during single episodes of musth, were expected to show a decline in health, as musth intensity and duration increase. (This relied on repeated samplings of identified individuals during single episodes of musth.)

Correlation between the two signals and relationship to social dominance hierarchies:

If both musth and tusk length are positively associated with higher health indicator values, then we can reasonably expect them to be correlated with each other. Thus they may be used together complementarily as signals of overall health and fitness. Furthermore, if health is an important criterion for signalling genetic quality to females, it may also be reflected in male-male dominance interactions. Dominance was examined in relation to sexual behaviour because elephants tend not to defend territories or food resources. Nevertheless, when guarding a female, the mate as a resource would be of great value to a dominant male (Poole, 1989a). Dominance is thus likely to play a significant role in male reproductive success and in female choice. Hence the following hypotheses were tested:

1. MCI and tusk length are correlated with each other.

2. Dominance in male-male interactions is associated with greater ability to come into musth and with longer tusks.

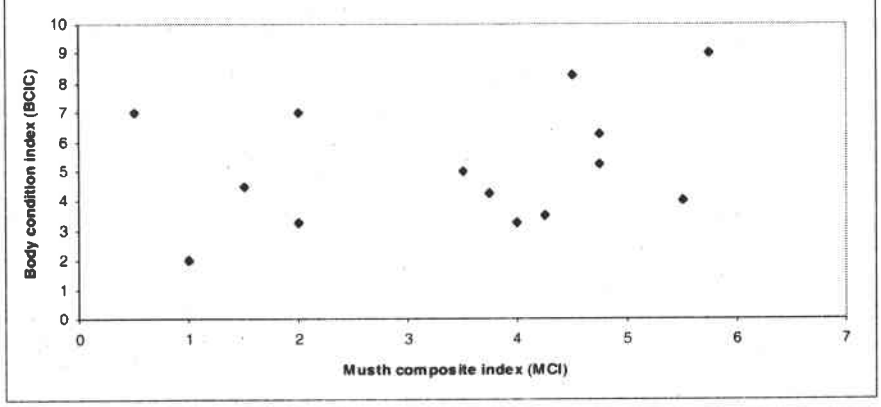
Study area

The study was carried out in the Nagarahole National Park in Karnataka, southern India, from mid-November 1998 to early May 1999. Healthy populations of large mammals such as the elephant (*Elephas maximus*), tiger (*Panthera tigris*), gaur (*Bos gaurus*), spotted deer (*Cervus axis*) and sambar (*Cervus unicolor*) are found in this area throughout the year. The Park is located between 11° 50' – 12° 15' N and 76° 0' – 76° 15' E, and has an area of 644 km^2. The study was carried out in an approximately 100 km^2 area on the eastern side of the Park.

Vegetation types in the study area included mostly dry and moist deciduous forests with an east-west gradient from drier to wetter types. The park receives much of its rainfall (900-1500 mm (Karanth & Sunquist, 1992) during the first monsoon (June-September), and continues to receive small quantities at other times, including the second monsoon (October-December). The south-eastern side borders the Kabini reservoir, which resulted when the Kabini River dam was completed in 1974. Clearance of forest vegetation to accommodate this reservoir has led to increased utilisation of this area during the dry and hot summer months of March-May, when the water level in the Reservoir drops and the extensive grassy banks exposed by the receding waters are exploited by grazing ungulates and elephants.

The flora is dominated by deciduous species such as *Anogeissus latifolia, Tectona grandis, Lagerstroemia microcarpa, Albizia spp., Grewia tileaefolia, Bombax ceiba, Ficus spp., Butea monosperma, Careya arborea* and *Emblica officinalis*. Common shrubs include *Ziziphus spp., Lantana camara* and *Helicteres isora*. Extensive teak and eucalyptus plantations are found along the banks of the reservoir. *Bambusa arundinacea* and

Fig. 3. Relationship between musth intensity (indicated by MCI) and body condition index (BCIC), from sightings of male elephants in musth. There was a minor trend of association (r = 0.27), but no significant relationship between MCI and BCIC.



Dendrocalamus strictus grow thickly along the banks and in the interior areas.

The population of elephants in the park was estimated to be roughly 1448 (Alva, 1994), of which some are likely to be migratory. Between November and December maximum elephant movement occurred in the Antharasanthe Range, away from the Kabini reservoir. During this time elephants used waterholes near the Park boundary in close proximity to agricultural fields. In January and February (after the crops were harvested), elephant movements were higher in the more interior areas of the Park, although some males frequented the Kabini reservoir banks, feeding on bamboos and other shoreline vegetation. During March-April, however, peak elephant activity occurred along the Reservoir banks. Many female-led groups may have converged to form large groups totalling up to 50 animals while grazing the banks. This may have been an additional attraction for adult males who may have followed the family groups into this area. Interior areas of the Park were almost devoid of elephants as the smaller waterholes began to dry up in late February.

Data collection was facilitated greatly by the large congregations and tendency of elephants to remain resident on the banks of the Reservoir during March and April. As a result, social interactions could be clearly observed at close proximity and recorded continuously for long periods of time per day.

Methods

Identification, ageing and measurement of individuals

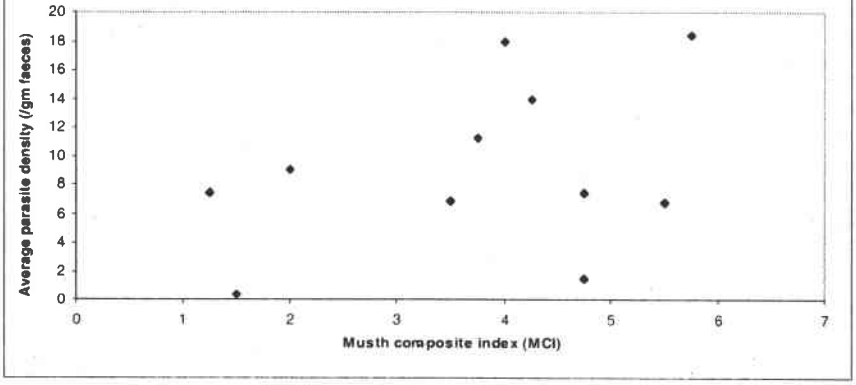
Individual male elephants were identified by photographing them and recording details of their tusks, ears, tails, backbone, "handedness" of trunk (or sidedness, as each individual used only one side of the trunk tip consistently when grazing), pink colouration, warts, wounds and bumps. These methods have been successfully used to uniquely identify large numbers of African elephants (Douglas-Hamilton, 1975; Moss, 1988). For the duration of this study and the number of elephants identified, a combination of all or most of the above features proved satisfactory for accurate characterisation of different individuals. During the study 37 male elephants were positively identified (4 of these were estimated younger than 15 years old). Of these, 30 elephants were used in the analysis (two of which were estimated to be less than 15 years). Eleven elephants were seen in musth, of which data from 10 elephants were used in analyses.

Ages were estimated in the field by assessing height, tusk thickness at lip level, ear folding at the top edge, temporal depressions and body size. Elephants were assigned to 5-year age class intervals ranging from 10 to 50 years (8 classes) in the field. Whenever possible the circumferences of forefoot prints were recorded as this value doubled gives a rough field estimation of the elephant's height (Sukumar *et al*, 1988). Photographic records for measurement of height and tusk length were obtained by photographing elephants broadside on and then photographing a Field Assistant standing in exactly the same spot as the height reference. This method gave an error of 3-5% in repeated photographic encounters of individuals. The heights measured in this manner were consistently lower than those corresponding to the standard age-height-weight chart for elephants of southern India, established by Sukumar (1989). However, for the purpose of this study, absolute heights of individuals were not as important as consistency in the method of height estimation. Since the bias appeared consistent across all individuals, the heights obtained in this manner were considered suitable for further analysis.

Subjective Indexes

The overall external body condition was used as a first measure of the health status of individuals. A simple cumulative score of body condition, called the body condition index (BCI), was obtained on each encounter with an animal by scoring visibility of the backbone, ribs, pelvic girdle, pectoral girdle, buccal depression and temporal depression on a scale of 0-3. The scores for each of the physical features was then added up to give an additive BCI score. From previous field observations, older animals were generally thought to show increased facial depressions. Hence the BCI composite index, BCIC (described above), was divided into the BCI (Body), BCIB, and the BCI (Face),

Fig. 4 Relationship between musth intensity (indicated by MCI) and parasite load of identified male elephants in musth. There was a minor trend of association (r = 0.38), but no significant relationship between MCI and parasite load.



BCIF, for better resolution of differences reflecting health, if any. These indexes could take the following ranges of values: 0 to 18 for BCIC, 0 to 12 for BCIB, and 0 to 6 for BCIF.

Musth intensity was rated similarly, to provide a cumulative musth composite index (MCI, ranging in value from 0 to 9), by subjectively assessing the following three externally visible characteristics of musth (Poole, 1987):

1. *Temporal gland swelling*: Values ranged from 0-3, depending on whether there was no swelling, the temporal gland area was flush with the skull, the gland was slightly swollen or the gland was prominently swollen.

2. *Temporal gland secretion (TGS)*: A copious discharge of fluid from the swollen temporal gland in male Asian elephants is a sure sign of the occurrence of musth. Rating of this feature ranged from 0-3 depending on the length and width of TGS flow down the side of the face.

3. *Urine dribbling*: This was rated on a scale of 0-3 depending on the rate of passive flow of urine, which is known to be a common feature of musth males, especially during peak musth. During this study, however, urine dribbling was observed only on two occasions. In the first case it was observed as an irregular wetness on the inner side of the hind leg of a musth male, and in the second case the entire inner side of the hind leg was wet and the male, in peak musth, was in hot pursuit of a female elephant. The actual dribbling of urine in the form of droplets, a thin stream or a steady flow, as described in African elephants (Poole, 1987), was not observed during this study.

Helminth parasite assessment

Samples of freshly dropped faeces were collected for quantitative estimation of helminth parasite propagule (eggs or ova) densities, after the method of Watve (1992). 4-8 gms of fresh faeces from identified male elephants were collected and preserved in 10 ml of 10% formalin in the field. These were later filtered to remove fibres and large plant material, and centrifuged at 2000-3000 rpm for 5 minutes to concentrate ova in the pellet. The pellet was resuspended in 10 ml of saturated zinc sulphate solution and centrifuged at 2000-3000 rpm for 5 minutes to concentrate ova in the top layer of supernatant solution. An L-shaped wire loop was used to transfer the floating eggs onto a microscope slide for counting at a magnification of 100x.

The main types of parasites identified (using the references: Soulsby, 1973; Sloss & Kemp, 1978; Watve, 1992) were:

1. Strongyles and strongyle-like eggs of Class Nematoda (not distinguishable, but probably including *Quilonia* spp., *Murshidia indica* and *Coniangium* spp.) formed the bulk of the ova counted and ranged from 74-89 microns x 35-50 microns.

2. Spirorid nematode, *Parabronema* spp. 79 x 35 microns.

3. Tapeworm, *Anoplocephala* spp., 89 x 55 microns.

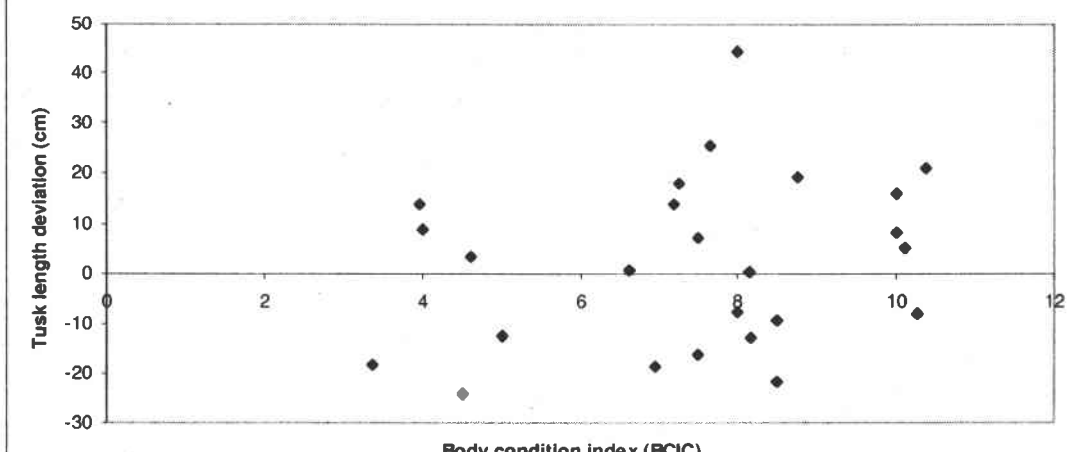
4. Other large trematode eggs, fluke eggs, 220-300 x 80-100 microns.

Total parasite loads per gram of sample were calculated for each individual. This value, representing internal helminth parasite load, was expected to provide a close approximation of the overall parasite resistance of individual hosts.

Behavioural sampling

Behavioural sampling of interactions between identified individuals was carried out using mainly focal group sampling (FGS). In FGS continuous monitoring of interacting elephants was carried out by focusing on each individual of the group in turn and recording its behaviour for 10-15 secs (including all actions initiated and received by that individual and its recipient or initiator), before moving on to the next

Fig. 5. Relationship between tusk length deviation and average body condition index (BCIC), of identified male elephants. There was a minor trend of association (r = 0.25), but no significant relationship between tusk length deviation and BCIC.



animal. This method ensured that all individuals of the group were represented approximately equally in terms of time and maintained a reasonably continuous record of behaviours of all individuals throughout the sampling interval.

Nine group interactions between identified individuals were examined for dominance interactions. The chosen behaviours were subjectively designated as dominant or subordinate, *a priori* (see Appendix), as small sample sizes precluded a conventional dominance analysis. Typical dominance behaviours observed were approach-retreat sequences, the use of trunk, tusk or body to push subordinates, and directed threats such as stamping or rubbing the forefoot in mud and throwing trunkfuls of earth over the head while facing the subordinate individual. Eleven group interactions were analysed for evidence of musth and other sexual behaviours. A complete list of behaviours used for analysis is provided in the Appendix.

Of the interactions recorded, 5 were paired interactions (Dyads) and 4 interactions involved 3 males (Triads). Two of the 4 triadic interactions had a single musth male interacting with 2 non-musth males. Dominant and subordinate behaviours were tallied for each individual and dominance within dyads was assigned to the individual that demonstrated higher frequency of dominant behaviours and/ or lower frequency of subordinate behaviours. Triads were analysed for dominance in pair-wise interactions and dominance was assigned as described above.

Statistical Analysis

All distributions were assumed to be normal and hence parametric statistics such as Pearson's r, Student's t-tests, single factor ANOVA and binomial distribution probability test for parametric distributions were used. If a correlation was found to be significant but low, the Spearman rank correlation test was used to provide additional information.

In order to normalise the tusk length distribution (Sections 4.2.4 and 4.5.2), best fit curves were fitted to the data using the program CurveExpert (version 1.3). Deviations of measured tusk lengths from the standard curve were then used to assess the relationship between tusk length and other parameters.

Results

Details of parameters

Data was collected on identification of individuals, height, tusk length and circumference, external body condition (BCI), musth intensity (MCI), parasite load (/gm faeces) and social behaviour. It was not possible to collect all types of data from every encounter with elephants, nor to obtain re-sightings of every identified male. However, 17 identified males were re-sighted at least once during the study period and 11 were re-sighted more than once. Distribution of heights, tusk lengths and tusk circumferences (at the level of the tusk lip) across the sample of all identified elephants is shown in Table 1. The measured heights of all individuals showed good agreement with the subjective field assessments of age (Pearson $r = 0.85$, $df = 23$, $p < 0.001$) when compared with those of tusk length (Pearson $r = 0.61$, $df = 23$, $p < 0.02$) and tusk circumference at lip level (Pearson $r = 0.76$, $df = 23$, $p < 0.001$) (Fig. 1). Hence in further analyses, height was used as a proxy for age (since age could be resolved only to the level of 5-year age classes).

For all other parameter data collected, summary details are shown in Table2. Faecal samples were obtained more than once from 10 individuals, which allowed for an assessment of intra-individual variation in total parasite loads. For these 10 individuals intra-individual variation was relatively high, and ranged from 0.5 to 33.2 parasite propagules/gm with an average variation of 13.1 propagules/gm (equivalent to 109% of the average parasite load in the sample population). In

Fig. 6. Relationship between tusk length deviation and average parasite load of identified male elephants. There was a very minor trend of association ($r = 0.13$), but no significant relationship between tusk length deviation and parasite load.

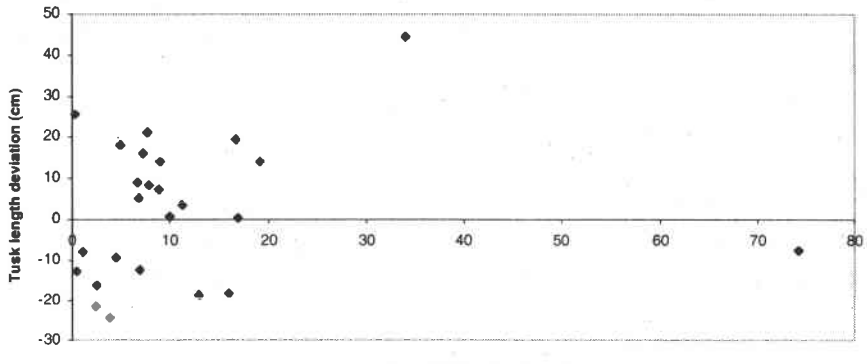


Table 1 Summary data on heights, tusk lengths and tusk circumferences at the level of tusk lip (TCLL) for all identified male elephants. Elephants are grouped into 8 age classes, based on subjective assignment of age in the field (n = number of elephants).

Age class	N	Height (cm) Average (±S.E)	Tusk length (cm) Average (±S.E)	TCLL (cm) Average (±S.E)
10-15	1	198.7	45	22.7
15-20	3	215.5 (±20.0)	65.1 (±26.9)	22.8 (±3.6)
20-25	5	216.8 (±16.7)	69.7 (±32.8)	24.5 (±11.2)
25-30	7	236.9 (±16.0)	92.4 (±37.0)	29.0 (±8.5)
30-35	3	251.1 (±13.0)	90.3 (±33.0)	30.7 (±4.0)
35-40	4	251.1 (±28.6)	95.7 (±28.3)	31.4 (±3.7)
40-45	1	254.3	111.1	36.1
45-50	1	262.4	88.7	38.9

the case of BCIC, intra-individual variation was relatively low for the 15 individuals that were sampled more than once. It ranged from 0.25 to 6.0, with an average BCIC variation of 2.7 (equivalent to 36% of the average BCIC in the sample population). For all re-sighted individuals, parameter values were averaged when comparing across individuals.

Investigation of age effects on all parameters

The age of an elephant can affect the development of several character traits and is responsible for some proportion of the observed variance across individuals. Since elephant tusks continue to grow throughout the life of an individual (Sukumar, 1989), age is expected to be partially responsible for longer tusks in older males, regardless of their health. In the case of musth, however, the effect of age on the ability of males to attain and sustain musth has not been clearly established. Although captive Asian elephant bulls have been known to exhibit signs of musth in their early to mid teens (Eisenberg *et al.*, 1971; Chandrasekharan *et al.*, 1992) wild African elephant bulls were seen exhibiting signs of musth only after the age of 20 years (Poole1987, 1989a). It is possible that the intensity of musth is affected by age due to physiological processes not necessarily related to health. Thus, the confounding effects of age on the two secondary sexual characters of interest, as well as on the two chosen health indicators, were examined and eliminated as described below. In all cases, individual's heights were used as proxies for their age.

Age effect on tusk length:

Tusk lengths were significantly correlated with heights (Pearson r = 0.57, df = 23, $p < 0.005$ and Spearman r_s = 0.57, n = 25, $p < 0.005$), indicating the strong influence of age on tusk growth. This was an expected relationship and was eliminated before proceeding further with analyses. For this purpose, a quadratic curve was fitted to the data to obtain the best fit between tusk length and height (r = 0.764, Fig 2). This curve gave the following relationship:

$$\text{Tusk length} = -0.732 + (0.114 * \text{Height}) + (0.001 * \text{Height}^2)$$

This curve was used to predict the expected or average tusk lengths for all heights measured. Individual tusk length deviations from this curve were then used instead of actual tusk lengths to investigate relationships between tusk growth and other parameters, as previously done by Watve and Sukumar (1997).

Age effect on musth:

During the study, only males subjectively aged between 25 and 40 years exhibited symptoms of musth. When elephants were grouped into 10-year age classes, the modal class for musth males was the 30-40 year class, containing 67% of all musth males seen, with only 1 out of the 7 males in this class not exhibiting signs of musth during the study interval. There was no correlation between the average MCI (musth composite index) and heights of individuals, and hence no correction for age effects was required.

Age effect on health indicators:

Body condition indexes were checked for correlations with height. Significant correlations were obtained for BCIC (Pearson r = -0.48, df = 23, $p < 0.01$ and Spearman r_s = -0.39, n = 25, $p < 0.05$) and BCIB (r = -0.54, df = 23, $p < 0.005$ and Spearman r_s = -0.51, n = 25, $p < 0.005$), reflecting a possible improvement in external body condition with increasing age (the r value is negative because lower BCI values indicate better external body condition). However, this was found to be an effect of musth because removal of

Table 2 Summary information of data collected from wild male elephants during the study. For those elephants encountered more than once, average parameter values per individual were used in the calculations below. (n = number of elephants).

Parameter	n	Range	Average	Standard Deviation	C.V.
Height (cm)	25	198.7 - 269.8	234.5	19.0	0.08
Tusk length (cm)	25	45 - 127.8	83.6	20.8	0.25
MCI	10	0.5 - 5.5	3.4	1.60	0.53
BCI(Composite)	28	3.38 - 11	7.6	2.15	0.28
BCI (Body)	28	1 - 7	4.4	1.57	0.36
BCI (Face)	28	1 - 5	3.2	0.98	0.31
Parasite (/gm)	30	0.25 - 74.2	12.0	14.5	1.21

all BCI values belonging to musth males caused reductions in both of the above correlation values ($r = -0.03$ and -0.12, respectively, non-significant relationships). This indicated that external body condition was not related to age when animals were not in musth, and thus no correction for age effects was required in the case of BCI. Facial depressions, approximated by BCIF, were not correlated with height (or age) in musth and non-musth animals. This contrasted with the common field perception that older animals generally tend to have more prominent facial depressions. There was no significant relationship between heights of individuals and their average parasite loads, and thus no correction for age effects was required.

Investigation of relationships between and among health indicators

Interactions among health indicators

No significant correlations were found between the three body condition indexes and parasite load, in both musth and non-musth animals. This indicated that the two types of health indicators were independent of each other in this study.

Season effect

The effect of different seasons on BCI and parasite load was investigated by testing health indicator data in month-wise pairs. Significant differences in parasite densities were found only between the months of January and April (using Student's t-test for samples with unequal variances, $p < 0.015$). However, the sample size in January was 2, in comparison with a sample size of 23 in April. Thus, it is likely that a few very high values in April were responsible for the significant differences in parasite densities between the two months.

The data set was then divided into Season 1 which included the winter months of December, January and the first half of February, and Season 2 which included the summer months of the second half of February followed by March, April and early May. There was no significant difference between the means of these groups, and hence no corrections were required for this factor.

Relationship between musth and health status indicators

Musth intensity and age

Data from 9 males in musth were analysed for differences in musth intensities with age. Three males each were estimated to be in the age classes 25 – 30 years, 30 – 35 years and 35 – 40 years, and were tested for the effects of age class on average intensity of musth (using ANOVA). However, there was no significant age class effect, indicating that age did not significantly influence the musth intensity in males in this study.

Musth versus non-musth individuals

Data from individual males were separated into musth and non-musth categories and tested for significant differences between their average parameter values (using Student's t-test for samples with unequal means). For musth individuals, data collected when they were not in musth were not used in this analysis. Some parameters showed significant differences between musth and non-musth males (Table 3). Significant height, tusk circumference (TCLL) and tusk length (TSL) differences between musth and non-musth individuals could be explained on the basis of age, since musth was observed only in animals over 25 years of age in this study. The most interesting finding was the significant difference in average BCIC, BCIB and BCIF between musth and non-musth individuals (Student's t-test, $p < 0.05$. See Table 3), which indicated that musth males were in better physical condition than non-musth males. However, this apparent difference in health between musth and non-musth males was not indicated

Table 3 Comparison of parameter values for non-musth and musth male elephants, with results of Student's t-test for difference of means. n = number of elephants. (* = indicates significance at $p<0.05$)

Parameter	non-musth average (n)	musth average (n)	t-test p value
Height (cm)	227.1 (16)	247.6 (9)	0.001*
Tusk circumference at lip level, TCLL (cm)	26.6 (16)	31.52 (9)	0.004*
Tusk length, TSL (cm)	78.29 (16)	92.9 (9)	0.044*
Tusk length dev. (cm)	1.23 (16)	3.98 (9)	0.367
Average BCIC	8.67 (19)	5.03 (9)	0.000*
Average BCIB	5.22 (19)	2.51 (9)	0.000*
Average BCIF	3.45 (19)	2.54 (9)	0.014*
Average parasite density (/gm)	12.15 (20)	8.04 (9)	0.157

by the other chosen health indicator, average parasite load per individual.

Health status indicators in relation to musth intensity

Trends in body condition index with changes in musth intensity:

Data obtained from musth individuals were investigated for finer resolution of patterns in health indicators during musth. There was no significant correlation between MCI and BCIC when the data from all musth individuals were pooled (Fig. 3), although there was a minor trend of increasing BCIC (declining body condition) as musth intensity increased. All BCIC values were then split into two groups, early and late musth, based on their respective MCI values. For this, all MCI values between 0.5 and 3.75 (n = 8) were considered to be early musth samples, while all MCI values between 4.0 and 5.75 (n = 7) were treated as late musth (or closer to peak musth) samples. The BCIC values of these two groups were not significantly different from each other (using Student's t-test for samples with unequal means), indicating that external body condition may not vary with musth intensity. Intra-individual variation may have been responsible for the lack of a consistent trend in the relationship between MCI and BCIC over time. Hence data obtained from repeated sightings of 3 males who remained in musth over considerable periods of time (observed musth intervals ranging from 5 to 22 days) were assessed qualitatively for intra-individual trends. There were marginally increasing values of BCIC (declining health) during the observed musth interval of two males, while the third male showed initially increasing BCIC followed by a decrease. There was no significant association between MCI and BCIC, nor between the number of days in musth and BCIC, in individual males. Thus there was no evidence for a consistent decline in external body condition over time in musth males.

An important, though expected finding, was that early musth BCIC values were significantly different from non-musth BCIC values (Student t test, n1 = 8, n2 = 48, $p<0.001$). This was an expected result (following from section 3.4.2 above) indicating that significantly better body condition was associated with early musth when compared with the non-musth state.

Trends in parasite load with changes in musth intensity:

Data on musth individuals were similarly studied with regard to parasite loads. However, as with BCIC, there was no clear relationship between parasite load and MCI when all musth data were pooled (Fig. 4). Division of the data into early (n = 6) and late (n = 6) musth stages based on MCI values as above, revealed no significant difference between the parasite loads of early and late musth groups. In addition, examination of intra-individual trends in the parasite loads of 3 resighted musth males during the course of their period in musth (observed musth intervals ranging from 4 to 22 days) showed no clear trend of increasing parasite loads with increasing intensity and progression of musth. Thus when using parasite loads as the health status indicator, there again appeared to be no decline in health over time in musth males.

However, when early musth data were compared with non-musth individuals, there was a significant difference between early musth parasite densities and non-musth parasite densities (Student t test, n1 = 6, n2 = 31, $p<0.05$). This result is important when considered in conjunction with the results from the MCI-BCIC analysis above. Significantly lower parasite loads in early musth individuals support the findings above, by indicating that the internal parasite load of individuals in the early musth stage is lower when compared with that of individuals not in musth.

Table 4 Parameter advantages (+) and disadvantages (-) of the dominant male elephant in 9 recorded dyadic interactions. The dominant male was considered to have the parameter advantage if it had greater height, longer tusks, greater tusk length deviation (i.e., deviation from the fitted tusk length curve), lower BCIC value, lower parasite load or was in musth (while the subordinate individual was not in musth). Significance of the association between parameter advantage and dominance, across all dyadic pairs, is given by the binomial test p-value.

(* = indicates significance at $p<0.05$)

Pair (Dom-Sub)	Height	Tusk length	Tusk dev.	BCIC	Par./gm	Musth
KFI - KUN	-	+	+	+	+	
ERR – IXT	+	-	-	-	+	
LAN – DCR	+	+	+	-	-	
LAN – LKN	+	+	-	-	-	
DAD – PIN	+	+	+	+	-	
KAL – XTT	+	-	-	+	+	+
BAL – LAN	+	+	+	+	+	+
KAL – IXT	+	+	-	+	+	+
BAL - DCR	+	+	+	-	+	+
Propn. positive:	0.89	0.78	0.56	0.56	0.67	1.00
Binom.Test p-value:	0.018*	0.070	0.246	0.246	0.164	

Relationship between tusk length and health status indicators

Tusk length and health status indicators
(a) Bsody condition index

Tusk length deviations were tested for correlative association with BCI. There was a weak but non-significant positive trend when the two parameters were plotted against each other, indicating slightly worsening body condition with increasing positive deviation of tusk length (Fig. 5).

(b) Parasite load

Parasite loads showed no relationship with tusk length deviations (Fig. 6).

Tusk length correction using subjective age classes

The use of height as a proxy for age may have reduced extreme trends of long or short tusks if height is genetically linked to tusk length and if heights vary greatly across ages. To eliminate this potentially confounding effect, a second standard curve was fitted to the tusk length data, using the subjective age classes assigned in the field (class intervals = 5 years) to rank individuals. This had the effect of collapsing the data into 8 groups and magnifying tusk length deviations from the standard values for each group. Best fit ($r = 0.82$) was achieved by using an exponential association curve with the equation:

$$\text{Tusk length} = 102.37 \{ 1 - e^{-0.474(\text{Age class})} \}$$

Tusk length deviations obtained from this correction were then tested for relationships with BCI and parasite densities. However, tusk length deviations obtained from this curve also did not produce significant correlations with BCI or parasite load. These findings indicated that helminth parasite densities and body condition indexes were not related to tusk growth in the elephants used in this study.

Musth-tusk length relationship

There was no significant difference in the average tusk length deviation between animals that exhibited musth and those that did not exhibit musth during the study period (Table 3). There was also no significant relationship between MCI and

tusk length deviation. This indicates that longer tusks are not necessarily related to an individual's ability to attain musth, nor with the intensity of musth exhibited. Thus the two proposed signals appear not to be complementary in signalling the health status of male elephants.

Behaviour analysis

Dominance interactions

Dyadic interaction pairs of male elephants (n = 9) were compared to find out which parameter advantages were generally associated with the dominant individuals. The following 6 parameters "advantages" were considered: greater height, longer tusks, greater tusk length deviation (from the quadratic standard curve), lower average parasite density, better average body condition (lower BCI score) and occurrence of musth (Table 4). Simple calculation of the proportions of dominant individuals enjoying a particular parameter advantage over their subordinates showed that the dominant individual had the advantage of musth on every interaction between a musth and non-musth individual (proportion positive = 1.00, n = 4). Dominant individuals also had the advantage of greater height in 89% of interactions, while the advantage of longer tusks was associated with the dominant individual in 78% of interactions. Binomial distribution probability tests showed that only the height advantage (in addition to musth) was significantly different from 0.5 (equal probability of having or not having the parameter advantage over the subordinate animal (see Table 4).

From this analysis of dominance behaviours in a small sample of interactions, musth and height advantage appeared highly likely to be associated with dominance in male-male interactions. Other parameters such as tusk length, tusk length deviation, BCI and parasite density were not significantly associated with dominance in male elephants. One cannot, however, rule out the importance of these other factors in dominance, as musth is not always present in either one or both of an interacting pair of males, and there was a single case recorded, of domination by the shorter individual of an interacting pair.

Discussion

Musth as a signal of health and genetic quality

Probably the most important finding of this study was the relationship between musth and health status. Male elephants which exhibited external signs of musth of all stages, had significantly lower average BCI scores (indicating better health) than males which did not attain musth during the study. Early musth males had slightly lower BCI scores, though not significantly different scores, than late musth males. This indicated that throughout the periods of musth monitored in this study, males did not show significant deterioration of external body condition as musth progressed. It may imply that maintaining good external body condition is important throughout an episode of musth. It is also possible that a highly productive environment such as Nagarahole is able to provide nutrition to sustain reasonably good health in musth males despite the physiological burden imposed by this condition.

Inter-individual parasite loads did not show any significant difference when all musth males were compared against all non-musth males. However, early musth males were found to have significantly lower average parasite loads than males that did not achieve musth. This supports the conclusion above that in order to attain musth, males may need to be capable of achieving a state of health that is significantly better than the average health condition of non-musth individuals. Better health may correspond to a lower internal parasite load and to better external body condition, among other qualities, and thus the exhibition of musth may serve as an honest signal of good health and genetic quality in those males that can attain this physically costly condition. However, it must be cautioned that due to the low sample sizes and the inability to repeatedly sample all musth animals over their entire musth period these significant findings require further data collection and verification before they can be generalised or extrapolated to other areas.

Tusk length as a signal of health and genetic quality

During this study there was no evidence to show that tusk lengths were negatively correlated with average BCI and parasite loads. Consequently, there is no evidence from this study that tusk length may serve as an honest indicator of good health in male Asian elephants.

The results of this study appear to contradict those of Watve & Sukumar (1997). There are several possible reasons why this difference occurred:

(1) Intra-individual variation was not controlled for adequately in either of the two studies. A better understanding of intra-individual variation is required before any conclusions can be drawn. Watve & Sukumar (1997) did, however, control for seasonal variation in parasite loads, which was not possible in this study due to limited background data on parasite load variations across seasons. This is a possible source of intra-individual variation, especially since the study extended through the hot dry summer, which may have stressed some animals more than others and exaggerated the differences in their average parasite loads and BCIs.

(2) Host-parasite interactions between elephants and their helminth parasites may show variations in different habitats. Fluke and sprirorid nematode ova were detected in the Nagarahole samples, which were not reported from the Mudumalai population. There may be some variations in host-parasite ecology between these two study areas that may need to be considered.

Thus, although tusk lengths did not appear to signal good quality in male elephants in this short study, the use of tusk length as a signal cannot be completely rejected because longer tusks were associated with dominance in 78% of

interactions. They may thus marginally influence female choice. Longer time periods may be required to assess the role of tusk lengths in sexual signalling and dominance, and a more appropriate health indicator may be required, as external body condition and helminth parasite loads may fluctuate greatly over short intervals of time. These short-term fluctuations would not be reflected immediately in tusk length growth, and hence may lead to incorrect conclusions about their value as sexual signals.

It is possible that tusk length may serve as an indicator of long term or cumulative adaptation to environmental resources, whereas musth, being expressed for short terms on a regular basis, may provide a more immediate reference on an individual's ability to cope with current environmental fluctuations. This may explain why patterns associated with musth were better reflected in the two chosen health indicators while differences in tusk lengths failed to show correlations with the same health indicators.

Musth, tusk length and signal-based sexual selection

Several mate selection theories have been based on the use of extreme character development as effective sexual signals by males. Of these, the handicap principle (Zahavi, 1975) and the theory of heritable true fitness (Hamilton & Zuk, 1982) were considered most relevant to the current study, as they emphasise the costs associated with producing exaggerated signals. In the case of the handicap principle, the cost is expected to be so high as to prevent unhealthy males from being able to produce the signal (Zahavi, 1977).

This study provided evidence in support of musth as an honest signal of quality and of heritable true fitness in resisting chronic parasite infections to female elephants. However, since there was no clear trend in the health indicator values with increasing musth intensity or duration, it was not clear how much of a burden or handicap is imposed on males that attain and sustain their musth over long periods of time. Given that there is no clear evidence of ways in which musth increases the survival chances of males displaying this condition, it can still be speculated that musth may have evolved by female choice and sexual selection, rather than by natural selection, in Asian elephants.

There was little evidence from this study that relatively longer tusks may serve as honest signals of health or resistance to chronic parasite infections. In addition, elephants that exhibited musth during the study interval did not have significantly better developed tusks than those that did not exhibit musth. However, more information is required from a larger sample of males and over a longer time interval, before conclusions can be drawn with regard to the use of tusks as sexual signals by male Asian elephants. Although extremely long and crossed tusks could potentially serve as a signal of handicap, medium-sized and uncrossed tusks can increase the survival of the individual by functioning as digging implements for minerals, for debarking trees, for resting the heavy trunk and as a weapon of offence and defence. Thus it appears unlikely that tusk lengths would serve as effective signals of handicap, whereas musth, which appears to serve few survival purposes, seems a more likely candidate as a handicap signal. Instead, long tusks may serve as a signal of long-term adaptation to the local environment, a possibility that was not explored in the current study.

Even if tusks are relatively unimportant sexual signals, it cannot be concluded that tusks have no role to play in mate selection and reproductive success. Behavioural analysis showed that musth could potentially increase a male's mating success in another way: by allowing it to dominate over other males. Similarly, longer tusks were associated with dominance in 78% of the social interactions recorded. Since dominance can promote access to females as well as prevent other males from coming near receptive females, males with longer tusks may be able to "influence" females to choose them. In this way, relatively longer tusks may indirectly increase male reproductive fitness.

In general, females are likely to use information from several signals when exercising their choice over males (Zahavi, 1975). This study has provided evidence in favour of one such signal, musth. Previous studies suggest that female African elephants in oestrus preferred musth males to non-musth males (Poole, 1989b). However, while the occurrence and mechanisms of female choice have not been scientifically studied in Asian elephants, there is anecdotal evidence of females consorting with musth males (de Launey, 1938; Eisenberg *et al.*, 1971; Eisenberg & Lockhart, 1972) as well as occasionally rejecting musth males (Stracey, 1963). Clearly the complementary aspect of sexual selection, female choice, needs to be studied in detail before the existence of sexual signalling in Asian elephants can be confirmed. Further studies are also required to understand whether other visual, chemical or vocal signals are used for signalling between the sexes in elephants.

Further research and applications

All interpretations of the results reported above are subject to verification in future studies, due to the small sample sizes obtained in this study. Despite this limitation the study can be of value to conservationists interested in promoting long term viability of the species and of small and threatened elephants populations. The following are possible applications of the findings of this study, and suggestions for further research:

(1) A simple non-invasive method of assessing the health of elephant populations over regular intervals may be developed by using a combination of BCI and parasite density values. As seen in the case of musth versus non-musth individuals, there are significant measurable differences in these two health indicators over short intervals, which could also serve as sensitive indicators of declining or improving health trends in individuals and populations over different seasons and years.

(2) Studies on crop raiding by elephants have shown that male elephants are often responsible for most of the damage (Sukumar, 1989; Thouless & Sakwa, 1995; Bhima, 1998; Hoare, 1999). Sukumar & Gadgil (1988) had suggested that

this could be viewed as an adaptive strategy of "high-risk, high-gain" followed by male elephants, in order to attain better body condition, increase their chances of attaining the musth condition and thus increasing breeding success. The current study lends support to this speculation, by demonstrating the relationship between musth (especially early musth) and better health.

(3) The suggestion was put forward to selectively remove the most frequent crop raiding bulls from raiding elephant populations, as this might alleviate human-elephant conflict and reduce a serious conservation problem (Sukumar, 1991). However, if the local pool of male elephants is small, capturing the most persistent male crop raiders might remove the most healthy and reproductively successful males and may adversely affect the genetic fitness of the local breeding population in the long term.

4) The importance of musth and height in determining dominance may have important implications for reproductive success of makhanas (tuskless male Asian elephants). In light of the changing ratios of tusked to tuskless males due to poaching, if the most healthy tusked individuals are removed from a population, makhanas may gain selective reproductive advantage over less fit tusked males. If musth is an important sexual signal and makhanas tend to produce and sustain an intense musth phase over longer periods of time, this could cause a further skew in favour of makhanas in the future. This may be an interesting topic of investigation in future scientific studies of Asian elephants.

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Appendix

Ethogram of social behaviours of wild elephants recorded at Nagarhole National Park, November 1998 – May 1999:

Dominance and threats

- Approach by dominant with concomitant or consequent turning away/moving away by subordinate
- Approach by dominant with head swinging (up & down) or with trunk slung over the tusks
- Placement of trunk on face/back/rump/tail of subordinate
- Pushing subordinate with tusks, trunk base, head butt or body side
- Hit subordinate with trunk
- Mount subordinate from behind
- Placement of trunk into mouth of subordinate
- Facing subordinate and throwing mud over the head slowly
- Rubbing or swinging forefoot above the ground while facing subordinate
- Swing trunk out forcefully towards subordinate
- Sensing directly and overtly towards subordinate with trunk
- Lock tusks with subordinate and push him backwards
- Kick subordinate with hind foot
- Approach with head up and tusks pointing forward at subordinat
- Move close to subordinate from further away
- Displacement of subordinate for feeding

Subordination

- Passive receipt of dominance behaviours without retaliation
- Turning away/moving away from dominant elephant's approach
- Penis descends and hangs limp in response to approach by dominant
- Urination or defecation in response to approach by dominant

Musth

- Frequent tests of female genital area
- Stand still & alert >5 seconds
- Dig tusks in shallow water
- Walk with head swinging up and down

Female interest in / preference for male

- Approach male
- Turn around and present posterior to approaching male
- Spread legs when male tests genital area
- Urinate/defecate when male approaches female's posterior
- Passively accept male dominance behaviours (listed above)
- Move along with male when he leaves the female group

Female rejection of male interest

- Walk away when male approaches or attempts to mount
- Run away with/without vocalisation when male approaches persistently

Plate 1 A male elephant in musth. In addition to the temporal gland secretion down the cheek, the hind leg appears wet, probably due to urine dribbling

Plate 2 A musth male with a female herd. Body size dimorphism between adult male and female elephants is evident in this picture

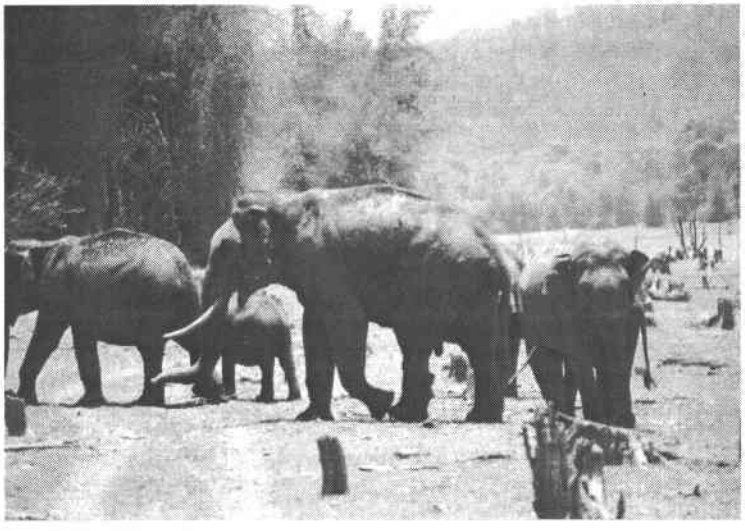
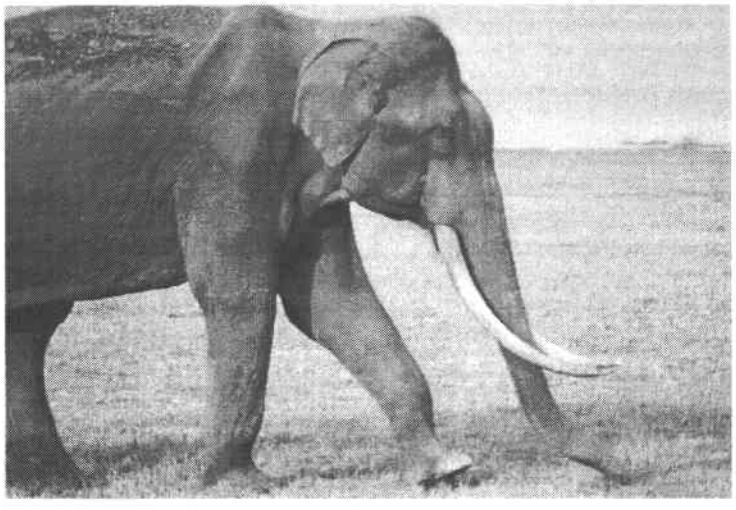


Plate 3 Are longer-tusked males preferentially chosen by female elephants? Long and crossed tusks such as these may be a handicap for the males possessing them



Plaet 4 A male elephant showing relatively poor external body condition. The degree of visibility of skeletal components such as pectoral and pelvic girdles, backbone, ribs and cheek bones were used to subjectively score the body condition index

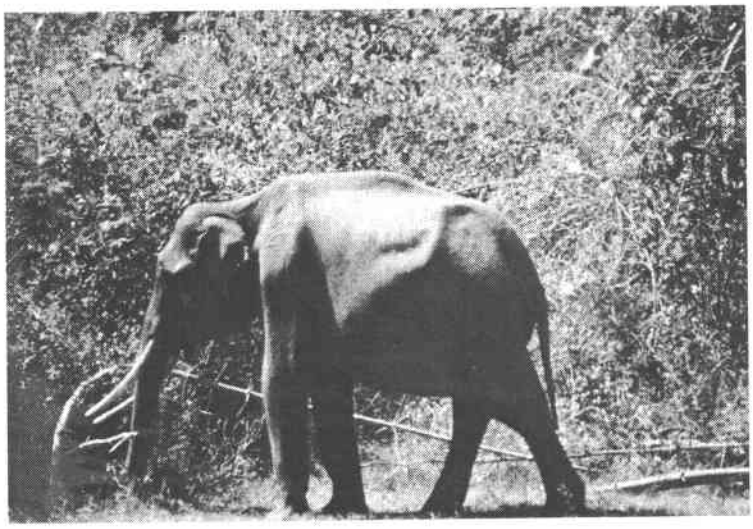


Plate 5 Patterns of holes, cuts and tears in the ears were used to identify elephants. Other features used for individual identification were size and shape of tusks, pattern of ear fold, length and shape of tail, etc.

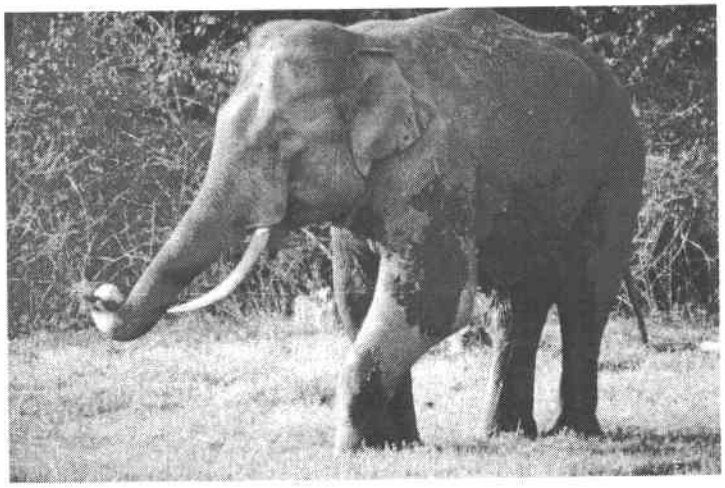


Plate 6 A wild bull elephant crossing the road. Such photos can be used to measure the shoulder height and tusk length.

All photographs were taken at the Nagarahole National Park, South India by Cheryl Nath.

The economic value of conserving the Asian elephant: contingent valuation estimates for Sri Lanka

Ranjith Bandara and Clem Tisdell

Abstract The Asian elephant (*Elephas maximus*) is one of the world's most seriously endangered species of large mammals. However, the economic value of conserving it from a total economic evaluation perspective has been little studied. This paper addresses this matter for Sri Lanka. It summarises the results of a contingent valuation survey of willingness to pay for the conservation of the elephant of a sample of urban residents in Colombo. The majority of respondents favoured the survival of the wild elephants, and were willing to pay (WTP) Rs. 110.16 per month amounting to a total of Rs 1,322 per year on average for a period of five year to support this goal. Extrapolating this value to the other urban centres in Sri Lanka, we found that urban dwellers are WTP Rs. 506.7 million per month, amounting to a Rs 2,713.3 million per annum and Rs. 40248.61 million for a period of five years. The annual return on this capitalised sum is Rs. 2012.43 million per annum in perpetuity at a 5% real rate of interest. Comparing this amount with our economic estimates of annual total crop and property damage caused by elephants in Sri Lanka (Rs.1121.42 million per annum) shows that urban residents could compensate farmers for these damages and be better off than in the absence of elephants in the country. This suggests that there is a strong economic case for the conservation of the wild elephant population in Sri Lanka, at least at their current population level. The economic value to urban residents of the continued existence of wild elephants in Sri Lanka appears to be about twice the extent of economic damage caused to farmers by elephants.

Keywords Asian elephant, Sri Lanka, contingent valuation method, crop damage, compensation, conservation.

Introduction

In many respects, the survival of the Asian elephant (*Elephas maximus*) is more precarious than that of the African elephant (Bandara & Tisdell, 2002a). IUCN (1996) declared the Asian elephant to be one of the most seriously endangered species of large mammals in the world. At present, it occurs in only thirteen countries in Asia, including Sri Lanka (Kemf & Santiapillai, 2000) and its population has fallen significantly. The Sri Lankan elephant population, for example, underwent a marked reduction starting from the mid-nineteenth century (Santiapillai & Jackson 1990; De Silva, 1998). Fragmentation and loss of natural habitat are the major factors contributing to this decline and these help generate human-elephant conflict (Desai, 1998). This situation largely results from the *ad hoc* development projects carried out during the last fifty years (Weerakoon, 1999), and is exacerbated by the lack of co-ordination between different government departments and wildlife authorities. Moreover, poor integration of economic aspects and lack of attention to public preferences for elephant conservation compounds the problem.

Several techniques are available for measuring the economic value that members of the general public place on the conservation of wildlife and other natural resources. These include the hedonic pricing approach (HPA), the travel cost method (TCM), and the contingent valuation method (CVM) (Carson *et al.*, 1996). However, the HPA and TCM have been criticised by a number of authors for failing to measure the non-use or intangible values of wildlife adequately (see Stevens *et al.*, 1995; Oglethorpe & Miliadou, 2000). The CVM is free from this particular criticism. It is able to elicit types of benefits that these other methods cannot elicit (Kotchen, 2000). CVM uses survey questions to elicit people's stated preferences for public goods such as conservation of elephants (Ready *et al.*, 1996; Loomis & Ekstrand, 1998; White *et al.*, 2001). However, CVM also has limitations. It can for example, involve errors in estimation of economic value due to strategic, design, part-whole and hypothetical biases (Bateman & Turner, 1993).

Nevertheless, CVM is a widely applied monetary evaluation method. For example, it has been widely applied to the valuation of environmental and natural resource-related goods such as the preservation of wildlife species and outdoor recreational amenities (see Seip & Strand, 1992; Diamond & Hausman, 1994; Jakobsson & Dragun, 1996; Loomis & White, 1996; Wills & Powe, 1998; Witzer & Urfei, 2001; Bandara & Tisdell, 2002b). In CVM, the non-use economic values of a given environmental amenity are generally measured based on the willingness to pay for an improved situation, or using the willingness to accept compensation for a damaged or diminished situation. An appealing aspect of the contingent valuation method is that it allows us to estimate total economic value (Pate & Loomis, 1997). It is widely used. Carson *et al.*, (1994) provide a bibliography of 1,600 CVM studies and related publications.

In economics, the importance of total economic valuation of wildlife and other natural resources is increasingly recognized. Estimates of total economic value combine willingness of stakeholders to pay for their direct interactive use of wildlife for harvesting, tourism or other purposes plus economic values generated by other than direct interactive use such as from the knowledge that a species continues to exist (existence value) or that it will be available to future generations (bequest value). Such willingness to pay can be influenced by feelings of moral obligation towards

Ranjith Bandara and **Clem Tisdell**
School of Economics
The University of Queensland
Brisbane, Queensland 4072,
Australia

a species (cf. Tisdell, 1997; Etzioni, 1988). CVM is designed to capture all values that influence willingness to pay to conserve (or eradicate) a species. Therefore, it is a considerable advance on those economic techniques that merely measure economic value generated by direct use of a species. As a rule, these only given partial indications of economic value. Nevertheless, economic methods, such as CVM, represent only one philosophical approach to value. One should be clear that despite its wide perspective, CVM does not constitute a complete or exclusive approach to valuation (Tisdell, 1997; cf. Lehman, 1993). Yet, provided this is kept in mind, methods, such as CVM, designed to determine total economic valuation can significantly enhance our appreciation of social choices involving conservation of wildlife. The purpose of this article is to show how analysis using CVM can provide new perspectives on the desirability of conserving Asian elephants in Sri Lanka.

Our study involved first a CVM survey of a sample of urban residents in Colombo, the capital of Sri Lanka, in order to determine their WTP for the conservation of the Asian elephant. This was then used to estimate the willingness of Sri Lankan urban dwellers, as a whole, to pay for conservation of the Asian elephant. A dichotomous choice form of contingent valuation is applied to quantify the conservation value of the wild elephant. An analysis is undertaken to investigate the underlying factors that determine the willingness of urban respondents to pay for the conservation of the elephant. Furthermore, in this analysis we consider whether urban residents' WTP for the conservation of elephants is sufficient to compensate farmers for the damage caused by elephants and to raise farmers' tolerance of the present elephants on their farming fields. The survey procedures are outlined first. This is followed by analysis of the results. The economic losses associated with crop and property damages caused by elephants are then compared with the estimated urban WTP benefits in order to determine whether the urban residents' potential contribution for conservation of elephants would be sufficient to compensate farmers for the crop and property damage caused by elephants and consequently raise farmers' tolerance of the presence of elephants

Methods

Contingent valuation market to assess the conservation value of the elephants in Sri Lanka

Interviews with urban respondents involved four different steps. In the first step, the respondents were presented with updated information about the present status of the elephant population in Sri Lanka, and the policy and institutional issues that need to be addressed to conserve elephants in the country. Respondents were then told why it is important to adopt new approaches to ensure the survival of the elephant in Sri Lanka in the long-term. They were informed that existing protected areas are inadequate in size to ensure the long-term survival of wild elephants if elephants are confined to these areas. Furthermore, there is little or no prospect of a significant increase in the size of these areas. Thus, the survival of elephants seems to depend on their use of both protected areas and non-protected areas. Socially acceptable strategies for an appropriate level of co-existence between farmers and elephants are needed. Such co-existence hinges on greater compensation for farmers to tolerate elephants to a greater extent than currently.

In the second step, the survey respondents were presented with an alternative policy designed to address these issues. They were asked to assume that an autonomous body, reputed for its efficient and honest work, would introduce a sound conservation programme so that the current downward trend in elephant population could be halted while addressing other elephant related issues. The respondents were informed that this organisation would initially implement the following measures for the conservation of the elephant: a) Provision of extra protection around existing national parks and protected areas, b) translocation of excess and troublesome elephants, c) domestication of the elephants for local and foreign zoos, tourist establishments, temples, study centers, or for use as work animals, and d) establishment of animal orphanages and recreation centers to promote eco-tourism. Respondents were also informed that this policy alternative was developed based on the assumption of that the conservation of elephants can be achieved through integrated policies involving both public and private landholders in the elephant's range and other interest groups, such as city-dwellers.

In the third step, the respondents were informed about the need to finance the proposed programme and the required support of the general public to establish a 'trust fund' to support the proposed conservation programme. Moreover, they were also told of possible benefits that they would be able to obtain after the successful implementation of this programme. The benefits presented to the respondents were: a) greater possibilities to view more elephants in a single herd in the wild, b) greater opportunities to see elephants in the wild during a short number of visits to a given national park, c) opportunities to domesticate more elephants for the purpose of religious festivals and the local tourism industry, and d) increase in agricultural crop production due to the mitigation of HEC in the main agricultural regions in the dry zone of the country.

Finally in the fourth step, the respondents were presented with the contingent market valuation question: "*For the next five years, would you be willing to pay Rs X from the monthly income of your household, that is Rs X per year, starting from January 1st 2002, towards the establishment of the proposed trust fund to implement the above mentioned programs to conserve the elephants in the country*". Respondents were offered a set of bid values at four different stages conditioned to their response for the first WTP elicitation question. After survey respondents were presented with WTP elicitation questions, two follow-up questions were asked. These contained categories of reasons for the response to the contingent market and the respondent's preferred method of payment. These questions help to identify protest responses as well as motives for preservation.

Sample, data collection procedure and method of analysis

The surveyed population was purposefully chosen from urban residents in Colombo. The population density, level of urbanisation, living standards and life style of residents were taken into account for the selection of a sample of urban residents. A sample of 300 residents was chosen from three main housing schemes in Colombo, *Jayanthipura*, *Jayawadanagam*, and *Anderson Flats*. The Urban Development Authority of Sri Lanka (2001) classifies these schemes as upper middle class, middle class and lower middle class housing schemes respectively. This classification is based on the value of the property and other urban facilities in the area where these housing schemes are located i.e. public schooling, shopping centers and recreational sites. A hundred residents from each of these housing schemes were chosen as the sample. A stratified sampling procedure was adopted in selecting this sample.

An interview schedule (IS) was used to gather the information used in the analyses presented in this paper. This consists of five different sections. The first section of the IS contained the personal profile of the respondent. The second contained questions to assess the attitudes of the respondents on 'development' and 'environment'. Section three presented respondents with information about the present status of elephant conservation and the problems that are encountered in conserving elephants in the existing protected area network. Section four of the IS contained the most important questions in the survey, where respondents were presented with dichotomous choice elicitation to assess their WTP for the conservation of elephant. Section five of the IS contained a set of questions for the interviewer. In these questions, interviewers were asked about the level of understanding and sincerity of the respondents. Nine graduate students from the Faculty of Graduate Studies of the University of Colombo were used as interviewers to administer the IS. A face-to-face survey was conducted to gather the information. Hadker (1997) suggests that this is a more useful method compared to mailed questionnaires and telephonic surveys in developing country contexts.

A non-linear logit regression model was constructed to analyse the respondents' responses to the WTP elicitation questions. Jaibi & Raa (1998) provide a list of economic applications of this model and Pate and Loomis (1997) describe this model as the most commonly used non-linear model in CV studies. Sellar *et al,*. (1986) outline the merits of the logit model, and Kanninen & Khawaja (1995) discuss the advantages of use of logit analysis for a contingent valuation survey with dichotomous format. One such advantage is the opportunity to use logit analysis, a non-linear method, to regress a binary (dichotomous) dependent variable on one or more independent variables. McFadden (1974) has also outlined the bases of the dichotomous choice theory corresponding to the logit specification.

In this study, we used the probability of the respondents' responses to principal WTP elicitation questions $\{P_i /(1 - P_i)\}$, where P_i = Probability of yes to the WTP elicitation questions as a dependent variable and considered factors that influence their probable responses. A number of socio-economic, demographic and attitudinal variables were included as independent variables for the preliminary logit analysis. The variables were: the respondent's age (*AGERE*), attitudes to alternative elephant conservation approaches *(ATHEC),* bid value (*BIDVA*), awareness of the current conservation issues (*CONSE*), concern about future generation needs (*FUPRE*), pro-conservation perception (*GREEN*), association with environmental guilds or groups (*MEMBE*), concern about non consumptive use-value of the elephant (*NONUV*), personal income (*PERIN*), pro-development concern (*PRODE*), occupation *(OCCUP),* position in the household (*RPOSF*), total family income (*TOFIN*), and years of schooling (*YRSCH*). The choice of these variables was partly based on choices in several previous

Table 1 The factors influencing respondents' responses for the payment principle questions : The final logit regression results

Variable	Coefficient	*t*-statistics
CONSTANT	-5.021	-2.098
Respondent's age *(AGERE)*	-0.872	-3.392
Rupee value from the WTP question *(BIDVA)*	-1.029	-4.198
Awareness about current conservation issues *(CONSE)*	1.045	4.685
Opinion on pro-conservation perception *(GREEN)*	3.322	7.583
Opinion on the non use-value of the elephant *(NONUV)*	1.284	2.904
Personal income *(PERIN)*	4.785	9.213
Attitudes towards pro-development activities *(PRODE)*	-0.043	0.904
Position in the family *(RPOSF)*	1.224	2.253
Years of schooling *(YRSCH)*	2.990	5.207

Summary statistics:

Dependent variable = the probability of saying 'yes' to the principle WTP questions, Number of observations =300; log- likelihood is 73.8654,

F statistic: 31.1846; $\alpha = 0.05$; df = 9; $R^2 = 0.0.6050$; Adjusted R^2 0.5861.

CVM studies of environmental valuation (see Whitehead, 1992; Miller & Lindsay, 1993; Bateman & Langgord, 1997; Witzer & Urfei, 2001).

Results

The preliminary logit regression analysis was undertaken by using the Statistical Package for Social Sciences (SPSS) Version 10.0 to identify the factors associated with respondents' responses for the WTP elicitation question at the $p < 0.05$ significance level. This analysis reveals that some of the independent variables cited above were either statistically not significant, or were highly correlated with other variables at the $r > 0.8$ level. Hence, it was decided to exclude these variables from the final logit regression analysis. Several goodness of fit measures were used to estimate overall statistical performance of the estimated model in this study. These results indicate that the overall ability of the model to yield a correct prediction of urban residents' WTP for the conservation of elephant is significant at the 0.05 level of statistical significance. A summary of the final logit regression results is presented in Table 1.

Discussion

Factors influencing the respondents' response to conservation value questions

As indicated in Table 1, most of the estimated coefficients have a positive influence on the probability of saying 'yes' to the principal conservation value questions by the respondents in the sample. The positive sign for the *CONSE* variable supports the hypothesis that the probability of the respondent saying 'yes' to the WTP question increases with the respondent's awareness of the present status of HEC and the issues involved in the conservation of elephants in Sri Lanka. Loomis & Ekstrand (1998) observe a similar situation in relation to conservation of the Mexican spotted owl. As might be expected, the coefficient for the *NONUV* is positive and significant in the model. This suggests that a respondent who values the non-use values of elephant (such as altruistic bequest and existence values) has a higher probability of answering 'yes' to the WTP question. This is understandable because the elephant in Sri Lanka is closely associate with Sri Lankan, their history, religion, culture, folklore, mythology and ceremony.

The coefficients for the attitudinal variables such as *GREEN,* are positive and significant. The result suggests that respondents with pro-conservation attitudes are likely to contribute more towards the conservation of the elephant. Loomis & Larson (1994) observe a similar situation in a CV survey of the grey whale. On the other hand, the variable *PRODE* was used in the model to assess the response of anti-conservation attitudes on the probability of saying 'yes' to the WTP question. The *PRODE* was not significant. This is understandable because the majority of the respondents in the sample disagreed with development programs that cause environmental problems. In our preliminary discussion when we put the proposition "*Sri Lanka should not encourage development programs such as tobacco cultivation in central highlands that cause serious environmental damage*", 88.6% respondents agreed, implying that they were rather 'green', and inclined strongly towards environmental protection. Hadker *et al.,* (1997) observe similar attitudes in a CV study in India. In this study, it was found that about 72% of respondents strongly disagreed with development programs that hurt the environment.

BIDVA had a negative influence on the probability of the respondent saying 'yes' to the WTP question. This means that the larger the bid value presented in the interview to the respondent as a WTP elicitation question, the less willing these respondents were to pay for elephant conservation. Miller & Lindsay (1993) notice a similar relationship in a CV survey which was conducted to analysis WTP for a state gypsy moth control program in New Hampshire. Loomis & White (1996) also observe a similar result in an analysis of economic benefits of rare and endangered species.

Among the socio-economic characteristics, age, personal income, years of schooling, and respondent's position in the family were considered as influences on the probability of respondents being willing to pay for the conservation of the elephant. The positive sign of the coefficient of the *YRSCH* indicates that the probability of saying 'yes' for the WTP question increases with an increase in the number of years of schooling. This is understandable because more years of schooling would arguably increase the knowledge a person has about social, political, economic and environmental happenings. Moreover, the education would help a person comprehend news about environmental effects of economic development. Several CV studies find a similar relationship between level of education and respondent's response towards the WTP elicitation questions. For example, Whitehead (1992) noticed that the level of education is often positively correlated with the WTP amount in an *ex ante* willingness to pay analysis. Pate & Loomis (1997) describe the rationale behind this relationship in a case study of wetland and salmon conservation in California.

The variable *AGERE* is significant with a negative coefficient. This implies that younger respondents were more willing to say 'yes' to the WTP question than their older counterparts in the sample. Heinen (1993) observes a similar situation in a study of people's attitudes towards the wildlife in the *Kosi Tappu* Wildlife Reserve in Nepal. In this study, he found that the positive attitudes towards the preservation of nature could be measured by the individual willingness to pay amounts which correlate highly with the respondents' age, years of schooling and the gender. He also notices an interesting relationship between age and the years of schooling. Younger respondents are found often to have more years of schooling than the older ones in the sample. This is quite similar to the situation found in Sri Lanka.

The variable *PERIN* is significant. The positive sign of it implies that the respondents whose personal income is greater are more willing to pay for the conservation of the elephant than the respondents whose personal income is lower. A number of other CV studies have obtained a similar result. Boyle & Bishop (1987) estimate the effects of the income

on the determination of WTP amount for the conservation of endangered species. Carson *et al.,* (1996) found that the sum individuals are less willing to pay for the preservation of quasi-public goods tends to rise with their income. Loomis & Larson (1994) estimate an individual's WTP for increase in the quantity of an environmental public good in relation to a number of socio-economic factors including household income. Findings of Hadker *et al.,* (1997) suggest that the higher income earners in the metropolitan area of Bombay have a stronger interest in environmental conservation than the lower income earners.

The variable *RPOSF* is significant with a positive contribution to the likelihood of being WTP for conservation of elephants. However, this result may be linked to the traditional Sri Lankan family culture and values. In this setting, families are represented by the head of the household. In most cases, the head of the household is the father (or the mother in the absence of the father) or the oldest child (in the absence of both the father and mother). As a result, in this study over representation of heads of households in the age group of 30 years and above was unavoidable. This cultural situation restricted the opportunities to interview the other members in certain households. In most cases, such opportunities were found only where the head of the household was absent at the time of the interview and he or she permitted another family member (in most cases the most educated person in the family) to represent him or her in the interview.

The aggregation and extrapolation of WTP benefits

Of the 300 respondents, bids of 34 respondents were identified as protest bids. These responses were removed from the sample so that genuine WTP could be analyzed. Therefore, a total of 266 WTP amounts were used in aggregation and extrapolation of WTP benefits. This was carried out at three different levels: a) from the sample to Colombo metropolitan area, b) from the Colombo metropolitan area to other major urban centres, and c) from major urban centres to the entire urban population in Sri Lanka. In this process, the authors, mindful of the sensitivity of sample effects, referred to a study done by the Department of Census and Statistics of Sri Lanka on economic and demographic aspects of the population in the Colombo metropolitan area (Department of Census and Statistics, 1998). It was found that household characteristics of the urban population in Sri Lanka were quite close to the sample of the present study. However, it must be noted that the mean WTP values used to extrapolate from the sample to the population refer to the ones after the removal of protest bids.

In our extrapolation process, we found that urban residents in Colombo metropolitan area were WTP Rs. 166.35 million per month for the conservation of elephant. This amounts to an annual value of Rs 1996.22 million. As the payment will be made over a period of five years, the total net present discounted value of these annual amounts, at a 5% real rate of discount, equals Rs. 9,075.02 million. Extrapolating to these results to all major urban areas in Sri Lanka, it was estimated that residents in these areas were WTP Rs. 438.48 million per month for the conservation of elephant. This amounts to an annual value of Rs 5,261.17 million. As the payment will be made over a period of five years, the total present discounted value of these annual amounts, at a 5% real rate of discount, equals Rs. 24,554.20 million. Finally, when we extrapolate WTP for the entire urban population in Sri Lanka, using a population size of about 6.67 million (this figure was drawn by deducting 11.3% from the total population of 7.49 million people in urban areas to represent the protest responses based on the findings of the case study presented in this paper), we found it was Rs. 734.83 million per month. This amounts to an annual value of Rs 8818.01 million. As the payments are specified over a period of only five years, the total present discounted value of these annual amounts, at a 5% real rate of discount, equals Rs. 40248.61 million.

We know that urban residents are WTP Rs. 8818.01 million per year for five years but we do not know their WTP beyond that. Damages caused by elephants will, however, continue in perpetuity given current populations of elephants. One possible way to compensate farmers would, in principle, be to invest the urban dwellers' contribution over five years in the capital market to give an estimated return on the capitalised sum of Rs. 2012.43 million per annum at a 5% real rate of interest. This could arguably be considered an indirect indication of the willingness of urban dwellers to pay in principle in perpetuity to conserve wild elephants.

It is also worth mentioning that although in this study, we asked respondents about their WTP for the conservation of elephants for only five years, some (maybe most) respondents certainly would probably be willing to pay beyond this period. Furthermore, this amount could be increased by at least another 100%, if we extended our extrapolation to the population of residents in the rural areas where elephants do not occur or interfere with farming practices.

Urban residents WTP for conservation of elephants exceeds value of crop and property losses of farmers

As mentioned elsewhere in this paper, one the of objectives of this study is to find out whether the urban residents' WTP for conservation of elephants is sufficient to compensate farmers for the crop and property damage caused by elephants, and to raise farmers' tolerance of the presence of elephants. In this analysis, it was assumed that if urban dwellers could compensate farmers for losses associated with crop and property damages caused by elephants, given the current elephant population, and were better off than in the absence of wild elephants, the current population of elephants would be (Kaldor-Hicks) superior to the absence of wild elephants.

According to Bandara & Tisdell (2000b) the total value of the crop and property damage caused by elephants in Sri Lanka is about Rs. 560.71 million per cropping season or Rs. 1121.42 million per annum. These authors have derived this figure by extrapolating the elephant damages estimated in three selected case studies (see Bandara & Tisdell, 2002c; Jayawardene, 1998;

and De Silva, 1998) carried out in three different locations in the elephant's range. However, before we use this figure to reach any conclusions, it must be noted that the crop and property damage calculated in this analysis did not pay much attention to the possible cost that could be associated with elephants other than crop and property damages. Under normal circumstances, the total economic cost should include the cost of control measures undertaken by farmers to scare away the crop-raiding elephants, income foregone by farmers in having to replace some crops with others that are less attractive to elephants, and the management cost borne by government departments to undertake various programs for the conservation of elephants and the mitigation of HEC. Such comprehensive assessments of total losses associated with the elephant are yet to be estimated.

Nevertheless, when we compare the economic estimates of crop and property damage caused by elephants of Bandara & Tisdell (2000b) with above estimated return on the capitalised sum of Rs. 2012.43 million per annum, it shows that urban residents' financial support for the conservation of the elephant significantly exceeds the economic losses caused by the elephant. This means that our estimated return of Rs. 2012.43 million per annum on the capitalised sum in perpetuity is more than sufficient to compensate farmers for their estimated crop losses of Rs. 1,121.41 per annum; in fact almost twice the needed sum.

When compensation is paid, control of elephants by farmers is likely to be much reduced. Furthermore, a lot of their current control costs are ineffective in aggregate, either because elephants have become resistant to control measures or because, in many cases, control measures merely result in elephants moving from one farmed area to another (cf. Rollins & Briggs, 1996, p.369). Consequently, in the latter case, a type of prisoners' dilemma problem exists. If compensation for damage caused by elephants leads to much reduced control of elephants by farmers, they should achieve a net economic benefit because their control costs will be greatly reduced (or in the extreme case, eliminated) and the aggregate damage experienced by them from elephants will increase little or not at all. Nevertheless, there might be a small increase in damage in aggregate, if, for example, elephant populations increase slightly due to less harassment of elephants. Despite this, it is clear that, if compensation were paid to farmers, a sum of less than Rs 1,124.42 million per year would compensate them if allowance were made for the reduced control effort of farmers. The latter will reduce farmers' costs of control.

Conclusion

This study was conducted to survey a sample of urban residents in the Colombo metropolitan area to determine their willingness to pay for the conservation of the Asian elephant in Sri Lanka. The finding of this analysis indicates that there is a strong economic case for ensuring the survival of wild elephants in Sri Lanka. There is strong evidence that the current population of wild elephants in Sir Lanka is economically preferable to their absence considering the interests of all stakeholders, urban residents and farmers.

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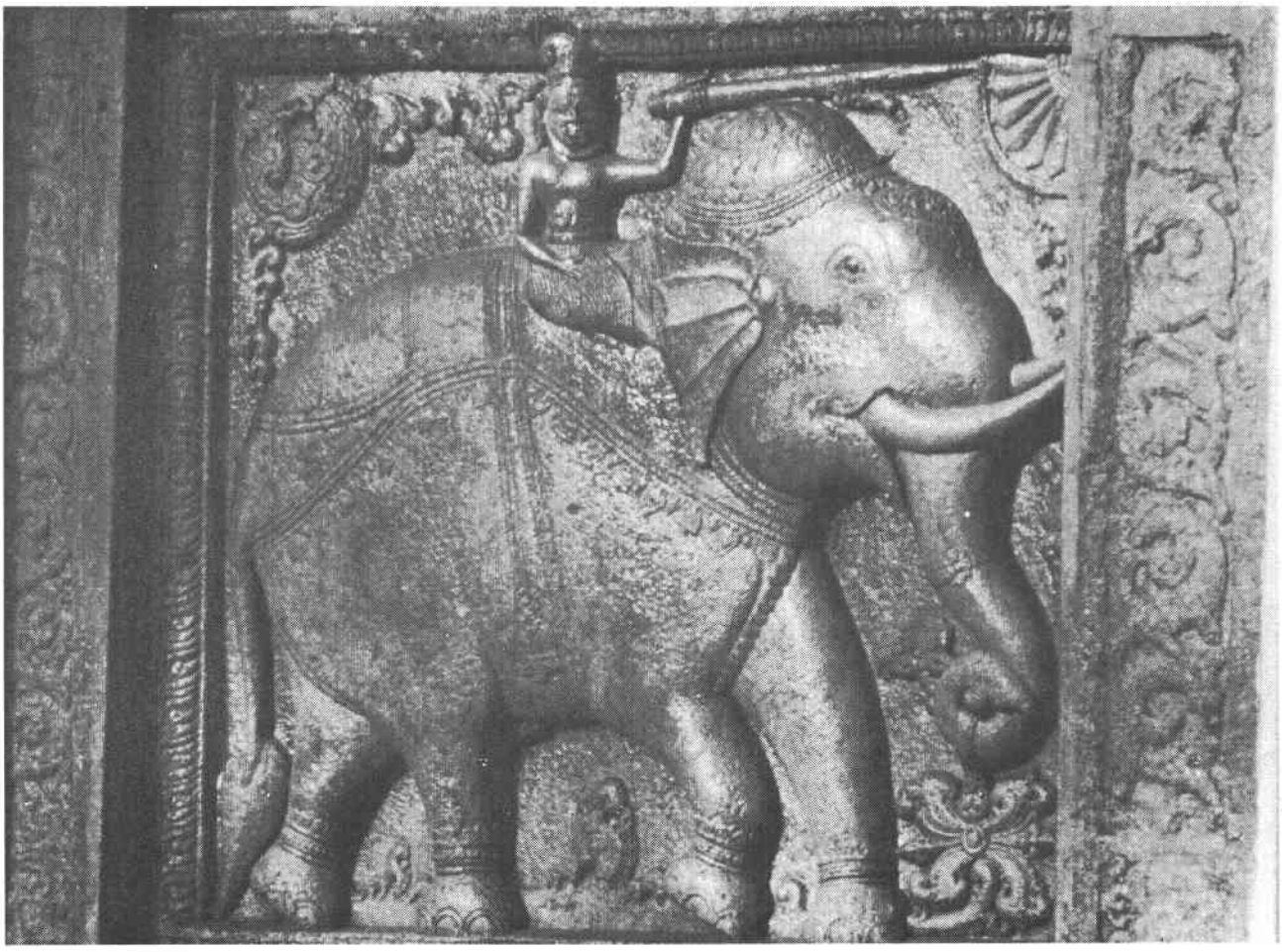


Elephant (18th Century) at the entrance to the Temple of the Tooth Kandy
(Photo: Dr. H. I. E. Katugaha)

Guidelines for the management of captive Asian elephants and the possible role of the IUCN/SSC Asian Elephant Specialist Group

Fred Kurt and Khyne U Mar

Abstract Many reports refer captive Asian elephants as "domesticated" animals. However, most of the elephants living in captivity have been wild-caught and a large number of them are the result of wild bulls mating with females in captivity. Although captive elephants have existed since 3,500 years in close contact with man, yet they have not been the subject of sustained captive breeding, nor have they been selected for particular characteristics as it was, and still is, the case with really domesticated animals such as horses, sheep or dogs. It is therefore inaccurate to refer to the captive Asian elephants as domesticated animals. There could be as many as 14,000 Asian elephants in captivity, with Myanmar accounting for 40%. At least 1,047 Asian elephants are kept world wide in zoos and circuses. Therefore the total captive population includes at least 15,000 elephants. The chances of survival of captive populations are practically zero in intensively kept elephants and very insignificant for those kept in traditional zoos where mortality rates are extremely high at young ages. But the survival chances are relatively high in the Pinnawela Elephant Orphanage in Sri Lanka, modern zoos as well as in extensive keeping systems with low mortality rates at young ages. Well maintained elephant parks, orphanages, and transit homes allow for the maintenance of elephants free of chains and in social groups, thereby enabling the animals to express their natural behaviour patterns, and provide them with exercise and opportunities to socialize. Elephants kept in such a way make more sense to the visitors than do "dancing" elephants or elephants that are forced to ride bicycles, paint canvas, play football, guitar or mouth-organ.

Keywords Asian elephant, management in captivity, domestication, captive breeding.

Introduction

During the IUCN/Asian Elephant Specialist Group (AeESG) meeting that was held in Phnom Penh, Cambodia in May 2002, the AsESG formed a "Captive Elephant Taskforce". Some AsESG members met again at the Workshop on Captive Elephant Management in Trichur in October 2002 and again the Chairman of AsESG, Prof. Raman Sukumar, asked for ideas concerning the aims of such a taskforce. In this paper we have drafted a few ideas along the following lines: First of all the AsESG should desist from referring to "domesticated" elephants. Then one should ask what are the aims of IUCN and the IUCN Specialist Groups as compared to the aims of animal welfare organizations and those zoos concerned with management problems of captive elephants. Then very brief overviews are given on existing and forthcoming guidelines on the management as well as on the estimated sizes of captive populations. Different aspects of the significance of captive populations are broadly discussed after keeping systems have been defined. Finally we have made some proposals concerning further activities of AsESG regarding the management of captive elephants.

Fred Kurt
Institute of Wildlife Biology
University of Veterinary Medicine
Vienna, Austria
E-mail: fred.kurt@t-online.de

Khyne U Mar
Department of Zoology
University College
London,
England, UK
E-mail: khyne_umar@hotmail.com

Are captive elephants really domesticated?

Numerous reports consider captive Asian elephants as "domesticated" animals (c.f. Lair, 1997). However, most of the elephants living in captivity have been wild-caught and a large number of elephants that have been bred in the range countries are the result of matings between captive females and wild males. Although captive elephants have existed since 3,500 years in close contact with man, yet they have not been the subject of sustained captive breeding, nor have they been selected for particular characteristics as it was, and still is, the case with really domesticated animals such as horses, sheep or dogs. It is therefore inaccurate to refer to the captive Asian elephants as domesticated animals (e.g. Baker & Manwell 1984; Herre & Röhrs, 1990; Stevenson, 2002).

Misuse of the term "domesticated" leads to the fact that many captive elephants were, and still are, treated as cattle and managed accordingly. For example, in old fashioned western zoos and circuses the elephant is the only wild animal still kept more or less permanently in chains. Imagine the reaction of animal welfare organizations, if suddenly zoos would keep rhinos, hippos or tigers in chains! All members of AsESG should consider tamed Asian elephants as what they are, as captive wild animals.

What are the aims of the IUCN, modern Zoos and Animal Welfare Organizations?

The IUCN aims to conserve the biodiversity of the planet earth with particular emphasis on the maintenance of threatened species and their genetic diversity and the

maintenance of ecological processes. The Asian elephant is considered an endangered species. Furthermore *Elephas maximus* must be considered a keystone species as well since it plays an important role in ecological processes (e.g. dispersion of seeds, acceleration of soil fertility in cooperation with insects and other invertebrates) in its habitat. The Asian elephant can also be regarded as a flagship species promoting conservation of numerous less popular plant and animal species surviving in its habitat (Leader-Williams & Dublin, 2000).

In 1993 some modern zoos formulated the "World Zoo Conservation Strategy" and started to take responsibility for the *ex-situ* conservation of certain animal species including the Asian elephant. Accordingly these zoos would like to keep elephants in as natural ecological and social conditions as possible. This means that the environment must be provided to ensure species-specific behaviour patterns, e.g. food preparation or social possibilities for forming a dominance hierarchy, family units and successfully rearing of offspring. The World Zoo Conservation Strategy aims to maintain a natural socio-ecological set-up, refers to results of field research on wild populations and aims by environmental enrichment to reduce the frequencies of abnormal behaviour as well as the increase of behavioural diversity, the range or number of behaviour patterns, the positive utilization of the environment and the ability to cope with challenges in a more normal way. Elephants kept in near-natural conditions convey more understanding of the species and its requirements to the visitor and provide insight into the necessity to protect the species. Furthermore near-natural conditions promote breeding in captivity and hence, add to the conservation of genetic and behavioural diversities.

During the past few years, animal welfare organizations have helped raise elephant welfare standards. A considerable number of new elephant welfare organizations have been formed. They campaign, train and provide resources to improve living conditions of captive elephants in western zoos as well as several range states including India, Sri Lanka, or Thailand. Animal welfare activities refer mainly to the fitness (e.g. health, body condition) of the individual, but hardly touch on socio-ecological considerations to maintain captive populations living in near-natural conditions. In traditional elephant keeping establishments the captive animals are not able to enjoy what Webster (1984) terms "the five freedoms" (freedom from malnutrition, from thermal and physical discomfort, from injury and disease, from fear and stress, as well as freedom to express most normal patterns of behaviour). Nevertheless assessment of the fundamentals of animal welfare organizations is the fundamental basis of the maintenance of the Asian elephant in captivity.

Table 1 Estimated numbers of captive Asian elephants in range countries, zoos and circuses (worldwide), population trends and employment (+ occurs, ++ occurs often, - not found).
CRM = ceremonies; BEG = begging shows; ECO = ecotourism.

			used for				
country	total	population trend	logging monitor	CRM	BEG	ECO	source
Bangladesh	50	decrease	+	+	-	-	Islam (1996)
Cambodia	144	decrease	+	+	+	-	Ratanakorn (2002)
India	3600	stable	+	++	+	+	Bist *et al.*, (2002)
Indonesia	400	decrease?	(+)	(+)	++	+	Mikota (2002)
Lao PDR	920	decrease	++	?	?	?	Ratanakorn (2002)
Malaysia	8	?	+	-	-	-	Daim (1996)
Myanmar	5700	stable	++	+	-	-	Mar (2002)
Nepal	127	stable?	-	(+)	-	++	Dhakal (2002)
Sri Lanka	186	decrease	-	++	++	(+)	Jayewardene (2002)
Thailand	2568	decrease	+	(+)	++	(+)	Ratanakorn (2002)
Vietnam	225	decrease	+	?	?	+	Sawson (1996)
Total	13928						
Zoos/circus	c.1094	decrease					Koehl (2001)
Grand Total	c.14975						

Taking the above-mentioned definitions into consideration, AsESG has to assist all serious animal welfare activities, but according to the aims of the IUCN, the AsESG has to promote the aims formulated by the World Zoo Conservation Strategy as well. The goals of the strategy should accordingly be valid for any conservation-minded facility keeping captive Asian elephants.

Existing guidelines for the management of captive Asian elephants

The earliest work concerning the care of captive elephants was decidedly the *Hastyayurveda* which appears to have been written in the 5th or 4th century BC. The *Arthasastra* of Kautiliya (300 BC – 300 AD) deals, in two chapters, with capture, keeping, care and training of elephants. The *Matangalila* of Nilakantha, another ancient source, may go back to a thousand years or even to a much earlier date. Next to these three standard texts are a number of other old Buddhist and Hindu sources referring to the management of captive elephants such as the *Tanjore Manuscript* (a compilation of several older texts), the *Gajanirupana*, the *Gajacikitsa*, the *Gajalaksana*, or the *Brhat-Sarnhita* of Varahamihira (c.f. Edgerton, 1931). All the rules and regulations given in these texts formed the basis for the management of captive elephants in areas under the control of Buddhist and Hindu rulers in South Asia.

In the 19th and early 20th centuries, the British civil servants recorded many local practices, improving them if necessary, and formulated a number of guidelines to regulate the capture, care, daily food rations, work schedules and working loads of timber and army elephants in India and Myanmar (e.g. Sanderson, 1879; Evans, 1912; Milroy, 1922 or Ferrier, 1947; Krishnamurthy & Wemmer 1995a; 1995 b). State-run elephant establishments had guidelines on elephant husbandry which were later prescribed as Department Standing Orders and are still implemented (Khyne U Mar pers. comm.) A system of record keeping right from the early days of elephant management under colonial rule provides valuable data on the performance of individual animals. Several forms of reportage are routinely practiced. These records also provide guidelines, particularly to the new entrants to the administrative set-up, in the proper usage of working elephants under their custody (Khyne U Mar pers. comm.).

In India, the Central Zoo Authority has prescribed standards and norms for all zoos in the Recognition of Zoo Rules (1992). But no such standards and norms exist for the care of hundreds of privately owned elephants. In the last seven years "*Standard and Norms for Elephant Owners*" has been drafted (Bist, 1996) and for Kerala, the "*Captive Elephant Management Rules 2002*" have been drawn up by Dr. V. Cheeran and his colleagues. These new guidelines are paramount in improving the living conditions of captive elephants. However, the fact that only few captive elephants are breeding and that few live in a social and ecological environment and are in physical and psychological conditions conducive to breeding, has hardly been recognized.

In North America and Europe a considerable number of management guidelines have been formulated by governmental and non-governmental organizations. Many of them are rightly criticized by elephant experts or welfare organizations as being not strict enough to guarantee a minimum of species-specific requirements. However, most of these guidelines consider the Asian elephant as a species with highly evolved social behaviour and therefore recommend the keeping of the species in groups. In Europe for example, a radical change came with the "EEP Management for Elephants in EAZA Institutions" (2000). Among many other points, it was suggested that "matriarchal family units are developed and kept together, i.e. the intention to keep female offspring within their family group during their life" (Dorrestyn, 2001).

In 2002, the "*Review of the Welfare of Zoo Elephants in Europe*" was commissioned by RSPCA and carried out by Ross Clubb and Georgia Mason of the Oxford University, which summarized results from a few rather traditional zoos and found poor welfare of most zoo elephants and demanded improvement of the elephants' social and physical environments. They concluded: "The factors responsible for the poor welfare of zoo elephants should be empirically investigated as a matter of urgency. The zoo elephant population should be frozen, i.e. breeding and importation should be ceased until these factors have been identified. Only zoos that then solve these problems should be allowed to keep elephants in the future."

In her "*Management Guidelines for the Welfare of Elephants*", Miranda F. Stevenson (2002) has compiled all the requirements for a near-natural keeping of elephants in modern zoos and the *Elephant Management Policy Statement of Federation of Zoos in Great Britain and Ireland* stipulates that "Elephants must only be kept in zoos as part of an overriding conservation mission so that they are in actively managed breeding programmes....Their presence must enable progressive educational activities and demonstrate links with field conservation projects and benign scientific research, leading to continuous improvements in breeding and welfare standards. Zoos must exercise a duty of care so that standards of husbandry practices, housing, health and welfare management are humane and appropriate to the intelligence, social behaviour, longevity and size of elephants..."

How many Asian elephants live in captivity?

Accurate numbers of captive Asian elephants in the range states are not known. According to most recent estimates their total population numbers about 14,000 animals (Table 1). The largest population is found in Myanmar (40% of the total population from the range states), followed by India (26%) and Thailand (19%). At least 1,047 Asian elephants are kept world wide in zoos and circuses. Therefore the total captive population includes at least 15,000 elephants. But the captive population is dwindling rapidly as a result of many factors such as low reproduction and high (juvenile) mortality, restriction of capturing operations, or lack of employment opportunities as logging was banned in many south Asian countries.

Table 2 Definitions of management systems

Examples	Extensive Jungle-based timber and wildlife camps	Intensive Temples, urban tourist centers	Alternative Modern zoos elephant parks
Mainly used for:	Riding, transport, hauling, heaving	Parades, circus tricks, begging	Display, reproduction, research
Daily activities, food:			
- Free movements:	Forefeet hobbled but free in nearby forest	12 – 22 h/day chained in stands or stables	Chains and hobbles exceptionally
	± Determined by elephants	Determined by man	± Determined by elephants
	Divers		Divers
- Activity centers:		Monotonous	
	± By elephants, except prepared ration		By man
- Quality of food:		By man	
	± Permanently except		Several feeding periods/d
- Choice of food:	when bathing,sleeping	1-3 feeding periods/d	
	By man and elephants		By elephants
- Food intake:		By man	Determined by elephants
	Determined by elephants		
- Bath, skin care:		Determined by man	
- Place for sleep:			
Social behaviour:			
- Pop structure:	Heterogeneous	± Homogeneous	Heterogeneous
- Social contacts:	Permitted	Hindered	Permitted
Reproduction:			
- Reprod. rate:	Relatively high	Very low	Relatively high
- Neonate mort.:	Relatively low	Very high	Relatively low
- Rate of raising:	Relatively high	Very low	Relatively high
- Role of "aunts"	Important	Not existent	Important
Musth			
- Musthbulls kept:	Permanently in chains	Permanently in chains	In bull enclosure
- Social contacts:	Not permitted	Not permitted	Permitted
- Musth period	Relatively short	Relatively long	Relatively long
Owners & mahouts:			
- Ownership:	Mainly government	Mainly private	Private
- Soc.status owner	High	High	High
- Soc.status keeper	Relatively high	Increasingly very low	Relatively high
- Skill of keeper	High	Increasingly low	High
- Fluctuations of mahouts/keepers	Low	High	Low
- Tool used:	Stick or rod, blunt pointed ankus	Stick or rod, blunt pointed ankus, sharply pointed knife and ankus, poles, spears	Blunt pointed ankus
- Accidents:	Rare	Increasingly common	Very rare

Nevertheless there are exceptions. In India, Myanmar and Nepal the populations of captive elephants appear to be stable.

In all the range states considerable shifts of captive elephants from forest to urban areas have been reported. In India for example, restriction of logging operations in the north-east and the Andaman Islands imposed by the Supreme Court in 1996 resulted in a great exodus of captive elephants from these regions, while their number has increased in Kerala from about 250 in 1983 to more than 700 with a male-biased population structure at present (Fig.1). The city of Jaipur (Rajasthan) has about 100 captive elephants with a female-biased population structure (Fig.1) and has become a major elephant center. Captive elephants all over Thailand suddenly became unemployed after the government banned logging in 1989. Now most of them are involved in illegal logging, and many are given amphetamines to speed up work. Unworkable elephants are sent to slaughter houses and their meat sold (Mahasavangkul, 2002).

Keeping systems

The multiple and diverse deployment of captive Asian elephants requires various keeping systems (Kurt, 1995) whose extremes can be defined as follows (Table 2): Working elephants in jungle villages live in extensive keeping systems. They are used as riding, carrying and towing animals. During their rest periods they live, with hobbled front feet, in the nearby forest, where they find food and meet their tame and wild conspecifics. In South India, depending on tradition, additional fodder is given. Examples are the timber elephants of the Myanma Timber Enterprise (MTE) of Myanmar or those under the care of forestry authorities in Assam, Tamil Nadu, Karnataka or Kerala where captive elephants are increasingly used as riding animals for wildlife patrolling, conservation research and tourism.

In Myanmar most of the elephants are maintained for work, particularly logging, and a definite schedule of work is allocated. Work hours are adjusted according to the seasons thereby avoiding the hottest part of the day. A working elephant is able to work six hours a day over a period of eight months in a year. After the work hours, elephants are allowed to forage at nights with front limbs loosely hobbled to restrict their movement. Elephants can move distances of 8-15 km per night. The amount of work that an elephant can do in a day depends on the sex and age of the animal, its general body condition, size of timber, the state of drag paths, nature of terrain, quantity and quality of food available in the vicinity of the forest and the ambient temperature of the season. Pregnant elephants and female elephants with suckling calves are given rest until the neonate reaches the

Table 3 Significance of captive Asian elephants according to keeping systems (0 = not significant; 1 = low; 2 = medium; and 3 = relatively high).

Keeping System	economical owner	mahout	religion social	urban tourism	education	ecological forestry	keystone	total (T1)
Intensive								
Temple	3	1	3	3	1	0	0	11
Tourist Co.	2	1	0	3	1	0	0	7
Circus	3	1	0	1	1	0	0	7
Intermediate								
Trad. Zoos	3	2	0	1	2	0	0	8
Pinnawala	3	2	0	3	3	0	0	11
Extensive								
Timber Co.	2	2	0	0	2	3	3	12
Tourist Co.	2	2	0	0	3	3	3	13
Alternative								
Modern Zoos	3	3	0	2	3	0	0	11
Transit House	1	2	0	0	0	0	0	3

age of one year. Bulls in musth are not allowed to be put in the work force and are given rest at secluded areas. However, during the pre-musth period, when most of the maiting takes place, captive bulls can roam freely during the night.

During the hottest period of the year, when food quality is at a minimum, the animals are shifted to a new camping ground and given complete rest. In Myanmar, working elephants will continue to play a vital role in the timber operations of the MTE for the foreseeable future (Mar & Win,1997; Mar, 2001; 2002).

Intensive keeping systems (Table 2) are those in which animals are kept in temples or by private owners more or less individually, fed exclusively on prepared fodder and at night or if idle, shackled with longer or shorter chains to a hind foot or to both one hind and one front foot. Contact with captive conspecifics is avoided. Contact with wild conspecifics is unlikely because intensive keeping is concentrated in urban regions. Today intensively kept elephants are rarely employed for work (e.g. sawmills), but increasingly used in religious processions, political demonstrations or wedding ceremonies. Restricted movements and the practical absence of contacts with conspecifics has led to extreme aggressive behaviour towards mahouts or elephant handlers and to the evolution of stereotypic behaviour (e.g. Kurt & Garai, 2002). The intensive keeping system has been adopted by western circuses today, and in the former times, zoological gardens too followed it. The keeping system in traditional zoos as well as in the Elephant Orphanage at Pinnawala, Sri Lanka can be considered as intermediate between extensive and intensive systems. For example, during the day the elephants are kept free in their paddocks but in the night, they are shackled or otherwise kept solitary in small cages.

In very modern zoos alternative keeping systems (Table 2) are evolving now very fast according to the guidelines of the *World Zoo Conservation Strategy*. In these systems elephants live in appropriate family groups which are paramount for the process of learning and socialization (Garai, 2002a; Kurt, 2001; 2002; Clubb & Mason, 2002; Stevenson, 2002) and only subadult and adult bulls are kept singly if necessary (e.g. during musth). A further alternative keeping system is found in Elephant Transit Homes situated in the Uda Walawe National Park in Sri Lanka, where young elephants are kept in a semi-natural environment with minimal contacts with humans (e.g. bottle-feeding) to avoid imprinting processes which could later complicate the release of the captive animals into the wild.

Significance of captive Asian elephants

Captive elephants have an economical significance for owner, keeper or mahout. They may be important as a motive force for forestry operations. Furthermore they may have a religious significance (mainly in Buddhist and Hindu countries) or a social significance for non-religious ceremonies. Captive elephants can be an attraction in urban tourism, they can be paramount for education (including eco-tourism) concerning life sciences and conservation. Last but not least, captive Asian elephants can still have an ecological significance in selective timber harvesting and as keystone species in the maintenance of biodiversity and ecological processes (Santiapillai & Widodo, 1992).

For each of these above categories the degree of significance has been crudely estimated and given 4 scores: 0: insignificant; 1: low, 2: medium and 3: high significance. Relative low total significance (total less than 10 points) is found in elephants kept in transit homes, urban tourist centers, circuses or traditional zoos (Table 3). Relative high

Table 4 Living conditions and population dynamics of captive Asian elephants according to keeping systems (0 = not present; 1 = low; 2 = medium; and 3 = relatively high)

keeping system	*individual fitness*			*population dynamics*				total
	vet care	body condition	food	activity	social behavior	social structure	reproduction	(T2)
Intensive								
Temple	2	2	1	1	0	0	0	6
Tourist Co.	1	1	1	1	0	0	0	4
Circus	1	1	1	1	0	0	0	4
Intermediate								
Trad. Zoos	2	2	1	1	1	1	1	9
Pinnawala	2	2	2	3	3	3	3	18
Extensive								
Timber Co.	2	2	3	2	3	3	3	18
Tourist Co.	2	2	3	2	3	3	3	18
Alternative								
Mod. Zoos	3	3	2	3	3	3	3	20
Transit House	1	1	1	1	1	1	0	6

significance (total ≥ 10 points) is found in elephants kept in temples, the Pinnawela Elephant Orphanage (Sri Lanka), modern zoos, timber and tourist camps (Table 3). It must be stressed that relative high significance has different reasons. Those living in jungle camps reach high values mainly due to their value for local people, education and ecology, while those living in temples reach a relative high significance due to their economical, religious and tourist value.

Living conditions and population dynamics of captive Asian elephants

Living conditions can be defined by the individual fitness, the food offered, the daily activity as well as aspects of population dynamics such as social behaviour, social structure of the population and reproductive performance (Table 4). Individual fitness depends on the degree of care by veterinarians and keepers/mahouts and becomes apparent in the body condition of the animals. Both aspects have been assigned scores: 1: low, 2: medium, and 3: high. The food offered to elephants can be monotonous (1), diverse (3) or intermediate (2). Monotonous food consisting of the leaves, branches and stems of one to three plant species is common for elephants kept in temples and urban tourist centers. But also in most of the traditional zoos and circuses food can be considered as monotonous (Schwammer, pers. com.). The same applies to the baby elephants kept at the Transit Home in Uda Walawe National Park (Sri Lanka). Beside the daily portion of milk, the animals survive on only a few wild growing species of grass. Elephants living in jungle or forest-based extensive systems find a most diverse diet. In modern zoos as well as in the Pinnawela Elephant Orphanage the diversity of food must be considered as intermediate.

For elephants kept in extensive systems daily life includes, besides work, the search for food, skin care, socializing and sleeping at a species-specific place. There are no or at least hardly any stereotypes. Their daily species-specific activity is considered as medium (2). Elephants kept in extensive and intensive systems are brought twice a day to certain watering areas by their mahouts, where they are scrubbed and massaged with the husk of the coconut or the skin of the bread-fruit, or stones or bark. Elephants kept in intensive systems are fed once a day or repeatedly with prepared food. When they are not working they often remain idle. Stereotypes occur regularly. The daily species-specific activity is considered as low (1). The same applies to elephants kept in traditional zoos, circuses and in the Transit Home at Uda Walawe. However, a high degree (3) of diverse daily activities is found in modern zoos and in the Pinnawela Elephant Orphanage.

Species-specific social behaviour is very rare or practically absent (0) in elephants kept in intensive systems. But it is relatively high (3) in the Pinnawela Elephant Orphanage, in extensively kept elephants as well as in modern zoos. Low social activities (1) are found in traditional zoos as well as in the Transit Home. Low or even an absence of social behaviour is due to the respective management systems, where intraspecific interactions are either not allowed by owners

Table 5 Significance of captive Asian elephant populations for conservation (0 = not significant; 1 = low; 2 = medium; & 3 = relatively high)

keeping system	total T1+T2	promoting conservation	reproductive potential	chances of pop. survival	natural biodiversity	Total
Intensive						
Temple	17	1	0	0	0	18
Tourist Co.	11	1	0	0	0	12
Circus	11	0	0	0	0	11
Intermediate						
Trad. Zoos	17	1	1	0	0	19
Pinnawala	28	3	3	3	0	37
Extensive						
Timber Co.	30	2	3	2	3	40
Tourist Co.	31	3	3	3	3	43
Alternative						
Mod. Zoos	31	3	3	3	0	40
Transit House	9	3	?	?	3	>15

and keepers/mahouts or hardly possible because of a monotonous social structure of the captive groups concerned (Fig.1).

In most intensively kept populations social structures can hardly be recognized (0) since only members of certain age and sex classes are kept (e.g. mainly subadult and adult bulls in temples, or older females in circuses, or juveniles in many urban tourist resorts). Groups in traditional zoos consist mainly of middle aged or old females and rarely include bulls or younger members (Fig.1). Therefore their social structure can be considered as being comparatively low (1). The same applies to elephants in the Transit Home at Uda Walawe, where only orphaned neonates, infants and juveniles are kept. The populations in the Pinnawela Elephant Orphanage, as well as those in jungle based camps are socially well structured (3).

Reproduction is practically absent in intensive keeping systems and – of course - in the Transit Home. But reproductive performances are relatively high at the Pinnwela Elephant Orphange and in extensively kept populations. The sum total of crude evaluations of different parameters of living conditions and population dynamics is low (<10 points) in intensive keeping systems as well as in traditional zoos and the Transit Home, but is significantly higher in the Pinnawela Elephant Orphanage, in modern zoos as well as extensive keeping systems (Table 4).

The significance of captive Asian elephant populations for conservation

The significance of captive elephants for the economy, religious education as well as for the natural environment are the root-causes for the *ex-situ* conservation of the species. The same applies to parameters of living conditions and population dynamics (t1 and t2 in Table 5). To assess crudely the significance of captive elephants for the conservation of the species it must also be taken into consideration that captive elephants can promote conservation efforts, that some of the populations can add to the natural biodiversity and that captive propagation is possible in some populations.

There is a wide variety of ways in which captive Asian elephants can promote conservation efforts. Riding elephants enable researchers to carry out ecological and behavioural studies in wild areas. Zoo elephants living under near-natural conditions are paramount for fundraising as well as conservation orientated education in urban areas. And in protected areas, riding elephants are an important asset for wildlife and conservation research as well as eco-tourism. It must be stressed, however, that more and more captive elephants are being misused in spectator shows which have little or nothing to do with the species-specific behaviour or good taste and aim to entertain the crowds in a very questionable way. Often such shows owe their existence to some of the most cruel training methods.

Several captive populations reproduce on a more or less regular basis. It must be stressed, however, that there is no self-sustainable captive population at present due to a lack of well managed breeding programs. Nevertheless there are smaller populations with a high (3) potential for reproduction as can be seen in the Pinnawela Elephant Orphanage, modern zoos and extensive keeping systems. In intensive keeping systems, reproduction is practically absent (0), due to several reasons, the most important being the lack of economical incentives for the owners to breed elephants. But many intensively kept elephants are neither physiologically nor psychologically able to reproduce. They show serious retardation in body growth (Kurt & Kumarasighe, 1998; Weihs *et al.*, 2002); they never went through a species-specific socialization process (Garai, 2002a) and tend to practice infanticide (Kurt & Mar, 1996), or they are kept under such tremendous physical and psychological suppression by their keepers/mahouts that neither their sexual organs nor their sexual behaviour can develop normally (Hildebrandt *et al.*, 2000; 2001). Many females kept in traditional zoos become so obese that reproduction is impossible after an age of 30 years (Hildbrandt & Göritz, 1995; Kurt & Mar, 1996).

The chances of survival of captive populations are practically zero in intensively kept elephants and very insignificant for those kept in traditional zoos where mortality rate is extremely high at young ages (Fig. 2). But the survival chances are relatively high in the Pinnawela Elephant Orphanage, modern zoos as well as in extensive keeping systems (Sukumar *et al.*, 1997) with low mortality rates at young ages (Fig. 2). Finally the significance of captive populations increases when they add to the natural biodiversity of the species habitat. Summarizing the single values of qualifications for different keeping systems (Table 4), the following conclusions can be drawn: Elephants living in intensive keeping systems, circuses or traditional zoos have low significance for conservation of the species (total < 20 points). But elephants living in the Elephant Orphanage at Pinnawala (Sri Lanka), modern zoos and extensive keeping systems have a relative high significance for conservation. The same may apply to Transit Homes (see below).

The role of the AsESG in the management of captive Asian elephants

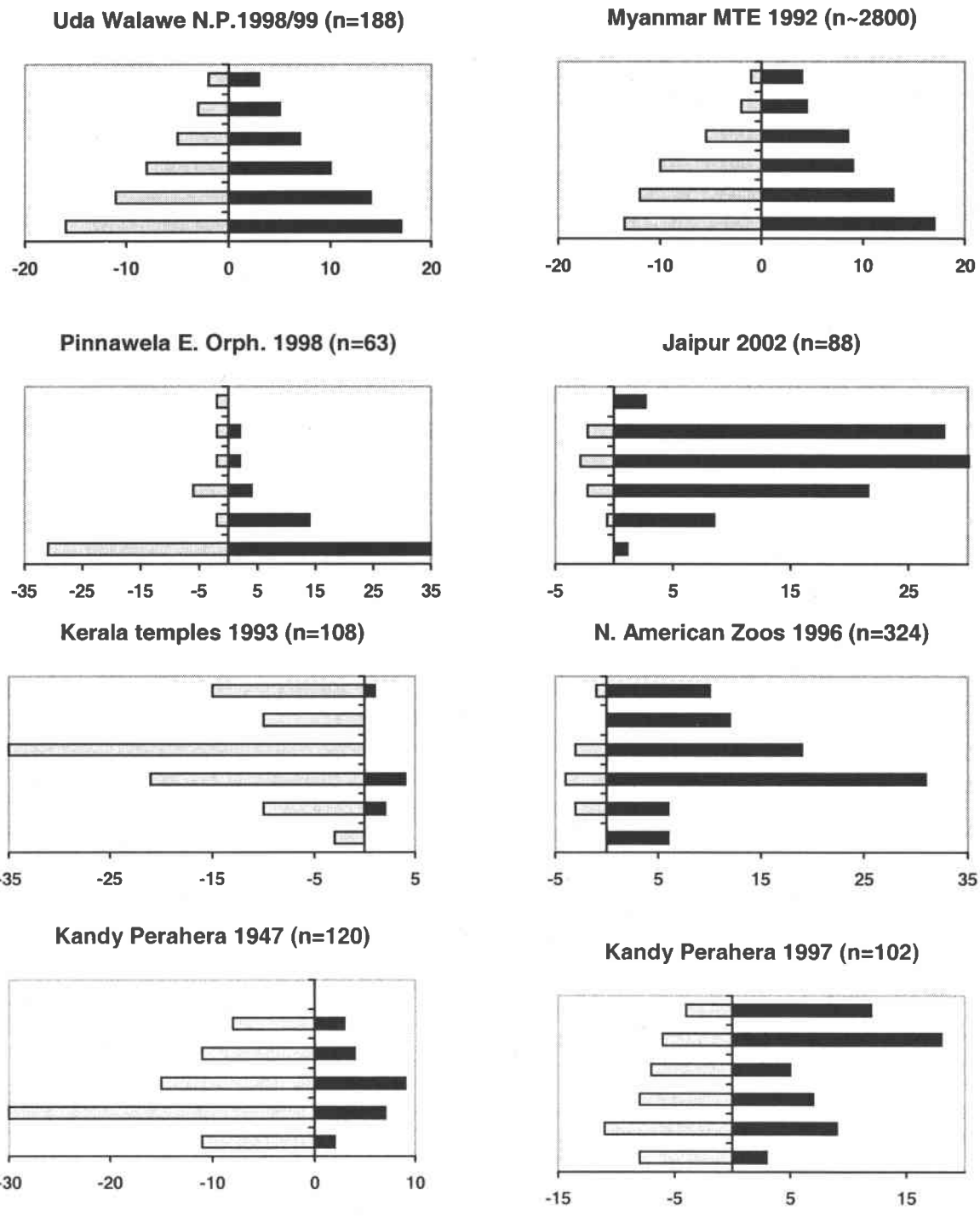
The adequate management of captive Asian elephants can only be reached by coming together of people with varied talents such as wildlife experts, veterinarians, elephant owners, and managers and every effort must be made to ensure that all captive Asian elephants meet the maximum welfare requirements. The authors would like to highlight the following reasons why the AsESG ought to become involved in the conservation orientated management of captive Asian elephants:

1. The relative high number of Asian elephants living at present in captivity which is estimated to include some 25-33% of the total population of *Elephas maximus* living today.

2. The importance of traditional knowledge on elephants and biodiversity of the natural elephant habitat by local, often tribal, elephant people. Regional AsESG members need to identify individuals who keep traditional medical and other knowledge of elephants (capturing, taming etc.) and document their

Fig.1. The population structures of wild (Uda Walawe N.P.) and captive Asian elephants presented as a % of the size of the toal population (n).

In the ordinate six age classes are distinguished:
Bottom: 0-10 years, followed by 11-20, 21-30, 31-40. 41-50, and >50 years (top).
Males: grey, females: black. (Sources: Kurt, 2001; Mar, 2001; 2002, pers. com.)



knowledge before it is lost. The employment of these traditional specialists in jungle or forest-based captive elephant establishments can be a great boost for conservation, applied research and local politics. In collaboration with local NGOs, the AsESG should play a leading role in the setting up of vocational training programs for the families of the mahouts in order to supplement the mahouts' income (e.g. integrated farming, weaving traditional fabrics etc.). This would hinder the emigration of the mahouts and their families to the urban areas.

3. The importance of AsESG as a data base on species-specific ecological and
3.
behavioural characteristics which are important to alter unsuitable keeping systems and to improve living conditions of captive elephants. Furthermore, the AsESG should encourage the formation of data bases and studbooks by regions. The AsESG/IUCN/SSC can monitor the demography of captive elephants only after a proper registration of captive elephants, owners and elephant holding facilities is made.

4. The international prestige of the AsESG must be used to set up an International Veterinary Consultancy Group to give free advice and medical care in the range countries. Each range country should sign a memorandum of understanding (MoU) to share elephant database. Appropriate software should be created to enable each country to maintain a computerized registration database and to exchange data with neighbouring countries.
4.

5. The AsESG should establish a network that could lobby the respective governments
of elephant range countries to strengthen and improve existing national laws in order to enforce at least the Prevention of Cruelty to Animals Act and thereby help

Prevent the misuse or abuse of elephants in captivity.

It is doubtlessly more important for species conservation to maintain large wild populations in their natural habitat than considerable captive populations. However, the pressures on a number of wild populations by human elephant conflicts, poaching of young elephants and other disturbances by man (e.g. destructive agricultural practices, fuel wood extraction etc.) seem to be the reasons that cause continuous inflow of wild elephants into captive populations in the years to come. Taking this fact into consideration government and non-government conservation agencies have to fight for relevant elephant keeping facilities where elephants are kept under modern welfare guidelines but also under the considerations of conservation, such as captive propagation of genetic and behavioural diversities, conservation minded education and promotion. This goal is best reached by:

1. Maintenance of jungle based establishments and, where selective logging had to be stopped, local people and captive elephants working in these stations should be employed in research, eco-tourism and education.

2. In urban areas zoological gardens should be improved so that they reach the standards defined by the International Zoo Conservation Strategy.

3. For elephants living in establishments for religious and other traditional ceremonies (intensive keeping systems) AsESG should encourage the improvement of elephant welfare and, if necessary, restrict or reduce the size of these populations.

4. AsESG should find ways to update the scientific knowledge on elephants of range officers, managers and representatives of animal welfare organizations. The life of elephants in their natural habitat must be the model for conservation minded keeping systems.

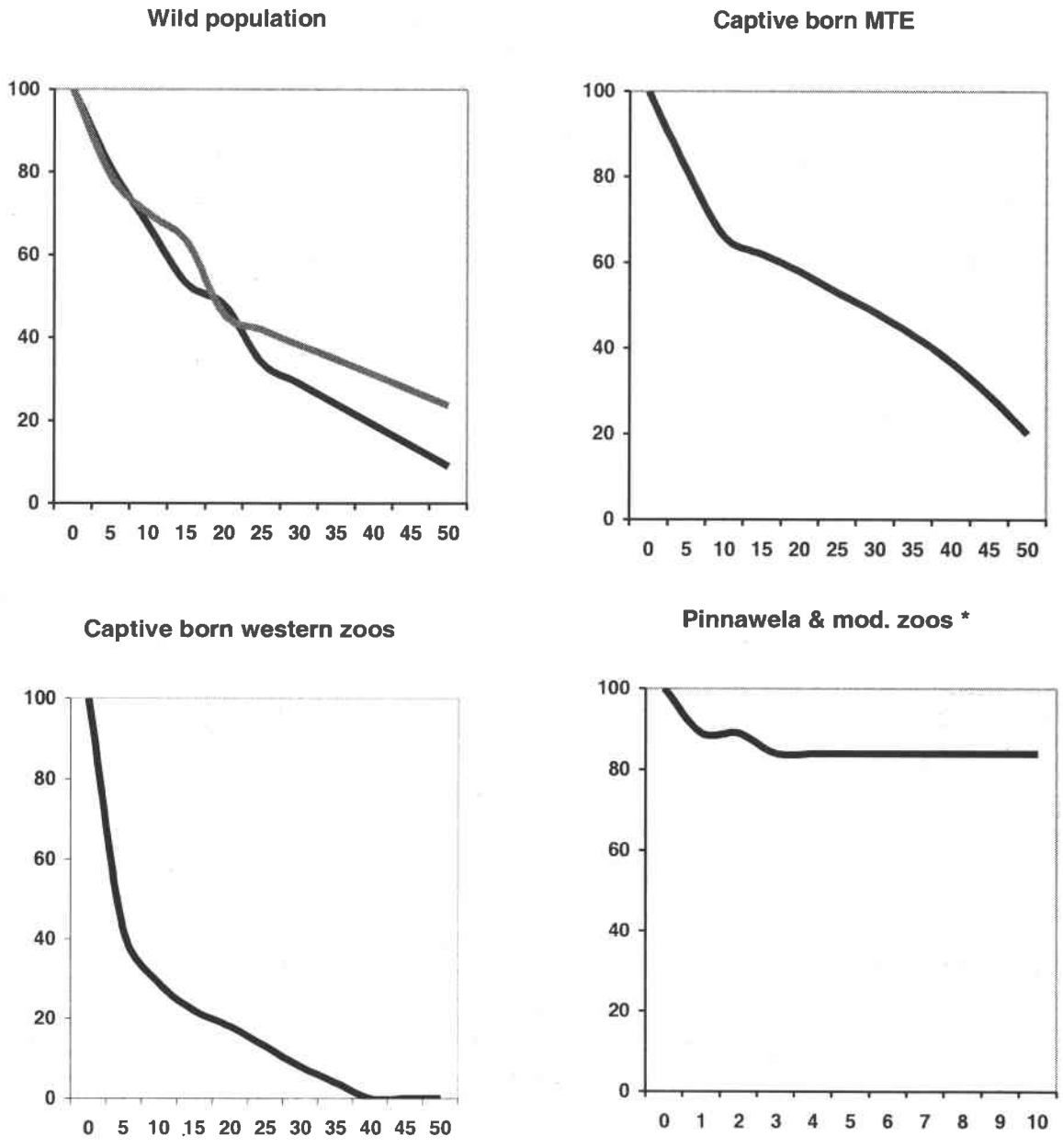
5. AeSG could assist all agencies concerned with captive elephants to find alternative keeping systems where the animals can be kept under near natural conditions, where genetic and behavioural diversity is maintained and, if suitable, where a release into natural habitat is possible. Remarks on such alternatives are made in the following:

Alternative keeping systems: Elephant Parks and Transit Homes

2000 years ago Kautiliya's *Arthasastra* proposed the establishment of a Mrgavana, a fenced park for (tamed) elephants and other wild animals. Such a recommendation needs to adopted today. Large areas of at least a quarter of a km² could be fenced and furnished with adequate water, shade etc. to become a home for orphaned and otherwise problematic (e.g. dangerous, surplus) elephants. Elephants kept in such an elephant park have to be fed and regularly checked by veterinarians. But otherwise contacts between men and elephants should be reduced to a minimum. The Pinnawela Elephant Orphanage may become a good example of such an elephant park after renovation although the area is relative small. In Spain a large park is currently being established for surplus of zoo born Asian elephant bulls. There are already two large parks in the country for problematic African elephants (Cabarceno and Reserva Natural el Castillo de las Guardas). There is a tremendous experience in South Africa on elephants kept in fenced range areas and it would be worthwhile to learn from South African experts (see Garai, 1997; 2001; 2002).

In addition to the Elephant Orphanage in Pinnawala, Sri Lanka there are several other, more or less similar establishments, where orphaned neonate, infant, and juvenile elephants are cared for (e.g. in Thailand, in Assam or in Malaysia). As known from the studies in Pinnawela, many orphans show retarded body growth, their daily food intake is significantly lower than that in young elephants growing up with their mothers and/or allomothers, they are not familiar with efficient methods to prepare the food and they are socially not fully integrated (c.f.

Fig.2. (Survival rate according to age of wild (adapted from Sukumar 1991 and Kurt 2001) and captive populations (Kurt 2001, Mar 2001, 2002). Males or total: black; females: red lines. * data from Emmen (Holland) and Hagenbeck (Germany).



Kurt, 2001; 2002; Garai, 2002a, Weihs *et al.*, 2002). The fact that many orphans are kept socially more or less isolated, i.e. lack of "aunts" and other subadult and adult helpers, may be *inter alia,* a reason for the extreme high mortality at young ages, as often seems to be the case. It is well known that certain adult females are extremely altruistic and therefore willing and capable of nursing the orphans (even females that have not reproduced before). Such allomothers should be available in all orphanages as well as in all transit homes. They would guarantee that behavioural diversity is preserved.

As it is well known from translocated juvenile orphans in African elephants (Garai, 1997; 2001; 2002b; Garai & Carr, 2001) socially non-integrated elephants may face later difficulties in mating (bulls killing females or even buffaloes and rhinos) or parturition (killing of newborns, as it is also very well known from Asian elephants kept in western zoos). Such observations must be taken seriously, since they teach us that survival of reintroduced juvenile elephants may only be a short-term success. Success of reintroduction can only be measured long term, once we know that the elephants are capable of fending for themselves, remain healthy, are integrated into a social organization, can reproduce and do not cause problems. Accordingly all released orphans should be marked, not necessarily with radio–collars but with easily visible optical marks as well as with chips, and they should be monitored continuously from the moment of release. This is also important from the point of view of animal welfare. If monitoring is not carried out properly certain animals may escape and later end up dead when the radio–collar tightens round the neck with the growth of the elephant, slowly choking the animal.

Well maintained elephant parks, orphanages, and transit homes allow the keeping of elephants free of chains and in social groups in appropriately furnished paddocks. This allows the elephants to express their natural behaviour patterns, and provides them with exercise and opportunities to socialize. Elephants kept in such a way convey more understanding of the species and its requirement to the visitor and insight into the necessity to protect the species than "dancing" elephants or elephants that are forced to ride bicycles, paint canvas, play football, guitar or mouth-organ.

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The Asian elephant (*Elephas maximus*): its habitat, status and distribution in Arunachal Pradesh, India

Bharath Sundaram , Surendra Varma, Arun Venkataraman and Raman Sukumar

Abstract The survey assessed forest contiguity, distribution and status of elephants in some areas of Arunachal Pradesh to identify likely gaps in the protected area network. The survey also examined changes seen in elephant distribution between 1984 and the present. The study was carried out through field and questionnaire surveys in the administrative districts of the state. Elephant habitat maps with vegetation types and elephant distribution information were produced. The encounter rates of elephant signs per kilometre were calculated to ascertain specific zones of high, medium and low elephant abundance. Based on the results, East Kameng, Tirap and Papam-Pare had high, medium and low abundance areas respectively. Qualitative information on district wise elephant status, distribution and conservation is also presented. The survey found very patchy habitat in many areas and many areas that are important for elephants do not fall under the protected area network. The paper also discusses specific recommendations for conserving the species and its habitat.

Keywords Elephant, Assam, Arunachal Pradesh, Human-elephant conflict.

Introduction

Arunachal Pradesh, the largest state in the north-east India, covers an area of 83,743 km^2 between 26° 28'-29° 30' N and 91° 30'-97° 30' E. Lying in the Eastern Himalayan region of the Himalayan biogeographic zone, Arunachal Pradesh is located at the junction of the Palaearctic and Oriental (Indo-Malayan) realms (Rodgers & Panwar, 1988). Arunachal Pradesh comprises mountains that ring eastern Assam, terrain thrown up by the sharp twisting of the Himalayan ranges as they turn suddenly from a southeastern to a southerly direction. These mountains drop precipitously into the tropical lowland evergreen forests of the region. Because of the wide gradients in elevation (50 m-7,000 m asl) and annual rainfall (1,000 mm-5,750 mm), an array of forest types, ranging from tropical evergreen forests, tropical semi-evergreen forests, riverine semi-evergreen forests, sub-tropical pine forests, temperate broadleaved forests, temperate coniferous forests, alpine forests, and high montane grasslands are seen. Such a diversity of habitats harbouring rich plant and animal life, packed into a relatively small area, makes Arunachal Pradesh a hotspot of global biodiversity. It is also home to over 5,000 species of plants (including 600 species of orchids), 500 species of birds and 29 species of mammals listed under Schedule I of the Indian Wildlife Protection Act. These include 4 species of large cats, 7 species of primates, and 3 species of goat antelopes. There are over 100 species of amphibians and reptiles recorded from the region (Anon. 1994).

Arunachal Pradesh shares international borders with Bhutan in the west (border length 160 km), China to the north and northeast (1,080 km), and Myanmar to the east (440 km). Culturally diverse, Arunachal Pradesh, with a population under 10 lakh (of which 70% are tribal people), has 21 major tribal groups with over 100 ethnically distinct subgroups and over 50 distinct languages and dialects. Spread over 14 districts, the people of Arunachal Pradesh practice semi-nomadic swidden agriculture (also called *jhoom* cultivation), terraced wet agriculture, high montane pastoralism, and traditional trade and barter. Arunachal Pradesh is a land of mighty rivers such as Siang, Dibang, Lohit, and Kameng, all of which join the Brahmaputra in the Assam valley. Over 70% of Arunachal Pradesh is forested, and 11.8% of the total land area falls under the protected area network (Fig. 1), with one Biosphere Reserve (BR) (Dibang-Dihang Biosphere reserve), one Tiger Reserve (TR) (Namdapha Tiger Reserve), one National Park (NP) (Mouling National Park), 10 Wildlife Sanctuaries (WLS) and one Orchid Sanctuary (Sessa Orchid Sanctuary). Eighty-six Reserved Forests (RF's) account for an additional 12.7% of the total area. The rest of the forested areas come under the purview of the 3,649 villages in Arunachal Pradesh and are classified as Village Forest Reserves (VFR's) or Unclassed State Forests (USF's).

At least two populations of the Asian elephant (*Elephas maximus*) extend along the Himalayan foothills and plains from northern West Bengal eastwards through Assam, Bhutan and Arunachal Pradesh (Sukumar, 1989). It has also been estimated that 10,000 km^2 of hilly habitat may be available for elephants in Arunachal Pradesh alone. The Arunachal Pradesh Forest Department estimates the population of elephants in the state at 4,000, which is twice that of an earlier estimate (Lahiri-Choudhury, 1980). This discrepancy

Bharath Sundaram, Surendra Varma, Arun Venkataraman & Raman Sukumar
Asian Elephant Research and Conservation Centre
(A division of the Asian Nature Conservation Foundation)
Centre for Ecological Sciences (CES)
Indian Institute of Science (IISc)
Bangalore 560 012
India

could be due to the fact that elephants moving into Arunachal from Assam were also counted (AESG Report, 1981). In collaboration with the Forest Department, the Task Force of the IUCN/Asian Elephant Specialist Group (Lahiri-Choudhury, 1980) mapped the distribution of elephants in northeast India (Lahiri-Choudury *et al.,* 1984). However, widespread destruction of foothill forests through developmental and other anthropogenic activities have shrunk the range of the elephant, consequently restricting it to smaller landscapes having very little connectivity. An increase of encroachment in forested areas has also led to an increase in elephant-human conflict.

The prime objectives of this survey were to assess the forest contiguity and status of elephants, to identify possible gaps in the protected area network in some areas of Arunachal Pradesh, to examine the changes seen in elephant distribution between the 1984 study and the present one, and to project all the data on maps that could be used by both the Forest Department and researchers for better management and further research.

Methods

The status and habitat available for elephants were determined through field surveys and questionnaire surveys. Field surveys were undertaken in East Kameng, West Kameng, Papum-Pare, Lower Subansiri, Dibang Valley, Lohit, Tirap and Changlang districts of Arunachal Pradesh. Survey of India toposheets were used to assess forest contiguity in the low- and mid- elevation (100-900m) areas. Information regarding the area was first gathered from the Divisional Forest Office, after which animal trails in the forest were identified. These trails were then traversed on foot, and data on elephant signs, i.e. dung, pad marks, scratch marks, and feeding signs were collected. GPS locations were taken at kilometre intervals, and the habitat at that point was classified by noting geographical features, and the four species of trees characteristic of the vegetation in the nearest vicinity were noted. Direct sightings of elephants were also recorded as and when they occurred. Proximity to the closest human settlements was also noted. In addition to field data collection, secondary information was gathered through questionnaire surveys in villages and Divisional Forest Offices. This included information on distribution, movement patterns, and numbers of elephants. Since very few elephants in Arunachal Pradesh are resident, data on seasonality of sightings/movement were also collected. Fieldwork was carried out during the dry periods of 2001.

Encounter rates (frequency of sighting elephant signs per kilometre traveled on foot) were calculated (Table 1). From these encounter rates it was possible to determine, within the study area, specific zones of high (encounter rate in the range 4 and above), medium (encounter rate in the range 2.5 to 4), and low (encounter rate in the range 1 to 2.5) elephant abundance.

Maps were created using MapInfo Professional, ArcView GIS, and GMView. Layers of political boundaries, protected area network, forest cover were created using VMap Level 0 data (the data set was derived from 1-km resolution Advanced Very High Resolution Radiometer (AVHRR) data spanning a 12 month period, from April 1992 to March 1993), and Global Land Cover Characterization datasets obtained from the International Steering Committee for Global Mapping, Geographical Survey Institute, Japan. The GPS survey points were overlaid on the forest cover map (Fig. 2), and inferred elephant distribution (from secondary information) was plotted (Fig. 3).

Results

The elephant ranges in Arunachal are mainly distributed along the foothills adjacent to Assam. Elephants are found usually between the altitudinal range from 2,000 to 6,000 m asl but there is some evidence to show that they could migrate to higher levels in search of food and other resources especially during winter months. A total of 1,600 elephants were estimated for the state during 2001 elephant census (Forest

Table 1 List of areas where ground surveys for dung were carried out, with encounter rates for each area

Area	District	Forest Division	Protection Level	Distance walked (km)	Number of signs	Encounter rate/km
Chessa	Papum-Pare	Bandardewa	RF, USF	12	28	2.33
Chessa	Papum-Pare	Bandardewa	RF, USF	8	15	1.88
Kimin	Papum-Pare	Bandardewa	RF, USF	15	24	1.6
Deomali	Tirap	Deomali	RF, VFR	15	79	5.27
Deomali	Tirap	Deomali	RF, VFR	7	29	4.14
D' Ering	East Siang	Pasighat	WLS	16	88	5.5
Tipi	East Kameng	Khellong	WLS	12	78	6.5
Seijosa	East Kameng	Khellong	WLS	15	89	5.93

Department, unpublished report). Within Arunachal Pradesh, elephants occur in Papum-pare, Lower Subansiri, East Siang, East &West Kameng, Lohit Dibang Valley, Tirap & Changlang districts.

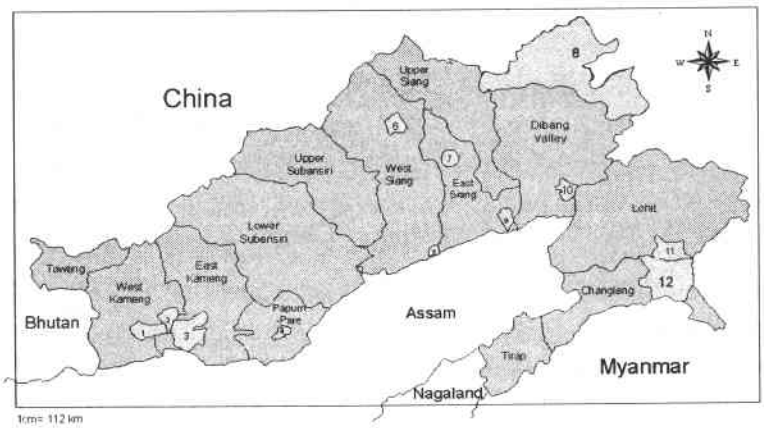
East and West Kameng districts

Areas surveyed in these two districts include Pakhui WLS and Khellong Forest Division, both of which support abundant elephants and experience severe human-elephant conflict. The high abundance may be due to these areas bordering Nameri NP and Sonitpur RF in Assam, from where elephants tend to move out. While the forest types in Pakhui WLS range from semi-evergreen to evergreen with patches of secondary *jhoom* forests, the forests in the Bhalukpong side (Khellong Forest Division- Amartala, Doimara and Papum RF's) are mostly degraded, with some patches of evergreen forest still existing due to their inaccessibility. Elephants range right from the foothills of the Dhansiri river (at the Bhutan border), to Papum RF east of Pakhui WLS. A specific area of high human-elephant conflict is Tipi (a town close to Bhalukpong). The position of the Tipi Orchid Research Centre (situated in a natural elephant pathway), increased levels of human encroachment, and the construction of a Territorial Range Office on an elephant path have been the reasons for increasing levels of human elephant conflict. Project Elephant has recognised the Kameng –Sonitpur interstate area (ca 4,300 km^2) as an Elephant reserve (National Elephant Conservation Action plan, 1992), but this area experiences a lot of pressure in Assam due to the large-scale transformation of land for cultivation.

Papum-Pare and Lower Subansiri Districts

The areas surveyed in these two districts include the Itanagar WLS and Bandardewa Forest Division, which had medium elephant abundance, with highly migrant animals. These areas are also highly fragmented and degraded due to human encroachment and illegal deforestation. Areas such as Poma, Jote, Kimin, Hoj, Tarajuli, Chessa, Hollongi, Changmara, Kokila, Tengabari, and Balijan have a matrix of habitats composed of semi-evergreen forest, evergreen forest, and cultivation. Unplanned development in the Itanagar area has also destroyed much of the habitat and has been identified as an issue of concern in 1984 (Lahiri-Choudhury, 1985). An elephant reserve has been planned in Papum-Pare district, but the success of this plan depends entirely on how effectively encroachers can be removed. This area shows very little influx of elephants from Assam because the areas on the Assam side are completely under cultivation.

In the Subansiri range of Panir RF (Bandardewa Forest Division) disturbance affecting elephants has been observed. Dolunmukh is a village bordering Panir RF, which has not reported the presence of elephants for the past 10 years due to such disturbance. Though the disturbance has ceased a few years ago, elephants are yet to return. These areas have large patches of semi-evergreen and evergreen forests. More interestingly, Dolunmukh was reported to have been an area of high human-elephant conflict (Lahiri-Choudhury *et al.*,



1. Eagles Nest WLS
2. Sessa Orchid Sanctuary
3. Pakhui WLS
4. Itanagar WLS
5. Kane WLS
6. Yordi Rabe Supse WLS
7. Mouling NP
8. Dihang-Dibang BR
9. D' Ering Memorial WLS
10. Mehao WLS
11. Kamlang WLS
12. Namdapha TR

Wls- Wildlife Sanctuary
NP- National Park
BR- Biosphere Reserve
TR- Tiger Reserve

1984). A major hydroelectric project involving the construction of a dam across the Subansiri is also being planned.

Lohit District

The floodplain areas of the Lohit River, such as the Paya and Digaru Ranges, were surveyed in the Lohit Forest Division within this district. Of the 7 ranges here 2 showed seasonal presence of elephants. Dung encounter rates indicate that these areas have medium elephant abundance. Affected heavily by flood, the landscape in these areas is highly amorphous. Struck by a major earthquake in 1950, many of the natural forests of this area were destroyed due to inundation and the changing of the course of the Lohit River. The habitat in this area is a combination of secondary riverine forest, *Saccharum* grasslands and plantations. Plantations were established following the earthquake to restore some of the original forest. In providing fresh herbage for elephants after the first rains, this area assumes immediate importance and hence it is necessary to bring these areas under the protected area network. This area is also heavily disturbed due to the presence of '*khutis*' (herds of unproductive cattle). Overgrazing was seen the Digaru area. The Paya and Digaru areas are approximately 300 km^2 in size, and this area supposedly has at least 10-12 *khutis* (ca. 2500-3000 heads of cattle). Such large number of cattle is bound to put undue pressure on the grassland ecosystem, and should be brought under control. Choudhury (1999) has also cited illegal capture of elephants to be common in this district, but no such instances were observed during this study.

Dibang Valley District

The areas in and around Mehao WLS were surveyed. Mehao WLS (281.5 km^2) lies along an elevational gradient and evergreen forests are found up to 900 m (an area of around 100 km^2). This area shows medium elephant abundance, and appears to be highly disturbed with a high degree of encroachment (especially in the Koronu and Ippipaani areas), where the people are not aware that they are living in the midst of a wildlife sanctuary. Elephants that use the Dibru-Deomali elephant corridor sometimes visit this area.

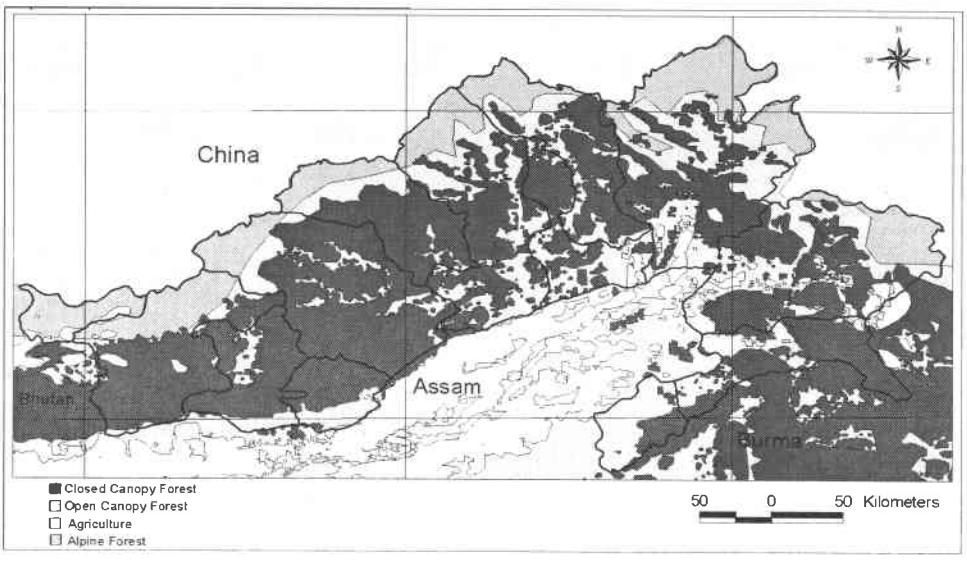
Changlang District

Namdapha TR (1985 km^2) is located on the Myanmar border, and movement of elephants to and from Myanmar cannot be totally ruled out. This area was found to have low elephant abundance. A survey by our team in 1999 also yielded very poor results as far as elephants were concerned. The forest types in Namdapha TR range from semi-evergreen to evergreen on the lower reaches. Evergreen forest habitat has been found to be sub-optima for elephants and this may be the reason for their low abundance.

Tirap District

In this district, the Deomali Forest Division (286 km^2) was surveyed. The Arunachal Pradesh Forest Corporation used this area for timber operations until 1997 and selectively felled patches are recuperating. This is an area of high elephant abundance, with elephant influx from Nagaland in the west, as

Fig. 2 Extent of forest cover in Arunachal Pradesh



well as movement of elephants from neighbouring Joypur RF in Assam. A large number of natural salt licks (*pungs*) were found in the Namsangmukh area. These areas are classified as VFR's and RF's, and must be incorporated into the protected area network, taking into account their value for elephants. Elephants also frequently move from Tinsukhia and Digboi areas (especially around Dibru-Saikhowa NP) to this area and vice-versa

East Siang District

The D'Ering Memorial WLS was surveyed in this district. The D'Ering WLS (184 km²) is composed mainly of *Vettiveria* grasslands and plantations of *Dalbergia* and *Bombax*. It is another area of high elephant abundance and is used seasonally by elephants (before and during the monsoons). The area is also flood prone and is rendered a virtual island during heavy rains and flood. Heavy siltation occurs in the areas affected by flood. Elephants frequently cross over from Jonai and Kobo Chapori in Assam to this area. Cited as an important movement path for elephants (Choudhury, 1999), the Dibru-Deomali elephant corridor includes D' Ering WLS, Jonai and Kobo Chapori areas (Assam), Dibru-Saikhowa NP, Joypur RF and Deomali Forest Division. Consequently, this whole area (ca 4000 km²) is under the Dibru-Deomali Elephant Reserve. Presently D' Ering WLS is not protected effectively due to the shortage of manpower and resources. As a result many people from Pasighat and Mebo use it as a hunting ground. Frequent burning of the grassland also occurs.

Discussion

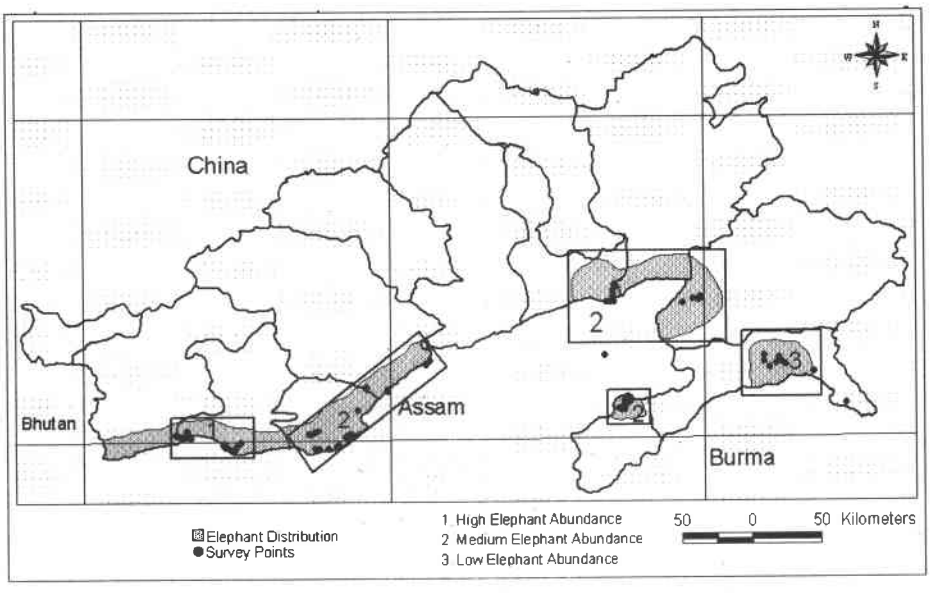
Habitat patchiness and Elephant-Human Conflict

Most of the areas surveyed, excepting a few, showed very patchy habitat. Mosaics of forest types such as semi-evergreen, degraded *jhoomed* forests, degraded grasslands and degraded riverine forest are interspersed with cultivated lands. During their attempts at maintaining normal ranging pattern, elephants encounter an increased interface between natural vegetation types and cultivation. Elephant-human conflict was a common problem in most of the areas surveyed. The people of Arunachal Pradesh have always been living in close proximity to their forests, but uncontrolled development has already destroyed many prime elephant areas, such as the foothill forests in Papum-Pare district and Lower Subansiri. The problem of elephant-human conflict is compounded by the fact that a large proportion of agriculture in Arunachal Pradesh is subsistence agriculture. Crop depredation affects the subsistence agriculturist very hard, and the existing system is not equipped to deal with this problem. The formulation and implementation of a compensation scheme will greatly help improve relations between the common people and the governmental agencies involved.

Gaps in the protected area network

Many areas that are important for elephants do not fall under the protected area network. The Deomali area in Tirap district is one such example. An important link in the Dibru-Deomali corridor, this area is presently classified as a VFR. It is not only important to bring some areas under the protected area network, but existing parks and sanctuaries must be well protected as well. The D' Ering Memorial Wildlife Sanctuary is a very important area for elephants as they use the grasslands extensively for feeding. Limitations of manpower and resources make the job of protection difficult, and a solution to the problem lies in finding a cost-effective remedy to ensure

Fig. 3 Distribution of Asian elephants in Arunachal Pradesh based on a questionnaire survey



protection by involving the local communities. Since the elephant populations in the northeastern region know no political boundaries, it is necessary to ensure their protection in the neighbouring states of Assam, Meghalaya and Nagaland. Unprecedented levels of deforestation in Assam often cause problems in the areas where cross-border movement of elephants is common, as for example in the Kameng (bordering with the Sonitpur and Balipara forests of Assam) and East Siang-Tirap (bordering with Dibrugarh-Digboi areas) zones. The Forest Department in these states must work out a common strategy for the protection of elephants on a region-wise scale by identifying these key areas.

Preservation of key habitats

Habitats such as the riverine semi-evergreen forests and grasslands are extremely important for elephants, as they are a ready source of forage, especially following the first rains. These habitats are constantly under threat due to possible conversion to cultivated land. A viable alternative to livestock grazing is stall-feeding and this must be promoted in a large scale in order to reduce the pressure on forest resources. It is very clear that there can be no long-term solution without the combined effort of the Forest Department and the indigenous people of the area.

Fig. 4 The location of Kameng Sonitpur area in the Arunachal Pradesh and Assam

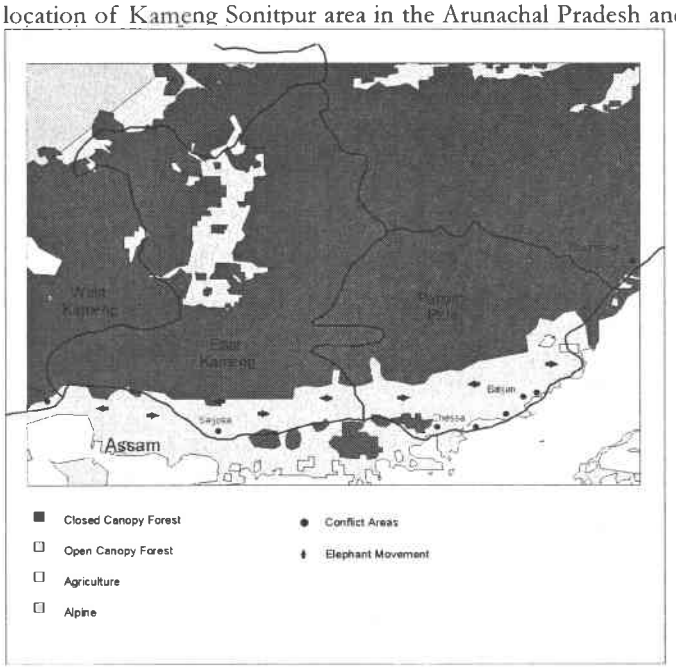


Fig. 5 Map of the Dibru-Deomali area of Arunachal Pradesh and Assam