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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.

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References

Caughley, G. (1977) *Analysis of Vertebrate Populations.* John Wiley & Sons, Chichester

Moss, C.-(1988) *Elephant Memories: Thirteen Years in the Life of an Elephant Family.* Willima Collins Sons & Co. Glasgow.

Said, M.Y., Chunge, R.N., Craig, G.C., Thouless, C.R., Barnes, R.F.W. & Dublin, H.T. (1995) *African Elephant Database 1995.* IUCN, Gland, Switzerland

Szechowyez, R.W. (1956) Some observations on the forests of Ceylon. *The Ceylon Forester*, **2**: 192-198

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.

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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

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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.

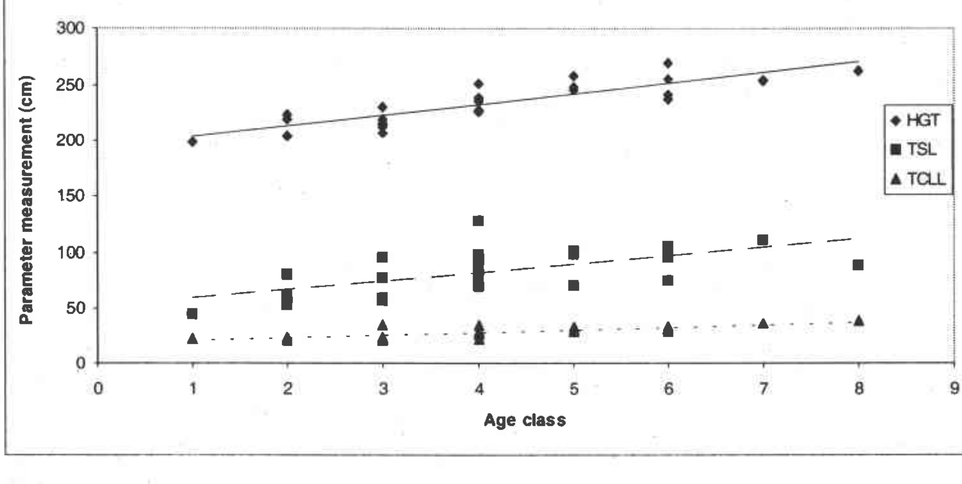
A similar theory put forward by Hamilton & Zuk (1982) argued that bright plumage in male birds might signal their genetic ability to resist chronic parasite infestations. Only very healthy birds would be able to invest in and maintain bright plumage, while weak and parasitized birds would have relatively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

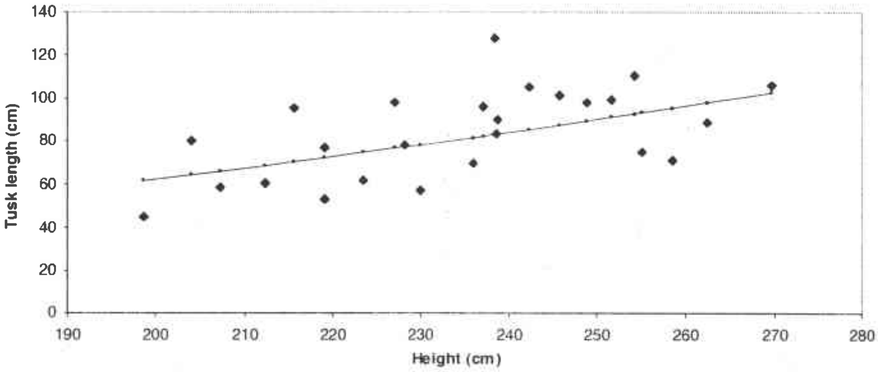
2. Female elephants in oestrus are selective in allowing male elephants to mate with them. This assumption of female choice of their mates is supported by long term studies of female African elephant behaviour (Moss, 1988; Poole, 1989b) and anecdotal evidence on captive and wild female Asian elephants (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 km². The study was carried out in an approximately 100 km² 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.