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RESEARCH ARTICLE

MORPHOMETRIC TECHNIQUE TO DETERMINE THE AGE OF ADULT ASIAN ELEPHANTS (*Elephas maximus*) IN RELATION TO THEIR FRONTAL NEUROCRANIAL PHENOTYPE

T. Muthukumarana


Morphometric Age estimation method on Asian elephants

Capturing a portrait image

Analyzing

Age estimating

Highlights

- Classifying the age of an adult elephant is a challenging task for a budding researcher
- In Africa, the hourglass morphometric methodology is used to distinguish a sub-adult from an adult.
- Since Asian elephants' neurocranium is more vertically elongated than that of the African elephant, the age classification model can be made based on their neurocranium.
- Accordingly, the adult elephants can be divided into four age clusters.

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MORPHOMETRIC TECHNIQUE TO DETERMINE THE AGE OF ADULT ASIAN ELEPHANTS (*Elephas maximus*) IN RELATION TO THEIR FRONTAL NEUROCRANIAL PHENOTYPE

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Abstract: When classifying the age of elephants, relying on a single formulae can be erroneous, and therefore, multiple morphological features should be tested. In this research, a morphometric pattern was used to determine the age of adult Asian elephants. Since Asian elephants' neurocranium is vertically elongated when compared to its African counterpart, it was attempted to develop an age-classifying model focusing on the features that are co-enhanced by the neurocranium. A scale was created using n = 4 diffeomorpho metric models, and n = 4 age clusters were assigned to the scale in relation to the diffeomorpho metric pattern. The age range was detectable in the final result relative to the physiognomy model scale.

Keywords: Asian elephants; Age classifying; Morphometric; Adult elephants.

INTRODUCTION

Elephants are the largest extant terrestrial animals on earth. For both longitudinal and cross-sectional research on elephants, it is important to identify their age. Misinterpretation of the elephant age is a common mistake in the past (Lindeque, 1991; Deraniyagala, 1955). For age classification in Asian elephants (*Elephas maximus*), various methodologies are utilized. These include analyzing the height, weight, body structure, ear fold-rate, depigmentation levels, molar-lamellae count, chewing frequency, eye lens weight, shoulder height, etc. (Eltringham, 2000; Varma et al., 2012; Kurt and Garai, 2007; Arivazhagan, 2008; Muthukumarana, 2017). Yet, all these measurements have different levels of individual phenotype and genotype variations. As an example, the ear fold pattern may have a four-decade error margin (Kurt, 2007).

There can be several methodical errors that may influence age estimations (Laws, 1966; Sikes, 1968; Hanks, 1972). Therefore, it is vital to look for multiple morphological features when determining the age. The age classes of infants (<1 year), juveniles (1 - <5 years), and sub-adults (5 - <15 years) can be determined in relative to their height. When elephants reach the age of post-twenty, they have reached the maximum height in their lives. Thus it can be a challenge to determine the age of a post-twenty-year-old elephant using the aforementioned methodologies, especially among elephants in the wild. Nevertheless, it is important to determine the adult age-range when it comes to studying the demography of the elephant population. Though the growth in height stops in their twenties, there will be further morphological changes as they mature. Studying such physiognomic features can help us to determine the age range of an elephant.

Age estimating techniques that are used so far can be categorized into two criteria, *viz*., estimating the age of a living or a dead elephant. For living elephants, most of the methods are used to distinguish infants, juveniles, sub-adults, adults that encompass age variations within a range of 20 years. However, elephants have a lifespan of 60 years, and it is essential to predict their ages beyond 20 years of age. Since techniques utilized initially do have individual variations and challenges in analyzing them with wild elephants, it is always better to use multiple methods to predict the age.

When compared to African elephants (*Loxodonta africana*), there are only a few published studies on age structures in Asian elephants (Arivazhagan, 2008; Moss, 2001). Nonetheless, for the conservation of Asian elephants, longitudinal research that aims at individual identification is crucial (de Silva, 2010). For such research, predicting the age of elephants is important. In African elephants, to distinguish a sub-adult (5 - <15 years) from an adult, the hourglass morphometric methodology is utilized. Furthermore, the same methodology will be applied from young adults (15-25 years old) to mature elephants (55-65 years old), but with a distinct pattern (Henley, 2012). Due to species-specific differences, this methodology is invalid for Asian elephants. The features of African elephants that are taken into account for hourglass analysis are enhanced by their viscerocranial bones. Considering the fact that Asian elephants' neurocranium is vertically elongated when compared to the African elephant (Muthukumarana, 2017), this study attempted to develop an age-classifying model focusing on the features that are co-enhanced by the neurocranium.

METHODOLOGY

Evaluation

To find a suitable method, a few portrait photographs of

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captive elephants with their known ages were recorded. The ages of those elephants were ranged from 20 to > 60 years. Various schematic lines were drawn, targeting the craniofacial morphology of the elephants. Out of them, the most successful was the hexagon pattern drawn targeting the twin domes and the area between the medial canthus of the eyes. It was identified that the hexagon pattern changes with the age. Furthermore, it was detected that elephants of similar ages had mutual hexagon patterns. To validate the accuracy of this study, it was carried out with many other elephants.

Collecting data

The portrait pictures of Asian elephants' anterior were captured both *in situ* and *ex situ*. Those pictures were classified according to their gender and age. For their age determination, initial methods were used, such as ear-fold, depigmentation and body conditions (Eltringham 2000; Kurt, Garai, 2007; Arivazhagan, 2008). When multiple methods are used to determine the age, the errors can be minimized. It was also convenient to get an accurate age for some captive elephants since their birth years are known.

Schematic drawings

In a portrait photograph of an elephant, a hexagon was drawn with a pattern resembling a diagonal asterisk in the middle (Figure 1). At first, the A1 line was drawn horizontally, touching the twin domes until both edges of the line reached the end of the surface level. This area outcrops the parietal bone region, which has a concave median. The B1 and B2 lines were drawn connecting the A1 line with the notch region between the auricular muscle and the auricle (pinna). Lines C1/C2 were connected with B1/B2 lines as those projected obliquely towards the medial canthus of the eye (remember that the medial canthus is positioned lower than the lateral canthus, but in a picture, it has the possibility to change if the elephant had elevated its head). The A2 line was horizontally connected to the C1 and C2 lines. As an angular bisection, from each six-angle vertex, the lines were connected towards the opposite corresponding angle vertex in uphill, downhill, and horizontally. Since, as the elephant gets older, the median horizontal line in the hexagon gets lowered. Generally, the older the elephant gets, the more it resembles the asterisk symbol. When taking the picture to layout the lines, it is highly necessary to get the picture at the correct angle. If not, it can result in erroneous feedback. Something to be aware of when drawing the lines is that debris and hair on the head can give an error value.

Age prediction

The length of the B1 vertical axis was measured, and that measurement was kept along the A1 vertical axis, starting from the left side edge of the A1. In relation to that measurement value, a straight vertical line was drawn (or can even keep a straight object vertically) downwards and checked whether that line cuts the right side of the above-scalene triangle (Figure 2). In young adults, the triangle

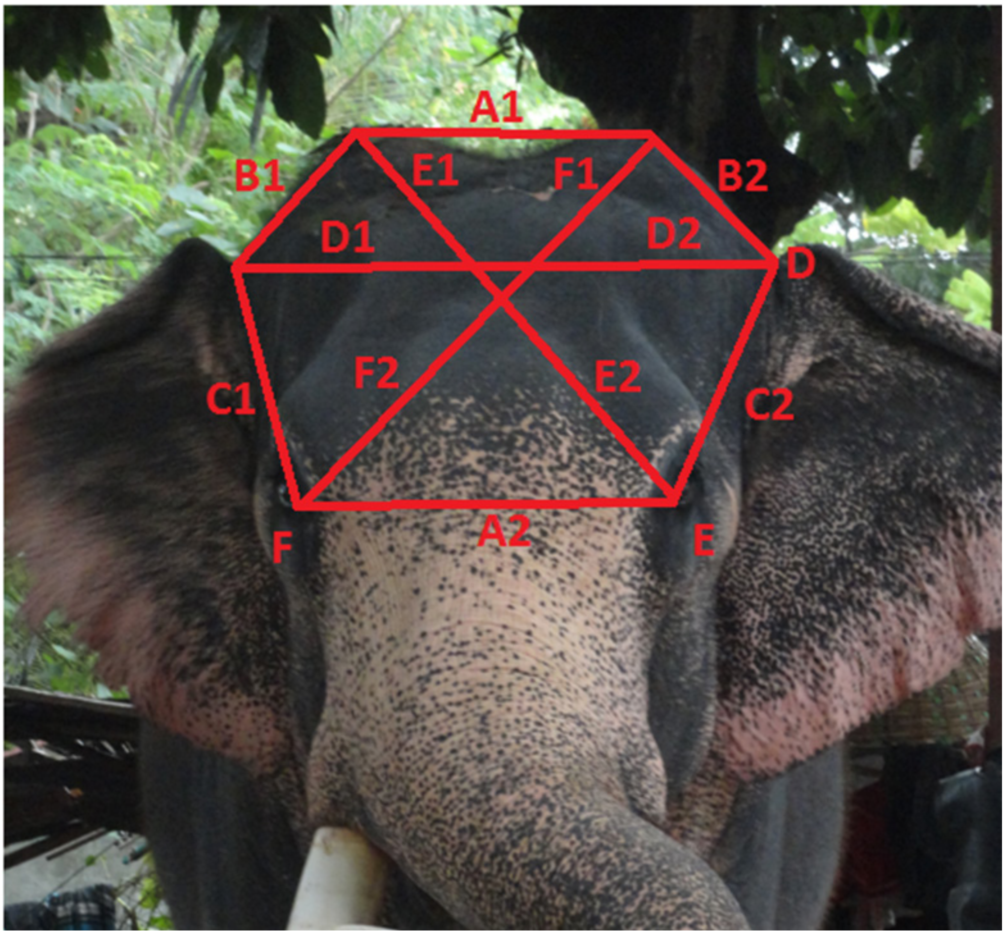

Figure 1: Layout of the geometric parameters.

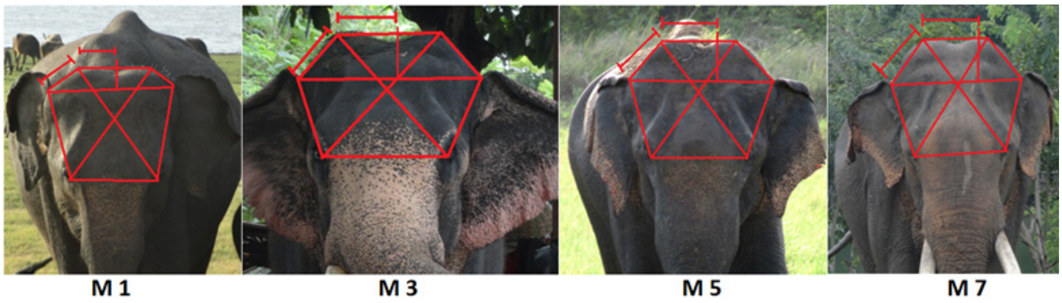

Figure 2: Diffeomorpho metric scale with various physiognomic models. The focal length of models as follows: M1 = 42 mm, M3 = 28 mm, M5 = 35 mm and M7 = 35 mm.

does not get cut, but in older adults, the triangle gets cut.

For the research, a catalogue scale was made (Figure 2). In the catalogue scale, 4 photographs of model adult elephants were included with morphometric lines drawn. Each model had a value allotted in odd numbers starting from 1-7. As the elephant's values on the scale increase, their age also increases. The elephants studied in this research were assigned relative to their scale numbers. On the scale, if there was an elephant detected to have features in between two images, it was assigned to the middle even number. If there was a measurement value higher than the model 7, it was assigned as the model 8, which was also the maximum. The aforesaid morphometric lines were drawn on those pictures, and they were assigned relatively to the catalogue scale.

Demographical Data Analysis

A total of 215 Asian elephants were studied according to the aforesaid methodology and were categorized into the given model catalogue. There were 144 males (66.97%) and 71 females (33.02%) in the sample. Also, there were 113 captive and 102 wild elephants. The focal length of those pictures' ranges from 20 - 75 mm. The ages of captive elephants were recorded based on their known ages, and the ages of wild elephants were classified based on their morphological appearance (Eltringham, 2000; Kurt, Garai, 2007; Arivazhagan, 2008). All individuals were assigned to four age clusters; 25 ± 5, 35 ± 5, 45 ± 5, 55 ± 5 - >60. The values for those age clusters were (i) 25 ± 5 / n=95 (44.18%), (ii) 35 ± 5 /n=42 (19.53%), (iii) 45 ± 5 /n=36 (16.74%) and (iv) 55 ± 5 - >60 /n=42 (19.53%). The aforesaid schematic lines were drawn on those pictures, and they were assigned relatively to the catalogue scale (Figure 2). Then, comparing scale with metadata, all the elephants were assigned to the models in the scale:

Age cluster 25 ± 5

Models 1 and 2 account for approximately 67.36% of the 25 ± 5 age cluster (Table 1). Only 32.63% of that cluster belong to model 3/model 4. This means the majority of elephants that are at the ages of 25 ± 5 will possess morphological features similar to model 1/model 2. This is the only cluster that has a significant decline trend in relation to the models' ascending order.

Age cluster 35 ± 5

Usually, this cluster is similar to a transition period from a young adult to a mature adult. The final sixth molar usually appears between the ages of 30 and 40. Even in relation to this research, from model 1 to model 8, there is an upward trend. It seems easier to distinguish between the 35 ± 5 cluster and the 25 ± 5 cluster.

Age cluster 45 ± 5

The majority of the elephants belong to models 5,6,7,8. The models 3 and 4 have small values of 11.11% while models 1 and 2 possess none. From models 3 to 8, there is an upward trend.

Age cluster 55 ± 5 - >60

With above average values, the majority of elephants in this cluster are found on models 7 and 8. For this cluster, models 7 and 8 have 76.19%, which is also the highest percentage value for a duo - models in the table. In relation to the models' ascending order, this cluster has the most significant upward trend.

Table 1. Final results where metadata of elephants with known ages were assigned to different models depending on their craniofacial morphometric pattern. The percentage values were calculated in relative to the ages.

Criterion	Model 1 /Model 2	Model 3 / Model 4	Model 5/Model 6	Model 7/ Model 8
25 ± 5	n=64 (67.36%)	n=31 (32.63%)	-	-
35 ± 5	n=2 (4.76%)	n=12 (28.57%)	n=13 (30.95%)	n=15 (35.71%)
45 ± 5	-	n=4 (11.11%)	n=12 (33.33%)	n=20 (55.55%)
55 ± 5 - >60	-	n=1 (2.38%)	n=9 (21.42%)	n=32 (76.19%)
Male:Female Ratio	45:21	37:11	21:13	41:26
Male to Female Difference	33 ± 12	24 ± 13	17 ± 4	33.5 ± 7.5

Model 1/Model 2

In terms of this study, these model criteria have the least clusters assigned to them (Figure 3). About 67.36% of elephants belong to the cluster of 25 ± 5. While only 4.76 % belong to the succeeding cluster, which is 35 ± 5.

Model 3/Model 4

These models have the highest number of clusters assigned to them and a declining curve as the elephants age. With the above average number, clusters 25 ± 5 (32.63%) and 35 ± 5 (28.57%) have the highest values.

Model 5/ Model 6

Though these models start from cluster 35 ± 5, yet the highest peak is reached at cluster of 45 ± 5. It gradually decreases towards the subsequent cluster 55 ± 5 - >60. The above average values come to clusters of 35 ± 5 (30.95%) and 45 ± 5 (33.33%).

Model 7/ Model 8

Cluster 55 ± - >60 has the highest peak. Furthermore, only the cluster 55 ± - >60 (76.19%) has an above-average value.

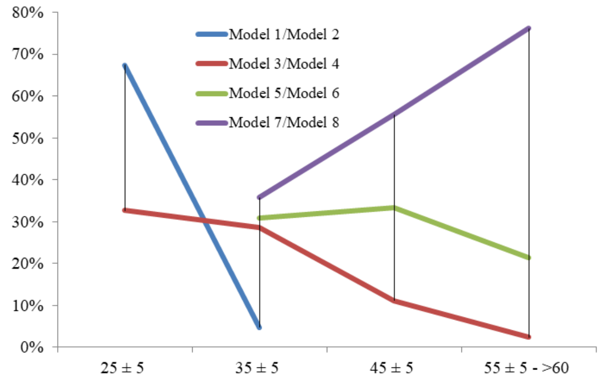

Figure 3: Diffeomorpho metric variation of models in relatively to different age clusters. This shows the frequency of the final results when the metadata of elephants with their known ages were assigned to the models. Note how the models' frequencies increase or decrease in relative to the age clusters.

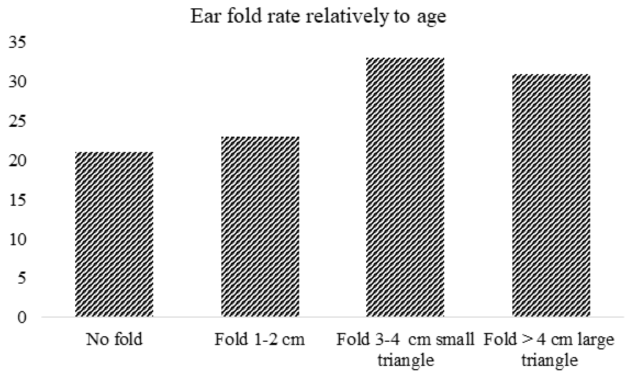

Figure 4: The number of year ranges for each age classifying ear fold rate (Kurt, 2001). No fold 0-21 (21 years), fold 1-2 cm (23 years), fold 3-4 cm small triangle (33 years) and fold >4 cm large triangle (31 years). The average value is 2.7.

DISCUSSION

In both African and Asian elephants, their heads get larger as they age (Rasmussen et al., 2002; Henley, 2012). When African males grow older, the temporal protrusions - width (eye sockets and temporal gland) and width of the trunk between the tusks become similar lengths, which is referred to in scientific literature as the "hourglass contour". In young African adults, the temporal protrusions – width is longer than the width of the trunk (Henley, 2012).

Since in Asian elephants the neurocranium is more vertically elongated than in African elephants, what is proven from this research paper is that, it is highly recognizable that the distance between the superior auricle notch and the twin domes increases as the elephant ages. That is why in figure 2 scale it can be observe that in the hexagon the median-horizontal-plane gets lowered as the elephant age (M1-M7). This could be because as an elephant age the twin domes, head and trunk base get more pronounced (Rasmussen et al., 2002). Also, the surface width of the twin dome- plane get shrunk in relative to the nasal septum area. It also provides evidence to support this theory as in infant elephants, the superior auricle's apex plane level is much closer to twin domes-plane level (Figure 5). In some cases, both the plane levels can be identical. Even in infants, the twin dome-plane axis can be laterally longer than the nasal septum area.

Figure 5: Note how the superior auricle's apex plane level is very close to the twin domes. Also note how the width of the twin-dome- plane is wider. The distance between the superior auricle's apex plane and the twin dome grows with age. Even the width of the twin-dome-plane gets shrunk.

Thus, if explored more, these morphological features can help to distinguish younger adults from older adults even at a glance. One of the most commonly used methodologies to estimate elephant age is the ear fold rate (Sukumar, 1989; Arivazhagan et al., 2008). Research has proven that elephants from different age ranges have a similar ear fold rate (Kurt, 2001). For example, "no fold" in the ear pinnae ranges from 0-21 years, and that range consists of two decades. According to Kurt (2001), such year ranges would consist of 2 - <3 decades (Figure 4). The average year range for ear fold estimation is 2.7 years. However, according to this study, the average year range for the models are estimated at 25 years (Figure 6).

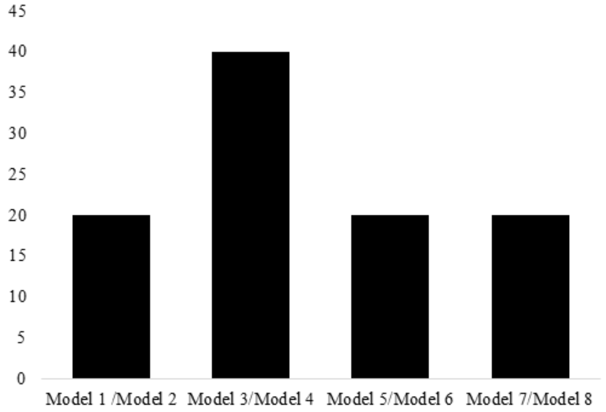

Figure 6: Quantity of years for each age-classifying morphometric patterns. Model 1/Model 2 (20 years), Model 3/Model 4 (40 years), Model 5/Model 6 (20 years), and Model 7/Model 8 (20 years). The average value is 25.

When studying the male-female ratio relative to their models (Table 1), there is no biased between the models and dimorphism. Even when it comes to assessing elephant body condition scores based on their musculoskeletal and body fat phenotype, there are no separate scales for males and females, respectively (Fernando et al., 2009; Krishnamurthy et al., 2009; Morfeld et al., 2016; Pokharel et al., 2017).

In southern India, captive elephants are made to perform certain exercises, such as nilavu (head lifting) etc. These exercises usually have a significant effect on the morphological features of the elephant. Even in such elephants, this morphometric technique can also be utilized, as it has been tested with some of them as well. When the methodology was tested with a few volunteers, they were able to utilize the methodology and predict the age, but with two errors that happened when drawing the schematic lines. Though there are few age determining methods, yet relying only in one method can give error values. Thus, the morphometric method that is presented here is tested by utilizing scientific methods and can be a useful contribution for science.

Limitations

Overall, this morphometric methodology can be utilized to distinguish a young adult from an older adult, thus helping budding researchers. However, the age criteria of 30-39 years can be somewhat problematic as it is similar to a transition period from a younger adult to an older adult. Therefore, to avoid unnecessary errors, it would be better to compare with other age-determining morphological features, to get a feedback more immaculately. In terms of critics, this morphometric methodology can be challenging in certain instances. As for example, if morphometric lines needed to be drawn, snapping the perfect portrait photograph can be strenuous on some occasions. Also, if there are large debris particles on the twin-domes' surface, be cautious for an error. Since, especially in wild elephants, the upper parts (head, frontal parts, shoulder, back, and pelvis) have a higher chance of debris (eg: sand, soil, plants, and mud) and also the hair density and length can be higher on the head surface.

REFERENCE

Arivazhagan, C. and Sukumar, R. (2008). Constructing Age Structures of Asian Elephant Populations: A Comparison of Two Field Methods of Age Estimation. *Gajah* **29:** 11-16.

De Silva, S. (2010). On Predicting Elephant Population Dynamics. *Gajah* **33:** 12-16.

Deraniyagala, P.E.P. (1955). Some extinct elephants, their relatives and the two Living Species. Colombo: Printed at the Govt. Press.

Eltringham, S.K. (2000). Longevity and Mortality. In: *Elephants: Majestic Creatures of the Wild*. Shoshani J (ed) Checkmark Books, New York, USA. PP 99-103.

Fernando, P, Janaka, H.K., Ekanayaka, S.K.K., Nishantha, H.G. and Pastorini, J. (2009). A simple method for assessing elephant body condition. *Gajah* 31: 29-31.

Hanks, J. (1972)a. Reproduction of elephant (*Loxodonta africana*) in the Luangwa Valley, Zambia. *Journal of Reproduction and Fertility* **30**: 13-26.

Hanks, J. (1972)b. Aspects of dentition of the African elephant, *Loxodonta africana*. *Arnoldia* **5(36):** 1-8.

Henley, M. (2012). Aging elephants-a practical guide. Save the Elephants.

Krishnamurthy, V., Wemmer, C. and Lehnhardt, J. (2009). Asian Elephant Body Condition Index. Available:https://www.asesg.org/PDFfiles/2009/Asian%20Elephant%20Body%20Condition%20Index.pdf.

Kurt, F. (2001). Elefant in Menschenhand. Filander, Furth.

Kurt, F. and Garai, M.E. (2007) The Sri Lankan Elephant in Captivity. Vijitha Yapa Publications, Sri Lanka.

Laws, R.M. (1966) Age criteria for the African elephant, *Loxodonta africana*. *East Africa Wildlife Journal.* **4:** 1-37.

Lindeque, M. (1991) Dentition and age estimation of Elephants in the Etosha National Park, Namibia. *Madoqua* 18(1): 17-25.

Morfeld, K.A., Meehan, C.L., Hogan, J.N. and Brown, J.L. (2016) Assessment of Body Condition in African (Loxodonta africana) and Asian (Elephas maximus) Elephants in North American Zoos and Management Practices Associated with High Body Condition Scores. *PLOS ONE 11(7): e0155146.* https://doi.org/10.1371/journal.pone.0155146

Moss, C.J. (2001). The demography of an African elephant (Loxodonta africana) population in Amboseli Kenya. *Journal of Zoology* **255(02):**145-156.

Muthukumarana, T. (2017). The Life of Last Proboscideans: Elephants.

Pokharel, S.S., Seshagiri, P.B. and Sukumar, R., (2017). Assessment of Season-dependent body condition scores in relation to faecal glucocorticoid metabolites in free-ranging Asian elephants. *Conservation Physiology* Vol 5: 1-14.

Rasmussen, L.E.L., Riddle, H.S. and Krishnamurthi, V.

(2002). Mellifluous matures to malodorous in musth. *Nature* **415:** 974-975.

Sikes, S.K. (1968) The African elephant, *Loxodonta Africana:* a field method for the estimation of age. *Journal of Zoology* (Lond.) **154:** 235-248.

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

Varma, S., Baskaran, N. and Sukumar, R. (2012). Field Key for Elephant Population Estimation and Age and Sex Classification. Resource material for synchronized elephant population count using block count, line transect dung count method and waterhole count. Asian Nature Conservation Foundation, Innovation Centre, Indian Institute of Science, Bangalore - 560 012.