Size-Age Class Scale for Asian Elephants

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Abstract. Population structure provides important information for managing and conserving free ranging Asian elephant populations. A variety of size-age classes, based on estimating height or age and measuring captive animals of known age, have been used previously. Here we propose a simple scale, using the individual's height relative to an adult female. We also indicate morphological characters of relevance, where determining relative height maybe an issue, as in the case of adult males.

Introduction

Elephants have potential life spans exceeding six decades and an extended period of growth and maturation. Therefore, elephants are among a handful of species, where body size can be used to delineate a number of age classes. Asian elephants (*Elephas maximus*) have a gestation period of around 22 months, the longest of any mammal (Hildebrandt *et al.* 2007). Consequently, at birth elephant offspring are comparatively large, fully formed and functional. Female Asian elephants start reproducing around 10–15 years of age (Mumby *et al.* 2015; Pushpakumara *et al.* 2016; Mendis *et al.* 2017). While males also become capable of reproduction around this age, they may not become reproductively active till later, due to social immaturity (Eisenberg & Lockhart 1972).

Population health is an important indicator for the conservation and management of wild populations. Asian elephants tend to occupy human-dominated habitats with poor visibility and actively avoid people due to conflict with them (Fernando 2000). Therefore, assessing the health of free ranging Asian elephants can be challenging. Body condition scoring based on a visual scale (Fernando *et al.* 2009) reflects relative fat mass (Chusyd *et al.* 2019). It is a useful indicator of short-term health and resource availability (Ranjeewa *et al.* 2018; Liyanage *et al.* 2021). However, population structure is a better indicator of long-term population health, as it reflects changes in reproductive output and survival over a period of years. It facilitates assessing the conservation status and viability of elephant populations and in detecting impacts of environmental events such as droughts and vegetation succession. Demographic data also enables monitoring impacts of anthropogenic habitat alteration, fragmentation and loss, hence of management actions such as habitat enrichment, elephant drives and movement restriction by electric fencing.

Assigning free ranging individuals to size-age classes is essential for cross sectional and short-term studies. Decades-long studies with individual identification can provide annual age structures, but still need to assign ages to individuals present at the studies' commencement. A few studies based on individual identification of free ranging African elephants have spanned over a decade (Moss 1988; Turkalo *et al.* 2018). In contrast, demographic information on Asian elephants has been based on shorter-term studies with and without individual identification (Eisenberg & Lockhart 1972; McKay 1973; Kurt 1974; Sukumar 1989; de Silva *et al.* 2011, 2013), and on records and measurements of captive elephants (Kurt & Kumarasinghe 1988;

Sukumar *et al.* 1997; Mumby *et al.* 2015; Pushpakumara *et al.* 2016).

Growth

Growth in elephants extends over many years, with height at birth being around 40% of adult size. Males and females achieve about 90% and 95% respectively of their adult height by age 15 (Mumby *et al.* 2015). Early literature on elephants suggested indeterminate growth or a secondary growth spurt (Laws *et al.* 1975; Sukumar *et al.* 1988). However, recent studies have shown that elephants also conform to determinate growth, which is the norm in mammals (Mumby *et al.* 2015).

Number of size classes

Change in height occurring over many years facilitates assignment of individuals to size-age classes. The number of classes used in previous studies of elephants has varied widely, ranging from 4 to 21 (Table 1).

The higher the number of classes, the more likely changes in age-specific survivorship can be detected. With increasing number, class width narrows and natural variation in height can result in greater overlap of heights between age classes. Consequently, incorrect assignment of individuals becomes more likely. Hence there is a trade-off between the number of size-age classes and unambiguous assignment. Additionally, with narrower size-age classes, reproductive stochasticity is likely to cause varying numbers of individuals in classes, which maybe confused with differences due to age-specific survivorship. Conversely, with fewer hence wider classes, the chance that differences could be missed is greater, particularly if they are transitory, affecting cohorts of one or a few years. As generalist herbivores, elephants are fairly resilient, especially as adults. Factors such as food scarcity due to drought, habitat loss or range restriction, causing malnutrition and increased disease susceptibility, are likely to disproportionately impact the younger age groups. Therefore, having the maximum number of size-age classes of younger age groups, to which individuals can be assigned with confidence, is desirable.

Height variability

Height in humans has an approximately normal distribution with a coefficient of variation of around 4.25, which means the heights of 95% of the population will be within a range of ±8.5% of the mean (Roser *et al.* 2019). Other species may have somewhat greater height or body length variation than humans (McKellar & Hendry 2009) but should have approximately normal distributions once controlled for sexual

Table 1. Number of size classes and method of assignment of Asian elephants in selected studies. M = male, F = female, 'Comparative height' = height assessment in relation to an adult female.

Study	Number of size classes			Method
	Total	Adult	Non-adult	
Eisenberg & Lockhart (1972)	4	1	3	Height
McKay (1973)	4	1	3	Height
McKay (1973)	9	M2, F1	7	Comparative height
Kurt (1974)	9	2	M7, F6	Comparative height
Kurt (1974)	4	1	3	Comparative height
Sukumar (1989)	12	5	7	Height
Arivazhagan & Sukumar (2008)	4	1	3	Height
Arivazhagan & Sukumar (2008)	6	1	5	Comparative height
Arivazhagan & Sukumar (2008)	21	M5, F4	16	Height
de Silva *et al.* (2011)	5	1	4	Comparative height
This study	6 (7*)	1 (M2*)	5	Comparative height

*Optional division of adult males into 2 classes.

and/or phenotypic polymorphism. Scatter in the age-height charts of captive elephants by Sukumar *et al.* (1988), Kurt & Kumarasinghe (1988) and Mumby *et al.* (2015) suggests that individual variation in height in elephants is similar to or greater than in humans. While constructing annual size-age classes are the ideal for assessing age structure, it is not practical to do so based on height, due to its inherent variability.

Genetics is likely to be the main determinant of intra-population variation in height. Height has a high heritability in humans and horses with a complex polygenic inheritance (Allen *et al.* 2010; Signer-Hasler *et al.* 2012) and can be assumed to be similar in other mammals. Inter-population variation may lead to particular populations of a species being noticeably different in size. In elephants, height variation between populations may be more than within a population (Kurt & Kumarasinghe 1988). Population level variation in height may occur due to genetics, evolutionary history (Cavallini 1995) and environmental factors (Yom-Tov *et al.* 2006).

Method of assignment

Free ranging elephants can be assigned to size-age classes based on height estimation through photographic methods (Arivazhagan & Sukumar 2008) or footprint measurements (Eisenberg & Lockhart 1972). A more commonly used alternative is to use relative height, by comparing an individual with an adult female (Table 1). Arivazhagan & Sukumar (2008) found assignment by photographic estimation and relative height to give comparable results in the field. However, height estimation of free ranging elephants is difficult, while scaling in relation to an adult female is relatively easy due to their adult female centric social organization. Scaling of height in relation to the mother (Turkalo *et al.* 2018) or an adult female in the group, controls for intra- and inter-population variation, as opposed to actual measurement and assignment in relation to a reference.

Nomenclature

Calf/new-born/infant/neonate

The word 'calf' is used to denote young of cattle and other animals as a general term. In cattle it is also used explicitly to refer to a specific age class from birth to weaning (8–9 months). In humans the term new-born/neonate is used from birth to 4 weeks and infant from birth to 1 year (MedicineNet.com). The terms calf, new-born, infant and neonate have been applied to elephants with wide variation (Table 2) and mostly without explaining the rationale, making their use confusing.

Juvenile

The term 'juvenile' is used in humans for those up to 18 years. In animal studies it is mostly used as a general term to refer to individuals that are not adult. In contrast, in elephants it has been used to denote a specific size-age class, but with wide variation in ages assigned (Table 2).

Sub-adult

The term 'sub-adult' is sometimes used to denote all ages below adult (Stull *et al.* 2021). The commoner use of the sub-adult moniker is as a specific non-adult category. In this usage, it denotes individuals that are morphologically but not functionally adult, where adult functionality is defined as being reproductively active. This usage has been applied across taxa, ranging from fish to birds and mammals. However, in elephants, the term sub-adult has sometimes been applied to animals of ages with juvenile morphology and not reproductively active, as well as those with adult morphology and are reproductively active (Table 2).

Estimated age of first reproduction in free ranging Asian elephant females is around 10–18 years (McKay 1973; Sukumar 1989; de Silva *et al.* 2013). As there have been no long-term field studies, confirmed age of first reproduction is available only for captive Asian elephants. The mean age of first reproduction of 7 captive-born females at the Pinnawala Elephant Orphanage, Sri Lanka was 12.5 ± 0.5 years (Pushpakumara *et al.* 2016) and in 416 captive-born females under Myanmar Timber Enterprise, Myanmar, it was 19.48 years (Hayward *et al.* 2014). An endocrine study of 11 females aged 3.5–15 years (age estimated at arrival as orphans for 9 individuals, 2 individuals captive-born) at the Pinnawala Elephant Orphanage, found 6 females aged 5.5–12 years, cycling at the commencement of the study and 4 to start cycling during the study at 4.5, 5.5, 7.5 and 15 years of age (Mendis *et al.* 2017). Age of puberty is related to nutrition (Schillo *et al.* 1992) and may occur at a younger age in captive elephants due to better nutrition. However, the mean age of first reproduction of the same Pinnawala Elephant Orphanage population was 14.6 ± 0.7 years (Pushpakumara *et al.* 2016). Therefore, age of first conception in captivity appears to occur well after puberty, whereas in the wild it is likely to be at or soon after, as males have unhindered access to females coming into oestrous. This creates an issue in the use of the term 'sub-adult' for female elephants, as those aged 10–15 years are likely to be functionally adult but since they continue to grow in height till about 15 years (Mumbi *et al.* 2015), they are not strictly morphologically adult.

Males are also likely to go through puberty around 10 years of age. However, in the wild they may not get to mate for over another decade, due to dominance of older males and female choice (Eisenberg & Lockhart 1972). Males continue to grow in height till at least 20 years (Mumbi *et al.* 2015). Therefore, males aged 10–15 years are physiologically adult, but not functionally or morphologically adult, hence the term 'sub-adult' appears well suited to them.

Adult

Adults are generally defined as those that are fully-grown and are reproducing. Most previous studies on elephants have used a single size class for adults (Table 1). Subdivision of adult elephants into multiple size-age classes has been based on assumed growth in height till about 40 years in females and 40+ years in males (Arivazhagan & Sukumar 2008). However, female elephants reach 95% of their height by 15–16 years age and males by 21 years (Mumbi *et al.* 2015). Therefore, division of adults into multiple size-age classes based on height appears unwarranted.

Table 2. Size-age classes used by selected studies on Asian elephants (M = Male, F = Female, AF = Adult Female).

Study	Calf/New-born/Infant/Neonate			Juvenile		Sub-adult		Adult	
	Term	Age	Size	Age	Size	Age [years]	Size	Age [years]	Size
Eisenberg & Lockhart (1972)	Calf	0–14 months	91–120 cm	14–40 months	121–150 cm	F 3.5–7 M 3.5–9	F 151–180 cm M 151–210 cm	F > 7 M > 9	F >183 cm M >210 cm
McKay (1973)	Infant*	–	<120 cm	–	F 120–180 cm* M 120–200 cm	–	F 180–200 cm M 200–220 cm*	–	F >200 cm M >220 cm
Arivazhagan & Sukumar (2008)	Calf	0–12 months	F <119 cm M <121 cm	1–5 years	F 119–170 cm M 121–180 cm	5–15	F >170–213 cm M 181–235 cm	>15	F >213 cm M >235 cm
Kurt (2009)	Neonate Infant	0–2 years 3–4 years	–	5–10 years	–	11–15	–	>15	–
de Silva *et al.* (2011)	New-born Calf	0–6 months 0–36 months	up to AF belly up to AF chin	3–7 years	up to 50% of AF height	8–12	up to AF height	>12	–

* Developmental/behavioural characters also given.

Table 3. Definition of the size classes proposed in this study. See also Figures 1 and 2.

Class	Name	Reference point on a fully-grown adult female		Approx. age
		Lower bound	Upper bound	[years]
1	Juvenile I	–	chest*	0–1
2	Juvenile II	chest*	lower border of neck	1–3
3	Juvenile III	lower border of neck	lower border of eye	3–6
4	Juvenile IV	lower border of eye	upper border of nasal protuberance**	6–10
5	Sub-adult male Adult female	upper border of nasal protuberance**	shoulder top	10–15
6	Adult male	shoulder top	–	15 +

* the inferior margin of chest wall and not the breasts

** the point of the angle between the nasal protuberance and the forehead

Proposed scale

The scale presented here is based on shoulder height. The defining height limits of a size-class are related to specific points on an adult female and virtual horizontal lines through those points provide the reference limits for each class (Figs. 1–3). Given that the difference in height from birth to 20 years is about 1.5 m, we divide elephants into 6 or 7 size classes. This gives a scale with fairly wide intervals, reducing overlap. The classes have more or less equal increases in height. Age-width attributed to each higher class is progressively wider (Table 3) to account for the slowing of growth with age.

Adult female

The mismatch between functionality and morphology in elephants creates an issue in terminology. Giving precedence to function over stature, we define an adult female as one that is reproductively active. In the field, any female with an offspring is identified as an adult. However, this results in the adult female class consisting of 'fully-grown' and 'not fully-grown' individuals, creating some contradiction in terminology.

A fully-grown adult female should be selected for use as a standard for relative height comparison. Field identification of fully-grown adult females is based on the presence of two or more offspring or post-reproductive (as indicated by not having any dependant offspring and empty breasts with elongated nipples, see Figure 4) or being one of modal height in a group with multiple adult females. In a multi-female group, the majority of adult females would fulfil the above criteria. Typically, multiple females are used as 'standards' in assigning members of a group to size classes. Obviously, any female that fulfils above criteria, but is atypical in height, should

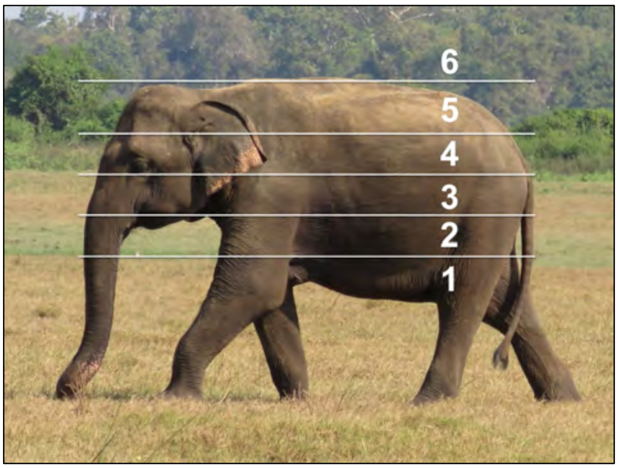

Figure 1. Adult female with lines indicating the boundaries between size classes.

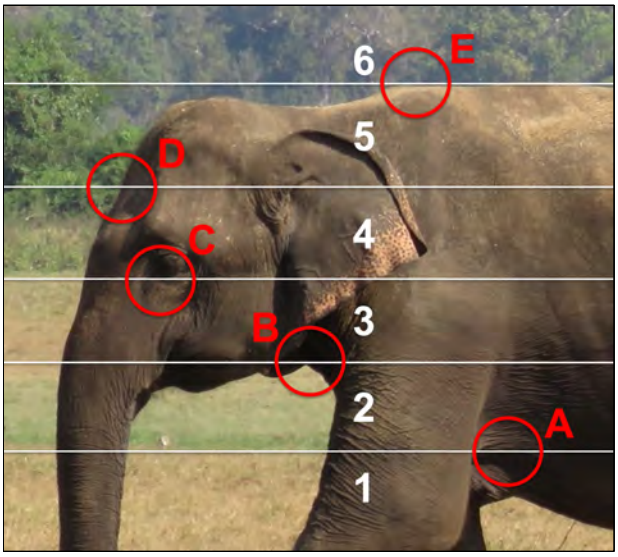

Figure 2. Points A–E (red circles) to set the boundaries (white lines) between size classes 1–6 on an adult female (see Table 1).

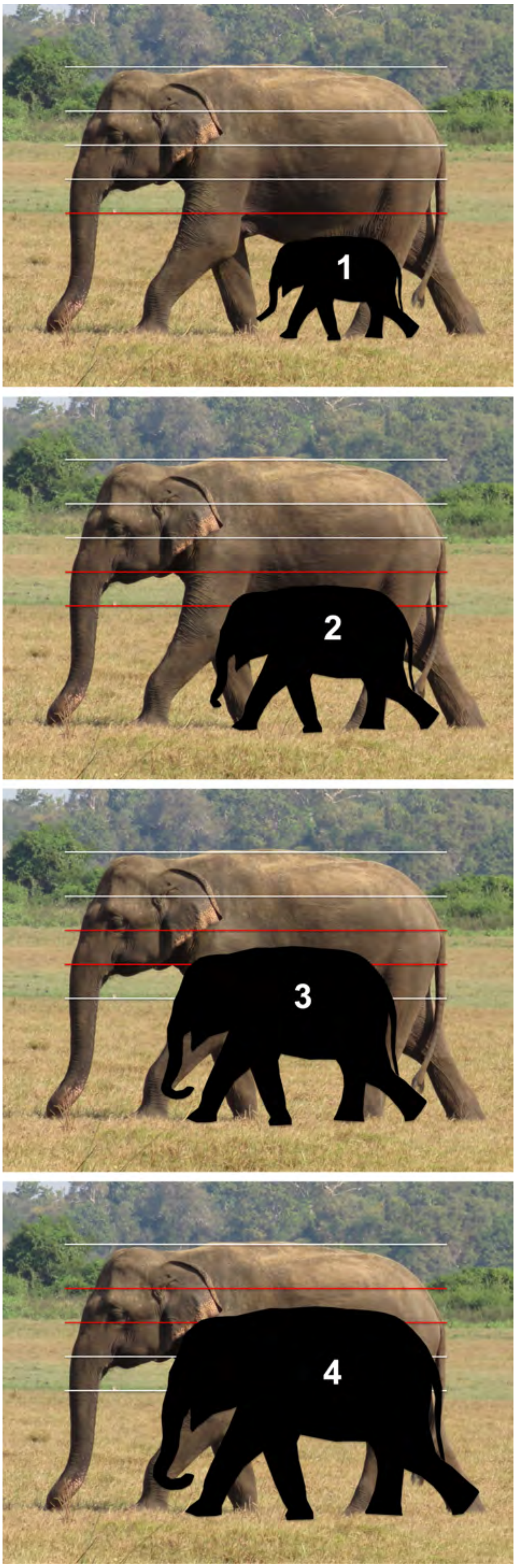

Figure 3. Size class scale with juveniles from size classes 1–4.

not be used as standard. As some of the reference points for the defining lines are on the head (Fig. 2), the head should be in a 'neutral' position, i.e. not looking up or down, when the assessment is made.

We recommend assignment be based on photographing elephants in the field and subsequent analysis, rather than direct visual assessment in the field. Ideally individuals should be photographed when standing on level ground next to a fully-grown adult female.

Juveniles

Juveniles are those in size classes I to IV (Table 3, Fig. 3).

Sub-adults

Females: The term sub-adult is not used for females. Therefore, females transition directly from juvenile size 4 to adult. Consequently, size 5 females are considered adult.

Males: Size 5 males are considered 'sub-adult'. Although post-pubertal, sub-adult males are socially immature and may display 'moda-musth' characterised by differences in chemical composition and mellifluous odour, as opposed to the malodorous odour of adult-musth secretions (Rasmussen *et al*. 2002).

Adult males

Adult males are those that are taller than an adult female.

Figure 4. Post-reproductive female. Note the empty breasts and elongated nipples.

Table 4. Characters for sub-dividing adult males.

Character	Young-adult	Mature-adult
Head		
Proportion head:body	Similar to adult female's	Proportionately larger
Parietal domes	Not well developed	Pronounced
Nasal protuberance	Not well developed	Pronounced
Trunk base	Narrow	Broad
Penis		
Penile bulge	Not prominent	Prominent
Penis shape	Slender	Bulky, venation prominent
Musth		
Urinating	Penis often extruded	Penis not extruded
Duration	<30 days	>30 days
Temporal discharge	Mild – moderate Mellifluous*	Copious, with staining of cheeks Malodorous*
Urine dribbling	None or spotty	Continuous, with staining of legs

* Rasmussen *et al*. (2002)

'Young-adult' and 'mature-adult' males

Males continue to grow in height into their twenties, gain in mass throughout their life (Mumby *et al*. 2015) and develop secondary sexual characteristics gradually. Therefore, adult males could be sub-divided into two size-age classes as 'young-adult' and 'mature-adult', representing the approximate ages of 15–25 and 25+ years, respectively. This would be useful for some studies, as there are likely to be behavioural differences between the two groups.

While mature-adults would be taller than young-adults, height comparison is not easy in males as they are often solitary. Young-adult males are characterised by secondary sexual characteristics that are relatively less developed (Table 4, Figs. 5–10). Characters such as increased folding of the superior border of ears, de-pigmentation, and tusk growth (Arivazhagan & Sukumar 2008) can also provide some indication of maturity but tend to be very variable. Individual variation also occurs in the characters listed in Table 4. Therefore, the assignment of individuals as young-adult or mature-adult should be done in consideration of a majority of the characters listed in Table 4 rather than just one or two of them. Since the categories are very broad, it should still be possible to assign individuals with confidence.

Figure 5. Mature adult male, adult female, young adult male (from left to right). Note the respective differences in heights and the head:body proportions and development of the three individuals.

Figure 6. Young adult male. Note small head and slender penis. Parietal domes, nasal protuberance and trunk base not well developed.

Figure 7. Mature adult male. Note the large head, prominent parietal domes, nasal protuberance and penile bulge.

Additional notes

Height estimation is ideally done in relation to the mother. However, mother-offspring pairs can only be identified with certainty for size classes I and II. For size classes III and IV, if the mother cannot be identified, which is particularly likely in the case of male offspring, any fully-grown adult female in the group can be used for comparison. For offspring of adult females that are not fully-grown, height is ideally assessed relative to a fully-grown adult female in the group, and not the mother. This creates a problem if an adult female that is 'not fully-grown' is observed with her offspring but without other adult females nearby. However, such observances are likely to be infrequent and in long-term studies the assignment can be corrected, as they are likely to be observed in larger groups at other times.

Figure 8. Mature adult male. Note the prominent parietal domes and nasal protuberance. However, the head is small in proportion.

While it may not be possible to obtain comparative height of all individuals at a single encounter, this scale can be easily applied to studies where repeated observations of the same individuals can be made, as detectable change in height occurs over months to years.

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Figure 9. Typical copious temporal discharge of mature-adult male in musth. Also note the prominent parietal domes and fairly developed nasal protuberance.

Figure 10. Mature adult-male in musth. Note the extensive urine dribbling, wetting and staining of the rear legs, prominent nasal protuberance and parietal domes, and broad trunk base. However, the temporal discharge is mild.

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