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# Constructing Age Structures of Asian Elephant Populations: A Comparison of Two Field Methods of Age Estimation

Chelliya Arivazhagan and Raman Sukumar

*Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India*

## Introduction

Construction of age structures of populations is central to studies of demography of large vertebrates (Caughley 1977). Unlike in the case of the African elephant (*Loxodonta africana*), there are few published age structures of wild Asian elephant (*Elephas maximus*) populations (Sukumar 1989, 2003). On the other hand, age/sex structures for several Asian elephant populations are available in reports, especially in governmental records pertaining to population censuses. Assessments of the dynamics of such populations based on the reported age structures are only as good as the field methods used for estimating the age of individuals.

It is generally accepted that the most accurate method of ageing ungulates is the degree of tooth eruption and wear. This method has been successfully applied to several African elephant populations that were culled in population-control measures several decades ago (e.g. Johnson & Buss 1965; Laws 1966, 1970; Krumrey & Buss 1968; Sikes 1971; Hanks 1972; Smuts 1977). Non-destructive methods have relied upon a comparison of field estimates of body measurements (typically height at withers or body length) or morphological characteristics with those of elephants of known age (Douglas-Hamilton 1972; Croze 1972, Laws *et al*. 1975; Hall-Martin & Ruther 1979; Jachman 1980). Such field techniques are most applicable to the endangered Asian elephant (Sukumar 1985, 1989), in which invasive procedures are not feasible or desirable. Shoulder height was found to be a very good parameter for describing linear growth in elephants (Laws 1966; Laws *et al* 1975), and Sukumar *et al.* (1988) used data on shoulder height from records of captive-born as well as captured Asian elephants to fit growth curves for male and female elephants in southern India based on von Bertalanffy equations.

Additional morphological characteristics that may be used for ageing include skull size, ear size, extent of upper fold of the ears, depigmentation of ears, temporal and buccal depression, and tusk thickness (for males). Thus, age may be estimated in the field either by photographing elephants for estimating shoulder height more precisely (Laws 1966; Douglas-Hamilton 1972; Croze 1972; Laws *et al* 1975, Hall-Martin & Ruther 1979; Jachmann 1980; Sukumar 1985) (henceforth referred to as the photography method), or by subjectively estimating age using a combination of visually-assessed height and the additional morphological characteristics mentioned above (Sukumar 1985) (henceforth referred to as the visual method).

The visual method is necessarily subjective but, if validated, would be very useful to apply in the large-scale elephant censuses, through the direct sighting method, that are carried out regularly in many elephant range countries. This paper thus compares the results obtained by the photography and visual methods with regard to age structure of the elephant population in Mudumalai Wildlife Sanctuary, southern India during 1999-2003.

## Methods

The study was carried out in Mudumalai Wildlife Sanctuary, southern India, which is part of the world's largest wild Asian elephant population, the Nilgiri-Eastern Ghats population. Elephants classified by the photography and/or the visual methods were placed in four major age classes – Calf (0-1 yr), Juvenile (1-5 yr), Sub-adult (5-15 yr) and Adult (>15 yr) with further refinement into 11 sub-classes (age charts in Tables 1 & 2).

**Table 1.** Rule of thumb age/height criteria for elephants (based on Sukumar 1985, 1989).

| Major age classes | Approx. height [feet] | Sub-classes [years] |
|---|---|---|
| Calf (0-1 yr) | 3-4 | |
| Juvenile (1-5 yrs) | 4-6 | 1-2, 2-3, 3-5 |
| Sub-adult (5-15 yrs) | 5½-7 - female; 6-8 - male | 5-10, 10-15 |
| Adult (>15 yrs) | >7 female; >8 male | 15-20, 20-30, 30-40, 40-50, >50 |

Individual male Asian elephants were identified by the characteristics of their tusks such as size, shape, broken ends, etc. Prominent adult female elephants of a herd were identified by a combination of ear characteristics (if present) such as cuts, holes and degree of folding, wounds or warts on the body, length of tail, presence or absence of hair at the end of the tail and general body structure (the traditional classification into the basic "*koomeriah*", "*dwasala*" and "*mriga*" types (see Choudhury 1976). Individual identification allowed us to avoid double counting of the same herds or adult males. We aged elephants using the following procedures.

*a. Visual method*

We used diagrams of elephant shoulder heights at different ages constructed from captive elephants of known ages (see Sukumar *et al.* 1988) as a field guide for elephants up to fifteen years old. Above the age of 15-20 years the annual increments in height are small (or the curve reaches an asymptote) and, thus, it is not possible to fix age visually from height alone. They were thus aged, with some degree of subjectivity, based on external morphological characteristics mentioned previously such as skull size, ear size, temporal depression, (degree of folding and de-pigmentation of ears, Table 3) and tusk thickness in males.

**Table 2.** Chart of age/height relationship based on the equations derived for captive elephants that have been suitably corrected for wild elephants (Sukumar 1985, 1989).

| Age [years] | Height [cm] | |
|---|---|---|
| | Male | Female |
| 0 | 90 | 89 |
| 1 | 121 | 119 |
| 2 | 139 | 135 |
| 3 | 155 | 149 |
| 4 | 169 | 161 |
| 5 | 180 | 170 |
| 6 | 190 | 177 |
| 7 | 198 | 183 |
| 8 | 205 | 188 |
| 9 | 212 | 193 |
| 10 | 217 | 197 |
| 11 | 222 | 200 |
| 12 | 225 | 203 |
| 13 | 228 | 206 |
| 14 | 231 | 209 |
| 15 | 235 | 213 |
| 20 | 250 | 228 |
| 25 | 262 | 234 |
| 30 | 268 | 238 |
| 40 | 272 | 240 |
| Asymptotic | 274 | 240 |

*b. Photographic method*

We used two variants of the photography method to estimate the shoulder heights of elephants.

i. Pole method (Foster 1966; Douglas-Hamilton 1972; Jachmann 1980), in which the lateral view of the elephant was photographed in an open area or while crossing the road where the fore foot and shoulder are clearly seen, and a second picture was taken after the elephant moved away of a calibrated vertical pole held by an assistant at the exact spot where the elephant had stood or crossed. This allowed an accurate measurement of shoulder height by a comparison of these two photographs that are at the same scale.

ii. Distance measurement method, in which we photographed elephants while they crossed a path or road, and, after they moved away, measured the distance (using a measuring tape) between the spot from where the photograph was taken and the spot where the elephants had crossed the path. This distance was typically in the range of 30-75 m. In case the elephants crossed at slightly different distances, the distance of the nearest elephant and that of the farthest elephant were measured. Intermediate values were allocated to the other elephants by visual judgment from the photographs. In actual practice the inter-elephant

**Table 3.** Ageing older female elephants based on external morphological characteristics (varies with individuals and needs to be quantified more precisely.; the ear folding may proceed behind the ear).

| Age [years] | Degree of ear folding or curling | Depigmentation of ears |
|---|---|---|
| 25-30 | Ear fold begins. Is clearly visible (25% fold) by about age 30 years | Depigmentation begins with small reddish dots at corner of the ear pinna |
| 30-40 | Fold progresses from front to back of ear. Over 50% fold by age 40 years | Depigmentation is clearly visible by the age of 40 years |
| 40-50 | Fold complete between age 40 and 50 years but the fold in still curled | Depigmentation becomes very prominent by the age of 45-50 |
| >50 | The ear fold flattens completely beyond 50 years | Above 50 years clearly seen as reddish layer along the outer side of corner of the ear |

distance did not exceed 5 m. Photographs were taken of each animal using an SLR camera with 200 mm-fixed focal length lens. The same instrument was used all through the study period. The height of each elephant in the photograph was measured from the sole of the forefoot to the top of the scapula (commonly termed as height at withers or shoulder height) using a scale calibrated at 0.5 mm interval. From the heights as measured on the image heights, factor of magnification, distance to the object, and the focal length of the camera lens used, shoulder heights were estimated.

We used the likelihood-ratio chi-squared statistic ($G^2$) (see Agresti 1996) to examine differences between the age structures arrived at by the different methods; the age structure from the photographic method was considered to be the expected category as this is the more objective method of age-estimation.

**Results and discussion**

A total of 653 elephants were classified by the photographic method and 777 elephants by the visual method. The frequency distributions of age and sex classes of elephants in Mudumalai Wildlife Sanctuary during 1999-2003 obtained from the two methods viz., visual method and photographic method are shown in Table 4. Adult females constituted the major age class of the population, as inferred from percentage of elephants in this age class by both photography and visual methods (41.7% and 39.6%, respectively), followed by sub-adult females (18.5% and 17.0% respectively) and juvenile females (12.6% and 13.8% respectively). Adult males constituted a very low percentage of the population, an inference derived from both the methods (2.5% and 1.7%, respectively). Sub-adult males constituted 7.0% and 5.5%, and juvenile males formed 10.3% and 11.3% of the elephant population in Mudumalai Wildlife Sanctuary as inferred from the photography and visual methods, respectively. However, calves could not be sexed, and equal percentage was allocated to both sexes. A comparison of data from the two methods revealed that the numbers of animals in the different age categories were independent of the type of method used for classification, both when data from both sexes were analysed together ($G^2$=16.27, df=21, p=0.75), as well as for females ($G^2$=6.432, df=10, p=0.78) and males ($G^2$=9.32, df=10, p=0.50) analysed separately.

Thus, the visual method seemed to perform adequately and can be used *in lieu* of the photographic method for obtaining demographic information during large-scale censuses when the

**Table 4**. Population and age structure (frequency in upper row, percentage in lower row) of elephants classified by photographic and visual methods in Mudumalai Wildlife Sanctuary during 1999-2003.

| | Females | | | | Males | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| Age class | Calf | Juvenile | Sub-adult | Adult | Calf | Juvenile | Sub-adult | Adult | |
| Photo | 25 | 82 | 121 | 272 | 24 | 67 | 46 | 16 | 653 |
| | 3.8% | 12.6% | 18.5% | 41.7% | 3.7% | 10.3% | 7.0% | 2.5% | 100% |
| Visual | 44 | 107 | 132 | 308 | 44 | 86 | 43 | 13 | 777 |
| | 5.7% | 13.8% | 17.0% | 39.6% | 5.7% | 11.1% | 5.5% | 1.7% | 100% |
| Total | 69 | 189 | 253 | 580 | 68 | 153 | 89 | 29 | 1430 |

**Table 5**. Forest department census data from Mudumalai for the year 2002.

| | Female | | | | Male | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Calf | Juv. | Sub-adult | Adult | Calf | Juv. | Sub-adult | Adult | Total |
| Block count | 23 | 8 | 59 | 160 | 24 | 9 | 22 | 22 | 327 |
| Waterhole count | 17 | 18 | 42 | 126 | 18 | 7 | 19 | 17 | 264 |
| Total | 40 | 26 | 101 | 286 | 42 | 16 | 41 | 39 | 591 |

photographic method is rarely logistically feasible. It must be acknowledged that the visual method suffers from some subjectivity and the extent of this is likely to depend on prior experience. Therefore, how well will this method work when employed by forest/wildlife department staff who may have limited experience or training in ageing elephants?

We compared data from the forest department census of Mudumalai Wildlife Sanctuary for the year 2002 (see Table 5) with our age-structure based on the photography method and found that they were significantly different from each other (photographic method versus forest department block counts $G^2$=71.12, df=7, p<0.001; photographic method versus forest department water-hole counts $G^2$=38.96, df=7, p<0.001; photographic method versus forest department total census $G^2$=81.86, df=7, p<0.001). When we tested the forest department census data with our age structure derived from our visual method we again found that they were significantly different from each other (visual method versus forest department block counts $G^2$= 82.78, df=7, p<0.001; visual method versus forest department water-hole counts $G^2$=46.63, df=7, p<0.001; visual method versus forest department total census $G^2$=99.20, df=7, p<0.001).

When the forest department census data are compared with our visual method data it is clear that the former underestimate the number of juvenile elephants of both sexes. It is most likely that elephant age/age class was being overestimated, a common problem even in the case of estimating the ages of captured elephants (Sukumar *et al*. 1988). Such overestimation is carried forward into the sub-adult and adult age classes of both sexes (see Table 6). In particular, the estimation of adult male to female ratios, an important parameter in demographic studies, is typically distorted in favour of males, giving a false impression of the prevailing ratios. While we have given the Mudumalai census data as an example of this bias, this is also true of most other census data derived for various forest divisions in the southern Indian states of Kerala, Karnataka and Tamilnadu we have examined.

We, therefore, suggest that field staff are given two training sessions, the first, well in advance of the census programme and, the second, just before the programme. The latter is being carried out across several forest divisions in southern India and may be extended to other divisions. In addition, if a trained researcher accompanies groups during the census and independently collects data, it would be useful in assessing the extent of error or bias in the dataset. We provide a guide for ageing elephants in a herd (Figs. 1 & 2). One possible reason for overestimating the ages of solitary males, in the absence of an adult female, is the lack of a reference to place the height of the male. Therefore, in the case of solitary males (or male groups), measuring forefoot circumference, which can be used to calculate height (see Sukumar *et al.* 1988), may also be used for age estimation. A pictorial field manual would also assist the staff in more accurate ageing of elephants in the field.

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**Table 6.** Percentage of ages/sex structure comparison between visual method and Forest Department census (Mudumalai during 2002)

| Age class | Visual method | | Forest dept. | |
|---|---|---|---|---|
| | % Female | % Male | % Female | % Male |
| Calf | 5.7 | 5.7 | 6.7 | 7.1 |
| Juvenile | 13.8 | 11.1 | 4.4 | 2.7 |
| Sub-adult | 17.0 | 5.5 | 17.1 | 6.9 |
| Adult | 39.6 | 1.7 | 48.4 | 6.6 |

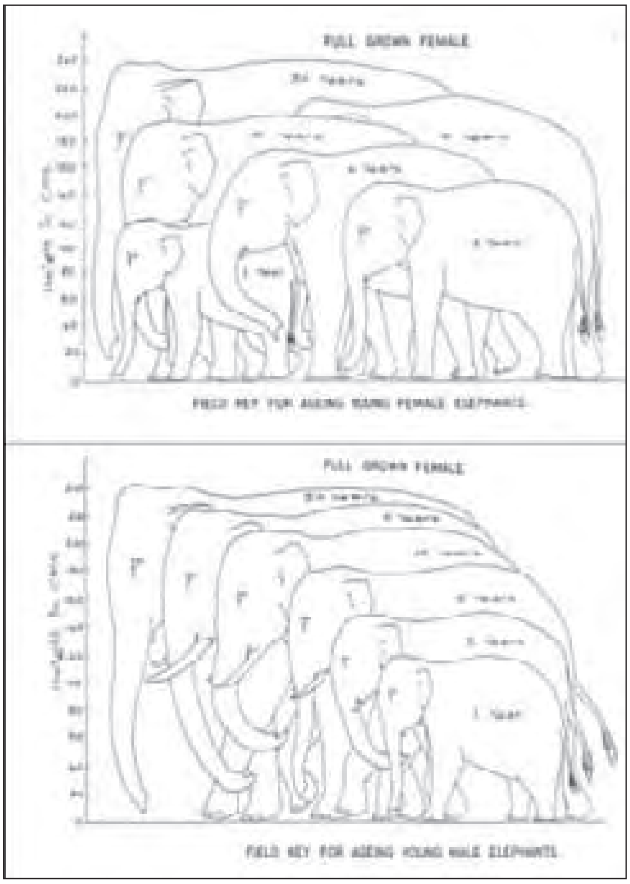


**Figure 1.** Diagrams of elephant shoulder heights at different ages constructed from captive elephants of known ages (source Sukumar *et al*.1988).

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**Figure 2.** Field guide for ageing Asian elephants in the field.

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*Corresponding author's e-mail: c_ari@rediffmail.com*

A herd of Elephant at Kabani back water, Nagarahole National park
Photo by Chelliya Arivazhagan