MORPHOMETRY AND AGEING OF CAPTIVE MALE ASIAN ELEPHANTS (*Elephas maximus*)

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Thesis submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled "**MORPHOMETRY AND AGEING OF CAPTIVE MALE ASIAN ELEPHANTS** ***(Elephas maximus)***" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy
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M.Sasikumar

CERTIFICATE

Certified that the thesis entitled "**MORPHOMETRY AND AGEING OF CAPTIVE MALE ASIAN ELEPHANTS** ***(Elephas maximus)***" is a record of research work done independently by **Shri. M. Sasikumar**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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" The throb of life is in love; in its absence
the body is bundle of bones and skin "

- Thiruvalluvar

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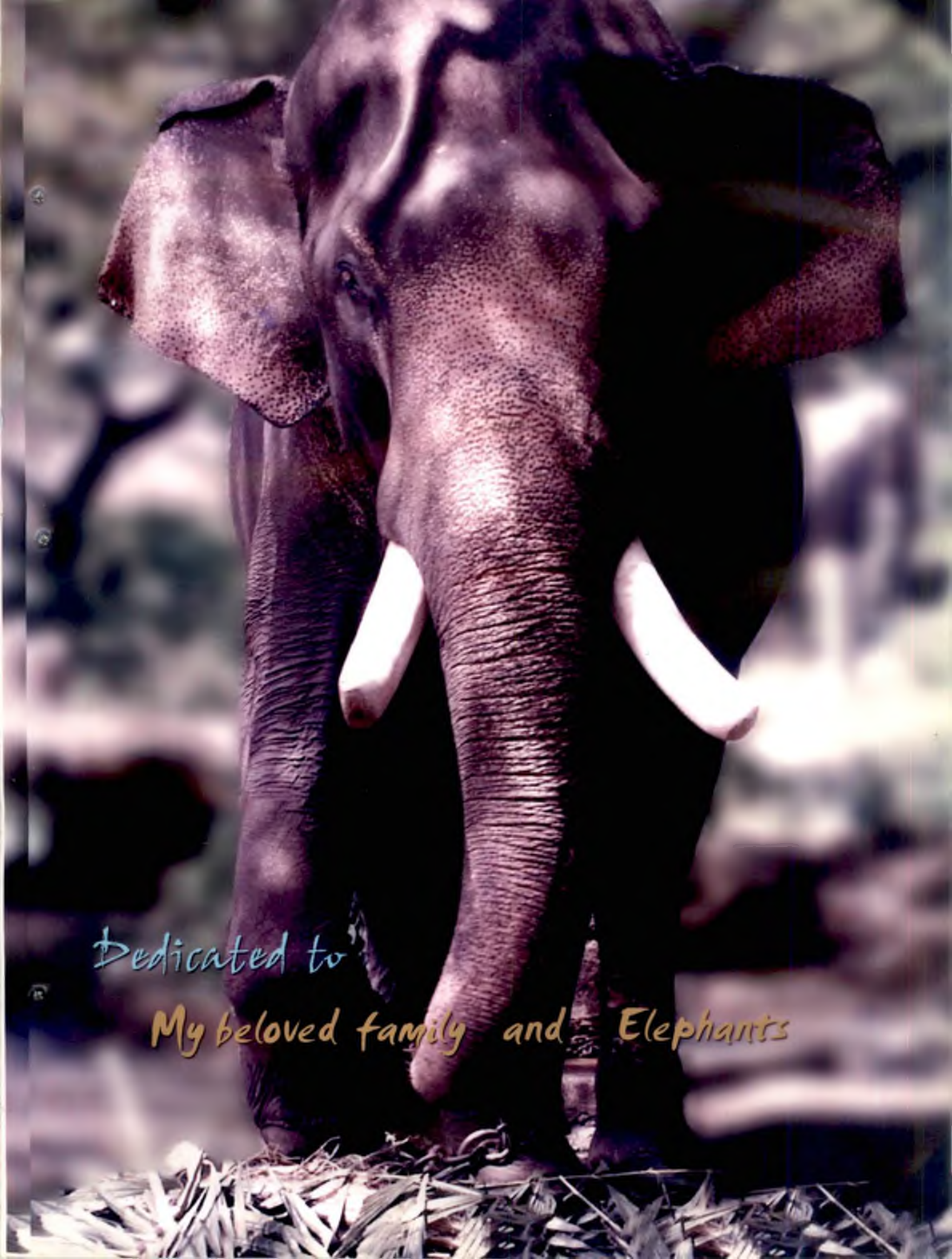
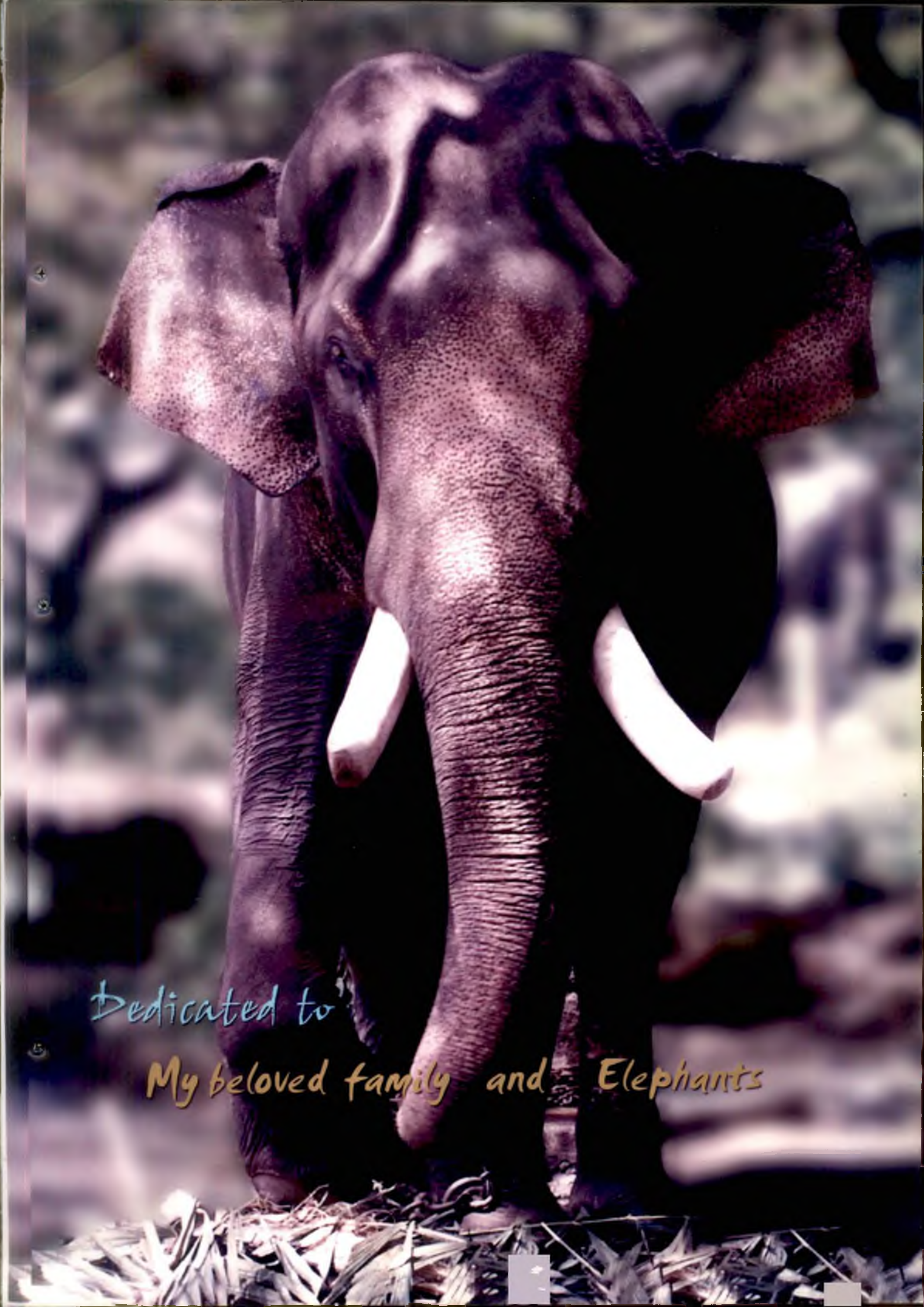


Dedicated to

My beloved family and Elephants



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Introduction

1. INTRODUCTION

Elephant, *'Lord of the Jungle'* and the gigantic beast of burden is the largest living terrestrial mammal in the world. The relationship between man and elephants had existed long before recorded history. It has close association with the rituals, rites, myths, history and cultural heritage of Asia for centuries. It is venerated as Lord Ganesha in Hindu mythology.

In India, elephants form a part of the festivals irrespective of religion. In the modern era, however elephants have been used in state pomp as status symbol, the great shikar meets, elephant capturing, logging operations, tourism, temple processions, circus shows and to a limited extent in agricultural operations.

Asian elephant's population is about 55,000 with 28,000 in India. Domesticated elephants were accounted to range from 3,400 to 3,600 across the country and Kerala domesticate about 612 of them (Bist, 2002).

Asian elephant is an endangered species throughout its range. It is threatened on account of pressures of poaching for ivory, loss of habitat and ever increasing incidents of human-elephant conflict. Poaching for tusks depleted the male population. But the female population had increased over several decades. This led to an over abundance of elephants especially in the protected area, which caused adverse impact on vegetation, thus increased human-elephant conflict.

The collection of morphometric details of different age groups could enhance our biological understanding and management of these endangered species. Weighing of elephants require specially arranged weigh-bridge and skilled persons. In a practical situation, it is a difficult task to take the body weight of elephants. To avoid these constraints body measurements are usually used to predict the body weight of elephants. It is a cost-effective and easy procedure. Animals can be easily trained to accept a measurement tape than to stand on a weighing scale.

Estimating the age of elephants applying prevalent traditional methods require long acquaintance with the animal. Elephants were characterized by features such as body size, tail length, spinal configuration, length and form of tusks, number and colour of toe nails, colour of eyes, pigmentation of penis, depigmentation and shining of the grey skin. Rare combinations are still venerated as 'white' elephants (Kurt and Kumarasinghe, 1998).

To strengthen the body weight prediction from body measurements and to scientifically device the different ageing techniques for tuskers, the present study was undertaken with the following objectives.

1. Recording the morphometric indices of captive male Asian elephants.
2. Evaluating the regional differences, if any, in the morphometric indices among tuskers.
3. Codify and modify easy ageing techniques based on physical features in elephants.

Review of Literature

2. REVIEW OF LITERATURE

Studies on morphometric indices and ageing techniques in elephants are scanty. A review of the related studies is presented under the following headings.

2.1 Importance and uses of morphometry and ageing in animals

2.2 Morphometric indices in elephants

2.3 Age estimation techniques in elephants

2.1 IMPORTANCE AND USES OF MORPHOMETRY AND AGEING IN ANIMALS

Benedict (1936) remarked that the gigantic size of elephant is always a matter of general interest, but accurate statements as to its size (expressed either as height or weight) were difficult to find.

Kurt and Nettasinghe (1968) reported that the estimation of body weight is of great importance for the purpose of determining approximate drug dosages not only for tranquilizing wild but also for the treatment of tame elephants.

Nair and Ananthasubramaniam (1979) reported that the literatures available on elephant husbandry are mainly confined to ailments and treatments, concentration of urine, milk and blood constituents and parasitic infestations and their remedial measures.

The reliability of applying a formula based on body measurements to predict body weight of elephants as accurately as possible; is for the purpose of scientific feeding and judicious treatment (Ananthasubramaniam *et al.*, 1982).

Sreekumar (1986) reported that recording the actual body weight with sensitive platform balance or weighbridge is not feasible in many places where the elephants are normally housed.

Jones *et al.* (1989) developed an equation to predict the body weight of horses using umbilical girth and body length measurements.

Systemic collection of biometric data on captive and wild elephants would enhance our biological understanding and management practices of these endangered species. The elephant's unorthodox body form has defied the use of standard measurements and no complete system of measures has been widely adopted and practiced (Wemmer and Krishnamurthy, 1992).

Virgl and Meisser (1993) reported that morphometric indices are useful indicators of health status of all living creatures and provide an insight into factors influencing complex habitat interactions.

Sastry *et al.* (1994) reported that the approximate age could be determined within certain limits by looking the eruption and wearing pattern of teeth, and also by the horn rings in cattle and buffaloes.

Xavier *et al.* (1996) compared the morphometric observations with the standard measurements to differentiate between small and large Travancore flying squirrel.

Hile *et al.* (1997) opined that accurate estimation of body weight would be useful in the evaluation of feeding programs, nutritional status, general health and in the calculation of dose level of drugs in elephants.

Wilson *et al.* (1997) measured the various body dimensions of special fed veal calves and correlated them with body weight and suggested that the body weight could be accurately predicted from body measurements and that the heart girth is the best single predictive parameter.

Xavier *et al.* (1998) studied the morphometric indices in painted bat as a measure of its habitat conditions.

The age of eruption of teeth is a reasonable and dependable guide for judging maturity in goats and the age is judged from its front teeth (incisors) on the lower jaw (Sharma *et al.*, 2002).

2.2 MORPHOMETRIC INDICES IN ELEPHANTS:

Benedict (1936) reported that the size of an elephant is expressed in terms of weight, height, girths and lengths, and that height was the parameter that was imparted much emphasizes. Considerable variations are present in the measurement of height with respect to the point at which the animal is measured, the muscular tonus and the position of the body. An equal degree of variability is observed in the determination of body weight of the same animal at different times, not only in the same month or year (even after adult growth has been attained) but also during the same time. An increase in weight is observed during ingestion of food and water, and a loss in weight during urination and defecation.

Johnson and Buss (1965) concluded that the height at shoulders and body length are closely related to body weight. The correlation coefficients were 0.99 in each case and hence the body weight could be estimated accurately from either body length or height at shoulders.

Krumrey and Buss (1968) found that close relationships exist between body measurements of female African elephants and calculated the correlation coefficient between body weight and height at shoulders as 0.99, and between body weight and body length as 0.97. Kurt and Nettasinghe (1968) reported the relationship between shoulder height, chest girth and body weight of Ceylon elephants *(Elephas maximus ceylonicus)* and evolved prediction equation for body weight with these parameters. They concluded that the body weight could also be estimated by measuring the footprint of the fore limbs. Because, twice the circumstance of one forefoot gives the shoulder height with a variation of 1 to 5 per cent from the exact value and subsequently the body weight could be estimated from shoulder height.

Laws *et al.* (1975) opined that the shoulder height or height at withers are very good dimension for describing linear growth of elephants and has a much smaller variance at age than body weight, because it is not subject to the rapid seasonal fluctuations.

Ananthasubramaniam *et al.* (1982) found that for accurate prediction of body weights of elephants, formulae devised on the basis of chest girth and neck girth measurements could be safely used and that they were more accurate than that involving body length, height at shoulders and chest girth.

Sreekumar (1986) concluded that there is a linear relationship between the height at shoulders and circumference of foot, in Asian elephants.

Sreekumar and Nirmalan (1989) opined that the best prediction equation for body weight in adult Asian elephants irrespective of sex was by using two parameters, the body length from the base of the forehead to the base of the tail and the chest girth. They concluded that using any single parameter or the inclusion of height as a third parameter would not improve the accuracy of prediction.

Hile *et al.* (1997) classified the elephants into different age groups using Minitab program and calculated all possible linear regressions for each group, and concluded that body weight in Asian elephants could be predicted from body measurements and that heart girth was the best single predictive parameter and that addition of body length improved the accuracy of prediction equation.

A 'thumb rule' applied in predicting the height at shoulders of wild elephant in the field is, "twice the circumference of the print of a forefoot" and this method gave reliable measurements for adult elephants (Basappanavar, 1998). Daniel (1998) reported that the elephants are not malformed or exceptionally short-legged; and that the thumb rule that twice the circumference of the forefoot would give the height at the shoulders was quite reliable in adult elephants and that it was the only way to predict the height of wild elephants.

Sikes (1967) reported a new method for age estimation in elephants, termed as "FM Technique". In that the stage reached in the molar progression, which occurs throughout the life of any elephants, was related to a fixed point namely the foramen mentale in the lower jaw and the stage reached in any individual elephant of either sex might be described as its "molar age" by the "FM formula" (a descriptive, non-mathematical formula).

Krumrey and Buss (1968) estimated the age of female African elephants using criteria of molar-usage intervals, degree of molar replacement and extent of molar wear. Based on estimated ages and body weights, a growth equation for female elephants upto 25 years was derived.

According to Bedi (1969) an elephant grow physically upto the age of about twenty five years and that the age could be guessed from its height, at any time before it had reached this age.

Laws *et al.* (1975) reported that the correct identification of the teeth in wear and erupting were critical, because only two teeth in the series of six are visible at any one time. Several methods of checking the identification were described, but the most useful one involves comparison of length/width plot of the tooth. Plotting the shoulder height measurements, body weights of male and female elephants against age revealed only a small scatter confirming the consistency of ageing. They found out that the sexes would show similar growth up to about 20 years and there after male appears to grow much faster than the female resulting in different attainment of maximum height and weight.

Hall-Martin and Ruther (1979) measured the shoulder height and back length of African elephants using stereo photogrammetric techniques and opined that the shoulder height could be used for age estimation. Fatti *et al.* (1980) debated the different systems of estimating age that were used based on the dental status of elephants.

Western *et al.* (1983) found a significant correlation between footprint length and shoulder height during age estimation in elephants and opined that the length of the hind foot print provided an easy and rapid method of estimating age of elephants.

Lark (1984) opined that the different age estimation techniques produced by analyses of different elephant populations cannot be validly applied to yet another population and one reason for this could be variation in diet between the populations.

Lewist (1984) used six size classes, which corresponded to the age ranges and then the shoulder height classes were assigned to each individual by simple visual examination.

Palit (1985) opined that elephants have to be classified under various age groups, for obtaining different population dynamics. Interpretations of the relationships between age and height, height and body length, height and circumference of foot were also given. Sukumar (1985) estimated the height of the elephants by using photographic technique and aged the elephants according to their height and concluded that by 15 years elephants were very close to their asymptotic heights and that age could not be judged merely on height.

Panicker (1985) observed that the traditional ageing methods in Asian captive elephants were by looking at the folds of ears and that the ear folds about an inch in thirty years.

The dentition of an elephant yield clues to the animal's age and species identity, provided the teeth are correctly identified and the reliable identifications could be obtained using three or more measurements in each tooth (Roth and Shoshani, 1988).

Jayewardene (1994) reported that elephants have tusks of different sizes and shapes, and that the tusks grow continuously throughout the lifetime. The ears of most wild elephants are scarred or damaged due to tear, pieces taken off and holes. These damages are a result of fights between elephants and also due to flight through thick jungles. He observed that the roll of the ear was not keeping with the age of the elephants and that there were very late rolling of the ear, partial rolling over and even a two inch roll in young elephants.

Basappanavar (1998) reported that a rough estimate of elephant age could be obtained from its ears and that in very young elephants of six to seven years of age the pinnae or top of the ears are not turned over. But with advancement of age it twirls over and in old elephants the turning over of the upper edge of the pinnae are very important and that the ear is usually ragged and torn especially along the lower edge. Methods of judging age by observing eye lens, temporal region, cheeks and teeth require more knowledge and measurements. Tusk circumference at the lip-line doubles between the time the males leave the family units (upto about 30 years of age) and the use of mass of tusk as a basis of age estimation in males is not reliable due to great variations. The temporal region of the skull (just above the eye) is sunken in relation to the rest of the skull and this is a sign of old age and not connected with poor physical condition. He added that the cheeks also get sunken as the age advances. The tuft of hair at the end of the tail is small and fairly hard in the early stages and as the elephant grow the hair becomes long and wiry and appears bunch like. As that the elephant grow older, few or entire tail hair disappear and tail appears bare.

Daniel (1998) reported that an elephant's age could be determined by its teeth and that the last molar tooth is in position on each side of the jaws, the period is set to be the animal's existence. A rough guess of age might be made by observing the condition of ears and that the upper edges of ears lap over an inch at the age of thirty, which increases to two inches between thirty and sixty years of age. He reported that an old animal has a lean head, deep hollow over the eyes, opacity around the margin of cornea, abnormal flow of tears, and torn and frayed edges for the ears. The skin of the trunk appears rough something like shark skin, the trunk lose certain amount of suppleness, skin over the body gets shriveled, tail becomes hard and end may be devoid of hair, skin around the nails appears rough or warty and the legs become thinner.

Kurt and Kumarasinghe (1998) revealed the different phenotypes in Sri Lankan elephants, defined by the occurrence and growth, and type of upper incisors. They also linked certain physical characters such as spinal configuration, extent of depigmentation on trunk, temples, ears and shoulders, as well as eye colour.

Raubenheimer (2000) reported that the tusks grew continuously throughout life and that the size is an important determinant of the hierarchial position of a particular elephant in a herd.

Elephants grow physically up to an age of above 25 years and that the age could be guessed from its height at any time before it had reached this stage. In an aged elephant, the temples become hollow, the ear becomes drooping and lobe flaccid (Selvaraj, 2001).

Materials and Methods

3. MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted at Punnathurkotta, the place that is renowned as *"captive elephant's sanctuary"* located in the southwest coastal region of the Arabian Sea in the state of Kerala. The elephants present in Punnathurkotta are maintained by the 'Devaswom Board' of 'Guruvayoor' Sri Krishna temple. The devotees of the deity as a part of offering donate elephants and they are housed at Punnathurkotta. There are 62 elephants maintained in this place including 53 male elephants, 6 female elephants and 3 tuskless male elephants *(Makhna)* of different ages.

3.2 MATERIALS USED

1. A weigh-bridge
2. A standard measuring tape in metric division
3. A cotton twine
4. A straight measuring rod

3.3 MEASUREMENT OF MORPHOMETRIC PARAMETERS

Fifty two clinically healthy captive male Asian elephants, varying in age from five to seventy years under excellent management and good nutritional regimes were measured. The various body measurements recorded are as follows.

3.3.1 Body Weight

The body weight of animals was recorded using a weigh-bridge in the morning before feeding. The weights (kg) were recorded twice and the averages obtained.

The measurements (cm) were recorded twice and the averages obtained. Each elephant was made to stand squarely on four legs on a level ground with its head straight in an upright steady position. The sites at which the body measurements were taken for few parameters are shown in Fig.1.

3.3.2 Body Lengths

Two types of body length were recorded. First one was recorded by measuring the distance between the base of the forehead along the curve of the back to base of the tail. Second one was recorded by measuring the straight distance between the point of the shoulder to base of the tail.

3.3.3 Neck Girth

The neck girth was measured by encircling the tape around middle of the neck.

3.3.4 Chest Girth

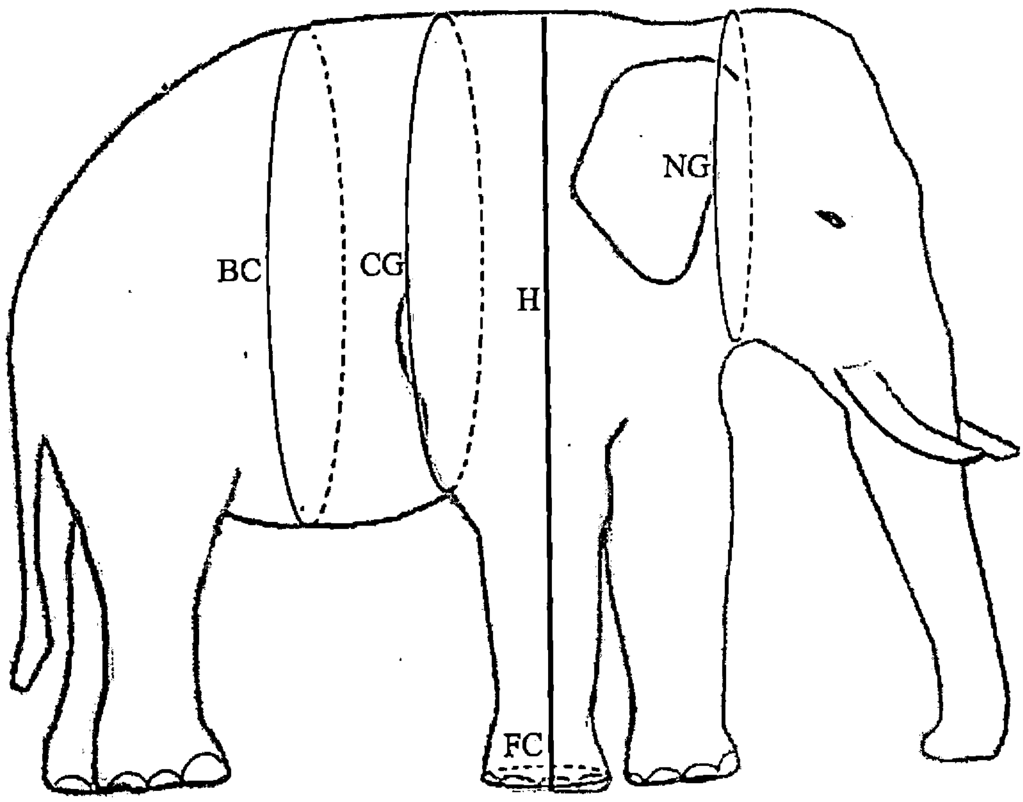
The chest circumference just behind the elbows was recorded.

3.3.5 Barrel Circumference

The barrel circumference was measured by encircling the tape around the midpoint of the body.

3.3.6 Height at the shoulders

The height at the shoulders was measured by fixing the tape to the tip of a straight rod, which was placed horizontally on the top of the shoulders. The straight line distance between the rod and the base of forefoot pad was taken as the height at the shoulders of the animal.



BC - Barrel circumference (cm)
CG - Chest girth (cm)
NG - Neck girth (cm)
H - Height at the shoulders (cm)
FC - Right forefoot circumference (cm)

Fig. 1. Sites at which body measurements were taken

3.3.7 Limb Lengths

The forelimb length was measured from the point of shoulder to the base of forefoot pad in both right and left sides, and the average obtained. The hindlimb length was measured from the point of hip to the base of hindfoot pad in both right and left sides, and the average obtained.

3.3.8 Limb Circumferences

The forelimb circumferences were measured below and above knee joint in both right and left sides, and the average obtained. The hindlimb circumferences were measured below and above hock joint in both right and left sides, and the average obtained.

3.3.9 Foot Circumferences

The circumference of the right and left forefoot were taken with a cotton twine, which was wound around the outer margin of the foot, including nails, at the level of sole and the length of the twine was measured with a measuring tape. The circumference of the right and left hindfoot, were also taken in the same way.

3.3.10 Trunk Length

The trunk length was measured from the mid point between the right and left inner canthus of the eyes to the tip of the trunk.

3.3.11 Tusk Lengths

The visible length and full length (from the inner canthus of the eye to the tip of the tusk) was measured in both right and left sides.

3.3.12 Tusk Circumferences

The tusk circumference was measured at the base, middle and tip of the tusk in both right and left sides.

3.4 MEASUREMENT OF PARAMETERS FOR AGE DETERMINATION

3.4.1. Ear

3.4.1.1 Ear Length

The ear length was measured at a maximum distance between the notch of the ear and the longest ventral extension.

3.4.1.2 Ear Width

The ear width was measured at a maximum distance from the cartilage anterior to the ear opening to the posterior tip (or longest frill, if the ear is torn).

The ear length and width were measured separately for both right and left side ears.

3.4.1.3 Appearance of the Ear

The appearance of the ear was determined by noting the tear of the ear margin and also tearing percentage in both right and left sides.

3.4.1.4 Curling of the Ear

The length and width of the curled upper border of ear was measured in both right and left sides.

3.4.2 Tusks

The direction of the tusks of each animal was classified into five forms based on the appearance.

i. Straight ii. Upward iii. Downward iv. Convergent v. Divergent

3.4.3 Ear Lobe

The ear lobe was classified into three forms with the following external appearance.

i. Round ii. Vertically long iii. More or less horizontally long

3.4.4 Hollow on the Temple Region

Three classes were identified based on the appearance of the hollow at the temple region.

i. Not pronounced ii. Shallow iii. Deep

3.4.5 Hollow on the Forehead

Three types of categorization were employed to score the hollow based on the appearance.

i. Not pronounced ii. Shallow iii. Deep

3.4.6 Blotches (Extent of depigmentation in percentage)

Extent of depigmentation (%) and also score with the following details were used to record the depigmentation on trunk, temples, ears, shoulders, limbs and body.

0 - Absent

1 - Depigmentation covers upto 25% of the area concerned

2 - Depigmentation covers 26-50% of the area concerned

3 - Depigmentation covers 51-75% of the area concerned

4 - Depigmentation covers more than 75% of the area concerned

Acquired depigmentation markings were not considered. Eyes and the opening of the temporal gland may be accentuated by more or less complete circles of depigmented skin. The extent of this accentuation was described as the extent of depigmentation of the trunk, temples, ears, shoulders, limbs and body in percentage as well as scoring from 0 to 4.

3.4.7 Eye Colour

The following colour chart was used to record the colour of the eye.

i. Grey ii. Dark brown iii Light brown iv. Honey

3.4.8 Eye Length

The eye length was measured as the distance from the inner to outer canthus of the eye.

3.4.9 Spinal Configuration

The spinal configuration was defined into three classes as follows.

i. Flat back – the back line is horizontal without knobs

ii. Broken back – the back line is generally vertical or sloping down from front to tail but shows one or more conspicious knobs.

iii. Sloping back – the backline is knobless and follows a slightly rounded sloping line from shoulder to tail base.

3.4.10 Skin Colour

General body colour was recorded.

3.4.11 Hair Distribution

The hair distribution in the elephants was recorded on the head, trunk, body and tail. The hair distribution was scored using the following parameters.

5 - More dense 4 - Dense 3 - Scattered 2 - Few 1 - Meagre 0 - Nil

The entire data set was divided into subsets according to the various developmental phases of the male elephants. Multiple regression analysis was used for the entire data set and subsets for predicting equations (Snedecor and Cochran, 1985). The standard error of estimation (SEE) of the predicted equations was taken as an indicator of the relative accuracy of prediction of the various equations. The divided age groupings are:

1. The Young ones (0-20 years) as Group I (G I)
2. The Sub adults (21-30 years) as Group II (G II)
3. The Adults (31-40 years) as Group III (G III)
4. The Old adults (41-70 years) as Group IV (G IV)

The Young one, Sub adult, Adult and Old adult groups consisted of 15 animals, 11 animals, 14 animals and 12 animals respectively. All possible linear regressions of body weight on body lengths, neck girth, chest girth, barrel circumference, height at the shoulders, limb lengths, limb circumferences, foot circumferences, trunk length, tail length, tusk length and tusk circumference using individual observations were worked out. Only the parameters had linear effects against body weight were considered to formulate prediction equations. The model was,

$$Y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + \ldots\ldots + b_i x_i$$

Where,

Y	-	dependent variable (body weight)
b_0	-	the intercept
b_i	-	regression coefficients
x_i	-	independent variables

The entire data set was again divided into three subsets according to the developmental phases of the elephants for ageing studies viz.,

1. The Young ones (0-20 years) as Group A

2. The Adults (21-40 years) as Group B

3. The Old adults (41-70 years) as Group C

Each group comprised of 15 animals, 25 animals and 12 animals respectively. Correlation analysis was used to correlate the various parameters with age of the elephants (Wright, 1986). By using the Mann-Whitney test for a two independent samples, the differences in the parameters between two age groups of elephants were worked to infer whether there is any significant difference between groups in terms of parameters (Siegel and Castellen, 1988).

Results

4. RESULTS

4.1 PREDICTION OF BODY WEIGHT FROM MORPHOMETRIC INDICES OF MALE ELEPHANTS

The relationship between the age and body weight of animals is shown in Fig. 2. The mean values of the observed body weights and body measurements that were used for the prediction equation in various age groups of male elephants are presented in Table1. Equations for predicting body weight in different age groups of elephants from various parameters and combinations of parameters with coefficient of determination (R^2 value), standard error of estimation (SEE) and significance of the predicted regression equations are shown in Table 2. The equations for predicting the height at the shoulders from right forefoot circumference for various age groups with coefficient of determination (R^2 value), standard error of estimation (SEE) and significance of the equations are shown in Table 3.

The parameters having higher correlation (≥ 0.86) with the body weight in each age group were used for deriving the prediction equations. If R^2 explains the per cent of variation between body weight and individual body measurements, 90 per cent of the variation in the weight of these elephants can be explained by their barrel circumference ($R^2 = 0.90$).

In different age groups, R^2 ranged from 0.72 to 0.96 with single predictive parameter and 0.79 to 0.98 with combinations of predictive parameters. In Group I, the addition of right forefoot circumference along with chest girth evolved a better prediction equation with higher R^2 value. These animals reached mature weight at approximately 20 years of age (Fig. 2). In Group II, the correlations between body weight and body measurements were most inconsistent of all. The right forefoot circumference was used as the best single predictive parameter in this group. The combination of height at the shoulders and neck girth with right forefoot circumference increased the R^2 value considerably.

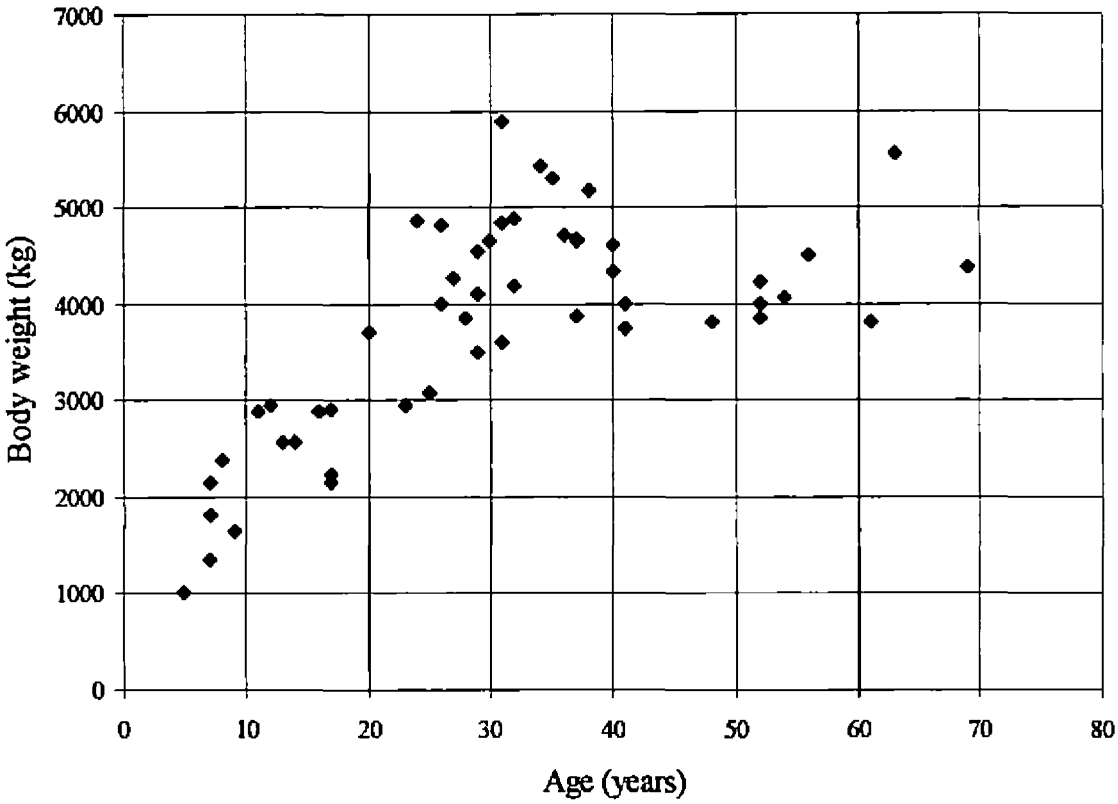


Fig. 2. The relationship between age and body weight in elephants (n = 52)

Table 1. Mean values of body weight and body measurements of male Asian elephants (Mean ± SE ; n = 52)

Sl. No.	Parameters	Group I (n = 15)	Group II (n = 11)	Group III (n = 14)	Group IV (n = 12)
01	Body weight (kg)	2340.33 ± 180.37	4055.46 ± 201.01	4720.00 ± 163.81	4156.67 ± 142.82
02	Neck girth (cm)	222.00 ± 8.20	285.18 ± 7.82	296.57 ± 7.68	276.08 ± 6.64
03	Chest girth (cm)	324.60 ± 9.75	397.36 ± 8.64	426.00 ± 7.39	405.5 ± 5.41
04	Barrel circumference (cm)	377.47 ± 11.03	455.82 ± 8.68	483.79 ± 8.44	467.17 ± 6.10
05	Height at the shoulders (cm)	219.47 ± 7.36	260.27 ± 5.48	284.71 ± 3.42	287.00 ± 3.28
06	Right forefoot circumference (cm)	115.00 ± 3.44	133.27 ± 3.59	142.93 ± 2.24	140.42 ± 1.75

Table 2. Regression equations for predicting body weight (kg) in male Asian elephants

Groups	Regression equations	R^2	Standard error of estimation (SEE)	Significance ($p \leq$)
G I to G IV (all age groups; n = 52)	- 5007.51 + 19.78 (BC)	0.90	369.48	0.000
	- 4463.63 + 21.32 (CG)	0.89	378.99	0.000
	- 5303.71 + 12.60 (CG) + 31.79 (FC)	0.93	306.63	0.000
	- 5210.83 + 7.87 (CG) + 32.98 (FC) + 5.88 (NG)	0.94	293.93	0.000
Group I (n = 15)	-3528.59 +18.08 (CG)	0.96	154.59	0.000
	-3676.88 + 10.57 (CG) + 22.50 (FC)	0.97	122.68	0.000
	-3598.93 + 9.90 (CG) + 16.60 (FC) + 3.73 (H)	0.98	124.52	0.000
Group II (n = 11)	-2261.81 + 47.4 (FC)	0.72	375.24	0.001
	-5358.89 + 24.67 (H) + 10.51 (NG)	0.79	345.07	0.002
	-4973.41 + 14.97 (H) + 7.72 (NG) + 21.99 (FC)	0.84	318.10	0.004
Group III (n = 14)	-3602.19 + 17.2 (BC)	0.79	296.05	0.000
	-4215.41 + 10.72 (NG) + 40.28 (FC)	0.85	260.25	0.000
	-4339.63 + 2.99 (BC) + 35.71 (FC)	0.85	271.44	0.000
Group IV (n = 12)	-5296.23 + 20.24 (BC)	0.75	260.58	0.000
	-7684.67 + 16.68 (BC) + 28.83 (FC)	0.85	211.99	0.000

R^2 - Coefficient of determination, BC - Barrel circumference (cm), CG - Chest girth (cm)
FC - Right forefoot circumference (cm), NG - Neck girth (cm), H - Height at the shoulders (cm)

Table 3. Regression equations for predicting height at the shoulders (cm) in male Asian elephants

Groups	Prediction equations	R^2	Standard error of estimation (SEE)	Significance ($p \leq$)
G I to G IV (all age groups; n = 52)	2.02 (FC) – 6.31	0.82	14.57	0.000
Group I (n = 15)	2.07 (FC) – 18.04	0.93	7.79	0.000
Group II (n = 11)	1.16 (FC) + 106.08	0.57	12.50	0.007
Group III (n = 14)	0.28 (FC) + 245.39	0.03	13.08	0.537
Group IV (n = 12)	1.5 (FC) + 75.81	0.64	7.13	0.002

R^2 - Coefficient of determination

FC - Right forefoot circumference (cm)

Prediction equation using barrel circumference gave the best prediction equation for Group III and IV. Equations involving both barrel circumference and right forefoot circumference raised the R^2 value in these groups.

The observed body weight of elephants in this study as well as the body weight derived by applying the best formula recommended by Kurt and Nattasinghe (1968), Ananthasubramaniam *et al.* (1982), Sreekumar and Nirmalan (1989) and Hile *et al.* (1997) and of the present study are given in Table 4. The accuracy of the prediction of body weight using general equation for all age as well as individual age group equation is presented in Fig. 3 and Fig. 4.

The correlation between right forefoot circumference and height at the shoulders for each group was also investigated. The undivided data had an R^2 value of 0.82. The group consisted of young one (GI) had more R^2 value (0.93) compared to other age groups of elephants. In the other age groups the R^2 value ranged from 0.03 to 0.64.

The observed height at the shoulders of elephants in the present study, and the height derived by applying the formula recommended by Sreekumar and Nirmalan (1989), and the height predicted by applying the equation derived in the present study are given in Table 5. The accuracy of the prediction of height at the shoulders by applying the best prediction equations for the whole population as well as for individual age groups are presented in Fig. 5 and Fig. 6.

4.2 ESTIMATION OF AGE BASED ON PHYSICAL FEATURES AND MORPHOMETRIC INDICES

A number of physical features were studied for the purpose of estimating the age of elephants. In the 52 elephants used for the study, the form of the tusks (Plate 1) of each animal differed widely and the upward directed tusks were more common

Table 4. The observed body weight and comparison of predicted body weight applying various formulae recommended by various authors

Sl. No.	Observed body weight (kg)	Predicted body weight (kg)					
		A	B	C	D	E*	F**
1	1000	1241.39	883.0	790.0	1164	675.60	968.12[a]
2	1340	1594.09	1472.4	1133.9	1650	1206.54	1388.51[a]
3	1800	1862.90	1988.0	1379.5	1974	1655.87	1736.27[a]
4	2140	1991.49	2605.6	1717.0	2118	2265.31	2180.83[a]
5	2380	2663.41	3093.0	2331.5	2784	2667.93	2526.92[a]
6	1650	1608.30	2216.6	1291.8	1668	1537.04	1624.08[a]
7	2870	3193.82	3482.0	2537.8	3234	3300.83	3016.17[a]
8	2940	2826.19	3434.6	2748.4	2928	3023.05	2791.48[a]
9	2560	2764.39	3594.0	2467.6	2874	2889.88	2692.27[a]
10	2565	2564.92	3383.2	2668.3	2694	2732.09	2564.07[a]
11	2890	2764.39	3612.4	2306.1	2874	2794.51	2624.77[a]
12	2150	2248.26	2471.0	2309.9	2388	2263.57	2204.38[a]
13	2230	2375.29	3246.0	2149.0	2514	2288.19	2233.37[a]
14	2900	2973.94	3068.8	2887.9	3054	3270.20	2977.97[a]
15	3690	3790.35	3742.2	3412.6	3684	4060.89	3595.42[a]
16	2950	3543.56	3715.4	2957.2	3504	3108.35	3249.92[b]
17	4860	5043.13	5160.0	4314.4	4494	4945.79	4832.69[b]
18	'3060	2973.94	3768.0	2696.2	3054	3015.88	3182.59[b]
19	4000	4317.79	4679.0	3565.6	4044	4153.94	4237.34[b]
20	4820	3424.28	4116.0	3040.0	3414	3681.15	4219.31[b]
21	4270	4598.94	5221.0	3374.8	4224	4184.57	4035.03[b]
22	3850	4317.79	5047.0	3122.8	4044	3994.99	3877.60[b]
23	3500	2867.89	3543.0	2644.0	2964	3080.04	3268.20[b]
24	4100	4485.06	5298.6	4456.2	4152	4070.59	4187.07[b]
25	4550	3917.93	4464.0	3469.3	3774	4600.74	4803.21[b]
26	4650	4743.97	5354.0	3809.5	4314	4501.89	4713.62[b]
27	3600	3495.52	3625.4	3548.6	3468	3687.16	3736.07[c]
28	4840	5104.43	4900.4	4574.8	4530	5002.78	4922.07[c]
29	5880	6188.82	5999.0	4827.4	5124	5545.74	5565.59[c]
30	4180	4456.89	4996.0	3621.4	4134	4216.94	4438.39[c]
31	4880	4832.44	5065.8	3766.4	4368	4635.06	4739.19[c]
32	5415	4892.03	5229.4	4485.4	4404	4978.16	5227.75[c]
33	5300	5515.04	6019.0	4903.0	4764	5039.42	5350.55[c]
34	4700	4743.97	5446.0	3809.5	4314	4470.10	4813.91[c]
35	4650	4570.29	4660.8	3892.3	4206	4299.13	4264.27[c]
36	4675	3892.19	4345.4	3699.0	3756	4143.08	4401.35[c]
37	3860	3471.67	3764.4	3808.0	3450	3897.09	4103.79[c]
38	5180	5515.04	5651.0	4255.0	4764	5357.32	5538.95[c]
39	4320	5547.51	5107.2	4217.9	4782	4543.38	4170.07[c]
40	4600	5197.31	5513.8	3979.6	4584	4690.89	4822.03[c]

Table 4. Continued...

Sl. No.	Observed body weight (kg)	Predicted body weight (kg)					
		A	B	C	D	E*	F**
41	3740	4048.35	3916.2	3828.4	3864	3837.20	3707.20 [d]
42	4000	4317.79	5341.4	4082.2	4044	4122.15	4151.59 [d]
43	4000	4317.79	4403.0	3934.6	4044	4408.26	3944.02 [d]
44	3800	3715.15	3901.6	3657.2	3630	4086.67	3748.39 [d]
45	3850	3665.57	4124.4	3425.2	3594	3838.94	3913.54 [d]
46	4000	3790.35	4147.0	3482.8	3684	4060.89	3940.93 [d]
47	4220	3892.19	4363.8	3826.7	3756	4047.71	3799.87 [d]
48	4050	3790.35	4055.0	4465.6	3684	4060.89	4191.13 [d]
49	4500	4317.79	4587.0	4746.4	4044	4376.47	4498.99 [d]
50	3800	4598.94	4577.0	4282.0	4224	4502.47	4081.99 [d]
51	5540	5515.04	5651.0	4368.4	4764	5134.79	5313.43 [d]
52	4380	4598.94	4669.0	4584.4	4224	4756.79	4579.51 [d]

A - Kurt and Nattasinghe (1968) $Y = -60.6 + 28.9\,x$

Y = Chest girth (cm)

x = cube root of body weight (kg)

B - Ananthasubramaniam *et al.* (1982) $W = 8.2\,g + 18.4\,ng - 3927$

W = Body weight (kg)

g = Chest girth (cm)

ng = Neck girth (cm)

C - Sreekumar and Nirmalan (1989) $W = -1010 + 0.036\,(L * G)$

W = Body weight (kg)

L = Body length from base of forehead to the base of tail (cm)

G = Chest girth (cm)

D - Hile *et al.* (1997) $W = 18.0\,(HG) - 3336$

W = Body weight (kg)

HG = Heart girth (cm)

Table 4. Continued...

E - G I to G IV equation* (all age groups)

* BW (n = 52, 0-70 years) = - 5303.71 + 12. 60 (CG) + 31.79 (FC)

F - G I, G II, G III, and G IV equations** (various age groups)

** BW^a (n = 15, 0-20 years), a = G I = - 3676.88 + 10.57 (CG) + 22.50 (FC)

BW^b (n =11, 21-30 years), b = G II = - 4973.41 + 14.97 (H) + 7.72 (NG) + 21.99 (FC)

BW^c (n =14, 31-40 years), c = G III = - 4215.41 + 10.72 (NG) + 40.28 (FC)

BW^d (n =12, 41-70 years), d = G IV = - 7684.67 + 16.68 (BC) + 28.83 (FC)

BW - Body weight (kg)

CG - Chest girth (cm)

FC - Right forefoot circumference (cm)

H - Height at the shoulders (cm)

NG - Neck girth (cm)

BC - Barrel circumference (cm)

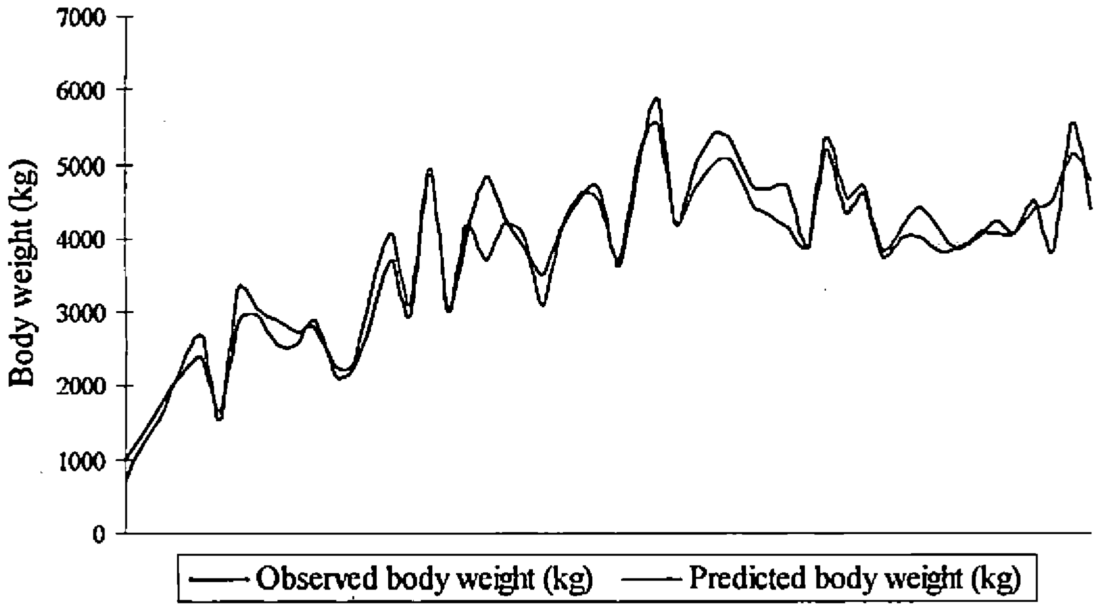


Fig. 3. The comparison between observed body weight and predicted body weight after applying the equation derived for all age groups (G I to G IV)

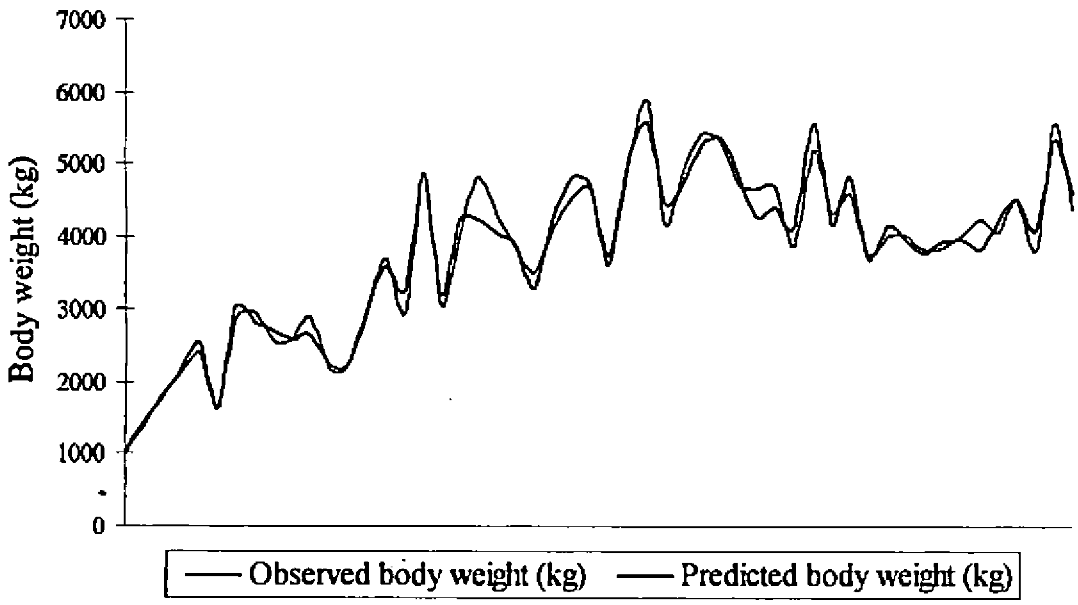


Fig. 4. The comparison between observed body weight and predicted body weight after applying the equations derived for each age group (G I to G IV)

Table 5. The observed height at the shoulders and comparison of predicted height at the shoulders applying various formulae recommended by various authors

Sl.No.	Observed height at the shoulders (cm)	Predicted height at the shoulders (cm)		
		A	B*	C**
1	165	175.51	173.47	166.19[a]
2	170	187.45	185.59	178.61[a]
3	205	201.38	199.73	193.10[a]
4	222	233.22	232.05	226.22[a]
5	225	229.24	228.01	222.08[a]
6	192	207.35	205.79	199.31[a]
7	245	249.14	248.21	242.78[a]
8	247	245.16	244.17	238.64[a]
9	220	239.19	238.11	232.43[a]
10	220	237.20	236.09	230.36[a]
11	230	233.22	232.05	226.22[a]
12	217	221.28	219.93	213.80[a]
13	213	217.30	215.89	209.66[a]
14	257	255.11	254.27	248.99[a]
15	264	277.00	276.49	271.76[a]
16	255	225.26	223.97	238.32[b]
17	280	296.90	296.69	280.08[b]
18	233	239.19	238.11	246.44[b]
19	270	267.05	266.39	262.68[b]
20	278	265.06	264.37	261.52[b]
21	248	261.08	260.33	259.20[b]
22	243	257.10	256.29	256.88[b]
23	238	247.15	246.19	251.08[b]
24	258	257.10	256.29	256.88[b]
25	281	306.85	306.79	285.88[b]
26	279	277.00	276.49	268.48[b]
27	271	263.07	262.35	282.63[c]
28	290	298.89	298.71	287.67[c]
29	295	306.85	306.79	288.79[c]
30	280	267.05	266.39	283.19[c]
31	272	282.97	282.55	285.43[c]
32	305	302.87	302.75	288.23[c]
33	258	290.93	290.63	286.55[c]
34	275	275.01	274.47	284.31[c]
35	289	269.04	268.41	283.47[c]
36	301	278.99	278.51	284.87[c]

Table 5. Continued...

Sl.No.	Observed height at the shoulders (cm)	Predicted height at the shoulders (cm)		
		A	B*	C**
37	288	277.00	276.49	284.59[c]
38	280	310.83	310.83	289.35[c]
39	290	259.09	258.31	282.07[c]
40	292	277.00	276.49	284.59[c]
41	272	255.11	254.27	269.31[d]
42	273	265.06	264.37	276.81[d]
43	290	282.97	282.55	290.31[d]
44	272	280.98	280.53	288.81[d]
45	280	267.05	266.39	278.31[d]
46	288	277.00	276.49	285.81[d]
47	282	273.02	272.45	282.81[d]
48	287	277.00	276.49	285.81[d]
49	297	280.98	280.53	288.81[d]
50	300	280.98	280.53	288.81[d]
51	303	296.90	296.69	300.81[d]
52	300	296.90	296.69	300.81[d]

A - Sreekumar and Nirmalan (1989) H = -1.60 + 1.99 C

H = Height at the shoulders (cm)

C = Right forefoot circumference (cm)

B - Group I to Group IV equation* (all age groups)

* H (n = 52, 0-70 years) = 2.02 FC - 6.31

C – G I, G II, G III, and G IV equations** (various age groups)

** H^a (n = 15, 0-20 years), a = G I = 2.07 FC - 18.04

H^b (n = 11, 21-30 years), b = G II = 1.16 FC + 106.08

H^c (n =14, 31-40 years), c = G III = 0.28 FC + 245.39

H^d (n = 12, 41-70 years), d = G IV = 1.5 FC + 75.81

H - Height at the shoulders (cm)

FC - Right forefoot circumference (cm)

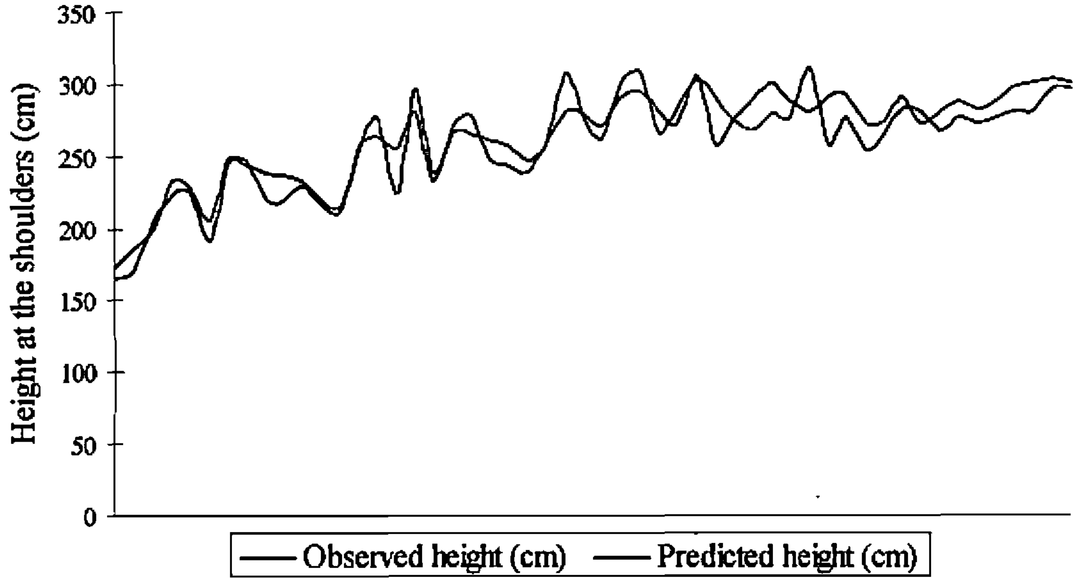


Fig. 5. The comparison between observed height at the shoulders and predicted height after applying the equation derived for all age groups (G I to G IV)

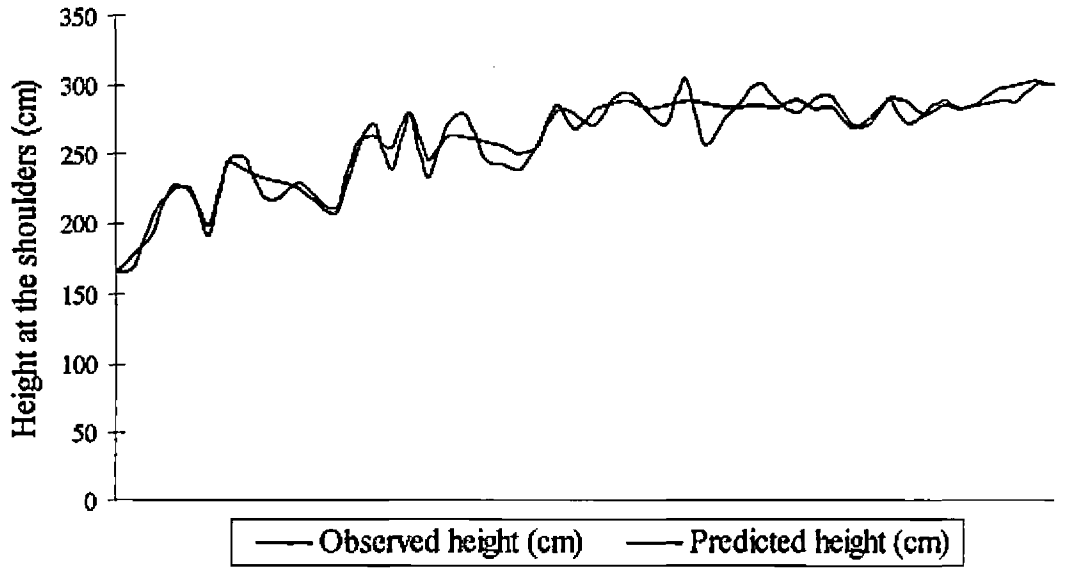
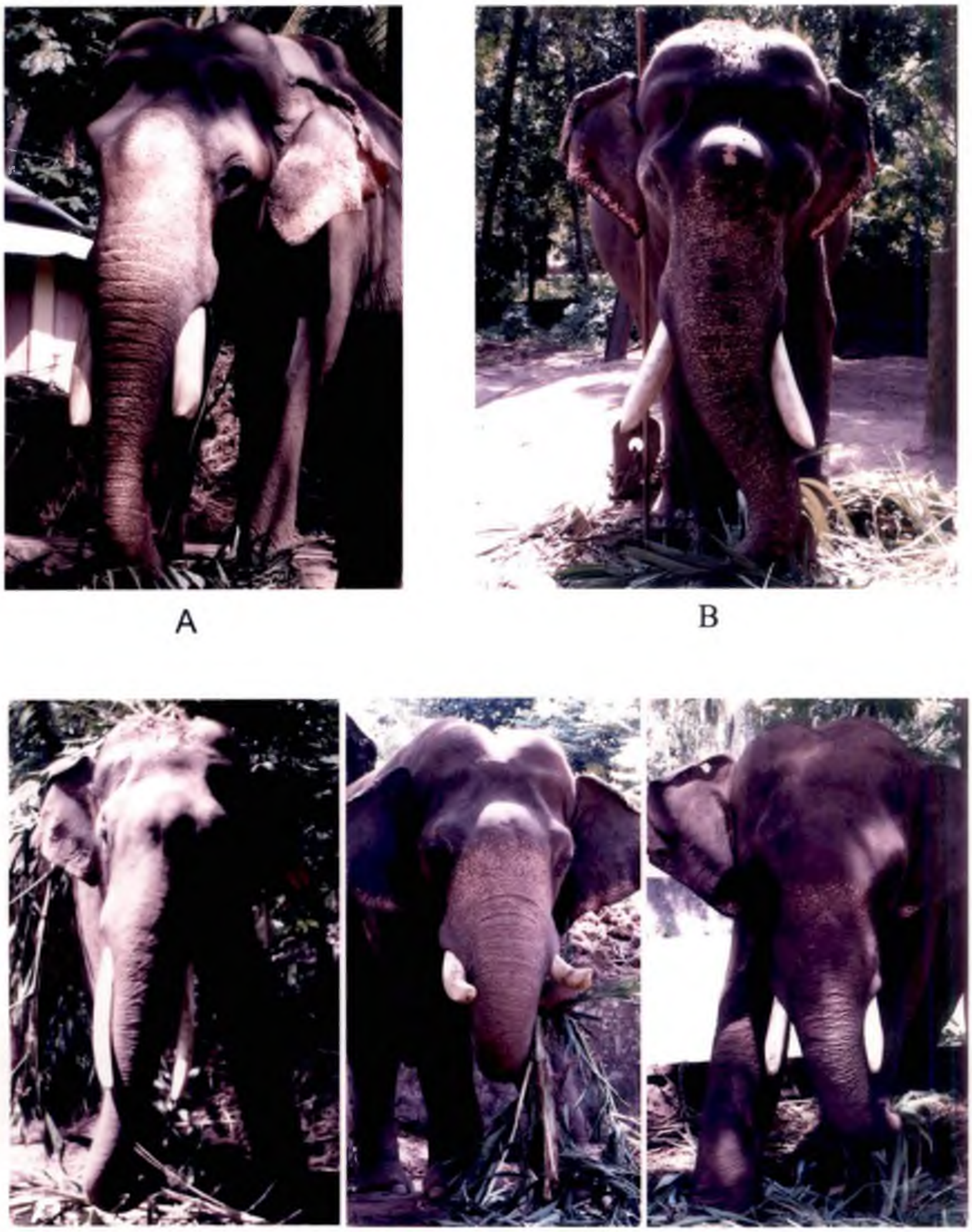


Fig. 6. The comparison between observed height at the shoulders and predicted height after applying equations derived for each age group (G I to G IV)



A B

C D E

A- Straight B- Divergent C- Convergent D- Upward E- Downward

Plate 1. Different forms of tusks

(36.53%) followed by the straight tusks (34.61%), are shown in Fig. 7. The forms of tusks in various age groups of elephants are shown in Fig. 8.

The form of ear lobe (plate 2) had no correlation with age or body weight. The lower tip of the ear was round (76.92%), and more or less horizontally long stretched (15.38%), and vertically long (7.69%), is shown in Fig. 9. The form of ear lobe in various age groups of elephants is shown in Fig. 10.

The elephants had predominantly light brown coloured eyes (51.92%), followed by honey yellow coloured eyes (42.30%), are shown in Fig. 11. The eye colour in various age groups of elephants is shown in Fig. 12.

The different types of spinal configuration are shown in Plate 2. The flat type was more common in the elephants (63.46%) followed by broken back type (28.84%), is shown in Fig.13. The spinal configuration in various age groups of elephants is shown in Fig. 14.

The skin colour of the elephants were predominantly black (84.61%) followed by brownish black (15.38%), is shown in Fig. 15. The skin colour in various age groups of elephants is shown in Fig. 16.

The correlation analysis was done between age of the elephant and the parameters such as extent of depigmentation on the trunk, ears, around eye and temporal region (Plate 3), hair distribution, hollow on the temple and forehead region (Plate 4), length and width of the ear, length and width of curling of the ear (Plate 5), tearing percentage of the ear, eye length, base and middle circumferences of the tusk, height at the shoulders, chest girth, neck girth, barrel circumference and right forefoot circumference. The correlations and the probability of these correlations are shown in Table 6. The depigmentation on the shoulder region and body are also shown in Plate 5.

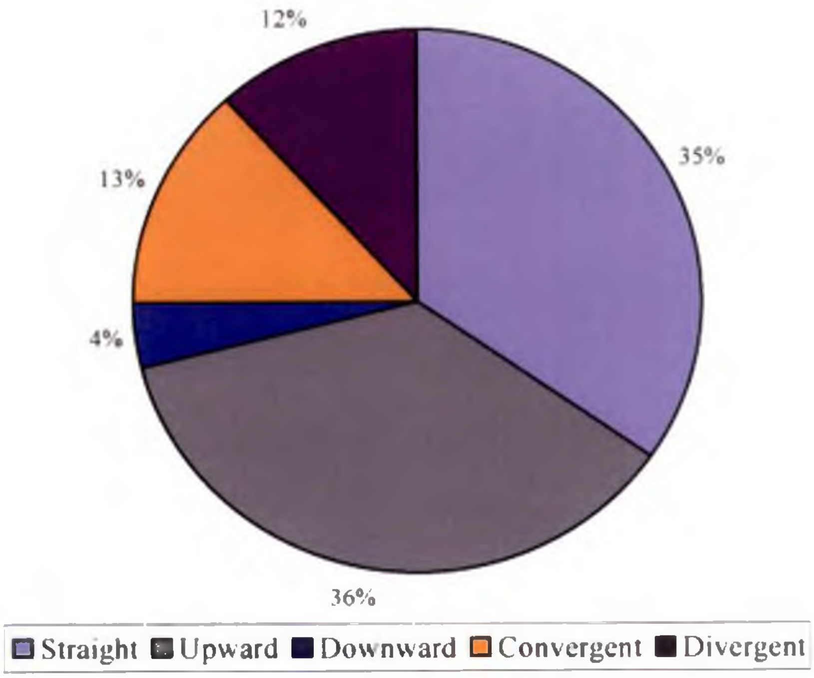


Fig.7. Forms of tusks in elephants (G I to G IV; percentage; n = 52)

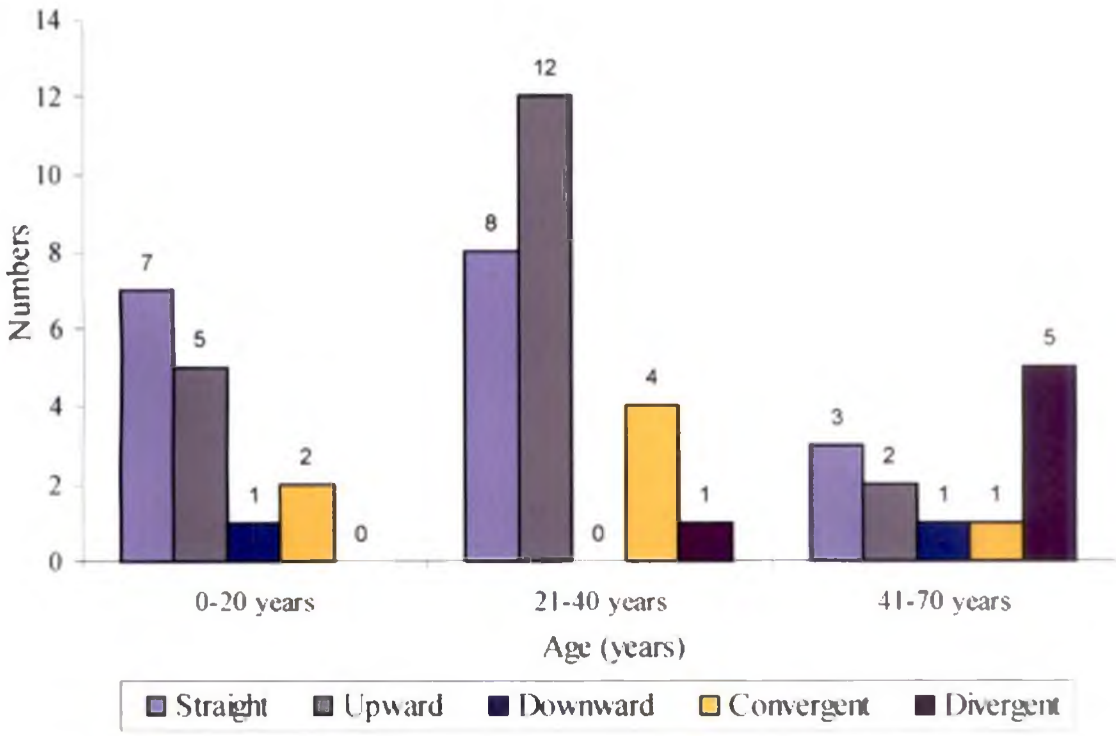


Fig.8. Forms of tusks in various age groups of elephants (G I to G IV)

Different forms of ear lobe - A. Horizontally long B. Vertically long C. Round
Different types of spinal configuration - D. Flat back E. Broken back F. Sloping back

Plate 2

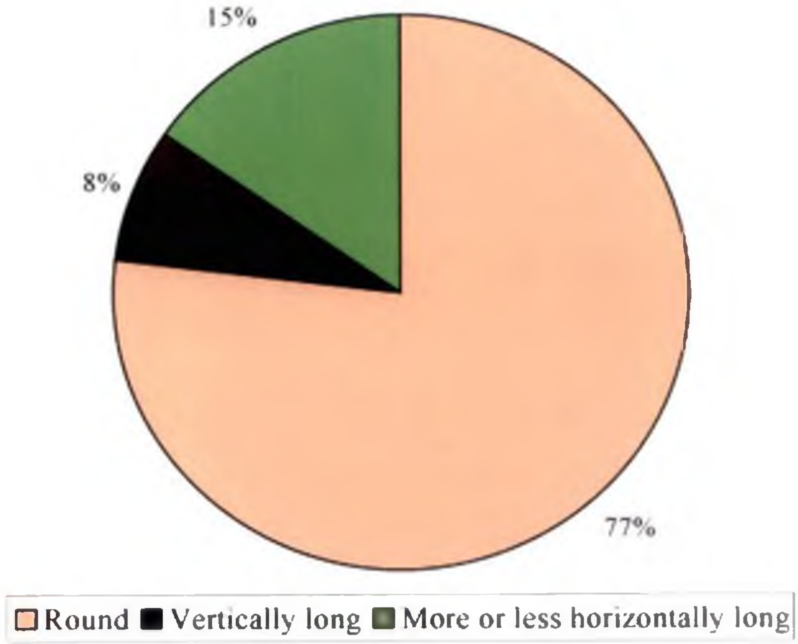


Fig.9. Forms of ear lobe in elephants (G I to G IV; percentage; n = 52)

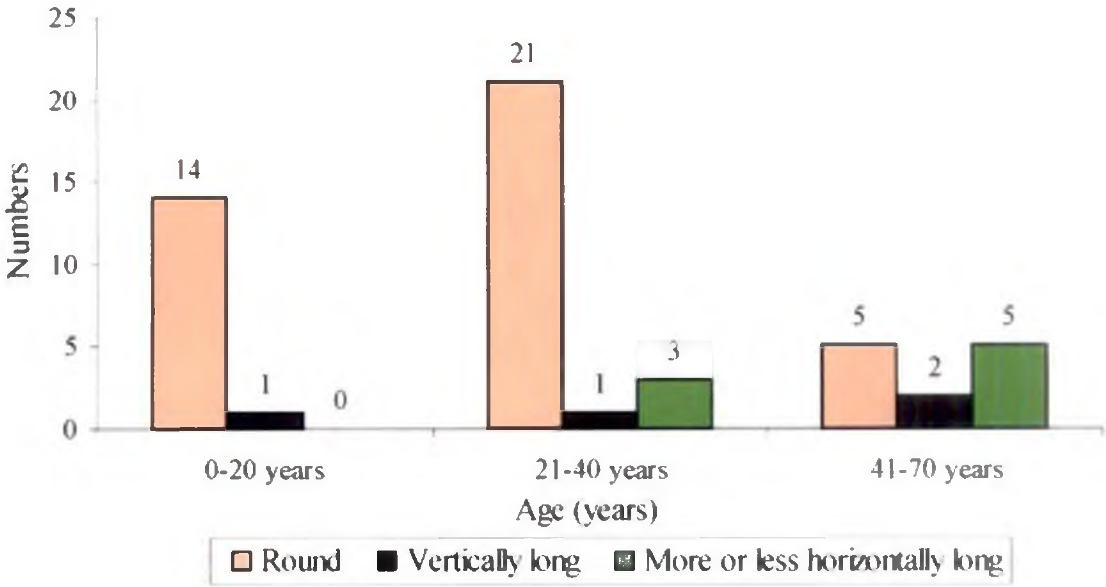


Fig. 10. Forms of ear lobe in various age groups of elephants (G I to G IV)

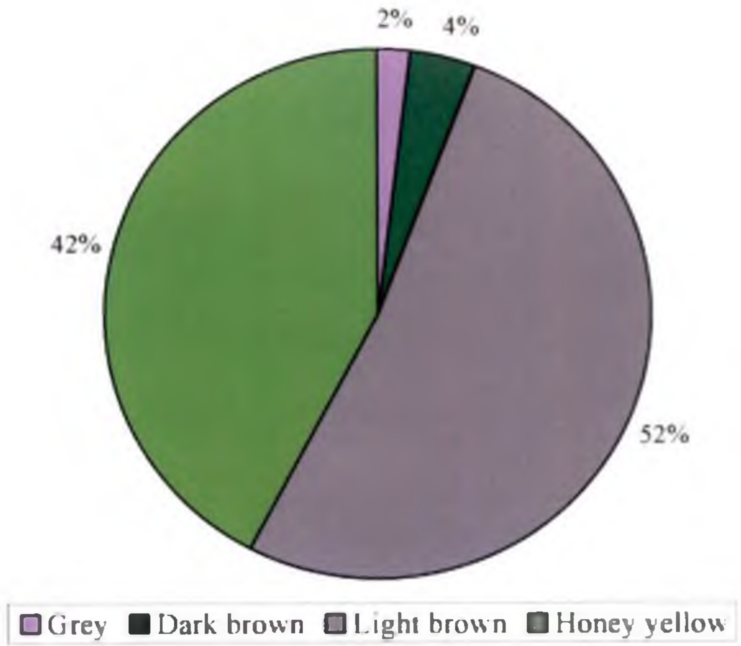


Fig.11. Eye colours of elephants (G I to G IV; percentage; n = 52)

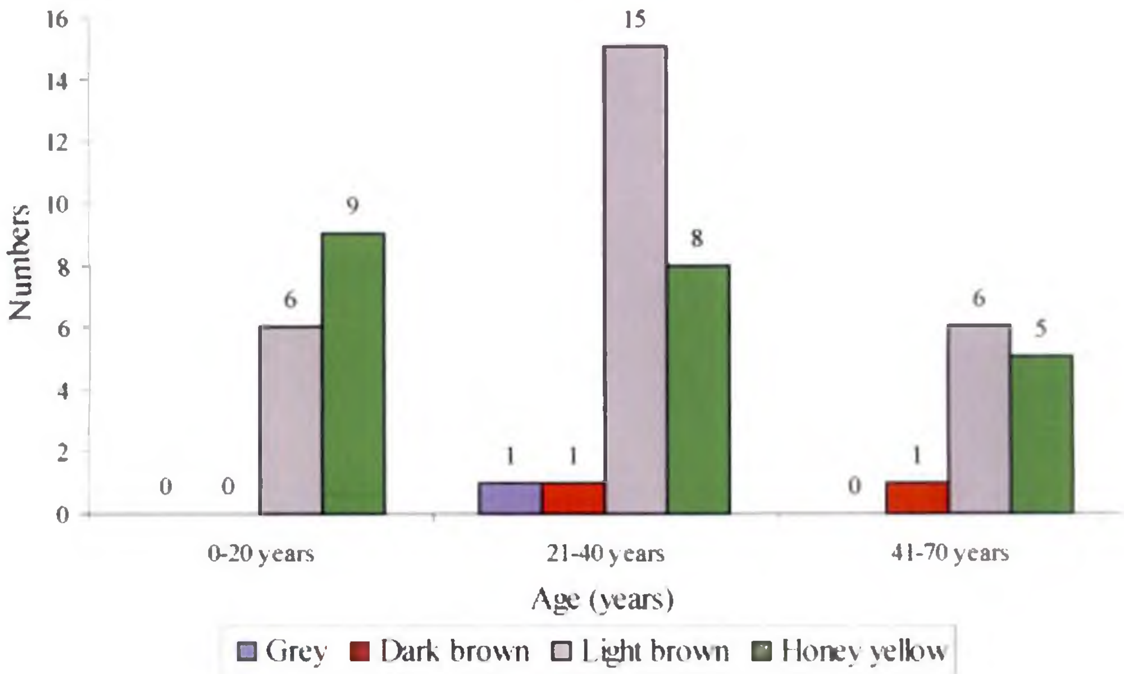


Fig.12. Eye colours in various age groups of elephants (G I to G IV)

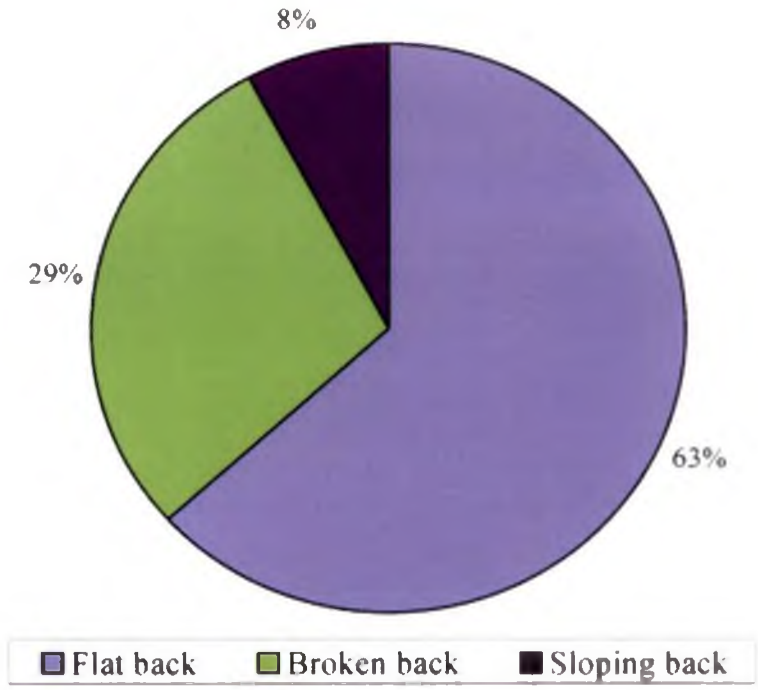


Fig.13. Spinal configurations of elephants (G I to G IV; percentage; n = 52)

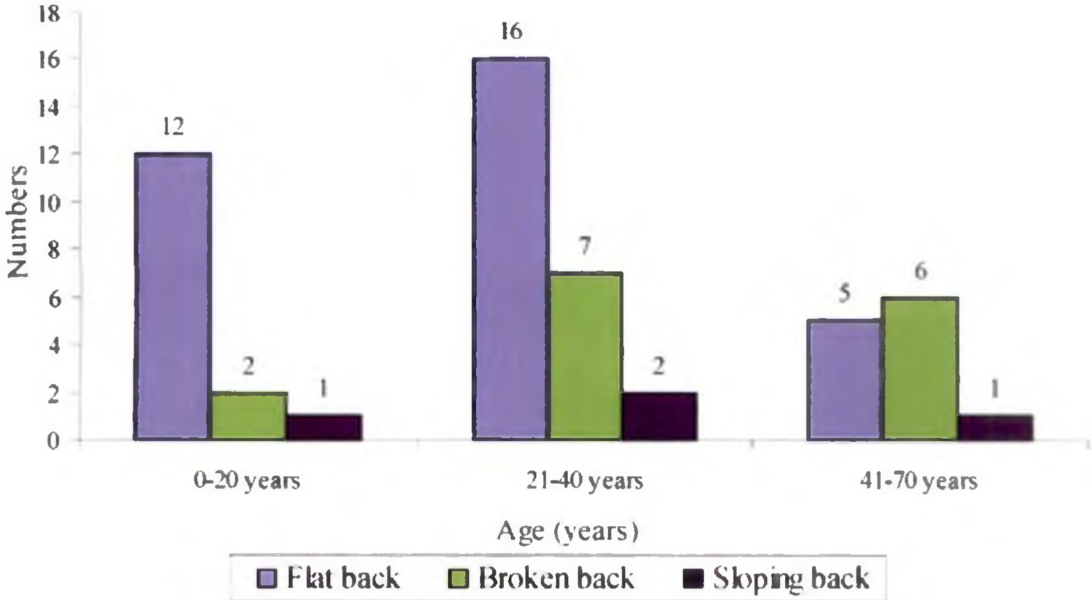


Fig.14. Spinal configurations in various age groups of elephants (G I to G IV)

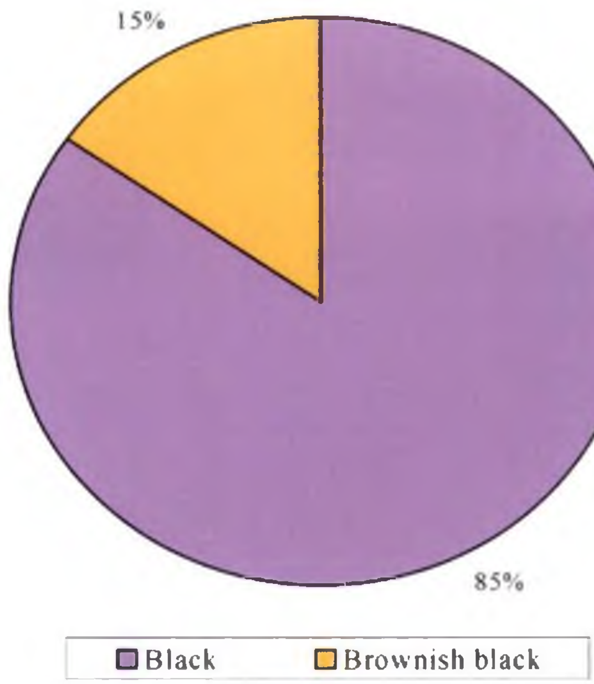


Fig.15. Skin colours of elephants (G I to G IV; percentage; n = 52)

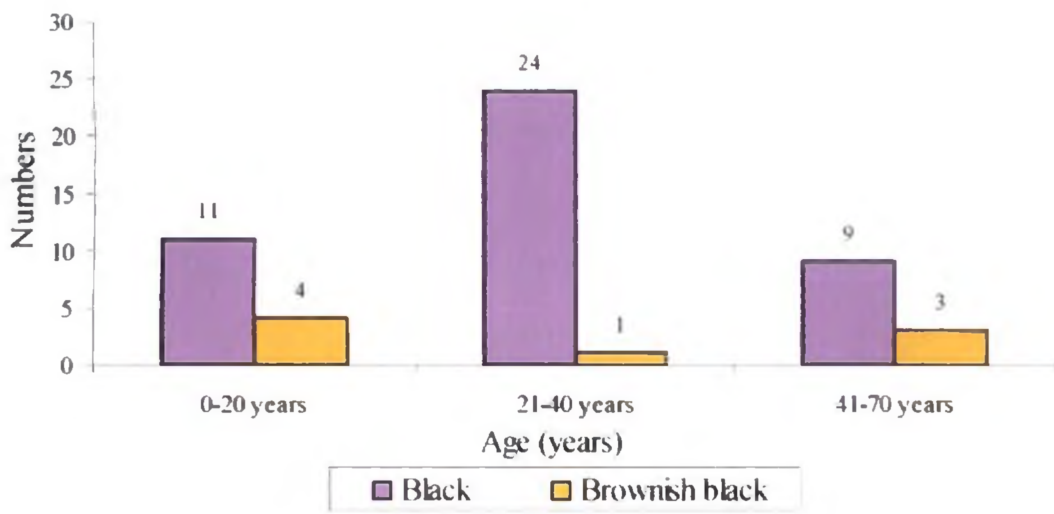
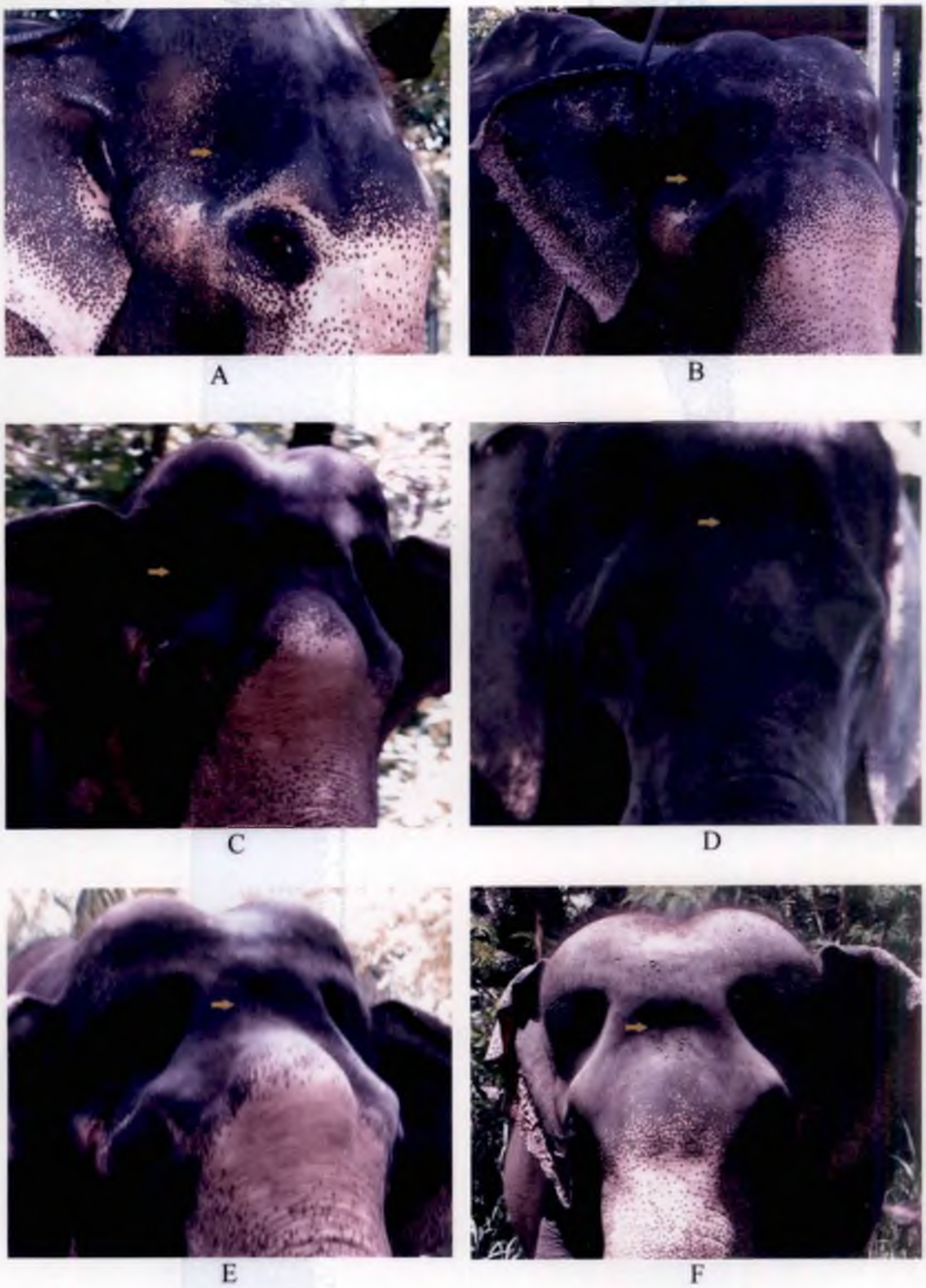


Fig.16. Skin colours in various age groups of elephants (G I to G IV)

A,B,C,D,E,F - Depigmentation on the ear as age advances
G - Depigmentation around eye and temporal gland
H,I,J,K,L,M - Depigmentation on the trunk as age advances

Plate 3



Hollow on the temple region - A. Not pronounced B. Shallow C. Deep
Hollow on the forehead region - D. Not pronounced E. Shallow F. Deep

Plate 4

A - Depigmentation on the shoulder region
B - Depigmentation on the body
C,D - Tearing of the ear
E,F,G,H,I - Curling of the ear as age advances

Plate 5

Table 6. Correlation coefficient for various parameters with age of elephants (n = 52)

Sl. No.	Parameters	Correlation coefficients (r)
01	Depigmentation on the trunk (%)	0.67**
02	Depigmentation on the ears (%)	0.68**
03	Depigmentation around eye (%)	0.41**
04	Depigmentation around temporal gland (%)	0.44**
05	Hair distribution (score)	-0.70**
06	Hollow on the temple region (score)	0.75**
07	Hollow on the forehead (score)	0.46**
08	Length of the ear (cm)	0.64**
09	Width of the ear (cm)	0.71**
10	Length of curling of the ear (cm)	0.66**
11	Width of curling of the ear (cm)	0.65**
12	Tearing percentage of ear (%)	0.28*
13	Eye length (cm)	0.41**
14	Tusk base circumference (cm)	0.79**
15	Tusk middle circumference (cm)	0.82**
16	Height at the shoulders (cm)	0.80**
17	Chest girth (cm)	0.68**
18	Neck girth (cm)	0.56**
19	Barrel circumference (cm)	0.68**
20	Right forefoot circumference (cm)	0.70**

* Significant at 5% level
** Significant at 1% level

A rule of thumb for interpretation of correlation coefficients

1. A value between 0 and ± 0.30 is considered as weak correlation
2. A value between ± 0.30 and ± 0.70 is considered as moderate correlation
3. A value between ± 0.70 and ± 1.0 is considered as strong correlation

The hollow on the temple region, width of the ear (Fig. 17), tusk base circumference, tusk middle circumference (Fig. 18), right forefoot circumference (Fig. 19) and height at the shoulders (Fig. 20) had high correlation with age of the elephant. Among these parameters tusk middle circumference had the highest correlation (0.82). The depigmentation on the trunk and ears (Fig. 21), length of the ear, length and width of curling of the ear, chest girth and barrel circumference had a moderate correlation with age of the elephants. The only one parameter, which had a strong negative correlation (-0.70) with age, was hair distribution (Fig. 22).

The mean values of various parameters in each age group of elephants with standard error are presented in Table 1 and 7.

In case of tearing on the margin of the ear (Plate 5), the Group C had the highest number (66%), followed by Group B (64%). But the tear percentage of ear was almost equal in all the age groups (Table 8).

Significant difference between two age groups of the elephants on the parameters studied for determining age were tested with Mann-Whitney test for two independent samples (Table 9).

There was a significant difference ($p \leq 0.01$) between the Group A and Group B in all the age determining parameters except hollow on the forehead. The comparison between Group B and Group C revealed that significant ($p \leq 0.05$) difference existed between the groups in the parameters such as depigmentation on the trunk, hair distribution, hollow on the temple and forehead region, width of the ear, circumference of tusk base and middle, and height at the shoulders.

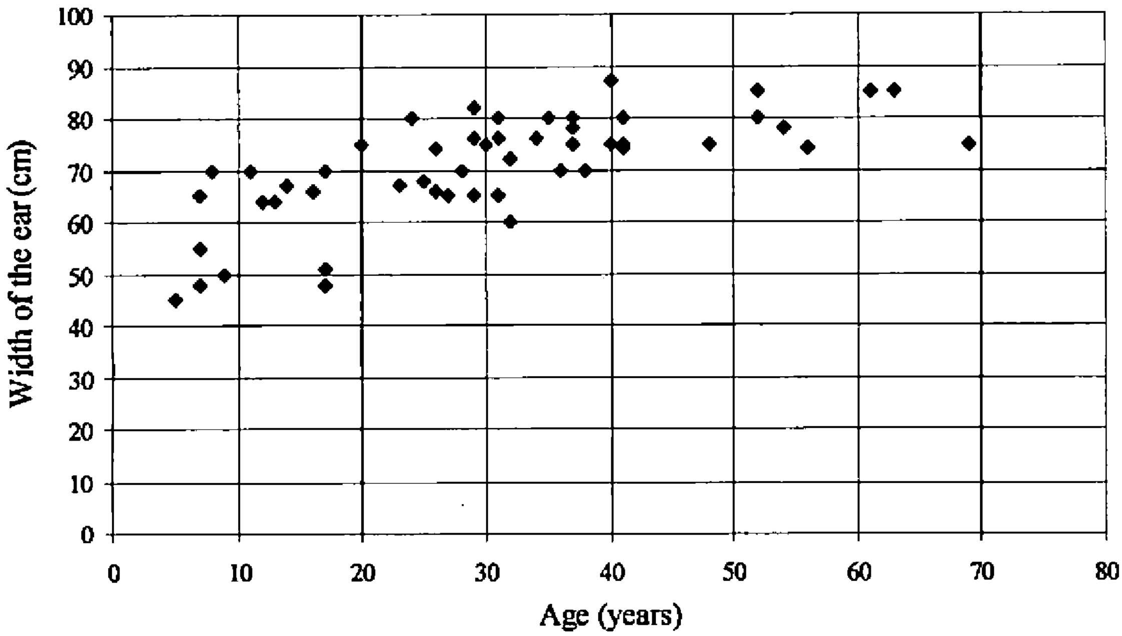


Fig. 17. The relationship between age and width of the ear in elephants

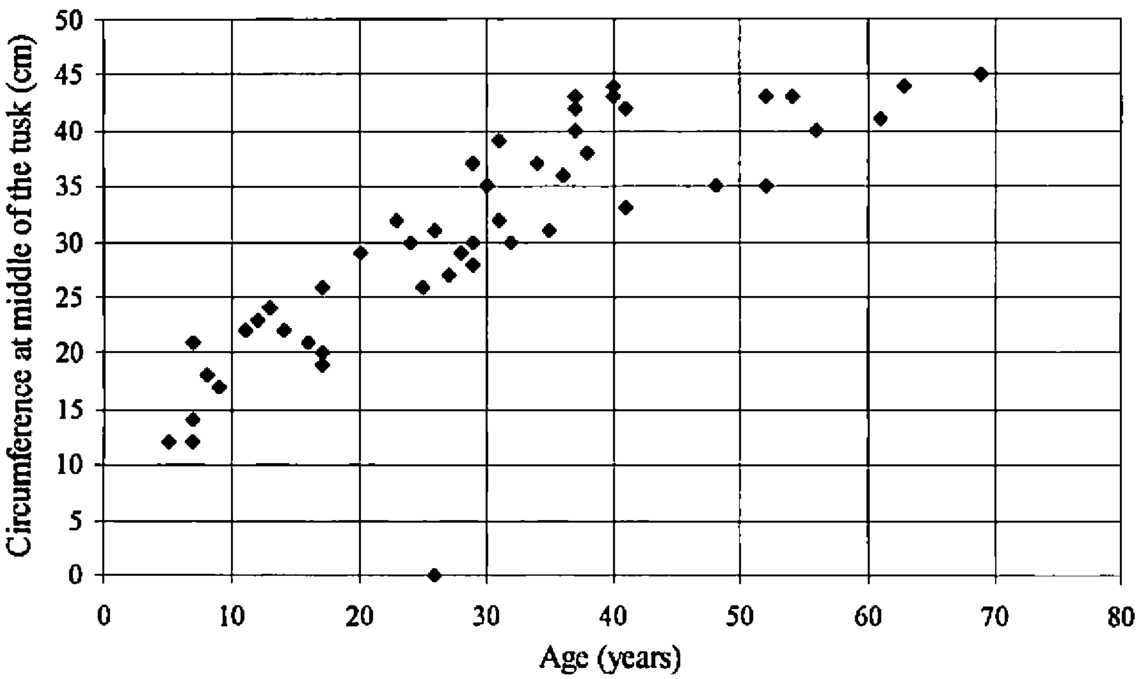


Fig. 18. The relationship between age and circumference at middle of the tusk in elephants

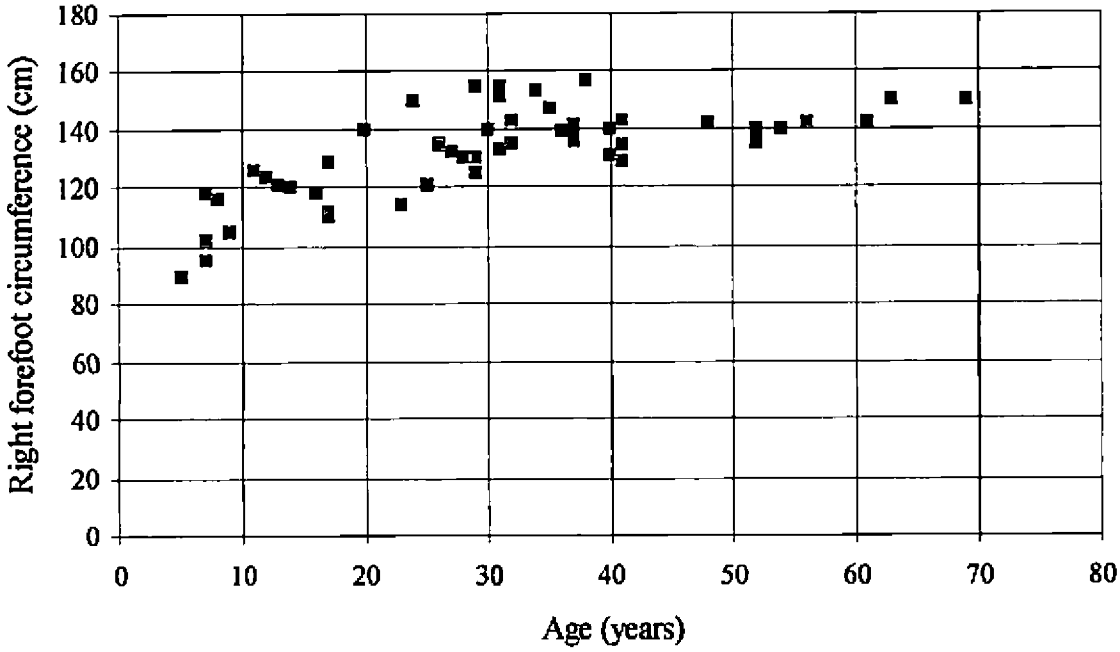


Fig. 19. The relationship between age and right forefoot circumference in elephants

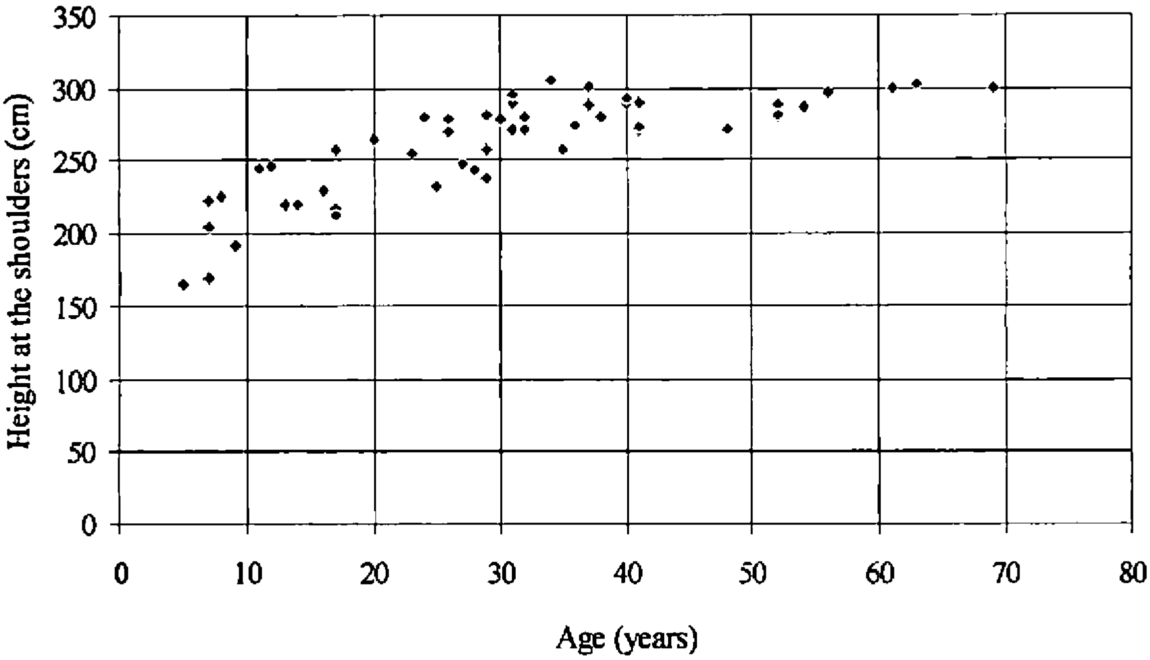


Fig. 20. The relationship between age and height at the shoulders in elephants

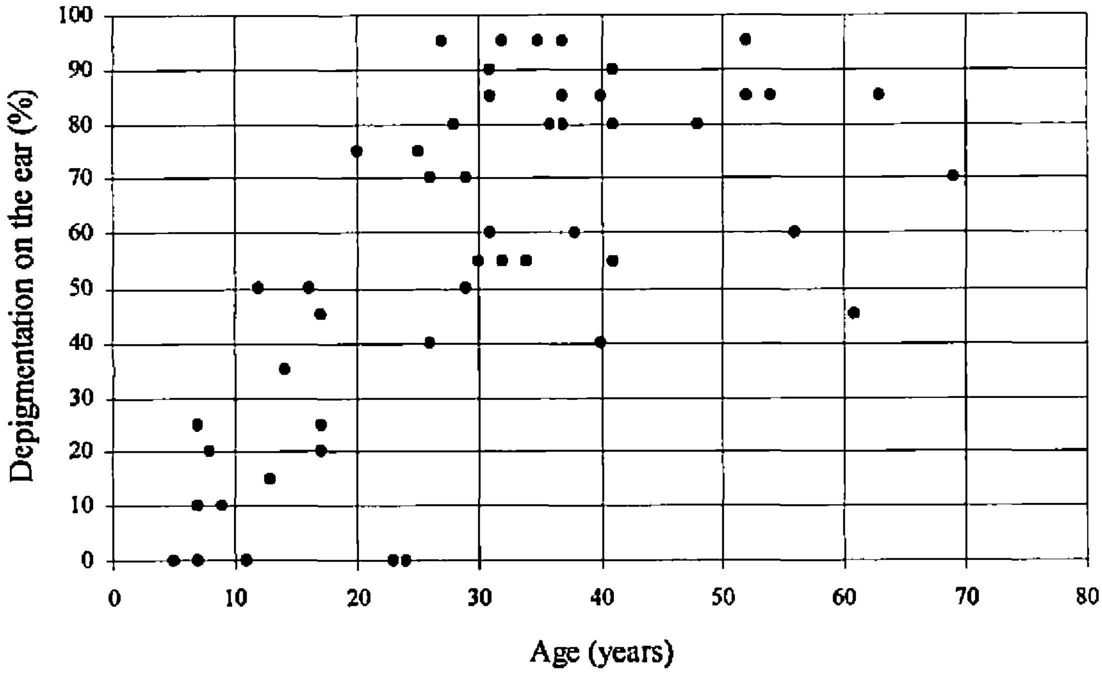


Fig.21. The relationship between age and depigmentation on the ear in elephants

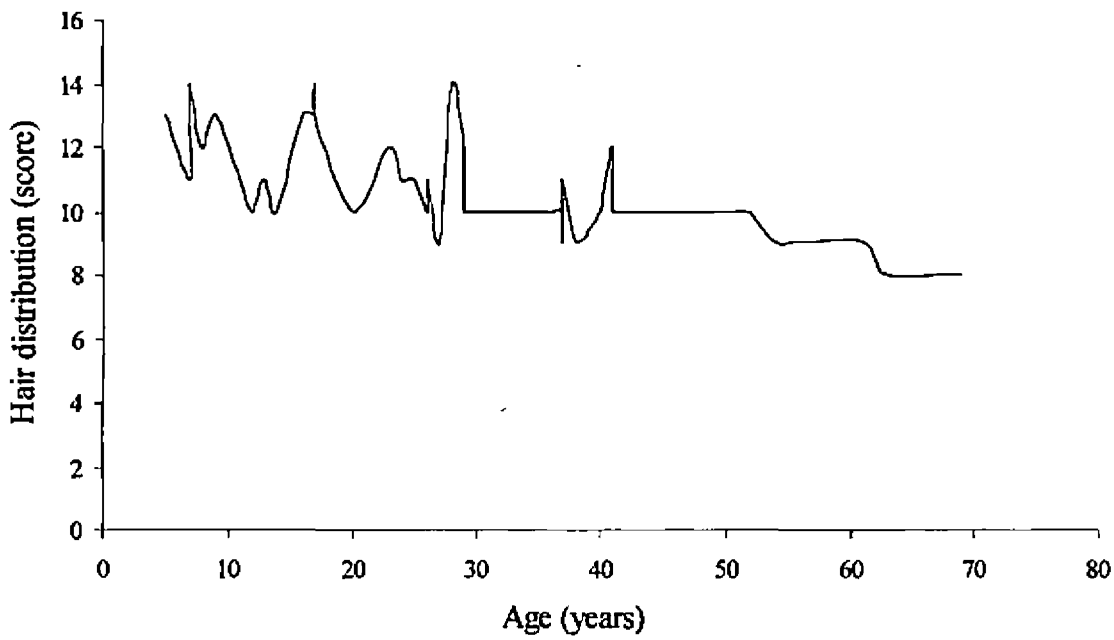


Fig. 22. The relationship between age and hair distribution in elephants

Table 7. Average values of various age determining parameters in each age group of elephants (Mean ± SE)

Sl. No.	Parameters	Group A (n = 15)	Group B (n = 25)	Group C (n = 12)
01	Depigmentation on the trunk (%)	16.7 ± 4.97	55.0 ± 4.47	71.8 ± 7.23
02	Depigmentation on the ear (%)	25.3 ± 5.66	66.6 ± 5.24	76.3 ± 4.44
03	Depigmentation around eye (%)	2.3 ± 1.61	12.6 ± 3.99	26.7 ± 9.34
04	Depigmentation around temporal gland (%)	9.7 ± 2.69	31.6 ± 5.72	47.5 ± 9.56
05	Hair distribution*	12.1 ± 0.37	10.4 ± 0.22	9.6 ± 0.31
06	Hollow on the temple region *	1.7 ± 0.13	2.4 ± 0.11	2.9 ± 0.08
07	Hollow on the forehead *	1.7 ± 0.11	2.0 ± 0.14	2.6 ± 0.16
08	Length of the ear (cm)	65.5 ± 2.46	79.5 ± 1.73	83.4 ± 1.86
09	Width of the ear (cm)	60.5 ± 2.57	73.3 ± 1.31	78.8 ± 1.26
10	Length of curling of the ear (cm)	17.3 ± 4.07	41.1 ± 2.23	45.8 ± 2.98
11	Width of curling of the ear (cm)	2.7 ± 0.77	6.4 ± 0.40	7.0 ± 0.67
12	Tearing percentage of ear (%)	15.8 ± 3.27	17.4 ± 1.50	16.8 ± 2.36
13	Eye length (cm)	6.5 ± 0.35	7.7 ± 0.26	7.7 ± 0.33
14	Tusk base circumference (cm)	22.7 ± 1.33	36.6 ± 1.12	41.6 ± 1.38
15	Tusk middle circumference (cm)	20.0 ± 1.25	34.3 ± 1.12	39.8 ± 1.29

* Scores averaged

Table 8. Tearing percentage of the ear in elephants

Age (years)	Group A (n = 15)	Group B (n = 25)	Group C (n = 12)
Number of animals having tear (right or left or both side of the ear)	4 (26%)	16 (64%)	8 (66%)
Percentage of area having tear (per cent average of all torn ear)	15.8%	17.4%	16.8%

Table 9. Comparison of mean of two age groups of elephants

Sl. No.	Parameters	Comparison of Group A and B - Normal deviate (Z)	Comparison of Group B and C- Normal deviate (Z)
01	Depigmentation on the trunk (%)	3.661**	2.441**
02	Depigmentation on the ear (%)	4.210**	1.354
03	Depigmentation around eye (%)	2.493**	1.232
04	Depigmentation around temporal gland (%)	2.571**	1.377
05	Hair distribution (score)	3.535**	2.143*
06	Hollow on the temple region (score)	3.353**	2.920**
07	Hollow on the forehead (score)	1.056	2.268*
08	Length of the ear (cm)	3.966**	1.060
09	Width of the ear (cm)	3.757**	2.188*
10	Length of curling of the ear (cm)	4.311**	1.506
11	Width of curling of the ear (cm)	3.762**	0.844
12	Tearing percentage of ear (%)	2.295*	0.300
13	Eye length (cm)	2.478**	0.151
14	Tusk base circumference (cm)	4.563**	2.704**
15	Tusk middle circumference (cm)	4.712**	2.879**
16	Height at the shoulders (cm)	5.244**	4.873**
17	Chest girth (cm)	5.009**	1.154
18	Neck girth (cm)	4.876**	1.592
19	Barrel circumference (cm)	4.991**	0.472
20	Right forefoot circumference (cm)	4.459**	0.650

* Significant at 5% level
** Significant at 1% level

Group A - Age between 0-20 years (n = 15)
Group B - Age between 21-40 years (n = 25)
Group C - Age between 41-70 years (n = 12)

Discussion

5. DISCUSSION

5.1 PREDICTION OF BODY WEIGHT FROM MORPHOMETRIC INDICES OF MALE ELEPHANTS

5.1.1 Age Groups

Grouping elephants based on age and growth pattern are discussed in this part. The elephants continue to grow throughout their lifetime and the rate of growth varies as is evidenced by the differences in the size of same aged animals (Jayewardene, 1994). The data collected from fifty two elephants varying from five to seventy years of age revealed that the elephants had various stages in its growth pattern throughout the life period.

The data was divided into various 'age groups' based on different developmental stages of the elephants. Certain elephants registered fast growth till 20 years of age and reached mature weight at this age (Kurt and Kumarasinghe, 1998). This fast primary growth showed linearity between most of the morphometric characters and body weight as opined by Laws *et al.* (1975). So, elephants in this phase of growth were designated as 'Young ones' in line with the study of Laws *et al.* (1975).

Above twenty years and upto thirty years of age the growth pattern was inconsistent and showed great variation in the linearity between morphometric characters and body weight. This variation observed might be due to a secondary growth spurt in male elephants after maturity, as reported by Laws *et al.* (1975). Benedict (1936) contended that certain anatomical measurements have correlation with vital activity of the elephant. After maturity the metabolic activity, hormonal stimulation and genetic exploitation of the various characters varies widely among elephants. The particular phase showed wide variation on the growth between elephants and hence grouped as 'Sub adults'.

Laws *et al.* (1975) pointed out that the growth in elephants were progressive upto 30 years and growth continued to about 40-50 years. In the present study marginal growth was observed form 30 to 40 years. At 40 years the growth became static. So, elephants in this consistent growth period were designated as 'Adults'. After 40 years of age elephants showed a decline in the morphometric measurements. This indicated old age and elephants beyond 40 years were grouped as 'Old adults'. Hile *et al.* (1997) grouped elephants from one to thirteen years as sexually immature animals and further three groups (18-28 years, 29-39 years, and 40-57 years) as sexually mature animals.

McKay (1973) and Barnes *et al.* (1992) classified elephants as infants (<1 year old), calves and sub adult, young adult, adult and large adult. The age specification in each group was not mentioned.

All the parameters that were used for deriving prediction equation continued to increase upto 40 years of age and then started to decline except for the height at the shoulders. It almost showed a gradual growth and/or stable level after 40 years of age. These variations after 40 years may be due to reduced feed intake and feed conversion efficiency leading to reduced muscle build up and shrinkage of body cells.

5.1.2 Prediction Equations for Determining Body Weight in Male Elephants of All Age (G I to G IV)

Among the different parameters assessed for the prediction equations to determine body weight, barrel circumference was the most important factor that influenced the body weight. No literature citations are available on this. The chest girth was the next best predictor of body weight. Observations of Kurt and Nettasinghe (1968), Sreekumar and Nirmalan (1989), Hile *et al.* (1997) and Kurt and Kumarasinghe (1998) are in agreement with the above facts. Krumrey and Buss (1968) opined that a close relationship existed between body weight, shoulder height and body length in female African elephants. This is in agreement with the present study carried out in male Asian elephants.

Ananthasubramaniam *et al.* (1982) reported that the neck girth, chest girth and height at the shoulders were the parameters that had high correlation in descending order with body weight. The present observations are different from this report. This difference might be due to variations in the nutritional status, number, sex, and age of the elephants utilized in these studies.

Addition of right forefoot circumference with chest girth in the prediction equation, improved the accuracy of body weight prediction. This finding is supported by Kurt and Hartl (1995). They stated that the measurements of thorax circumference, shoulder height and/or circumference of forefoot could be easily obtained and could be incorporated in the prediction formula to derive an easy and accurate prediction equation for body weight.

Prediction equation having the combination of chest girth, forefoot circumference and neck girth had the highest correlation with body weight. This result is not in agreement with reports of Sreekumar and Nirmalan (1989) and Hile *et al.* (1997). They have reported that the chest girth, body length and forefoot circumference combination had the highest correlation with body weight of the elephants. This difference in the present study may be due to the variations in the species, number, sex, and age of the elephants used for the studies.

5.1.3 Prediction Equations for Group I (0-20 years) Male Elephants

Correlations between all body measurements and body weight were very high in young elephants (0-20 years). Among different parameters that influenced the body weight, the chest girth had the highest correlation with body weight. The addition of other parameters along with chest girth did not improve the accuracy of prediction largely. So, there is not much of an advantage in using combinations of measurements to evolve equations to this age group. These findings are in agreement with that of Hile *et al.* (1997). They have reported that the chest girth was the best single predictor of body weight in immature group of elephants (1-13 years).

5.1.4 Prediction Equations for Group II (21-30 years) Male Elephants

Sub adult elephants (21-30 years) showed a general decrease in the relationship between body weight and measurements and also in the significance level of various equations compared to other groups. Hile *et al.* (1997) observed a drop in the correlation of all body measurements with weight in elephants of 18-28 years of age. The present observation revealed that right forefoot circumference was the best single predictor of body weight in this age group of elephants. This finding is not in agreement that of Hile *et al.* (1997). According to them the heart girth (chest girth) was the best single predictor of body weight in 18-28 year old group of elephants. This difference may be due to secondary growth spurt in male elephants after attaining maturity (Laws *et al.*, 1975). The maturation would lead to changes in the metabolic and hormonal activity of individual elephants and these changes differ between elephants. It might be a reason for this wide inconsistency in the relationship between measurements and body weight.

Hence, in Group II elephants the combination of measurements could be more effective than single measurement for the prediction of the body weight more precisely.

5.1.5 Prediction Equations for Group III (31-40 years) Male Elephants

Among different parameters studied for the correlation with body weight, the barrel circumference had the highest correlation with body weight. No literature citations are available on this. Hile *et al.* (1997) reported that the heart girth (chest girth) was the best single predictor of body weight in 29-39 year old group of elephants. But, the present revealed not much correlation between chest girth and body weight. This might be due to the differences in the parameters studied for prediction equations, sex, and number of elephants used in the cited reports.

5.1.6 Prediction Equations for Group IV (41-70 years) Male Elephants

Similar to elephants in the adult group, the barrel circumference expressed the highest correlation with body weight. Equations involving barrel circumference and right forefoot circumference improved the accuracy of prediction of body weight. No literature citations are available on this. Hile *et al.* (1997) reported that heart girth (chest girth) was the best single predictor and combination of other measurements would not improve the prediction of body weight in 40-57 year old elephants. The difference observed in the present study might be due to differences in parameters studied, number, and sex of the elephants utilized for the study.

In case of all age groups (G I to G IV) of elephants and Group I, the single body measurement (barrel circumference and chest girth) itself had high correlation with body weight. But, in elephants above 20 years of age, the combinations of morphometric parameters were needed to evolve higher correlation with body weight. The differences in the correlation of body weight and body measurements for the different age groups suggest that there may not be a single ideal equation for predicting body weight in elephants.

On comparison of accuracy of prediction of body weight using equation evolved by various researchers revealed that the formula predicted for all age group has drawbacks including greater discrepancies between observed and predicted body weight in elephants (Sreekumar and Nirmalan, 1989). It indicates that the equation might lead to mismanagement of some elephants (Hile *et al.*, 1997). So, for reasonable accuracy in the estimation of body weight from body measurements, the elephants have to be classified under proper age groups and specific formula for particular age group should be applied for prediction.

5.2 PREDICTION OF HEIGHT AT THE SHOULDERS FROM FOREFOOT CIRCUMFERENCE OF MALE ELEPHANTS

The height at the shoulders is a very good dimension for describing linear growth of elephants and it is not subject to the rapid seasonal fluctuations (Laws *et al.*, 1975). Measuring height of elephants has variations, since slight change in posture may affect the measurement. However, height is an important criterion in determining the worth of the animal financially and in selecting animals for temple rituals. The height at the shoulders is significantly related to the circumference of the forefoot (Benedict, 1936). Kurt and Nettasinghe (1968), Sreekumar and Nirmalan (1989), Hile *et al.* (1997), Basappanavar (1998), Daniel (1998) and Kurt and Kumarasinghe (1998) had also reported that the height at the shoulders of an elephant is approximately twice the circumference of right forefoot. The present finding is congruence with the above reports. In wild elephants one could adequately predict the approximate height from the impression of the footprint using this relationship.

The present study was consistent with this approximation for all age group and Group I elephants. There was no correlation between height at the shoulders and right forefoot circumference in elephants aged between 31-40 years. Only a moderate correlation was noted in elephants aged between 21-30 years and 41-70 years. These findings for various age groups of elephants are in agreement with that of Hile *et al.* (1997). The prediction of height at the shoulders from right forefoot circumference would be effective with all age groups (G I to G IV) equation and Group I equation. Though other age groupwise equations also predicted the height from right forefoot circumference with reasonable accuracy but significance value was less. So the prediction of height at the shoulders with these equations may not be reliable all the times.

The present study was compared with that of Sreekumar and Nirmalan (1989) and it revealed that the prediction of height at the shoulders from right forefoot circumference is quite reliable.

5.3 ESTIMATION OF AGE BASED ON PHYSICAL FEATURES AND MORPHOMETRIC INDICES IN MALE ELEPHANTS

5.3.1 Form of Tusks

The form of tusks of each elephant differed significantly. This finding is similar to that of Kurt and Kumarasinghe (1998). They have reported that the forms of tusks vary immensely among individual elephants and might serve as a distinctive optical mark for each elephants. Panicker (1996) reported that the tusks make an elephant appealing and they may be directed in several ways as converging in the front or diverging or curved upwards. The ideal quality for ritualistic need is that the tusks should be directed downwards, raised up and evenly separated. The present finding is in agreement with this report. Each age group of elephants consisted tusks of various forms, but none could be related with age of the elephants.

5.3.2 Form of Ear Lobe

The form of ear lobe varies considerably among individuals. This finding is in accordance with the finding of Kurt and Kumarasinghe (1998). They opined that the members of same mother families often possessed ear lobes of same shape and attributed it to hereditary origin. This holds true in the present observation also. Each age group of elephants consisted ear lobe of various forms. So, the form of ear lobe correlates neither with age nor with body weight.

5.3.3 Eye Colour of Elephants

Eye colour varied significantly among the individual elephants. The so called 'ideal' elephants should have clear eyes and they must be the colour of honey (Panicker, 1996). Kurt and Kumarasinghe (1998) observed more light brown coloured eyes followed by honey coloured eyes in Sri Lankan elephants and stated that it may be hereditary in nature. This is akin to the present findings.

Each age group of elephants had various eye colours. So, the eye colour did not have any correlation with age of the elephants.

5.3.4 Spinal Configuration of Elephants

Spinal configuration varied greatly among the elephants. Visually the ideal elephant's back must slope downwards (Panicker, 1996). Kurt and Kumarasinghe (1998) recorded similar results as that of the present study in Sri Lankan elephants and opined that the frequency of certain spinal configuration may function as optical signals. They added that, in bulls the spinal configuration tends to be more sloping down from shoulder to tail and this exaggerated body size optically. Each age group of elephants had various spinal configurations. So, the spinal configuration had no relationship with the age of the elephants and it may be a genetic factor.

5.3.5 Skin Colour of Elephants

Judging the elephant colour was a difficult task as to authenticate subtle colour changes. Basappanavar (1998) reported that the colour of the wild elephants was exceedingly difficult to be judged. This is akin to the present observation. The skin colour varied differently at different times and often was the colour of the soil that it had smeared over itself. The present finding is in agreement with that of Jayewardene (1994), who reported that the elephants are seen in different colours depending on different circumstances. An elephant just out of clear water appear dark gray and if the water was muddy, the skin takes on that colour.

The elephants maintained and cared at Guruvayoor predominantly had a black colour. The present result is in accordance with the report of Panicker (1996), who stated that the skin of the elephants is jet black. Each age group of elephants had various skin colours. From the observations, it was revealed that the skin colour does not have any correlation with age and it seems to be hereditary.

5.3.6 Correlation of Other Parameters with Age of the Male Elephants

5.3.6.1 Blotches or Depigmentation

The extent of depigmentation in trunk, ears, around eye and temporal gland had increased with age of the elephants. This finding is congruence with that of Kurt and Kumarasinghe (1998). They have reported that the extent of depigmentation of trunk, ears, temples and shoulders increased with age and in males eyes are significantly more accentuated by depigmentation than females. They added that the patterns of depigmentation varied immensely among individuals and might serve throughout as distinctive optical mark for each elephant.

Elephant has a large amount of melanin pigment in the body, which imparts the black colour (Panicker, 1996). Depigmentation might be the result of loss in melanin pigment, as age advances. Why the depigmentation is so confined to the trunk, ear, around eyes and temporal gland, remains unanswered? If, it was in the trunk and ear alone, we can come into a conclusion that, it may be due to active movement and continuous activity of trunk and ear throughout the lifetime of the elephants (Panicker, 1996). In young animals, depigmentation started on the trunk tip and base, on the upper distal tip of the ear and the ear lobe. In old animals, depigmentation increased and spread all over the trunk, and accentuated predominantly over the eyes, openings of the temporal glands and ears. A strong linking to hereditary factor may be attributed to this change.

5.3.6.2 Hair Distribution

The only parameter that had a strong negative correlation with age, in the present observation, was hair distribution on the elephant's body. As age advanced the distribution of hair depleted. The result is in agreement with the findings of Jayewardene (1994), who reported that, most of the baby elephants had lots of hair at birth and they shed hair gradually as they grow up. In captive elephants minimal loss of hair could be observed. This may be due to regular scrubbing (Panicker, 1996). The loss of hair may be due to normal physiological and anatomical consequences of all living creatures with increasing age.

5.3.6.3 Hollow on the Temple Region

The hollow on the temple region was not pronounced at early age and it became shallow, then deep as the age advanced. The result is in accordance with the reports of Daniel (1998) and Selvaraj (2001). They have observed that as elephants aged, the hollow at temple deepens. For aged elephants the temple region appeared sunken in relation to rest of the skull and is not connected with poor physical condition (Basappanavar, 1998). The present finding is in tune with these observations.

5.3.6.4 Hollow on the Forehead

The hollow on the forehead became shallow and then deep with increasing age. The results indicated that this parameter is not as reliable as that of hollow on the temple region to predict the age. Because, it had only a moderate correlation with age, but hollow on the temple region had a strong correlation with age. No literature citations are available on this aspect of study.

5.3.6.5 Length and Width of the Ear

The length and width of the ear increased continuously throughout the growth period of elephants. No literature citations are available on this aspect of study.

5.3.6.6 Length and Width of Curling of the Ear

The length and width of curling of the ear had increased with the advancement of age. This finding is in tune with reports of Panicker (1985) and Daniel (1998). They have opined that a rough estimate of elephant's age could be done by observing the folds of ear and that the ear margin folds about an inch in thirty years. In very young elephants of six to seven years, the pinnae of the any significant difference between Group A and Group B and hence might not be an useful tool for estimation of age in elephants between zero to forty years.

The parameters such as depigmentation on the trunk, hair distribution, hollow on the temple and forehead region, width of the ear, circumference of tusk base and middle, and height at the shoulders were significantly different between Group B (21-40 years) and Group C (41-70 years). These parameters increased with the increase in age of the elephants between 21 to 70 years of age. So, these parameters might be useful for estimation of age between 21-70 years. The parameters such as depigmentation on the ear, depigmentation around eye and temporal gland, length of the ear, length and width of curling of the ear, tearing percentage of the ear, eye length, chest girth, neck girth, barrel circumference and right forefoot circumference did not have any significant difference between Group B and Group C. So, these parameters might not be useful for age estimation between 21-70 years of age.

The estimates of the ages cannot be considered anywhere near so accurate as the estimates of the probable weights (Benedict, 1936). So, these morphometric measurements and physical features would be useful only for age approximation in elephants.

The depigmentation on the trunk, hair distribution, hollow on the temple region, width of the ear, circumference of the tusk base and middle, and height at the shoulders had strong correlation with age as well as significant difference between Group A and B comparison and also Group B and C comparison. All these parameters have linear relationship with age of the elephants. The measurements of these parameters could continue to increase throughout the life span of the elephants. So, all these parameters could be useful either singly or in combination for approximation of age in male elephants.

ears is not turned over and with advancing age it twirls over (Basappanavar, 1998). This is in agreement with the present findings.

The present finding does not agree with the finding of Jayewardene (1994), who observed a two inch roll of ear in young elephants, only a half of the ear rolled and very late rolling of the ear in aged elephants. He stated that the roll of the ear is not keeping in line with the age of the elephants.

5.3.6.7 Tearing Percentage of the Ear

Among different parameters studied, the only parameter that had weak positive correlation with age of the elephants was tearing percentage of ear. It revealed that the tearing percentage of ear had no relationship with age. No literature citations are available on this. It may be occuring due to different pattern of activity of individual elephants.

5.3.6.8 Eye Length

The length of the eye increased with increasing body growth of the elephants. But the eye length had not much variation among the elephants of different age. If there is any little error in the measurement, that will affect the result drastically. No literature citations are available on this aspect of study.

5.3.6.9 Tusk Base and Middle Circumference

The elephant's tusks grow continuously throughout the lifetime both in terms of length and circumference. This finding is supported by Colyer and Miles (1957), Jayewardene (1994), and Raubenheimer (2000). The tusk size as an age dependent character showed remarkable consistency throughout the life period (Laws, 1966 and Selvaraj, 2001). From the circumferences of tusk at the base and middle, one could able to predict the approximate age of the elephants.

5.3.6.12 Right Forefoot Circumference

The right forefoot circumference is a very reliable factor for estimating the age of elephants. Western *et al.* (1983) reported that the length of the hindfoot print provided an easy and rapid method of estimating age of elephants in situations where a clear imprint can be obtained. So, the age approximation in elephants could be done with forefoot circumference.

5.3.8 Tearing of the Ear in Elephants

Tear on the ear might be due to exposure of elephant to the working environment and their struggle for existence. This finding is supported by Jayewardene (1994), who reported that the ears of most wild elephants are damaged in some way, some are torn, others have pieces taken off and some have folds and these damages are a result of fights with other elephants and damage during flight through thick jungles. The ear was torn mostly along the upper and rarely middle edge. The present finding is different from the finding of Basappanavar (1998), who reported that the ear is usually ragged and torn especially along the lower edge. The extent of tear (percentage of tear) was almost equal in all age groups of elephants. So, the tearing of the ear did not have any correlation with the age of elephants.

5.3.9 Comparison of Parameters between Age Groups

The comparison was done to identify the parameters that can be useful for age estimation in elephants throughout their life period.

All the parameters that were studied for the estimation of age were significantly different between Group A (0-20 years) and Group B (21-40 years) except hollow on the forehead. These parameters increased with the age of the elephants upto 40 years and hence would be useful for estimation of age in elephants between zero to forty years. But hollow on the forehead did not show any significant difference between Group A and Group B and hence might not be an useful tool for estimation of age in elephants between zero to forty years.

The parameters such as depigmentation on the trunk, hair distribution, hollow on the temple and forehead region, width of the ear, circumference of tusk base and middle, and height at the shoulders were significantly different between Group B (21-40 years) and Group C (41-70 years). These parameters increased with the increase in age of the elephants between 21 to 70 years of age. So, these parameters might be useful for estimation of age between 21-70 years. The parameters such as depigmentation on the ear, depigmentation around eye and temporal gland, length of the ear, length and width of curling of the ear, tearing percentage of the ear, eye length, chest girth, neck girth, barrel circumference and right forefoot circumference did not have any significant difference between Group B and Group C. So, these parameters might not be useful for age estimation between 21-70 years of age.

The estimates of the ages cannot be considered anywhere near so accurate as the estimates of the probable weights (Benedict, 1936). So, these morphometric measurements and physical features would be useful only for age approximation in elephants.

The depigmentation on the trunk, hair distribution, hollow on the temple region, width of the ear, circumference of the tusk base and middle, and height at the shoulders had strong correlation with age as well as significant difference between Group A and B comparison and also Group B and C comparison. All these parameters have linear relationship with age of the elephants. The measurements of these parameters could continue to increase throughout the life span of the elephants. So, all these parameters could be useful either singly, or in combination for approximation of age in male elephants.

Summary

6. SUMMARY

Studies on morphometric indices and ageing techniques in elephants are scanty. The collection of morphometric details of different age groups of elephants would enhance our biological understanding and management of these endangered species. An attempt had been made to decipher the body weight prediction from body measurements and to scientifically device the different ageing techniques based on physical features of male elephants.

A total of fifty two clinically healthy captive male Asian elephants, varying in age from five to seventy years under excellent management and good nutritional regimes maintained by 'Devaswom Board' of 'Guruvayoor' Sri Krishna temple were utilized for studying the morphometric details as well as physical features.

For predicting the body weight the parameters such as observed body weight, body lengths, neck girth, chest girth, barrel circumference, height at the shoulders, limb lengths, limb circumferences, foot circumferences, trunk length, tusk length, and tusk circumference were measured.

For determining the age of elephants the physical features such as length and width of the ear, appearance of the ear, length and width of curling of the ear, forms of tusks, forms of ear lobe, hollow on the temple and forehead region, blotches (depigmentation), eye colour, eye length, spinal configuration, skin colour and hair distribution were studied along with body measurements.

Multiple regression equations were derived by using single parameter and various combinations of the parameters to predict the body weight and also to estimate the height at the shoulders from right forefoot circumference. The entire data were divided into subsets according to the various developmental phases of elephants and the formula were derived for the elephants of all age as well as various age groups. Several models were tried and the parameters having the highest correlation with the body weight were used for the prediction equations. The best found prediction formulas are,

Sl. No.	Groups	Prediction equations	R^2 value
01	All age groups (0-70 years)	BW = -5303.71 + 12.60 (CG) + 31.79 (FC) H = 2.02 (FC) – 6.31	0.93 0.82
02	Group I (Young ones; 0-20 years)	BW = -3676.88 + 10.57 (CG) + 22.50 (FC) H = 2.07 (FC) – 18.04	0.97 0.93
03	Group II (Sub adults; 21-30 years)	BW = -4973.41 + 14.97 (H) + 7.72 (NG) + 21.99 (FC) H = 1.16 (FC) + 106.08	0.84 0.57
04	Group III (Adults; 31-40 years)	BW = -4215.41 + 10.72 (NG) + 40.28 (FC) H = 0.28 (FC) + 245.39	0.85 0.03
05	Group IV (Old adults; 41-70 years)	BW = -7684.67 + 16.68 (BC) + 28.83 (FC) H = 1.5 (FC) + 75.81	0.85 0.64

Where,

R^2 – Coefficient of determination

BW – Body weight (kg)

CG – Chest girth (cm)

FC – Right forefoot circumference (cm)

H – Height at the shoulders (cm)

NG – Neck girth (cm)

BC – Barrel circumference (cm)

Correlation analysis was done to correlate the various parameters with age of the elephants. The forms of the tusks, forms of the ear lobe, eye colour, spinal configuration, skin colour and tearing of the ear had no correlation with age of the elephants. The parameters like hair distribution, hollow on the temple region, width of the ear, circumference of tusk base and middle, height at the shoulders, and right forefoot circumference had strong positive correlation with age. Hair distribution had strong negative correlation with age.

Depigmentation in trunk and ears, length of the ear, length and width of curling of the ear, chest girth, and barrel circumference had moderate linear positive correlation with age. The remaining parameters did not have much effect on age determination in elephants.

Average values of various parameters, in each group of elephants were calculated for easing the age approximation in elephants.

Significant differences of the parameters between two age groups of elephants were tested with Mann-Whitney test for two independent samples. For this purpose the entire data was divided into Group A (0 to 20 years - young ones), Group B (21 to 40 years - adults) and Group C (41 to 70 years - old adults). The comparison was made between Group A and B, and it revealed that there was a significant difference in all the parameters that were used for estimation of age except the hollow on the forehead.

Comparison of Group B and C revealed that the parameters such as depigmentation on the trunk, hair distribution, hollow on the temple and forehead region, width of the ear, circumference of tusk base and middle, and height at the shoulders had significant difference between Group B and C. The same parameters were significantly different in Group A and B also, except hollow on the forehead. It indicated that these parameters had a linear correlation with age and it increased as age advances.

The parameters that have high correlation with age as well as significant difference in comparison between groups could be useful for the estimation of age in male elephants with more precision.

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MORPHOMETRY AND AGEING OF CAPTIVE MALE ASIAN ELEPHANTS (*Elephas maximus*)

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ABSTRACT

The collection of morphometric details from elephants of different age groups would enhance our biological understanding and management of this valuable species. A total of fifty two clinically healthy captive male Asian elephants, varying in age, under excellent management, maintained by 'Guruvayoor Devaswom Board' were utilized for predicting body weight and height from body measurements as well as determination of age from physical features.

For prediction equations several morphometric parameters were measured. All possible linear regressions of weight on one, two, three and four body measurements were calculated. The equations having highest coefficient determination value (R^2) with least standard error of estimation was taken for predicting body weight and height in elephants. The data were also divided into age groups (Group I (Young ones; 0-20 years), Group II (Sub adults; 21-30 years), Group III (Adults; 31-40 years), and Group IV (Old adults; 41-70 years)) and all possible linear regressions were calculated for each group.

The best prediction of body weight (kg) for all age groups (G I to G IV) was obtained based on two parameters; the chest girth (cm) and right forefoot circumference (cm). Single and also the combination of various parameters were used for the prediction of body weight in different age groups. An equation to predict the height at the shoulders (cm) from right forefoot circumference (cm) for various age groups of elephants was also derived.

Various parameters were correlated with age of the elephants and average values of these parameters were calculated for age approximation.

The data were again divided into various age groups (Group A (Young ones; 0-20 years), Group B (Adults; 21-40 years), and Group C (Old adults; 41-70 years)) and comparison of parameters between two age groups was done. The

parameters such as depigmentation on the trunk, hair distribution, hollow on the temple region, width of the ear, circumference of tusk base and middle, and height at the shoulders had high correlation as well as significant difference in various age group comparisons. So, these parameters could be useful for age estimation in male elephants with more precision.