BEHAVIOUR PATTERN OF MUSTH AND NON MUSTH IN CAPTIVE 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 **"BEHAVIOUR PATTERN OF MUSTH AND NON MUSTH IN CAPTIVE 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.

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CERTIFICATE

Certified that the thesis entitled **"BEHAVIOUR PATTERN OF MUSTH AND NON MUSTH IN CAPTIVE ASIAN ELEPHANTS (*Elephas maximus*)"** is a record of research work done independently by **Dr. S. Sathasivam,** 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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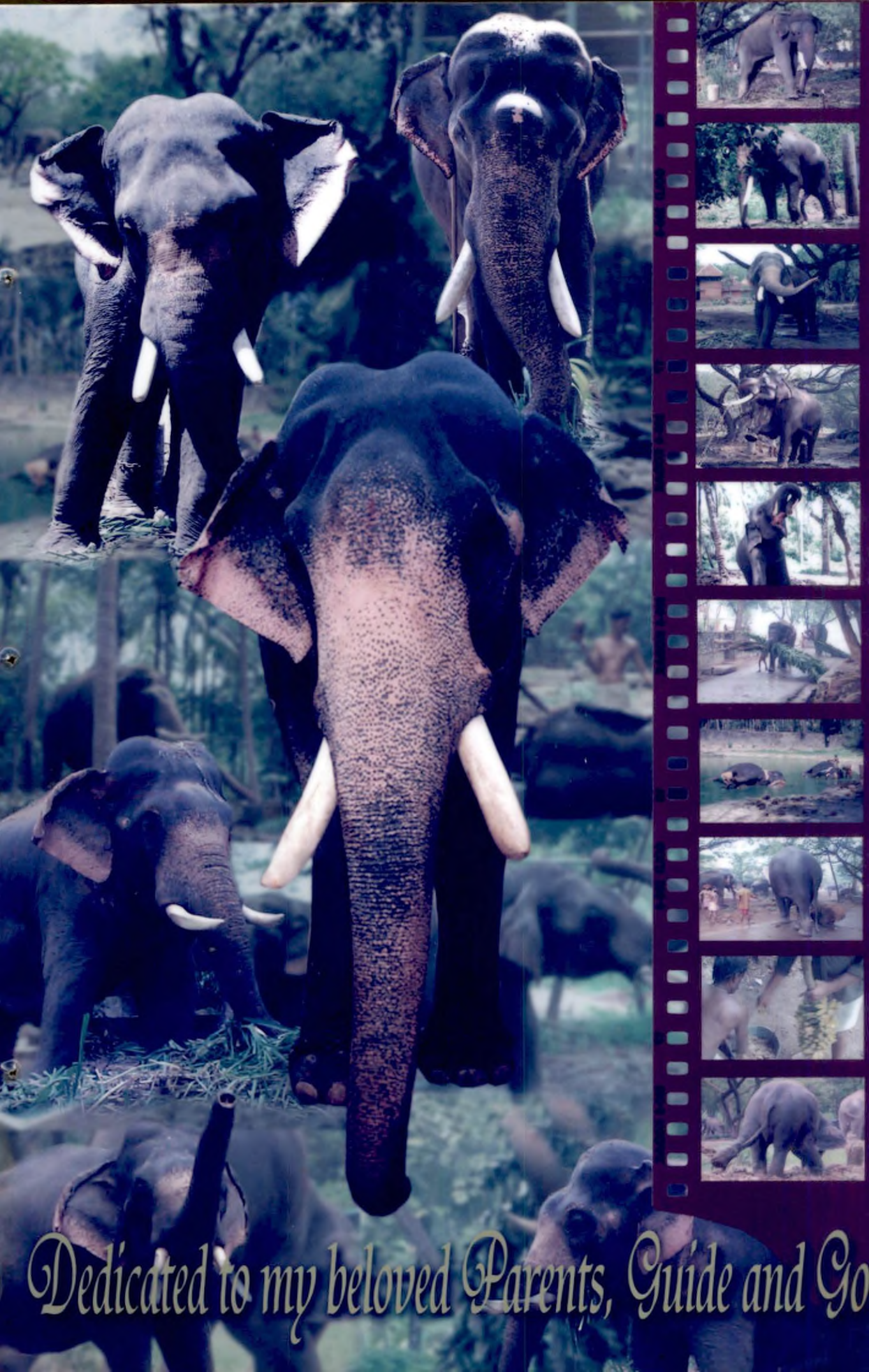

Dedicated to my beloved Parents, Guide and Go

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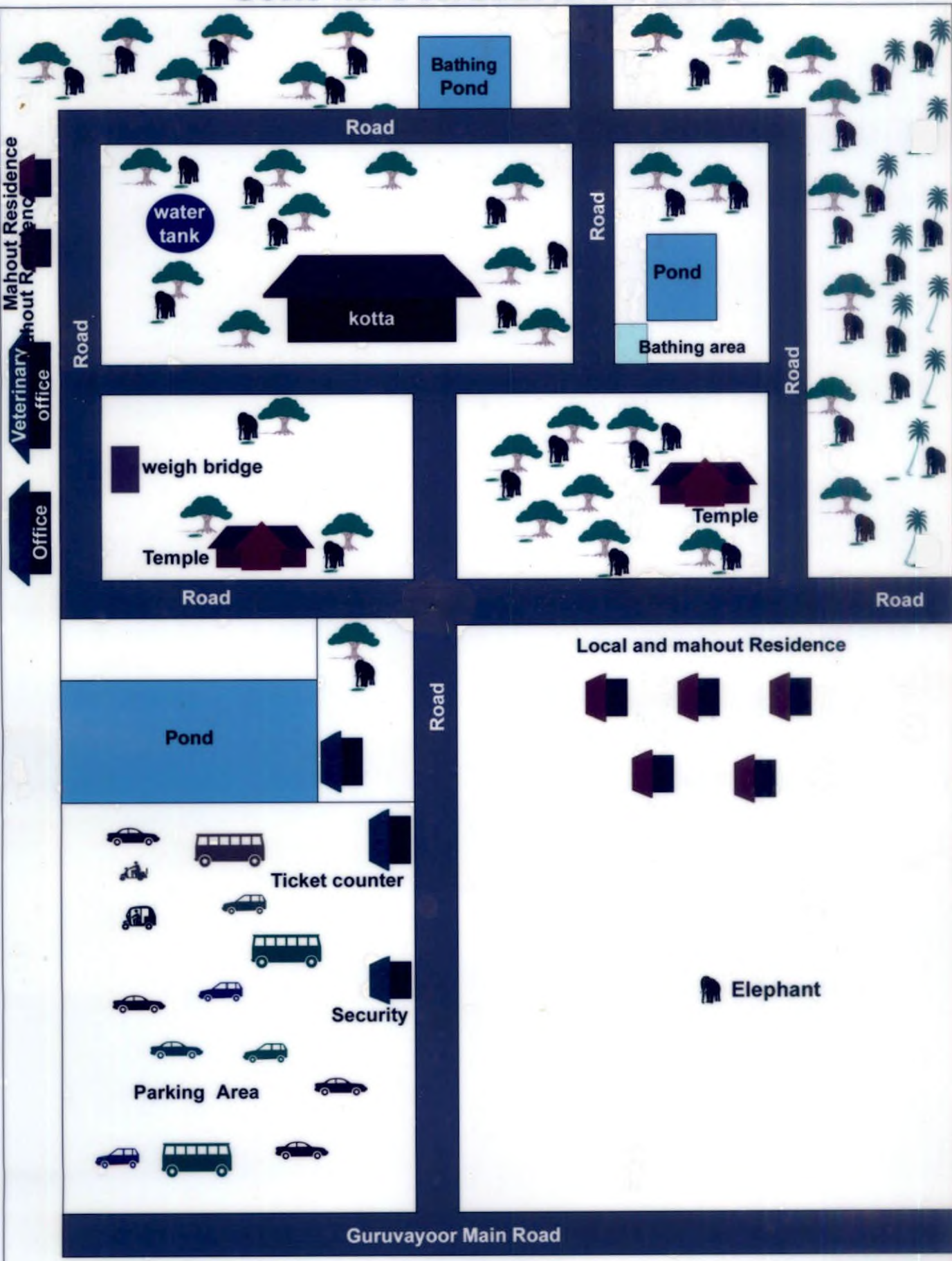

Introduction

1. INTRODUCTION

Elephants inspire both affection and awe and have been with man in war and peace as trusted friend from time immemorial, which made it as the most popular among other wild animals. The elephant's large statute, near human qualities of character and unique harmony of animal instincts has contributed to it becoming a symbolic figure in myths and religions. The kingly greatness of elephant is preserved in uncountable number of drawings and paintings, statues and carvings. Our epics and folklore are replete with legends about this magnificent giant. Classical literature and other writings of old manuscripts have accorded a position of dignity and divinity to the elephants. The elephant has a position of our cultural and political history, which continues to last even today.

Population of elephants in India estimated as 28,000 was considered as the largest remaining population of the Asian elephant in the world. Kerala is known as the *"Elephant State"* for its large captive elephant population. According to recent estimates there are about 3400- 3600 domesticated elephants in India, out of that 612 domesticated elephants are found in Kerala itself (Bist, 2002).

Asian elephants have been domesticated as early as fourth century B.C. as per "Hasthiayurveda" written by sage Palakapya. Captive elephants keeping in Kerala is very unique as 90 per cent of the population is that of the bull elephants. Bull elephant management is very risky and adventurous as at least 3 months in a year it would be in the most aggressive state called musth. Musth, with its sexual connotations has been known and described in Asian elephants, since ancient times. Musth starts, when they reach maturity (between 12-16 years) and continues, until they are middle aged. The term "musth" is a Hindi word that used to describe abnormal or drunken behaviour in elephant or human.

Musth is physiologically expensive and heightened sexual state. Most healthy males experience musth once in an year. In the wild Males in musth are more successful in competitions with subordinate males for gaining access to estrous cows.

In Kerala annually atleast nine persons are killed by musth elephants, which were engaged for ceremonial parade and timber hauling works. The musth aggression is associated with accelerated androgen level, which can be used to diagnose the musth, provided Radio Immuno Assay (RIA) facilities are available. In practical situation this is not always feasible as it involves high cost and expertise. The conventional system of sorting out the musth elephants from being engaged during that period is not based on scientifically proven techniques. So it requires the development of ethogram and behavioural score, which is associated with the androgen level and holistic documentation of musth episodes.

In such a context, this study aimed

1. To analyse the musth episodes in captive male Asian elephants.
2. To document the behaviour in different stages of musth.
3. To know the feeding and management practices in different stages of musth.
4. To measure faecal testosterone level from elephant faeces using (RIA) during non-musth and musth to investigate the biological relevance of musth including its potential use as a tool in reproductive biology.
5. To design detailed ethogram to distinguish behaviour in different stages of musth.
6. To correlate the behaviour in different stages of musth with faecal testosterone levels.

Review of Literature

2. REVIEW OF LITERATURE

2.1 FEEDING

Anon (1958) mentioned that the importance of giving different rations for idle and work elephants, pregnant and lactating cows and calves has been stressed in "Gajasastra". Eight types of food such as salt, grass, garlic, jaggery, gingelly oil, butter, curd, cooked and uncooked paddy, have been mentioned as dietary ingredients in this ancient work.

The daily requirement of nutrients for adult idle and growing elephants for metabolic body size ($w^{0.73}$) have been assessed and the same expressed in terms of dry matter (DM), total digestible nutrient (TDN), digestible crude protein (DCP), digestible energy (DE) and metabolic energy (ME) were 108 g, 70 g/kg, 6 g, 278 kcal, and 237 kcal, respectively for maintenance of adult elephants and 142 g, 70 g/kg, 7 g, 335 kcal, and 279 kcal, respectively for the young growing elephants as reported by (Anathasubramaniam, 1979). He also suggested the feeding schedule of working elephants as roughage (palm leaves coconut leaves, bamboo leaves grass etc) 159-200 kg and concentrates like horse gram, ragi, rice, and mineral mixture and jaggery 5 kg, 7 kg, 3 kg, 110 g, 50 g, respectively.

Nair and Anathasubramaniam (1979) analysed the nutritive value of palm leaves (*Caryota urens*) for elephants with a leaf –stem ratio of 1:1 and reported to contain 38.8 per cent drymatter.2.0 per cent crude protein, 9.3 per cent crude fiber, 22.9 per cent nitrogen free extract, 1.1 per cent ether extract and 3.5 per cent total ash with 0.35 per cent calcium and 0.23 per cent phosphorus.

Sukumar (1989) reported that the bark and leaves of browse eaten by Asian elephants in Southern India contained 0.25-5.72 per cent calcium and 0.08-0.21 per cent magnesium during the wet season and 1.77-3.74 per cent calcium and 0.07-0.4 per cent magnesium during the dry season. Grass leaves during the wet season contained 0.19-0.46 per cent calcium and 0.06-0.08 per cent magnesium, phosphorus concentrations.

Apart from natural grazing for at least 14-15 hours a day, the elephants are provided with grain rations in cooked form, twice a day. The quantum of ration for each individual elephant is determined by the forest veterinarian, according to age, size, capacity for work and several other factors. The elephants are necessarily exposed to the monotony of feeding on monoculture plants such as palm species. In Kerala most of the elephants are maintained exclusively on the nutritious *Caryota urens* palm (Krishnamurthy, 1998).

Compared with the wild, the diets of elephants in captivity are restricted between three to twenty food types (Taylor and Poole, 1998).

Elephant's capacity to digest food is poor, 40 per cent is digested and rest 60 per cent is passed out, as dung. The standard practice is to supply fodder at the rate of five per cent of the body weight and such as a cow elephants need 150-175 kg of fodder as against 200-250 kg for a bull (Cheeran, 1999).

Once a day ration or concentrate feed were given in most of the captive establishments. Any cereals like rice, ragi, millets and lentils like horse gram, moong dhal or green gram or Bengal gram can be combined together to compose the concentrate feed (Ponnappan and Radhakrishnan, 1999).

Mercy (2002) stated that the horses show close similarity to elephants when compared to other herbivores; Scientists are using the NRC standards of horses for feeding elephants. Dietary crude protein requirement of horse ranges from eight per cent in mature animals and up to 15 per cent for young growing animals, and are found to be almost adequate for elephants. The mineral requirements of elephant are also similar to that of horse.

2.2 MANAGEMENT

Ratnasooriya (1990) reported that, the management of elephants in musth usually involves chaining the animals away from contact with people, other elephants and the withdrawal of food to reduce the period of musth. Various traditional methods are also used including the mechanical stimulation of the nerve center in the anal fold (performed by the mahout with a metal ankus) and the provision of rhizomes of *Bambusa vularis*. Aerial parts of *Tetracera sarmentosa* and leaves of *Ficus tsielato* which are thought to suppress musth.

In captivity male African and Asian elephants during musth becomes decreasingly responsive to their handlers and may be extremely dangerous to keepers and often to other elephants. The length and severity of musth are variable, creating a problem in the management of this species (Niemuller and Liptrap, 1991).

The usual practice is to tether the elephants in musth on trees or pillars under shade with specially made strong chains on one of the hindlimbs and diagonally supports forelimb separately. The elephants are generally given sufficient quantity of palm leaves and water, some of the elephants were fed with cucumber 10 to 15 kg per day for a period of 15 to 30 days (Chandrasekharan *et al.*, 1992).

The management of elephants includes, provision of elephant enclosure, diet and feeding regime, exercise, medical and husbandry practices as reported by (Vellayan and Malik, 1992; Weilenmann and Isenbuge, 1992).

Thakuria and Barthakur (1994) reported the use of chemical sedatives for musth management in male African elephants. Valandikar and Raju (1996) reported the use of Xylazine, Haloperidol and Lasix, and special diet to control musth. Chandrasekharan and Cheeran (1996) reported the use of antiandrogen in controlling musth in captive elephants.

Krishnamurthy (1998) found that almost all temple elephants of Tamilnadu had well maintained stables specially designed for elephant, whereas in Kerala, the animals are tethered under the shade of trees within the temple premises.

Bist (1999) reported that wild elephants, usually bulls visited the Pilkhanas - places used to house captive elephants to mate with a female in estrus, or to share fodder. He also reported cases of wild bulls assaulting captive elephants.

Cheeran (1999) reported that the tethering site should have shade and proximity to water, surface should not be hard and must be preferably muddy with provision for drainage and convenience to dispose dung, urine and fodder refuses.

Kaimal (1999) suggested that a water tank with constant supply of water must be placed at a distance reachable to the trunk of the musth elephant and that the elephants must be showered with water at least once in a day to cool it. He also opined said that musth elephant must be chained by both fore and hind limb, with chain or fetter with 7/8" diameter links. He recommended a gap of 2 feet or (60 cm) between the tethering pole and elephants hind limb.

Krishnamurthy (1999) reported that the elephants of Tamilnadu forest department were released overnight into the forest with a long trailing chain fastened to the hind limb and a bell tied around the neck.

Namboothiripad (1999) opined that the tethering site of elephants should be free of slush and dirt as the microbes in it can cause disease on the legs such as foot rot. He suggested that the elephant should always be tied with its head in a slightly elevated position.

Ponnappan (1999) opined that the bath is very important to an elephant both in captivity and wild. The scrub bath is also an opportunity for the mahout to bond with his elephant; it is best to wash elephants in the morning.

Cheeran *et al.* (2002) reported that usually the animal in musth is tethered both on its hind limb and fore limb; which helps in removing the dung and left over to keep the site clean. Elephants may be off feed and there are chances for dehydration, hence the animal should be watered properly, injuries caused by the chains are the most common problems during musth.

2.3 BEHAVIOURAL STUDIES

The method of direct observation pays a unique role in the behavioural sciences. It is at once the necessary link between laboratory research and real world behaviour and the bane of our aspirations for more accurate, more objective information about behaviour (Altmann, 1974).

Captivity free elephants from the selective pressure imposed by predation and for the most part parasitism; and greatly limits the range of new habitats to explore in

the course of development which may modify adaptive behaviour and impact the degree and type of social behaviour exhibited. Yet captive and wild elephants demonstrate many of the same behaviour. Hence, behavioural studies on captive may be relevant to wild population and the detail of data available to researchers on individual animals held in captivity is typically much greater than for wild individuals, although the relevance to the wild must be considered when making generalizations (Adams and Berg, 1980; Schutle, 2000).

An ethogram is a complete catalogue of all behaviour and vocalizations occurring in a species (Banks, 1982). Because of adaptation to a new environment, loss of comfort and well being may be acute or chronic. To avoid injuries in the new environment, animals may modify or reduce the frequency of behaviour (Gonyou, 1986).

Sanford *et al.* (1986) ascertained that some species communicate their experiences by means of bodily attitude and other postural mechanisms. Also particular changes, in posture are often elicited by painful foci in particular parts of the body.

Ethogram, which is a catalogue of descriptions of the discrete, species typical behaviour patterns that form the basic behavioural repertoire of the species (Lehner, 1987).

In selecting measure for a particular behavioural study it is useful to know the array of behaviour which the animal is capable of showing, a largely complete description of such an array called an ethogram and is necessarily based on an extensive study of that species and they can be very useful if the behaviour description is precise enough (Fraser and Broom, 1990).

Kleiman (1992) indicated the importance of behaviour research in zoo because; the result from classical descriptive behavioural research and basic behavioural research has enormous potential to contribute positively to the science of animal management, animal welfare, long term breeding programs, conservation biology and the advancement of scientific theory.

In behavioural studies, the recording of an animal's responses to a particular set of environmental circumstances can provide much information on the mental, as well as the physical, state of the animal under observation. Also the response of an animal to a choice of environment provides an insight into an animal's mental and physical state (Moss, 1992).

Behavioural studies can be an important element to successful captive management of a species and can be even more critical for, developing effective strategies for many species (Stevens and Hutchins, 1993; Kleiman, 1994).

Gruber *et al.* (2000) in their study to determine the effect of penning and chaining elephants behaviour found that the elephants engaged in more comfort, ingestion and locomotion activities and fewer social interactions and stereotypic activity. When penned than when chained, variation in stereotypic activity was related to age with younger elephants more likely to show stereotypic activity than older elephants.

Behavioural observations are also a type of 'assay' that is used to quantify animal biological responses. As with physiological measurement, methods of behavioural observation should be validated and selected based on the objectives of the particular study (Mitlohner *et al.*, 2001). He opined that continuous observations are an accurate method for behavioural measurement and made focal animal

sampling using continuous sampling of individuals of feeding, lying, standing drinking and walking behaviour in heifers and indicated that one heifer was representative of the entire pen.

Schutle (2000) opined that, understanding of captive elephants behaviour is important not only for the maintenance of a viable captive populations, but also to enhance the survival and management of wild population, and large scale studies on the captive population should lead to new discoveries and offer fresh solution to the problems confronting the management of elephants.

Stavisky *et al.* (2001) in a behavioural study on group housed macaques, made behavioural observations in half hour samples composed of three 10 minute ad -libtium samples to determine rates of aggressive, submissive and afflictive interactions and ten instantaneous scan samples to determine the percentage of time animals spent engaged in a set of behaviour including eating, drinking, grooming stereotypic behaviour, resting, alertness, locomotion and play following procedures previously described. A single observer recorded data by hand over the entire collection period.

Elephants in captivity are easier to observe than the wild counterparts because they are acclimated to the daily presence of human visitors and staff and the design of viewing areas typically allows for unobtrusive viewing behaviour, (Scott, 2002) in a study on captive male elephants, closely observed male elephants behaviour in captivity and designed a detailed ethogram to distinguish different behaviour, thus characterizing behaviour indicative of and unique to, musth and expanded this behavioural context into anatomical and physiological aspects of musth. There was an increase in the frequency of stereotypic behaviour in the captive male elephants during musth.

Van *et al.* (2002) stated that the individual differences in animal behaviour could elucidate the difference in stress coping style. Other factors such as time and test situation has important role in determining an individual's behavioural reaction.

2.4 BEHAVIOURAL PARAMETERS OF MUSTH

The androgen levels in the blood usually increase considerably during the period of musth and it is stated to be the reason for the increased aggressive behaviour in musth elephants reported by (Jainudeen *et al.*, 1972; Rasmussen *et al.*, 1984; Cooper *et al.*, 1990; Niemuller and Liptrap, 1991).

Poole and Moss (1981) observed that a bull in musth would advertise his state using distinctive vocalizations, odors and postures. A bull in musth also has a distinct posture called the musth walk, during the musth walk a bull walks with his head well above his shoulders and with what can best be described as a swagger to his step. In contrast bulls not in musth often have their head down and a more shambling gait.

Rasmussen *et al.* (1984) reported that the traits scored as characteristic of and occurring only during musth in two Asian bulls was; temporal gland secretion, urine dribbling, retracted penis, glazed dye and reduction in food and fluid intake. Aggressive acts such as charging the keepers and trunking other elephants occurred during musth and there was deliberate objects ordinarily ignored. Such behaviour were seldom seen during 9 to 12 non-musth interval. During musth episodes when urination occurred during the observation period 2/3 of urine spots evoked flehmen responses of 1-4 flehmen/ hours.

Poole (1987) suggested that musth is analogous to the rutting period seen in some ungulates. For many species that rut, females and their offspring spend the remainder of the year feeding in areas apart from males. The rutting season is the only time of year females are in estrous and males compete for access to breeding them. In the males, antlers are full grown concurrent with elevated serum testosterone levels. Scent glands are most active in both sexes during the rut and the urine from males has a strong odor. Males often cease to feed during the rut and the early stages of pre rut reported by (Espmark, 1964; Geist, 1964;Lent, 1965; Struhsaker, 1966; Grubb and Jewell, 1973).

Main manifestations of musth are spreading of ears, alertness and fully opened ogling eyes with roving eye ball, stiff and tense body, extended blowing trunk and a charging or destruction tendency towards human being especially mahouts was observed by (Chandrasekharan *et al.* 1992). He ascertained that the elephants of an age group of 15 to 20 years exhibit a condition known as 'moda' or juvenile musth. Symptoms are characterized by easily irritable, mischievous and erratic behaviour, semi engorged temporal gland with a brown coloured foul smelling paste like secretion seen, these manifestations lasted for a period of 10 to 20 days.

Fowler (1992) described the typical picture of musth in a bull elephant includes significantly elevated serum testosterone level, aggressive behaviour, and drainage of fluid from the temporal glands on the side of the head between ear and eye, dribbling of urine from the prepuce somnolence, anorexia, dehydration and unusual vocalizations (e.g. Groaning).

External manifestations of musth are frequent micturation, protrusion of erect penis for long time striking on belly frequent dribbling of urine more violent and

prominent bulge in the perineal region (Thakuria and Barthakur, 1994; Sarma and Dutta, 1996; Saseendran, 1994).

Lincoln and Ratnasooriya (1996) mentioned that periodic increase in testosterone secretion during the gonadal cycle induces the development of musth; however, androgen withdrawal following a period of hyper secretion may be cause of some aspects of musth behaviour (aggression, unpredictability, disobedience), which make bull elephants very difficult to manage in captivity.

Schutle and Rasmussen (1999) informed that high degree of individual variability in the number of responses to a sample, especially in regard to the occurrences of flehmen with musth urine eliciting the greatest number of sniffs, check, place and flehmen behaviour.

Metabolically, musth is a series off interwoven, changing stages of increasing and decreasing lipid related constituents. Released chemicals can be quantitatively related to these internal physiological events; some observed behaviours appear to result from altered chemical signals observed by (Rasmussen and Perrin, 1999).

During musth several volatile compounds exhibit several distinct concentration patterns in both urine and temporal gland secretion. Based on present knowledge, musth can be sub divided in to metabolically and behaviourally into at least five states, non musth, pre-musth, early mid musth (temporal gland secretion), mid late musth (urine dribbling) and post musth as reported by (Rasmussen and Perrin, 1999). Metabolically these stages are interwoven; hormone levels, lipid related constituents and protein related events are constantly changing (increasing and decreasing) released chemicals can be quantitatively related to these internal

physiological events. Some observed behaviour appear to result from altered chemical signals. Later in early musth, a behaviour evoking ketone, cyclohexanone is released in temporal gland secretion reported by (Perrin and Rasmussen, 1994). Later in musth a particularly foul smelling ketone, 2 nonanone released in high concentration concomitantly in temporal gland secretion and in urine. Temporal gland secretion and urine messages often are multipurpose and of variable duration (Rasmussen, 1998).

Cheeran *et al.* (2002) stated that the wild bulls in musth are less aggressive than the bulls in captivity, may be they are wandering in search of cow in estrous and spend time in courtship and mating. Aggression shown by the captive bulls in musth is some sort of diverted aggression. The bulls in musth will keep other bulls off, from its mate. Excessive sexual activity is seen in early and mid musth.

Scott (2002) indicates that several behaviour increases in frequency and duration in musth males, when the males are in musth, they tend to explore more of their yard area and spend more time investigating the area compared to the time when they not in musth. There also was an increase in ear flapping during musth. She also observed that the mature male elephants generally performed fewer than three flehmen responses per hour to urine of any type. Whereas the pubertal male generally performed more than 4 flehmen responses per hour.

Rasmussen *et al.* (2003) observed that the over looked disruptive factor during musth is the severe discomfort presumably accompanying the enormous swelling of the facial temporal glands, males in musth are often seen jabbing their tusks into mud (tusking), reminiscent of pressure relieving techniques used to alleviate toothache. In the temporal gland, glandular tissue volume increases dramatically; the gland may enlarge to basketball size and impinge on adjacent

tissue. Including the eye area such pressure pain has the potential to profoundly affect behaviour. The degree of control and rational behaviour that these males exhibit during musth and the paucity of conflicts are testimony, however to effective societal restraints.

2.5 TESTOSTERONE LEVEL DURING MUSTH

According to Jainudeen *et al.* (1972) the phenomenon of musth is related to the level of testosterone in blood plasma, which increases from 0.2-1.4 ng/ml during the non-musth phase to 29.6-65.4 ng/ml during the full musth phase.

On average concentrations of circulating androgens, including testosterone, dihydrotestosterone and androstenedione, are low during non musth (<2 ng/ml) with occasional spike up to 10ng/ml) reported by (Jainudeen *et al.*, 1972; Rasmussen *et al.*, 1984; Cooper *et al.*, 1990; Niemuller and Liptrap, 1991; Brown *et al.*, 1993). Concentrations of testosterone increase dramatically during musth, averaging 10-20 ng/ml in pre and post musth and sometimes exceeding 50 ng/ml in peak musth. The ratio of androstenedione and testosterone also changes in favour of testosterone during musth (Niemuller and Liptrap, 1991).

Niemuller and Liptrap (1991) observed that severity of musth was assessed weekly using a scale of 1 to 5 for each of eight behavioural traits including urine dribbling, temporal gland secretion and aggression. A significant correlation ($p < 0.05$) was noted between plasma testosterone concentration and the musth score value in 5 of 6 musth episodes.

Saseendran (1994) mentioned the musth associated behaviour was found to be highly correlated positively with serum testosterone level. The mean serum

testosterone level in adult male elephants was 0.95 ± 0.15 ng/ml in non-musth, 7.32 ± 1.18ng/ml in pre-musth, 22.40 ± 0.16ng/ml in musth and 6.57 ± 1.56ng/ml in post-musth.

Testosterone levels rose during musth 26 fold compared to non musth and Dihydrotestosterone was elevated 12 fold in musth, maximal aggression behaviour episode occurred during peak elevation of testosterone and Dihydrotestosterone with correlations of 0.82 and 0.89 respectively. Aggressive episodes are dependent on elevated circulating androgens acting on androgen responsive neural tissue (Dickerman *et al.*, 1997).

Fecal androgen levels increased during musth period. Values were < 500 ng/g faeces in non-musth bulls where as concentration > 1.0µg/g faeces with peak values up to 15µg/g were recorded during musth as reported by (Schwarzenberger *et al.*, 2001).

Male elephants with age 8-13 years show honey moda, 14-18 years shows post moda and 25-35 years shows older adult musth with serum androgens levels are 13.2 ng/ml (10.3-16.8 ng/ml), 21.9 ng/ml (11.0-30.0 ng/ml) and 36.7 ng/ml (31.9-65.6 ng/ml), respectively (Rasmussen *et al.*, 2002).

2.6 TESTOSTERONE AND AGGRESSION

Testosterone levels are correlated with aggression (Creel *et al.*, 1992) male social dominance (Koren *et al.*, 2002). Mating also stimulates testosterone secretion (Sapolsky, 1993) therefore testosterone is also expected to peak during the mating season.

Hamilton *et al.* (2000) demonstrated that for all androgens, the mean fecal plasma concentrations were higher during the breeding season than the non breeding season. Fecal testosterone is a valid indication of reproductive status in the male southern hairy nosed wombat, with significant correlations observed between fecal testosterone, plasma testosterone and prostate bulbourethral gland weights.

Li *et al.* (2001) informed that reproductive behaviour and the fecal steroid concentration showed overt seasonal fluctuations. There were statistically significant correlation between some male reproductive behaviour, such as anogenital sniffing, urine sniffing, urine spraying wallowing, bellowing, antler adorning, antler swags, mud chasing, herding hinds, chin resting, mounting and copulating with the fecal testosterone concentrations. These results suggested that seasonal reproductive behaviour in stags are strongly associated with circulating testosterone

2.7 TEMPORAL GLAND

Eales (1925) believes that temporal gland is especially active during the period of heat of elephant.

In Asian elephants the musth gland becomes active, swollen and discharged the secretions in bull elephants only during musth (Jainudeen *et al.*, 1972; Rasmussen *et al.*, 1984 and Lee, 1991).

In Asian elephants, activity of temporal gland was limited only during musth periods in males with greatest concentrations of testosterone of 483.07 ± 8.9 ng /ml to 547.16 ± 150.53 ng/ml and of 380 ng/ml to 431.93 ng/ml of dihydrotestosterone, in comparison with the normal level of 0.06 ng per ml of temporal gland secretion of testosterone (temporal gland secretion testosterone) and 0.34 ng/ml of temporal

gland secretion of dihydrotestosteron (Temporal gland secretion dihydrotestosterone) reported by (Rasmussen *et al.*, 1984 and Rasmussen, 1988).

Chandrasekharan *et al.* (1992) noticed that the increase in size and weight of testis and the temporal glands in musth elephants than the non-musth elephants.

Adult musth temporal gland secretion are characterized by high concentrations of five, eight and nine carbon ketones, cyclic ketones and frontalin where as young male in musth release sweet smelling alcohols, ketones and esters, (Riddle and Rasmussen, 2002).

2.8 AGE OF OCCURRENCE OF MUSTH

Musth does not occur until the elephant has attained the age of puberty, which he puts at 25 to 30 years (Steel, 1885; Evans, 1901).

The temporal gland of the elephant secretes a mucoid substance, which flows out of the temporal pore. This gland has been associated with musth or musk or musth of the elephants, which first appears at about 16-18 years of the animals life. During this period the temporal gland is noticeably enlarged and it is hypersecretory in function. (Fernado *et al.*, 1963).

In the wild Asian elephants, however, males as young as 10-15 years experience musth (Jainudeen *et al.*, 1972; Gale, 1974) although most do not regularly exhibit musth until in their twenties.

Younger males, who are in musth for a much shorter period each year than older males sometimes only days or weeks (Poole, 1987) might approach an estrous female even when not in musth to try and sneak copulations before the older musth males get there. Otherwise due to their short musth period, their chance of access to female is extremely limited.

Musth usually occurs at about the same time of the year for each individual bull, beginning at the age of 10-15 years. Musth at the ripe age of 64-66, occurs too high in intensity and for a prolonged period of 5 months at regular interval (Valandikar and Raju, 1996).

The average age of occurrence of first musth was found to be 23.94,but in some elephants first musth occurred at 16 years of age and some symptoms of musth was noticed at 35years reported by (Prasad *et al.*, 2000). Musth can begin as early as 10 –15 years of age in captivity. But seldom is observed before age 25 in the wild (Brown, 2000).

Johnsingh and Williams (2002) mentioned that when elephant bulls are around 20 years old, they begin to experience a condition known as musth. Usually musth starts during 15-20 years of age (Cheeran *et al.*, 2002).

Younger males have in their musth secretion compounds, which are honey smelling (termed moda musth), which is in Sanskrit literature is described as capable of attracting honeybees (Rasmussen *et al.*, 2002). Behaviour and the released chemicals differ between sub adult males experiencing moda or juvenile musth and older adult males.

Behaviourally, young males are mischievous, where as older males are unpredictably aggressive and chemically, they secrete compounds that differ both qualitatively and quantitatively. These changes are most evident among ketonic compounds (Rasmusseen *et al.*, 2003).

2.9 DURATION OF MUSTH

Fernado *et al.* (1963) termed that three month period "pro-musth". As the period advances the third month there is a noticeable enlargement of the temporal gland, which then hyper secretes, resulting on a copious out flow that often trickles into the animals mouth. The animal's temperament changes completely. The docile domesticated beast has to be firmly tethered as it becomes unreliable and aggressive even to its keeper or mahout. This stage can last from a few weeks even up to three months.

Over 90 per cent of adult bull elephants in good physical condition will come into musth once a year and may remain in musth for 2 to 3 months at a time stated by (Jainudeen *et al.*, 1972). About 5 per cent animals experienced musth twice during certain years. When a bull exhibits musth it is related to age and nutrition and perhaps social status (Jainudeen *et al.*, 1972; Cooper *et al.*, 1990; Lincoln and Ratnosooriya1, 1996).

In captivity Asian bulls have an early more intense and larger musth period than in the wild, resulting from better health care, nutrition and less activity. Greater numbers of African bulls are now being kept in captivity; these bulls may show an increased incidence of musth (Rasmussen *et al.*, 1984).

Musth duration increases with age for during 25 – 30 years, musth lasts from day to weeks; for elephant ranging between 31-35 years, musth lasts for several weeks; for elephants living between 36-40 years, musth lasts for 1-2 months and for elephants above 40 years of age, musth lasts for 2-4 months. (Poole, 1987).

Duration and intensity of musth may be an honest signal of male condition (Poole, 1989). The duration and timing of musth period is dependent on a complex interaction of environmental and social factors such as rainfall, vegetation biomass, number of available female and male dominance status (Poole and Moss, 1981).

Lee (1991) observed a musth period of 1 to 10 days in bulls less than 35 years and period up to 120 days in older bulls. He also observed that musth in young bulls, was suppressed by older bulls the musth and presence of estrous females initiated it, whereas in old bulls, poor body condition either shortened or made to skip musth period.

The entire duration of musth comprising of pre, violent and post musth stages was found to vary from one to three months and in one case it lasted for five months. It ranged from 30 to 45 days in 15 elephants, 45 to 60 days in 20 elephants and 60 to90 days in 92 elephants (Chandrasekharan *et al.*, 1992).

The duration of musth seems to be determined by the bull's age and health .The older bull or bulls better in condition, exhibit musth for longer duration stated by (Sukumar, 1994). Saseendran (1994) reported a much shorter duration of 21.38 days in elephants at Mudumalai.

The average duration of musth in captive elephants was 99 days with standard deviation of 36 days. The duration varied between 10 and 205 days.

Individual animal tend to show similar duration during subsequent musth periods with slight increase in duration as the age advance (Prasad *et al.*, 2000).

Illness, debility, prolonged period of work, change in climate etc. may shift the occurrence of musth. Sick and debilitated animals, which fail to exhibit musth during the usual time, may come to musth when health is regained. The duration of the musth is seen to vary in different countries Sri Lanka wild bulls 1-34 days, Myanmar bulls 3-80 days, and in Kerala shows 12 per cent of the bulls exhibit musth for 1.5 - 2 months, 16 per cent of the bulls exhibit musth for 2 – 3 months (Cheeran *et al.*, 2002).

The musth period may last a few days to more than three months depending on the animal's age and body condition (Johnsingh and Williams, 2002).

2.10 SEASON OF MUSTH OCCURRENCE

Evan (1901) says it occur most frequently in the cold season (Cheeran *et al.*, 1991; Sarma *et al.*, 1996).

In wild Asian elephants, although musth is thought to be an annual event for each male in a given population, it tends to have non-over lapping musth periods so that throughout the year there are various males in musth (Eisenberg *et al.* 1971; Jainudeen *et al.*1972). But there were peaks in January – April (45 %) and August – November (30 %) corresponding to the two periods of maximum rainfall (Jainudeen *et al.*, 1972).

In the wild population, even though larger number of bulls used to exhibit musth during the breeding months of females, seasonal occurrences could not

attribute to it as the musth occurrences was found to change in accordance with the musth timing of older bulls, number of female elephants in estrous and food availability (Lee, 1991).

Stracy (1991) also mentioned about a great tusker in Nepal Hariprasad that exhibited musth in every rainy season.

Although the musth was seen distributed through out the year 85 per cent elephants experienced musth in winter season, the period from Dec to Feb, 5 per cent in summer season, the period from March to June and 10 per cent in rainy season, the period from June to November (Chandrasekharan *et al.*, 1992).

Sabapara and Raval (1993) also observed musth during the summer months. Number of occurrences of musth in different moths of a year was found to show a definite periodicity with peaks occurring August and January (post -monsoon periods of Kerala) (Prasad *et. al.*, 2000).

2.11 ROLE OF MUSTH

Elephants in estrous show a preference for breeding with musth males observed by (Moss, 1983). In the wild males begin to enter musth at about 30 years of age and remain in musth for the longer periods of time the older they get. Males in musth are dominant to any male not in musth, regardless of any differences in size.

Males exhibit interest in their own temporal area, especially during pre musth and early musth (Rasmussen *et al.*, 1984). Before overt temporal gland secretion particular emitted compounds (e.g., 2 butanone) may inform both males and females of impending musth. An emitted relatively short lifetime medley of c_5-c_9 ketones

and frontalin informs young bulls or females of the nearby and or recent presence of a dominant musth bull (Perrin *et al.*, 1996).

During musth, males spend less time feeding, leave the bachelor herd, wander long distance in search of females in estrus, become aggressive towards other male, vocalize with infrasound, produce copious secretion from the enlarged temporal gland and drip urine from the prepuce, most mating are achieved during this phase (Hall Martin, 1987; Poole, 1989).

Even younger or small males in musth may be more attractive to females than larger, older male that is not in musth (Poole, 1989). Young male elephants were found to be significantly less likely in musth if a larger musth male was present (Poole, 1989). Young males also lose the physical signs of musth minutes or hours after an aggressive interaction with a higher-ranking musth male. It seems that they are forced out of musth by repeated encounter with older males (Poole, 1987;Slotow *et al.*, 2000). By inference, large older males may delay the onset of musth in younger males.

A male in musth may be aggressive enough to challenge on older more dominant male, and often the musth male is dominant over non musth males regardless of their size, such successfully completed male-male competition can increase the winner association with female herds (Sukumar, 1989).

Sukumar (1994) stated that the elephants are not territorial animals in the strict sense of the term a musth bull may "scent mark an area by rubbing its temporal gland on trees this might deter to other bulls from venturing into the area". Bull coming into normal musth would have increased access to cows for mating and hence increased reproductive success.

Rasmussen (1998) females can distinguish males in musth using chemical cues such as cyclohexanone, a component of urine from Asian elephants in musth (Poole, 1987). In the wild young males have been observed to cease musth when in the vicinity of a large musth males. Males in musth travel long distance to mate and this may promote out breeding (Hall martin, 1987).

Rasmussen *et al.* (2003) a single compound frontalin in the male temporal glands secretion attracts pre ovulatory females, deters pregnant females and yet is ignored by non-reproductive active females and older males. Thus frontalin conveys clear-cut different messages to male and females. The older, males, however, pay additional attention to ketones, perhaps keying into dominance rank information or daily metabolic changes in other musth males.

2.12 CONSEQUENCES OF MUSTH

In captivity male Asian elephants in musth can be very dangerous and unmanageable and are usually restrained with chains away from contact with people (Eisenberg *et al.*, 1971).

Abrupt changes in male elephants health may have a dramatic effect on his musth experience. It has been reported that only healthy males experience musth in the wild, and that older males (over 50 years of age cease to go through musth) .A common practice for captive Burmese timber elephant is to reduce rations in an attempt to shorter the length of musth (Gale, 1974).

Inns (1982) reported that the weight of the testes and epididymis of sexually mature male tammar wallaby did not show any annual changes but there was a

significant increase in the size of the prostates and Cowper's gland and in peripheral testosterone concentrations during the breeding seasons.

The aggressive and violent elephants under musth have a tendency to pull and break the chains and to free at large. This causes the elephants to suffer with necrotic and ulcerative injuries on their legs due to pressure and bite of chains. Musth is physiologically exacting, often resulting in extreme weight loss (Chandrasekharan *et al.*, 1992).

During musth a medley of seemingly conflicting metabolic perturbations occur in serum. Serum creatinine levels (released from creatine phosphate) an energy storage molecule in muscle is elevated during late musth. But urea/ creatinine ratios (indicative of protein catabolism) are higher in post musth, suggesting that protein catabolism may continue for a time after overt signs of musth. However lack of changes in serum creatinine phosphokinase during musth suggests that muscle (protein) metabolism may be less affected than fat metabolism. (Schulte and Rasmussen, 1999).

The penis complex and associated Cowper 's muscle formed a bulge under the tail in a few individuals. Generally this bulge become more prominent during musth, there was no correlation between the size of the bulge and fertility (Hildebrandt *et al.*, 2000).

Schulte *et al.* (2000) opined that adult males still experience musth in captivity and remain at the same location for long period and rarely interact with other males. Thus they can neither establish dominance out of musth nor supercede the hierarchy when in musth. Further more, males do not compete for selection by a

female. Hence the desirable qualities of musth in captive males differ from wild males and the apparent benefits of musth may be lost.

Homeostasis is disrupted by wildly elevated and fluctuating androgen levels, which may alter metabolic rates, by loss of water through urine dribbling with potential thermoregulatory and dehydration issues, the latter perhaps partially compensated for by increased oxidation of fat, and by a varying ketonic states. High blood ketones are reflected in elevated ketone levels in breath, temporal gland secretion and urine and by elevated blood and urinary P^{H}. Such occurrences may be responsible for the somnolence observed at times in musth males (Rasmussen *et al.*, 2003).

2.13 NON-INVASIVE TECHNIQUE

Wasser *et al.* (1991) has stated that faecal steroid analysis offers the potential of addressing many timely, integrative problems in reproduction and conservation biology. There have been few efforts to inter relate behavioural ecology with endocrine activity in free-living mammals, primarily because of the unavailability of the necessary tools. Faecal steroid analysis may be important for understanding the complex interrelationship between an animal's physiology and its environment.

Over the last decades, non-invasive techniques have been developed to assess hormone levels from faces (Creel *et al.*, 1992). This promising method allows the collection of daily samples for longitudinal endocrine studies of wild animals and because their results reflect hormone secretion over composite periods of time (Creel *et al.*, 1997). They may give a better daily picture of individual hormonal levels compared with blood samples.

Faecal sample often are easier to collect, but a more labourious and expensive sample preparation process hampers analysis. The lack of suitable index (such as creatinine) to standardize results and a comparatively long excretion lag time. Lag time is important and must be considered when correlating specific events or behaviour with hormone activity. Collection of an appropriate sample also is more critical for faeces because steroid concentrations are not evenly distributed (Wasser *et al.*, 1996). Best results for faeces are obtained when samples are dried and the faecal powder is separated from fibrous material, although, wet sample analysis is valid provided the faeces are well mixed before sampling. It is obvious that when blood collection is not possible non- invasive techniques to monitor endocrine status is an invaluable management tools (Brown, 2000).

Wasser *et al.* (1996) developed and validated a non invasive method to quantify faecal steroids as a tool for monitoring long term ovarian activity in free ranging African elephants and found that majority of steroid metabolites was excreted in faecal than in urine. Extracting well-mixed faecal powder from freezes dried samples, taken from the central or pre mixed portion of the wet sample, substantially reduced intra sample variation in faecal hormone concentrations. Wasser *et al.* (1996) in a study on excretory fate of estradiol and progesterone in African elephants, extracted faeces by boiling 0 .18-0.2 g lyophilized faecal powder (20 min) in 10ml of 90 per cent ethanol: distilled water (Wasser *et al.*, 2000). The supernatant was recovered following centrifugation (500 g for 15 min). The pellet was resuspended in 5ml 90per cent ethanol, vortexed (1 min), and recentrifuged. Both ethanol supernatants were combined dried completely, and redissolved in 1ml methanol. Samples were diluted in assay buffer before RIA analysis.

Blood sample represents plasma hormone levels within a very narrow time frame whereas hormone represent pooled fractions of plasma hormones, there by

providing an integrated measure of physiological status. The validity of non-invasive hormone measurement relies on the assumption that steroid hormone concentration in faeces or excrements proportionally reflect circulating levels of these hormones. A method to detect steroid metabolites in one species does not necessarily work in other species (Goymann *et al.*, 1999).

Wallner *et al.* (1999) reviewed the difficulties in collecting plasma samples and the effects of the collection procedure it self, especially under free or semi free conditions, have led investigators to seek non-invasive approaches. The procedure for analyzing various steroids in urine and faeces are well established in primates (Stavisky *et al.*, 1995; Whitten and Russel, 1996).

Faecal samples from juvenile African elephants were collected within 30 min of defaecation and stored at –20° c. Over dried (100° c) sample was powdered and mixed thoroughly and a 0.5g sub sample was mixed with 10ml of 80 percent ethanol, shaken for 30 min and centrifuged at 1700 rpm for 15 min. one milliliter of the supernatant was drawn off and stored at –20° c until EIA analysis. (Stead *et al.*, 2000).

Faecal steroid analysis becoming more popular among the field and laboratory scientists, because of the benefits associated with sampling procedure that do not require restraint anesthesia and blood collection include less risk to both subject and the investigator, as well as the potential to obtain endocrine profiles that do not reflect the influence of stress and the collection of physiological data permits the evaluation of the relationship between endocrine status and behaviour (Stavisky *et al.*, 2001; Mostl and Palme, 2002).

Oates *et al.* (2002) has reported that faecal steroid analysis involves daily sample collection with no stress or risk to the animal and enables the reproductive changes over time to be monitored. Faecal steroid analysis therefore is a powerful tool in field studies using free ranging animals when ultrasound is not practical.

Noninvasive endocrine techniques allow repeated sampling of the same individual to study causes and consequences of variation in individual behaviour and physiology (Pelletier *et al.*, 2003).

2.14 FAECAL STEROID STORAGE AND EXTRACTION

Lasley and Kirkpatrick, (1991); Schwarzenberger *et al.*, (1996); Terio *et al.*, (2002) stated that routine monitoring of gonadal and adrenal steroids in captive populations provides valuable information regarding their physiology, health status and the impact of environmental factors and management practices. Therefore non-invasive faecal steroids assays have been developed to monitor concentration of excreted steroids in captive species.

Creel *et al.* (1996) reported that faecal steroids analysis has become a more widely appreciated field technique. Applications have expanded to consider steroids concentrations in relation to stress and aggression in males (Lynch *et al.*, 2002).

Korndorfer *et al.* (1998) stated that a technique for extraction of reproductive hormone from faeces is an important tool for monitoring reproductive functions and also for animal ethologists. As a non- invasive process, it presents several advantages permitting the monitoring of reproductive physiology under conditions and samples are collected, transported and stored.

Freeze-dried (lyophilized) samples before extraction are used and the dry weight of the samples as references for hormone levels to control the differences in water content. This method is commonly used to prepare faecal samples of birds and mammals for hormone analysis (Goymann *et al.*, 1999; Monfort *et al.*, 1998).

Faecal samples are collected in to 20ml plastic container and covered with 70 per cent ethanol to inhibit bacterial growth and degradation of steroids. Before extraction, samples are lyophilized. Thereafter, 0.25g faeces were extracted with methanol as described for the Indian rhinoceros (Schwarzenberger *et al.*, 2000).

The extraction and immunoassay of faecal steroids is an increasingly common technique, used in both captive and field studies to provide an approximate of an animals circulating concentration of hormones through non-invasive methods. Storage of fecal samples is of critical concern because faecal bacteria metabolize faecal steroids within hours after deposit. Ethanol is often used as a preservative for faecal samples stored for several hours at room temperature. A dynamic pattern of changing faecal metabolite concentration and after practical and analytical guidance to field workers for situations in which ideal conditions for stabilizing hormones are not available (Khan *et al.*, 2002). Subsequently, ethanol either alone or with sodium azide has been used as a preservative for short-term storage of five months for faecal samples (Wasser *et al.*, 1997) or long term storage for five months (Cavigelli, 1999) to 3.5 years (Curtis *et al.*, 2000).

Any freshly voided faeces were collected and stored individually in plastic containers without preservative at -15° c until processing. Any foreign material, such as soil and plant matter was removed from the samples before being freeze dried for approximately five hours and then reduced to a powder using a coffee grinder (Oates *et al.*, 2002).

Faecal steroid analysis is a powerful tool that can provide important information on the health, physiology and reproductive status of non-domestic species. However, studying free ranging animals requires that faeces be stored and transported from the collection site to the laboratory in a manner that prevents degradation or alteration of steroid metabolites. Concentrations of gonadal and adrenal steroid hormone were analyzed in faeces stored frozen at –20° c or at room temperature in 95 per cent ethanol (Terio *et al.*, 2002). Drying of samples in a solar or conventional oven resulted in variations in concentrations of steroid hormones, with the exceptional of androgens.

Materials and Methods

3. MATERIALS AND METHOD

3.1 EXPERIMENTAL LOCATION

Guruvayoor (10^0 35 ' N, 76^0 0 'E) is a temple town, which is located in the Thrissur District of Kerala State in India. The Guruvayoor Devaswom, which maintains 63 elephants, is considered as the world's largest single holder of tamed elephants. The present research work was carried out, utilizing the adult healthy captive male Asian elephants maintained by Guruvayoor Devaswom at Punnathurkotta under uniform management and nutritional regime.

3.2 EXPERIMENTAL ANIMALS

Six captive adult male Asian elephants were randomly selected, which had previous annual musth episode history. Elephants were grouped into four stages namely,

1. Non – musth
2. Pre – musth
3. Musth
4. Post – musth

Feeding and management during the above stages were recorded and analyzed.

3.3 FEEDING

The feeding schedule of elephants in Punnathurkotta were recorded and documented. The average feed allowance for elephants is fixed based on age, body weight and height of the elephants. The proximate analyses of feeds given to elephants were conducted by taking random feed samples. The quantity of feed given

to the elephants according to the body weight and its equivalent metabolic body weight was worked out. The nutrient availability was worked out as per feed allotted to the elephants was compared in accordance with the requirements prescribed by (Anathasubramaniam, 1979). In addition to the regular diet, the elephants were given restorative diet during the Karkkidakom month of July- August for 30 days. The proximate composition of the restorative diet is given in Table 1.

Table 1. The proximate composition of the restorative diet

Sl.No	Ingredients (kg)	Group A	Group B	Group C
		Above 4000 kg body weight of elephants	3000 to 4000 kg body weight of elephants	Below 3000 kg body weight of elephants
1	Rice (kg)	5	4	3
2	Green gram (kg)	2	2	1.5
3	Ashtachooram (g) *	50	50	50
4	Chavanaparasam (g) *	500	500	250
5	Liv 52 Bolus (nos.)	3	3	2
6	Bio boost Bolus (nos.)	6	4	2
7	Haematinic (ml)	200	200	100
8	Mineral mixture (g)	50	50	50
9	Salt (g)	100	100	50
10	Turmeric powder (g)	50	50	25
11	Gingelly oil (ml)	200	150	100

* Ayurvedic recipie

3.3.1 Proximate Analysis of Feed

Samples of leaves and stem of palm (*Caryota urens*), Napier grass (*Pennisetum purpureum*) and food given in normal, pre-musth, musth and post-stages were collected from the camp. The palm and Napier leaves and stems were chopped to a size of 2cm, mixed and quartered to obtain an 1.5 kg samples. Samples from this were taken for dry matter determination. The rest of the material was dried in hot air oven and pulverized. Thus samples were made available for analysis. Analyses of samples have carried out as per the methods described in (AOAC, 1990). The detailed proximate composition of feed is given in Table 2.

Table 2. Proximate composition of feed

Sl.No	Composition (%)DM	Palm leaves	Napier grass	Pre-musth diet	Cooked rice and gram	Cooked rice
1	Dry matter	38	19.05	44.94	23.54	17.35
2	Crude fiber	24.50	30.70	14.50	0.86	0.92
3	Crude protein	7.20	8.50	12.30	13.40	8.40
4	Ether extract	1.60	2.20	7.80	3.84	2.80
5	Nitrogen free extract	57.30	46.10	56.40	71.80	86.48
6	Total ash	9.40	12.50	9	10.10	1.40
7	Calcium (mg)	3.80	1.50	3.20	5.20	0.60
8	Phosphorus (mg)	1.70	0.80	1.52	3.70	0.28

3.4 MANAGEMENT

The management of the Asian elephants is quite anomalous in the conservation world, with circumstances quite bizarre compared to other large mammals. The elephant camp having 14.5 acres, which accommodated 63 elephants. Elephants were tethered under the shades of tree with adlibitum water supply. Elephants were tied in such a way that with their head and forequarters always in a slightly elevated position. Separate enclosure was designed and built ideally to accommodate sick elephants, which were in diseased condition. Elephants were trained to collect their feed (palm leaves) from the feed collection yard, where as grass was provided to their tethering site by truck. Elephants were normally bathed in the ground level water tank pond. Atmost care was given to foot, skin, tail, eye, ear and trunk. Tusk trimming was carried out once in two year. Each elephant has two or three mahouts irrespective of its size and age. About 162 mahouts were there to take care of the elephants. One full time veterinarian and one livestock inspector were available in the camp for veterinary assistance. Daily the mahouts have to report to the veterinarian on the feed intake and health status of the elephants. The veterinarian also inspects the animal during his daily field rounds.

Routine deworming and faecal examination were carried out in every six months. No regular prophylactic vaccination was followed, since there was no outbreak of diseases. The common diseases encountered were foot lesions, indigestion, abscesses and impaction of colon. Dung was removed regularly from the tethering site and stored in particular area. Once in every three to six months dung was removed from there and used as manure. The elephants were utilized for temple processions in Guruvayoor temple and other temples in near by area. Records maintained in the elephant camp were that of treatment, tusk trimming, livestock and restorative therapy register. The entry fee is fixed for public to generate income,

which partly meet the expenses of the camp. All the elephants in the camp were insured based on the age, height at shoulder and value of tusk.

3.4.1 Musth Management

As a general rule, the bulls were kept separately during musth, because of aggressive and unpredictable behaviour against normally familiar, well-accepted persons and complete incalculability during musth. The usual practice is to tether the elephants in musth on trees or pillars under shade with specially made strong chains on one of the hindlimb and diagonally opposite forelimb. Mischievous and violent elephants were tied with additional ropes in their hindlimb, which reinforces the restraining. Water tub with constant supply of drinking water was provided to the elephants. Elephants were showered with water atleast once in a day to cool the body. During pre-musth and musth periods, elephants were provided with special food, which are presented in the Table 3.

Table 3. Pre- musth and musth diet

Sl.No	Type of ingredients	Ingredients in quantity (kg)	
		Pre-musth	Musth
1	Pressed rice	5 kg	-
2	Dates	4 kg	-
3	Egg	25 nos.	-
4	Plantain	30 kg	20-30 kg
5	Cooked rice	5 kg	-

3.4.2 Daily Routine

The daily routine activities of the camp are presented in Table 4.

Table 4. Daily routine

Sl.No	Schedule	Activities
1	8.00 am	Muster
2	8.30 am	Cleaning and watering
3	9.00 am	Collecting feeds
4	9.15 am	Bathing
5	11.30 am	Feeding
6	2.00 pm	Watering
7	3.00 pm	Feeding

3.5 BEHAVIOURAL OBSERVATION

A preliminary study was conducted to familiarize with the elephants and their behaviour for developing methods of observation. The behavioural observations were made from 0800 to 1600 hours, which coincide with the daily routine of the camp. Observation periods lasted for one hour and behavioural events (i.e.,

behaviour that usually are of very brief in their duration) were recorded continuously (Martin and Bateson, 1993).

Behavioural data were obtained on each animal from 0800 to 1600 hours using direct observations. Behavioural data were collected by observing focal animals for 1 hour and continuously recording all the frequencies and intensities of selected behaviour from 50m distance. An ethogram of behaviour to be recorded was prepared as given in the Table 5. The observation period was sub divided into six short periods of one hour duration as (i) 9-10 a.m. (ii) 10-11 a.m. (iii) 11a.m.-12 noon. (iv) 12 noon –1 p.m (v) 2-3 p.m and (vi) 3-4 p.m. Each focal animal was observed for 6 days by selecting one period in each day. During the six days observation in each stage of non-musth, pre- musth and post- musth periods of each animal was observed in all the timing of the day. During musth period the diurnal observation was done weekly for the whole period of musth. A total of sixteen hours of observation in musth stages and six hours of observation in non-musth, pre musth and post musth stages on each animal were recorded. A total of 193 hours of observation were carried out during the present study.

3.6 RECORDING METHOD

3.6.1 Focal Animal Sampling

Focal animal sampling is a sampling method in which all occurrences of specified action of an individual or specified group of individual are recorded during each sample period and a record is made of the length of each sample period and for each focal individual, the amount of time during the sample that is actually in view. One of the great strengths of focal animal sampling is that in order to stay with a

focal individual, the observer can follow him and obtain the observation on him in situations in which he would not ordinarily be under observation (Altmann, 1974).

Focal animal sampling means, observing one individual for a specified amount of time and recording all instances of its behaviour usually for several different categories of behaviour (Martin and Bateson, 1993). The above definitions for focal animal sampling were used for the behavioural observations carried out during the study.

3.6.1 Ethogram

Ethogram, which is a catalogue of descriptions of the discrete, species typical behaviour patterns that form the basic behavioural repertoire of the species (Lehner, 1987). The present study was developed from the diverse array of behavioural descriptions for elephants provided by (Poole *et al.*, 1987; Saseendran, 1994; Langbauer, 2000 and Scott, 2002).

Table 5. Ethogram

Sl.No	Behaviour	Description
1	Feeding/ Drinking	Ingestion of food and consumption of water. Involves the individual gathering food or water with its trunk and lifting it into its mouth.
2	Dusting/Mudding	Individual lifts quantities of sand, dust, mud or dirt and tosses on to own body with trunk. Includes water bathing, when individual own body with water.
3	Trunk up	Lifting up above head towards a stimulus.
4	Body sway	Swaying the body from side to side repetitively.
5	Flehmen	The flattened surface of the tip of the trunk (nostril) is brought to the mouth and the trunk tip is placed into contact with the roof of the mouth. The elephant invariably has brought its trunk in contact, or in near contact, with something before flehmen.
6	Head high	Head held high so that tusks are horizontal to ground.
7	Object throw at keepers/ public	Individual throws stones or other objects towards keepers or public.
8	Aggression to trainer	Individual makes aggressive move or actions towards trainer.

Table. 5 Continued.....

Sl.No	Behaviour	Description
9	Penis jerking/ masturbation	Erected S-shaped penis repeatedly hitting ventrum.
10	Rubbing/ grooming	Individual rubs body against substrate such as tree or wall.
11	Chain pulling by trunk/tusk/foot	Pulling the chain tied in the limbs with trunk /tusk /foot.
12	Freezing of ears	Both earflaps remain erect for few seconds.
13	Temporal gland secretion	Temporal gland secretion seen as a moist patch on side of face.
14	Urine dribble	Continues dribbling of urine from the sheathed penis of musth bull. Gives hind leg a black, shiny appearance. Also has chemical communication function.
15	Self directed behaviour	Individual touches, rubs or grooms own body. May use mouth, trunk or appendages to contact any area of the body.

3.6.2 Behavioural Data Collection Chart

The behavioural data collection sheet developed by (Stead, 2000) for measuring the behaviour of African elephants is modified for the present study including relevant and more important behavioural measures. A detailed scoring sheet was given in the Appendix 1.

3.6.3 Documentation

Documentation of behaviour pattern was taken using camera (still picture).

3.6.4 Body Weight

The body weight of the elephants (before and after musth period) was recorded using a weighbridge in the camp at morning before feeding).

3.7 FAECAL SAMPLES

3.7.1 Collection and Storage

Faecal samples were collected weekly three times from six elephants in each stage. Samples were collected with in 30 minutes of defaecation. Faecal bolus collected was mixed thoroughly and handful of random faecal samples was placed in to a polyethylene freezer bag and stored at -20^0c till the preparation for extraction and RIA analysis (Stead *et al.*, 2000).

3.7.2 Extraction for Radio Immunoassay

Frozen faecal samples were dried in freeze dryer (ishlin)-50^0c until dry. Each sample was powdered and mixed thoroughly. A 0.2 g of the sub-sample was mixed with 5ml of 90 per cent ethanol in a test tube and vortexed briefly. The tubes were boiled in a water bath (90^0c) for 20 minutes, adding ethyl alcohol to avoid it from

boiling dry. The extract was brought up to pre-boil levels with 90 per cent ethanol and centrifuged at 1500 rpm for 20 minutes. The extracts were poured off into another storage vial. To the remaining faecal powder 90 per cent ethanol was added again and vortexed for 30 seconds and centrifuged at 1500 rpm for 15 minutes. The first and the second extracts were combined and dried down and reconstituted in one ml of methanol, and vortexed for brief period. The methanol extracts were stored at – 20^0c until RIA analysis (Brown *et al.*, 2000).

3.7.3 Radio Immunoassay of Faecal Testosterone

Faecal testosterone concentrations were determined using clinical Assay ™ gamma coat ™ (^{125}I) Testosterone radioimmunoassay kit (Radium Vial del Mare, Pomezia, Italia).

3.7.4 Principle

The unknown concentration of a hormone, H is determined by measuring how much of a known amount of the radioactively labeled hormone. H^*, binds to a fixed quantity of anti –H antibody in the presence of H. This competition reaction is easily calibrated by constructing a semi -logarithmic curve indicating how much H^* binds to the antibody as a function of H.

3.7.5 Procedure

1. To the bottom of the appropriate gamma coat tubes the following were added.
2. 100µl of testosterone control serum blank and testosterone serum standards (0,0.25,0.5,1.5,6.0,15.0ng/ml).
3. 100µl of samples (extracted faecal samples) were added to each tube.
4. 500µl of radioactive conjugate reagent was added to each tube and mixed on a vortex mixer set at low speed.

5. The tubes were incubated for 1 hour in a 37 ^{0}c water bath.
6. The contents of the tubes were decanted after incubation.
7. The tubes were counted in a gamma counter (1470 RiaCalc WTZ Program 3.6 Automatic gamma counter) for one minute suited for Iodine –125.
8. A standard curve was plotted with counts per minutes (CPM) values and testosterone concentration standards 1(0,0.25,0.5,1.5,6.0,15.0ng/ml on semi logarithmic graph paper.
9. The counts per minutes (CPM) bound for each tube corresponding to each samples were used to interpolate the unknown values from the standard curve.

3.8 DATA ANALYSIS

The data obtained were statistically analyzed using the MS Excel and statistical software package 'MSTATC'. Pearson product moment correlation of non- parametric analysis was used to find the correlation between behavioural scores and faecal testosterone levels in each individual elephants. The statistical significance of the faecal testosterone level between non-musth and musth stage was worked out using Student 't' test.

A

B

C

D

E

F

A. Temporal gland secretion

B. Temporal gland enlargement

C. Urine dribbling and Green Penis syndrome

D. Erection of penis

E. Masturbation

F. Flehmen response

Plate 1. Musth behaviour

A

B

C

D

E

F

A. Perineal gland enlargement
B. Trunk raising
C. Standing tall
D.Throwing objects (Hurling)
E. Chain pulling
F. Freezing of ears

Plate 2. Musth behaviour

A

B

C

D

E

F

A. Digging ground with tusk(Tusking)
B. Digging ground with trunk
C. Playing with inanimate objects
D. Head high & Jaw out
E. Face check (Temporal gland)
F. Splashing of water

Plate 3. Musth behaviour

A

B

C

D

E

F

A. Dusting or Mudding
B. Splashing of water
C. Watering
D. Watering
E. Grooming
F. Relation with mahout

Plate 4. General behaviour

A

B

C

D

E

F

A. Feed collection yard
B. Elephant collecting feed
C. Elephant carrying feed
D. Feeding
E. Feeding of grass (Truck)
F. Restorative diet

Plate 5. Feeding

A

B

C

D

E

F

A. Tethering place
B. Housing
C. Bathing of elephants (pond)
D. Individual bathing
E. Foot care
F. Treatment of elephant

Plate 6. Management

A

B

C

D

E

F

A. Tethering (2 chain)
B. Tethering (3 chain)
C. Tethering (Rope & chain)
D. Training of elephant
E. Commanding of elephant
F. Elephant (work)

Plate 7. Management

A

B

C

D

A. Lifting leg
B. Relation with mahouts (musth)
C. Pre musth ration
D. Feeding of banana (musth)

Plate 8. Musth management

Results

4. RESULTS

4.1 HISTORY

History of 63 elephants, comprising of 48 males of 16 to 69 years of age were taken to get a preliminary understanding of management practices in Punnathurkotta and the results are presented in the Tables 6 - 7.

4.2 FEEDING

The main ingredients of diet of elephants at Punnathurkotta are palm leaves and Napier grass. The quantity of diet for each elephant is fixed according to the dry matter intake capacity of elephants (5 % of body weight) and dry matter content of feed. The young elephants were divided into three groups of 1000, 2000 and 2500 kg body weight and adult elephants were divided into three groups of 3000, 4000 and 5000 kg body weight. The amount of palm leaves and Napier grass given to growing elephants were 60 to 100 kg and 20 to 50 kg, respectively. Similarly for adult elephants amount ranges from 140 to 240 kg and 50 to 100 kg, respectively. The amount of feed given to elephants and their nutrient requirements and availability were worked out and presented in Tables 8-13.

4.3 SEASONAL DISTRIBUTION

Seasonal occurrence of musth in 48 male elephants for the past three years were documented, analysed and furnished in the Tables 14-17 and graphically represented in Fig.1 and Fig.2. The whole year was divided into four seasons namely winter, summer, monsoon and post monsoon. The data were subjected to two-way random sampling analysis. The maximum percentage of musth episode was occurred in winter (30 %) followed by summer (29 %), post monsoon (27 %) and monsoon (14 %).

4.4 AGE AND DURATION OF MUSTH

The incidence of musth among elephants of different age groups are presented in Tables 18-21 and graphically represented in Fig. 3. The average age of first musth observed among elephants in Punnathurkotta was 24.10 ± 0.50 years. The lowest age at which first musth occurred was 16, where as the highest age of first musth occurrence was 29years.

Duration of musth occurrence was found to be influenced by age. In younger age group of 20 to 30years, the average duration observed was 69.86 ± 5.78 days. As the age (30 to 50 years) advanced the duration of musth was found to increase to 108.45 ± 6.81 days and in older groups of 50 to 60 years the duration was found to decrease to 97.45 ± 4.96days.

4.5 BODY WEIGHT

For the first time an attempt has been made to record the body weight changes during musth period. Six adult male elephants were weighed before and after occurrence of musth episodes and its body weight changes are presented in the Table 22. In growing elephants of 20 to 30 years age group, maximum weight loss of 120 kg was observed during musth, where as in older age group of 30 to 60 years the weight loss was only 40 kg.

4.6 BEHAVIOURAL OBSERVATION

Behavioural changes were observed by focal animal sampling technique using a behaviour data collection chart. A total of sixteen hours of observation in musth stages and six hours of observation in non-musth, pre- musth and post- musth stages on each animal were made. A total of 193 hours of observation were carried out for the present study. The behaviour observed were aggression, standing tall, erection/masturbation, mudding/dusting, throwing objects, relation to mahouts,

flehmen responses, splashing water or saliva, fanning of ears, swaying, chain pulling, grooming, trunk rising, lifting legs, trunk on tusk, tethering, feeding, watering, urination, defecation, obeying, temporal gland enlargement temporal gland secretion, bulging of penis base. Increased alertness, increased frequency of disobedience to mahout, with or without temporal gland enlargement, bulging of penis base were observed as the conspicuous behaviour during pre-musth, increased incidence and intensity of the above behaviour, with conspicuous temporal gland enlargement and temporal gland secretion were observed during musth. In post-musth, the elephants exhibited subdued musth aggressive behaviour. The average behavioural scores obtained for elephants in normal stages was about 12.33 ± 1.22. In pre-musth stage scores and post- musth stage the score were 34 ± 4.69 and 19.66 ± 3.10, respectively. In musth the score shot up to 70.29 ± 2.46 in first month, 78.70 ± 2.48 during second month, 68.15 ± 3.31 in third month, 58.15 ± 5.55, 51.25 ± 14.44 in fourth and fifth month, respectively. The individual elephants were observed for the behavioural studies in different stage like normal, pre-musth, musth and post-musth and the respective scores are given in the Table 23.

4.7 FAECAL TESTOSTERONE LEVEL

Faecal testosterone levels of six male elephants are presented in the Table 24. The level of testosterone in normal, pre-musth, musth and post-musth stages were presented in the Table 25. The mean faecal testosterone level during normal stage was about 770.96 ± 35.62 (ng/g). The levels has increased to 1821.58 ± 129.54 (ng/g) during pre-musth stages and reached a peak level of 4307.81 ± 242.40 (ng/g) in second month of musth stage. This level has once again drop down to 1072.75 ± 41.85 (ng/g) during post-musth stage. Faecal testosterone levels in each individual during pre- musth and musth were significantly increased than the normal and post-musth. This high faecal testosterone levels during the musth stages were found to be

positively correlated with the high behavioural scores during these periods. The higher the testosterone levels, the higher were the behavioural scores.

4.8 BEHAVIOURAL SCORE AND TESTOSTERONE

The positive correlation ($r = 0.82$, $P < 0.0002$) between behavioural score and faecal testosterone was observed in all experimental elephants. A significant difference in faecal testosterone level was found in normal and pre-musth, normal and musth, pre-musth and musth, musth and post- musth, normal and post- musth and post- musth and pre- musth. Comparison of faecal testosterone level and behavioural score of individual elephants are presented in the Figures 4 - 9.

4.9 INDICATORS OF MUSTH

Quantitative and qualitative indicators of musth are presented in the Tables 26 and 27.

Table 6. History of elephants

Sl.No	Name of the elephants	Age of the elephants (Years)	Age at first musth (Years)
1	Balaram	18	16
2	Junior Kesavan	18	17
3	Junior Madhavan	30	20
4	Bal Krishnan	28	18
5	Murali	27	16
6	Balu	30	27
7	Sudeepan	26	23
8	Kuttinarayanan	27	22
9	Akshayakrishnan	27	24
10	Junior Vishnu	27	22
11	Gopi Kannan	28	24
12	Vineetha Krishnan	26	23
13	Mukundan	24	16
14	Naveenatha Krishnan	21	20
15	Devadas	29	24
16	Vineeth	24	21
17	Siddharthan	25	20
18	Vishnu	39	27
19	Rajasekharan	38	26
20	Ramu	38	27
21	Kesavan kutty	38	24
22	Appu	36	25
23	Sathyanarayanan	39	26
24	Gopikrishnan	37	26

Table 6. Continued...

Sl.No	Name of the elephants	Age of the elephants (Years)	Age at first musth (Years)
25	Vinayakan	36	25
26	Nandan	32	27
27	Sreedharan	33	27
28	Achuthan	33	29
29	Sankaranarayanan	31	28
30	Kesavan	35	25
31	Chandrasekharan	32	21
32	Lakshmikrishnan	31	26
33	Prasakan	42	28
34	Indrasen	42	21
35	Gopikrishnan	42	25
36	Radhakrishnan	49	27
37	Kannan	42	23
38	Madhavankutty	41	28
39	Junior Lakshamanan	41	26
40	Krishnan	41	27
41	Pathamanabhan	64	27
42	Lakshmann	70	27
43	Valiyakesavan	54	28
44	Ramachandran	62	24
45	Kuttykrishnan	57	27
46	Kuttyshankaran	53	24
47	Ramankutty	53	25
48	Narayanakutty	53	28

Table 7. History of musth episode of experimental animal

Sl.No	Name of elephants	Date of birth	Present age	Age at first musth	Season		Duration		Body weight before musth	Body weight after musth	Disease during past year
					Past Year	Present year	Past Year	Present year			
1	Chandrasekhran	1972	32	23	December-March	October-February	88	107	3580	3540	Nil
2	Gopalakrishnan	1962	42	25	November-March	November-March	116	175	4800	4755	Nil
3	Junior Kesavan	1986	18	17	February-March	November-January	24	84	3220	3020	Nil
4	Prakasan	1962	42	28	December-February	December-February	64	43	4040	4000	Poor body condition, Digestive problems and chain wound
5	Sathya narayanan	1965	39	26	January-May	February-June	128	132	6290	6240	Nil
6	Vishnu	1965	39	30	January-April	January-March	107	80	4815	4760	Poor body condition, severe impaction and chain wound

Table 8. Calculated dry matter requirement of growing elephants

Body weight (kg)	Metabolic bogy weight = (Body weight$^{0.73}$)	Palm leaves (kg)	Grass (kg)	Dry matter requirement 142 g/kg Metabolic body weight	Palm leaves dry matter availability 1.45%	Grass dry matter availability 4%	Total dry matter availability
1000	154.88	60	20	21.99	22.80	4.80	27.60
2000	256.89	100	30	36.48	38.00	7.20	45.20
2500	302.34	120	50	42.93	45.60	12.00	57.60

Table 9. Calculated digestible crude protein requirement of growing elephants

Body weight (kg)	Metabolic bogy weight = (Body weight$^{0.73}$)	Palm leaves (kg)	Grass (kg)	Digestible crude protein requirements 7 g/ kg Metabolic body weight	Palm leaves dry matter availability 1.45%	Grass dry matter availability 4%	Total dry matter availability
1000	154.88	60	20	1.08	0.87	0.80	1.67
2000	256.89	100	30	1.80	1.45	1.20	2.65
2500	302.34	120	50	2.12	1.74	2.00	3.74

Table 10. Calculated total digestible nutrient requirement of growing elephants

Body weight (kg)	Metabolic bogy weight = (Body weight$^{0.73}$)	Palm leaves (kg)	Grass (kg)	Total digestible nutrient 70 g/ kg Metabolic body weight	Palm leave total digestible nutrient Availability 1.45%	Grass total digestible nutrient availability 44%	Total Total digestible nutrient availability
1000	154.88	60	20	10.84	14.76	26.40	41.16
2000	256.89	100	30	17.98	24.60	44.00	68.60
2500	302.34	120	50	21.16	29.50	52.80	82.30

Table 11. Calculated dry matter requirement of adult elephants

Body weight (kg)	Metabolic bogy weight = (Body weight$^{0.73}$)	Palm leaves (kg)	Grass (kg)	Dry matter requirement 108 g/kg Metabolic body weight	Palm leave dry matter availability 1.45%	Grass dry matter availability 4%	Total dry matter availability
3000	345.38	140	50	37.30	53.20	12.00	65.20
4000	426.09	200	70	46.01	76.00	16.80	92.80
5000	501.47	240	100	54.15	91.20	24.00	115.20

Table 12. Calculated digestible crude protein requirement of adult elephants

Body weight (kg)	Metabolic bogy weight = (Body weight$^{0.73}$)	Palm leaves (kg)	Grass (kg)	Digestible crude protein requirements 6 g/kg Metabolic body weight	Palm leave digestible crude protein availability 1.45%	Grass digestible crude protein availability 4%	Total digestible crude protein availability
3000	345.38	140	50	2.07	2.03	2.00	4.03
4000	426.09	200	70	2.55	2.90	2.80	5.70
5000	501.47	240	100	3.00	3.48	4.00	7.48

Table 13. Calculated total digestible nutrient of adult elephants

Body weight (kg)	Metabolic bogy weight = (Body weight$^{0.73}$)	Palm leaves (kg)	Grass (kg)	Total digestible nutrient 58 g/kg Metabolic body weight	Palm leave total digestible nutrient availability 1.45%	Grass total digestible nutrient availability 4%	Total total digestible nutrient availability
3000	345.38	140	50	20.03	34.44	19.60	54.04
4000	426.09	200	70	24.00	49.20	28.00	77.20
5000	501.47	240	100	29.01	59.04	33.60	92.64

Table 14. Season of musth in the age group between 20 to 30 years

Sl.No.	Name of the elephants	Season of musth		
		2002 (Year)	2003 (Year)	2004 (Year)
1	Junior Madhavan	Dec-Feb	Nov-Feb	Nov-Feb
2	Balakrishnan	Nov-Mar	Mar-Apr	Nov-May
3	Murali	Feb-May	Mar-June	Mar-June
4	Balu	Nov-Dec	Nov-Jan	Nov-Jan
5	Sudeepan	Oct-Nov	Oct-Nov	Oct-Dec
6	Kuttinarayanan	Apr-Jun	Apr-Jun	Apr-July
7	Akshayakrishnan	Nov-Dec	Nov-Dec	Nov-Jan
8	Junior Vishnu	Dec-Jan	Dec-Feb	Dec-Mar
9	Gopi Kannan	Nov-Jan	Nov-Jan	Nov-Feb
10	Vineetha Krishnan	Dec-Jan	Dec-Jan	Dec-Feb
11	Mukundan	Dec-Feb	Dec-Mar	Dec-Mar
12	Naveenatha Krishnan	Nil	Feb-Apr	Feb-Apr
13	Devadas	Dec-Mar	Dec-Mar	Dec-Mar
14	Vineeth	Dec-Jan	Dec-Jan	Dec-Feb
15	Siddharthan	Jan-Mar	Jan-Mar	Feb-April

Table 15. Season of musth in the age group between 30 to 40 years

Sl.No.	Name of the elephants	Season of musth		
		2002 (Year)	2003 (Year)	2004 (Year)
1	Vishnu	Jan-Mar	Jan-Apr	Jan-Mar
2	Rajasekharan	Apr-Sep	Apr-Sep	Apr- Oct
3	Ramu	July-Oct	Aug-Sep	Aug-Sep
4	Kesavan kutty	Sep-Jan	Sep-Jan	Sep-Jan
5	Appu	June-Oct	June-Oct	June-Nov
6	Sathyanarayanan	Jan-May	Jan-May	Feb-June
7	Gopikrishnan	Sep-Dec	Sep-Dec	Sep-Jan
8	Vinayakan	Dec- Apr	Dec-Apr	Dec-May
9	Nandan	Sep-Nov	Sep-Dec	Sep-Dec
10	Sreedharan	Mar-Aug	Apr-Sep	Apr-Sep
11	Achuthan	July-Oct	July-Oct	July-Oct
12	Sankaranarayanan	Nov-Jan	Nov-Jan	Nov-Feb
13	Kesavan	Apr-Aug	Apr-Aug	Apr-Sep
14	Chandrasekharan	Oct-Feb	Oct-Feb	Oct-Feb
15	Lakshmikrishnan	Nov-Jan	Nov-Jan	Nov-Jan

Table 16. Season of musth in the age group between 40 to 50 years

Sl.No.	Name of the elephants	Season of musth		
		2002 (Year)	2003 (Year)	2004 (Year)
1	Prakasan	Dec-Feb	Dec-Feb	Dec-Feb
2	Indrasen	Apr- July	Apr- Aug	Apr- Sep
3	Gopikrishnan	Oct-Feb	Nov-Mar	Nov-Mar
4	Radhakrishnan	July-Nov	May-Sep	May-Aug
5	Kannan	May-Aug	May-Sep	May-Sep
6	Madhankutty	Dec-Feb	Dec-Mar	Dec-Apr
7	Junior Lakshamanan	Dec-Apr	Dec-Apr	Dec-Apr
8	Krishnan	Mar-May	Mar-May	Mar-May

Table 17. Season of musth in the age group between 50 to 60 years

Sl.No.	Name of the elephants	Season of musth		
		2002 (Year)	2003 (Year)	2004 (Year)
1	Pathmanabhan	May- Sep	May-Aug	May-Aug
2	Lakshmann	Oct-Jan	Oct-Jan	Oct-Dec
3	Valiyakesavan	May-Oct	May-Sep	May-Aug
4	Ramachandran	Mar-May	Mar-May	Mar-May
5	Kuttykrishnan	Oct-Dec	Apr-May	Apr-May
6	Kuttyshankaran	Nov -Feb	Nov-Mar	Nov-Mar
7	Ramankutty	Oct-Dec	Oct-Dec	Oct-Dec
8	Narayanakutty	May-Oct	May-Oct	May-Oct

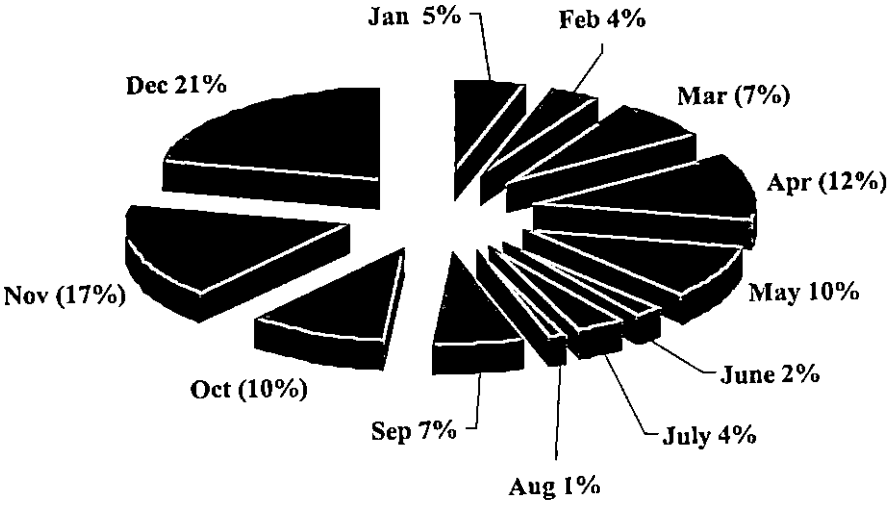

Fig 1. Occurrence of musth (Monthwise)

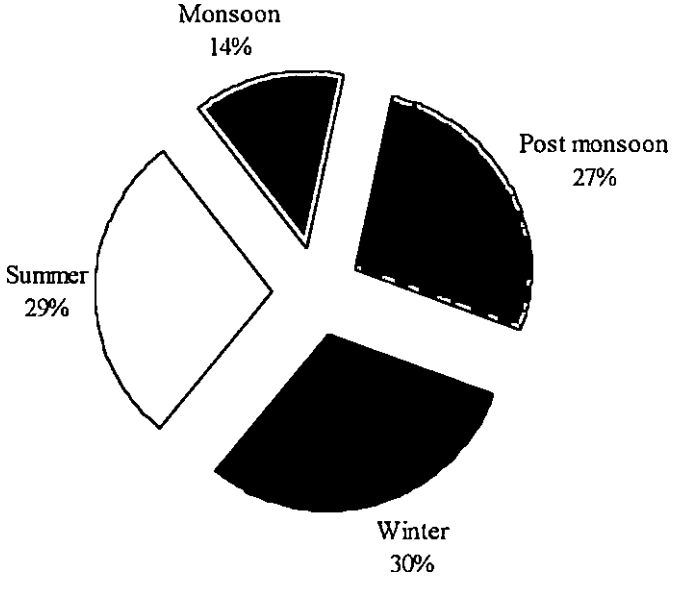

Fig 2. Occurence of musth (Seasonwise)

Table 18. Duration of musth in the age group between 20 to 30 years

Sl.No.	Name of the elephants	Duration of musth (Days)		
		2002 (Year)	2003 (Year)	2004 (Year)
1	Junior Madhavan	63	72	84
2	Balakrishnan	110	148	54
3	Murali	83	84	92
4	Balu	67	75	92
5	Sudeepan	33	49	71
6	Kuttinarayanan	56	59	67
7	Akshayakrishnan	43	56	62
8	Junior Vishnu	64	77	91
9	Gopi Kannan	66	81	95
10	Vineetha Krishnan	45	57	71
11	Mukundan	79	87	92
12	Naveenatha Krishnan	0	37	54
13	Devadas	75	84	93
14	Vineeth	39	51	63
15	Siddharthan	57	77	89

Table 19. Duration of musth in the age group between 30 to 40 years

Sl.No.	Name of the elephants	Duration of musth (Days)		
		2002 (YEAR)	2003 (Year)	2004 (Year)
1	Vishnu	92	107	80
2	Rajasekharan	136	159	164
3	Ramu	94	55	47
4	Kesavan kutty	86	94	108
5	Appu	106	112	135
6	Sathyanarayanan	115	125	135
7	Gopikrishnan	78	82	91
8	Vinayakan	107	106	131
9	Nandan	68	85	99
10	Sreedharan	127	167	179
11	Achuthan	100	101	107
12	Sankaranarayanan	61	78	94
13	Kesavan	129	140	152
14	Chandrasekharan	116	118	107
15	Lakshmikrishnan	65	74	89

Table 20. Duration of musth in the age group between 40 to 50 years

Sl.No.	Name of the elephants	Duration of musth (Days)		
		2002 (Year)	2003 (Year)	2004 (Year)
1	Prakasan	45	64	44
2	Indrasen	131	165	172
3	Gopikrishnan	110	116	175
4	Radhakrishnan	148	110	95
5	Kannan	97	111	127
6	Madhankutty	57	100	127
7	Junior lakshamanan	118	125	139
8	Krishnan	68	75	84

Table 21. Duration of musth in the age group between 50 to 60 years

Sl.No.	Name of the elephants	Duration of musth (Days)		
		2002 (Year)	2003 (Year)	2004 (Year)
1	Pathmanabhan	121	117	109
2	Lakshmann	109	99	84
3	Valiyakesavan	145	129	118
4	Ramachandran	85	70	59
5	Kuttykrishnan	64	45	37
6	Kuttyshankaran	116	126	142
7	Ramankutty	65	56	58
8	Narayanakutty	150	122	113

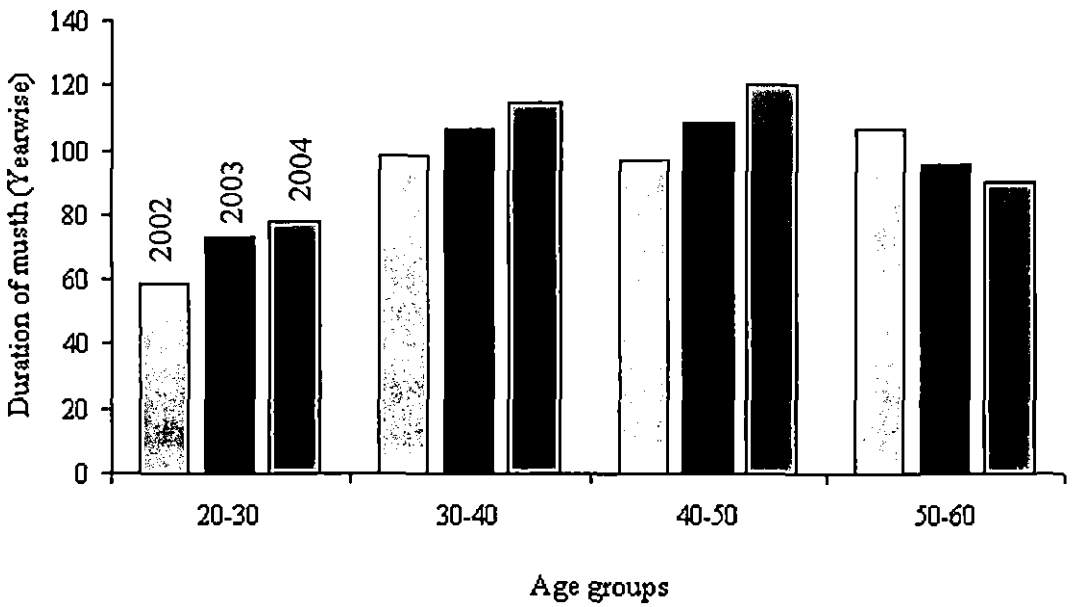

Fig 3. Age versus duration of musth (Days)

Table 22. Body weights of the elephants before and after musth episode

Sl.No	Age of the elephants	Name of the elephants	Body weight before musth (kg)	Body weight after musth (kg)	Loss in body weight (kg)
1	32	Chandrasekhran	3580	3540	40
2	42	Gopalakrishnan	4800	4755	45
3	18	Junior Kesavan	3220	3020	200
4	42	Prakasan	4040	4000	40
5	39	Sathyanarayanan	6290	6240	50
6	39	Vishnu	4815	4760	55

Table 23. Behavioural score

Sl No	Name of elephants	Normal stage	Pre-Musth	Musth																		Post Musth
				First month				Second month				Third month			Fourth month					Fifth month			
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1	Chandra sekhran	12	38	48	61	67	78	75	83	81	73	73	77	60	74	62	54	35					31
2	Gopala krishnan	8	20	54	74	79	80	74	76	88	88	91	91	79	86	84	82	65	78	87	59	19	10
3	Junior Kesavan	13	26	64	75	91	85	82	86	93	90	72	53	46	33	22							26
4	Prakasan	15	37	48	61	84	93	92	73	80	34												16
5	Sathya narayanan	10	53	67	67	75	74	61	73	87	81	59	85	59	68	72	74	50	42	40			19
6	Vishnu	16	30	64	69	71	58	74	78	88	79	67	64	65	61	36							16
Mean and standard error		12.33 ± 1.22	34 ± 4.69.	70.29 ± 2.46				78.70 ± 2.48				68.15 ± 3.31			58.15 ± 5.55					51.25 ± 14.44			19.66 ± 3.10

Table 24. Faecal testosterone level (ng/g) in individual animals

Sl.No	Chandrasekaran	Gopalakrishnan	Junior Kesavan	Prakasan	Sathyanarayanan	Vishnu
1	799.5	822.5	596	809.5	820.5	777.5
2	1687.5	1789.5	1326.5	2216.5	2103.5	1806
3	2521	2226	1459.5	3280	2530.5	2042.5
4	2833.5	2587.5	1894	3980.5	3102.5	2458.5
5	2959.5	2879.5	2087.5	5094	3651	2789
6	3969	3014.5	2456.5	4980.5	4015.5	3105.5
7	4120.5	3498	2569.5	5780.5	4621.5	3256.5
8	4956.5	3789	2764	4129	5365.5	3759
9	5505.5	4375.5	2905.5	4050.5	5689.5	4065.5
10	5850	4889.5	3278.5	2285.5	6986	4896.5
11	4125.5	5340	2874.5	920.5	5890.5	4125.5
12	3645.5	6103.5	2459.5	-	5875.5	3954.5
13	3449.5	5246.5	2256	-	5423.5	3257.5
14	3287.5	4840	2084.5	-	4526	2869
15	3021	3849.5	1756.5	-	3996.5	2164
16	2596.5	3161.5	1018.5	-	2856.5	1154
17	2159.5	3041.5	-	-	2324.5	-
18	1020.5	2646	-	-	2005.5	-
19	-	2081	-	-	1895	-
20	-	1735	-	-	1135.5	-
21	-	1342	-	-	-	-
22	-	1187.5	-	-	-	-
Mean and Standard error	3250.44 ± 327.76	3202.06 ± 313.19	2111.68 ± 184.59	3411.54 ± 503.08	3740.75 ± 396.01	2905.06 ± 283.05

Table 25. Faecal testosterone level (ng/g) in different Stages of musth

Sl.No	Normal stage	Pre-musth stage	Musth stages					Post -musth
			First month	Second month	Third month	Fourth month	Fifth month	
1	822.5	1326.5	2521	3256.5	4125.5	2164	1895	1154
2	596	2216.5	2833.5	3759	3645.5	3996.5	2081	1135.5
3	809.5	1789.5	2959.5	4065.5	3449.5	2856.5	1735	920.5
4	820.5	2103.5	3969	4896.5	3287.5	2324.5	1342	1018.5
5	777.5	1806	2042.5	4621.5	4125.5	2005.5	-	1187.5
6	799.5	1687.5	2458.5	5365.5	3954.5	1756.5	-	1020.5
7	-	-	2789	5689.5	3257.5	3849.5	-	-
8	-	-	3105.5	6986	2869	3161.5	-	-
9	-	-	2530.5	5780.5	5890.5	3041.5	-	-
10	-	-	3102.5	4129	5875.5	2646	-	-
11	-	-	3651	4050.5	5423.5	3021	-	-
12	-	-	4015.5	2285.5	4526	2596.5	-	-
13	-	-	3280	2569.5	2874.5	2159.5	-	-
14	-	-	3980.5	2764	2459.5	-	-	-
15	-	-	5094	2905.5	2256	-	-	-
16	-	-	4980.5	3278.5	2084.5	-	-	-
17	-	-	1459.5	3498	5340	-	-	-
18	-	-	1894	3789	6103.5	-	-	-
19	-	-	2087.5	4375.5	5246.5	-	-	-
20	-	-	2456.5	4889.5	4840	-	-	-
21	-	-	2226	4120.5	-	-	-	-
22	-	-	2587.5	4956.5	-	-	-	-
23	-	-	2879.5	5505.5	-	-	-	-
24	-	-	3014.5	5850	-		-	
Mean and Standard error	770..91 ± 351.62	1821.58 ± 129.07	2996.85 ± 185.54	4307.81 ± 242.40	4081.72 ± 285.12	2736.84 ± 188.59	1763.25 ± 157.20	1072.75 ± 41.85

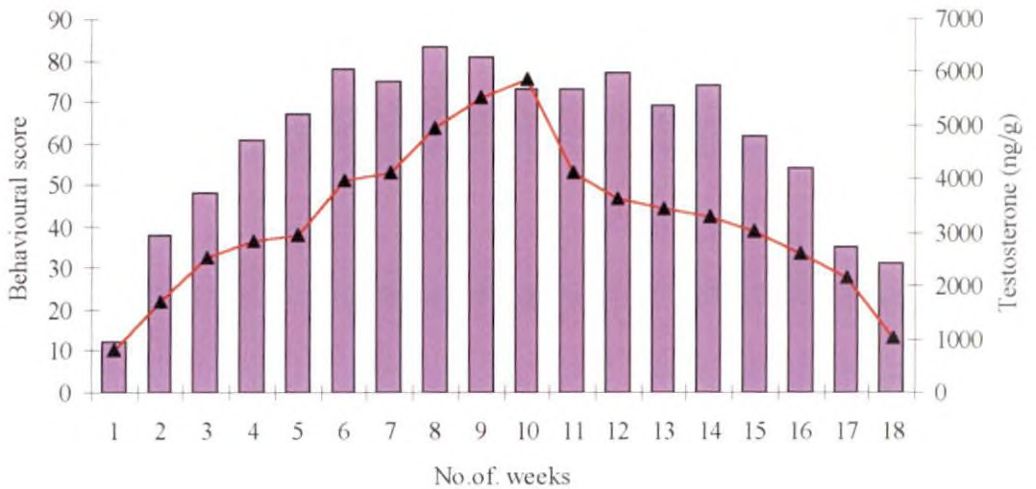

Fig 4. Comparison of behavioural score with testosterone level(ng/g) (Chandrasekaran)

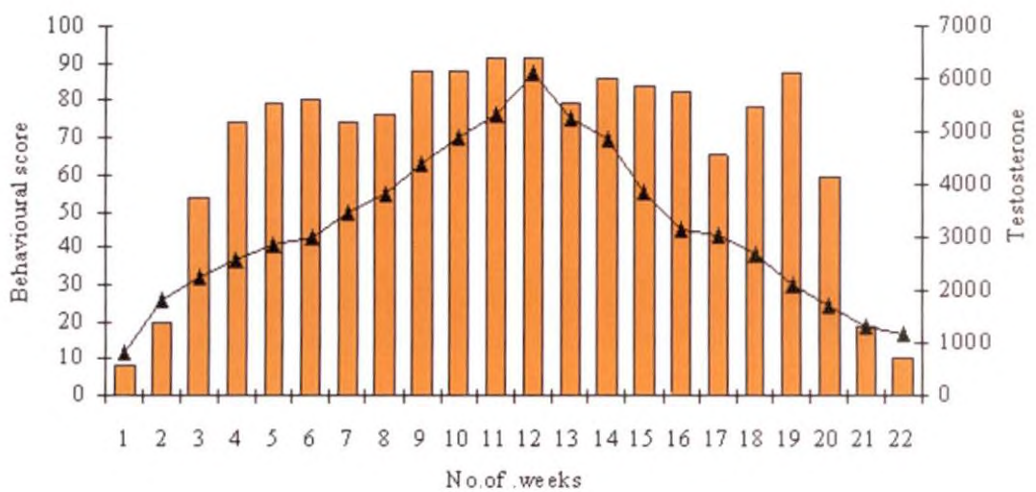

Fig 5. Comparison of behavioural score with testosterone level(ng/g) (Gopalakrishnan)

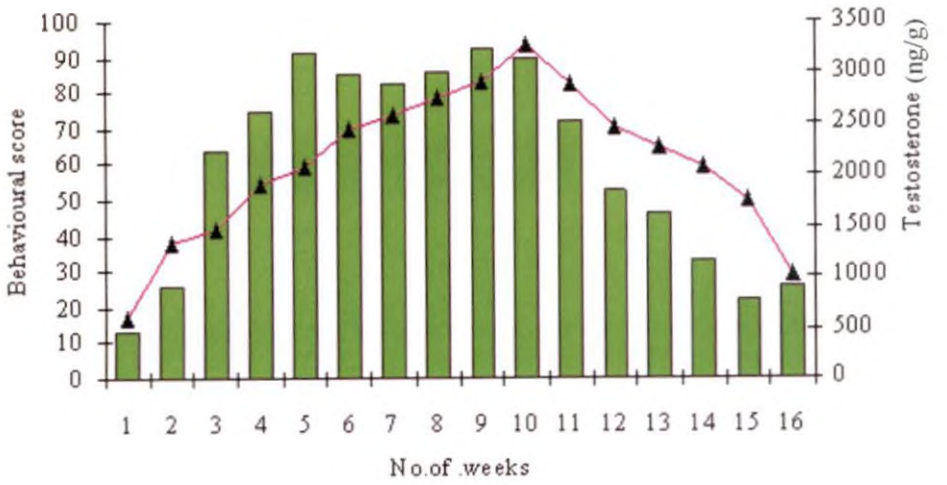

Fig 6. Comparison of behavioural score with testosterone level (ng/g) (Juniorkesavan)

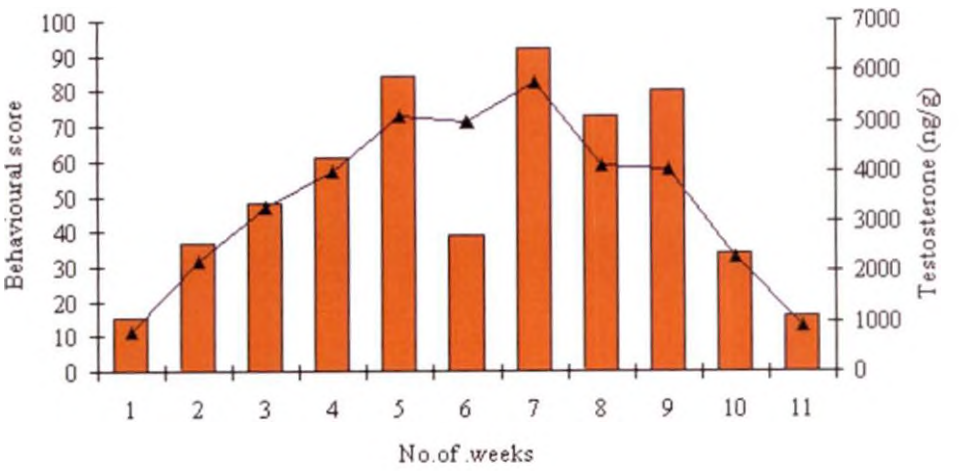

Fig 7. Comparison of behavioural score with testosterone level (ng/g) (Prakasan)

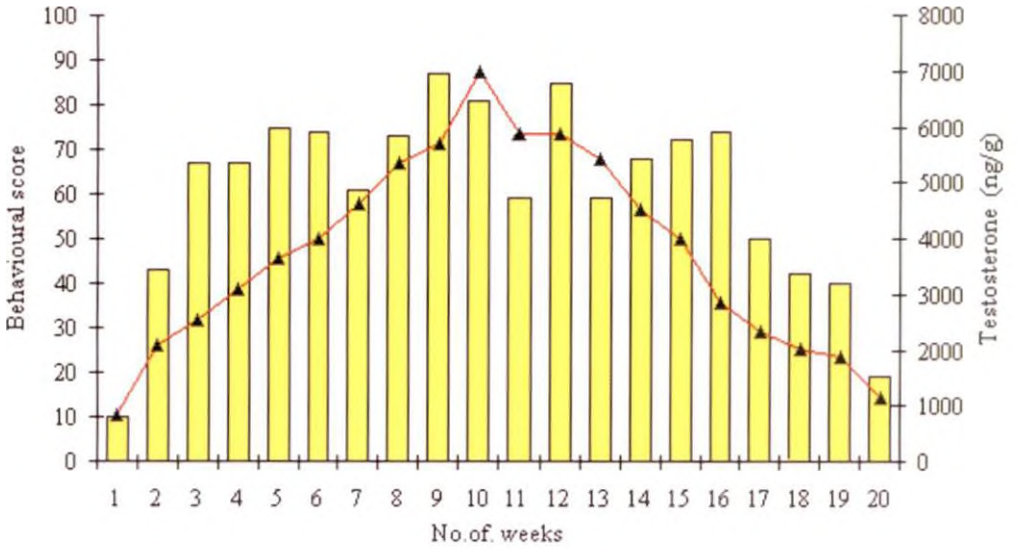

Fig 8. Comparison of behavioural score with testosterone level (ng/g) (Sathyanarayanan)

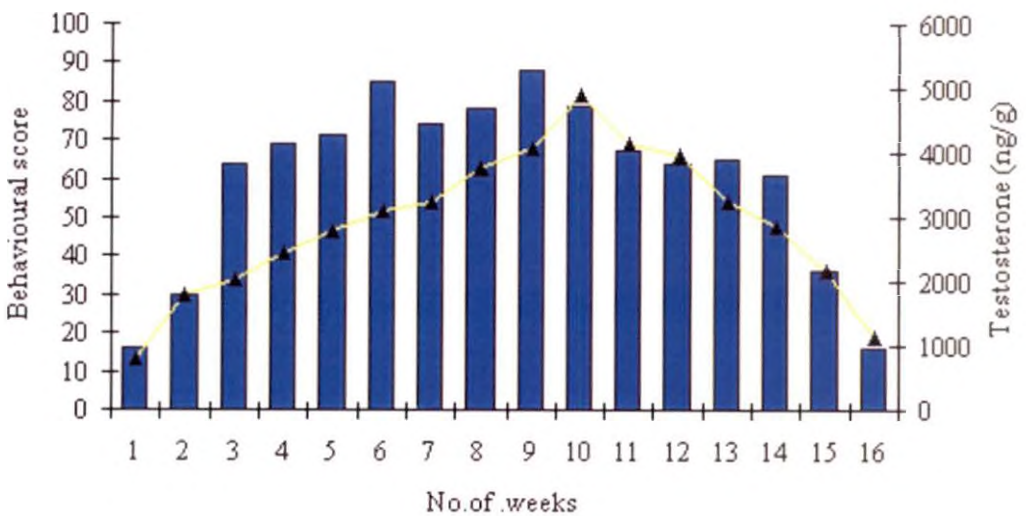

Fig 9. Comparison of behavioural score with testosterone level (ng/g) (Vishnu)

Table 26. Quantitative indicators of non-musth and musth stages

Sl.No	Behaviour	Normal stage	Pre-musth stage	Musth stages					Post-musth stages
				First month	Second month	Third month	Fourth month	Fifth month	
1	Temporal gland enlargement (inch)	3.5 ± 0.3	6.0 ± 0.4	6.75 ± 0.6	9.5 ± 0.9	8.5 ± 0.8	7.45 ± 0.7	6.25 ± 0.3	3.15 ± 0.5
2	Bulging of perineal gland (inch)	2.75± 0.2	4.75 ± 0.1	6.25 ± 0.1	7.15 ± 0.7	6.05 ± 0.6	5.95 ± 0.4	5.25 ± 0.7	3.05 ± 0.9
3	Flehmen response (Per hour)	3	5	6	8	7	4	2	3
4	Freezing of ears (Per hour)	0	8	12	17	14	7	6	0
5	Trunk on tusk (Per hour)	0	4	7	15	10	6	2	0
6	Trunk raising (Per hour)	3	8	12	17	15	9	4	3

Table 27. Qualitative indicators of non-musth and musth stages

Sl.No	Behaviour	Normal stage	Pre- musth stage	Musth stages					Post-musth stages
				First month	Second month	Third month	Fourth month	Fifth month	
1	Temporal gland secretion	Nil	Nil	Pointing to quarter	Half of jowl to entire jowl	Half of jowl to quarter jowl	Quarter jowl	Nil	Nil
3	Urination	Normal	Normal	Intermittent Dribbling	Continuous Dribbling	Intermittent Dribbling	Intermittent Dribbling	Intermittent Dribbling	Normal
4	Alertness	Attention	Very slightly Attention	Excited	Highly excited	Highly excited	Excited	Excited	Normal
5	Aggressiveness	Nil	Moderate	High	Very high	Very high	High	High	Nil
6	Obeying command	Response	Slight response	No response	No response	No response	No response	Slight response	Response
10	Standing tall	Normal	Occasional	Intermittent	Frequently	Intermittent	Occasional	Normal	Normal

Discussion

5. DISCUSSION

5.1 HISTORY

Out of a total 63 elephants, 48 male elephants of 16 to 69 years of age were taken for the study including six experimental animals and the results are given in the Tables 6- 7.

5.2 FEEDING

The feeding schedule of elephants are furnished in the Tables 8-13.The standard practice is to supply fodder at the rate of 5 per cent of the body weight Cheeran (1999). The daily requirements of nutrient for growing (500 to 2500 kg) and adult elephants (3500 to 5000 kg) were 142 g DM, 7 g DCP, 70 g TDN, and 108 g DM, 6 g DCP, 58 g TDN Anathasubramaniam (1979). In the present study estimated nutrient availability based on proximate analysis of feed ingredients for growing (1000 to 2500 Kg) elephants was, 20.32 per cent to 25.46 per cent higher in DM, 35.32 per cent to 43.31 higher in D.C.P, 73.66 per cent to 74.28 per cent higher in T.D.N respectively. Similarly for adult elephants (3000 to 5000 Kg) there were 42 per cent to 52 per cent excess in DM, 48 per cent to 59.89 per cent excess in D.C.P, 62.93 per cent to 68.68 per cent excess in T.D.N, respectively than the requirement suggested by Anathasubramaniam (1979). Based on the study it was concluded that the elephants in Punnathurkotta were fed above their requirements. This may be the probable cause of early occurrence and increase duration of musth in those elephants, which is supported by the Rasmussen *et al.* (1984) who reported an earlier starting, more intense and larger musth period in captive Asian bulls than in the wild, owing to better health care, nutrition and less activity.

5.3 SEASON

Although the musth was seen distributed throughout the year. A location specific difference in season of occurrence of musth was observed. In this study most of musth occurrence falls in the month of October (10 %), November (17 %), and December (21 %). A very few musth occurrence fall in June (2 %), July (4 %) and August (1 %) month of a year. Season wise occurrence of musth denotes a higher per cent during winter (30 %), followed by summer (29 %), post monsoon (27 %) and monsoon 14(%), respectively. In early reports Evans (1901) has stated that musth occurs among Burma elephants, when the atmospheric temperature was low i.e. mostly in the cold season. Among captive elephants of Sri Lanka maximum incidences of musth was observed during the periods of January to April and August to November in Sri Lanka Eisenberg *et al.* (1971) and Jainudeen *et al.* (1972). In Kerala highest incidence was observed during winter months (Chandrasekharan *et al.* 1992). In Tamilnadu incidence of musth mostly occurred during March and April month, whereas in Vandaloor zoo highest incidences were in October and November Saseendran (1994). From these reports it is presumed that there is a definite location specific season of musth occurrence. The probable reason for variation in season at musth occurrence may be attributed to environmental temperature, humidity, and day length period. Factors like level of feeding, health status and workload may supplement the incidence. In many times individual animals showed a periodicity of musth incidences in each year. Seasonal occurrences of musth in elephants at Punnathurkotta for past 3 years were presented in the Tables 14 - 17 and shown graphically in Fig. 1 and Fig. 2. Nevertheless in individual animals musth seems to occur regularly with same periodicity.

5.4 AGE

Information on the actual age at which first musth occurred among 48 elephants are presented in the Table 6. The average age of first musth occurrence observed in the present study was 24.10 ± 0.50 years with standard deviation of 3.5. Lee (1991) had reported that in the wild, musth was observed only after 25 years of age in African elephants and 20 years in Asian elephants. Some authors like Chandrasekharan *et* al. (1989) and Chandwick (1991) have observed musth to occur even among very young captive Asian elephants in the age group of 11 to 15 years. Saseendran (1994) had reported that in captivity first musth transpire after 20 years of age. Prasad *et al.* (2000) reported that first musth incidence occurred at the age of 23.94. In the present population, the first musth seems to be very late, even though these animals were maintained under good captive management conditions. The probable reason for this late occurrence of the musth in the studied population can be attributed to very close tethering of elephants which is less than 50 m distance apart, close proximity of adult male elephants especially, if it is in musth may suppress the forthcoming of musth in young elephants. Similar to the finding of Hall Martin (1987), Poole (1987), Poole and Moss (1981), Lee (1991), Slotow *et* al. (2000). Sukumar (1989) noted that vicinity of adult male elephants near to the young elephants might suppress the early occurrence of musth or skipping the musth in younger age. The average age of first musth incidence in age groups 10 to 20 years, 20 to 30 years, 30 to 40 years, 40 to 50 years, 50 to 60 years were 16.5 ± 0.5, 21.3 ±0.79, 25.93 ± 0.48, 25.62 ± 0.88, and 26.5 ± 0.59, respectively in the present study.

5.5 DURATION

The duration of musth observed in different age groups of 18 to 69 years for past 3 years are given in Tables18 - 21 and depicted in Fig.3. The average duration of musth in age group 20 to 30 years for past 3 years was 69.86 ± 5.78 days. In age group of 30 to 40 years duration was 106.61 ± 4.58 days, in age group of 40 to 50 years it was 108.45 ± 6.81 days and 97.45 ± 4.96 days in age group of 50 to 60 years.

The duration of musth in age group 20 to 30 years was from 58.66 ± 6.54 days in the first year of the study to 78 ± 3.95 days in the third year of the study. In age group of 30 to 40 years it ranges from 98.66 ± 6.15 in the first year of the study to 114.53 ± 8.9 days in the third year of the study. Whereas in 40 to 50 years group the variation was 96.75 ± 13.03 days in the first year of the study to 120.37 ± 15.74 days in the third year of the study. Duration of musth was found to show an increasing trend as age advances. Duration of musth depends on age, nutrition and perhaps social status as reported by Jainudeen *et al.* (1972), Poole (1987), Cooper *et al.* (1990), Lincoln and Ratnosooriya (1996), Sukumar (1996), Prasad *et al.* (2000) and Johnsingh and Williams (2002). In all age group upto 50 years of age, duration of musth was higher in individual elephants in each successive year.

In age group of above 50 to 60 years duration of musth decreased from the previous year i.e. from 106.87 ± 11.70 days to 90.00 ± 12.82 days. Lee (1991) opined that older bulls either shortened or made to skip musth period because of poor bodily conditions.

Duration of musth decreased irrespective of younger age, if animal are affected with common aliments. This may be the probable cause of decreased duration of musth in experimental animal Prakasan and Vishnu, when compared to

previous years. This fact is supported Saseendran (1994) and Cheeran *et al.* (2002) who stated that illness and debility may shift or skip the occurrence and duration of musth in individual animals.

When compared with other age groups, the average duration of musth in age group 20 to 30 years is significantly lower 69.86 ± 5.76 days. This may be the attributed to the presence of adult or dominant bull in their vicinity or lack of sexual maturity as observed by Poole and Moss (1981), Hall Martin (1987), Poole (1987), Sukumar (1989), Lee (1991) and Slotow *et al.* (2000).

5.6 BODY WEIGHT

In the present study the loss in body weight of the experimental animals before and after musth was 71.66 ± 25.77 kg. The body weight loss was significantly pronounced in the youngest elephant Junior Kesavan, which was in growing stage and in its second musth period. The elephant may not acclimatize to musth stress, which might have contributed to the drastic weight loss. Where as in adult animals (32 to 42 years) weight loss was very minimum, which may be due to early musth adaptation. Above facts are in accordance with Chandrasekharan *et al.* (1992) who reported that extreme body weight reduction in musth period in elephants. Hence it requires further scientific and systemic investigation to know the factor for significant body weight reduction in musth. The body weight of elephants were taken before and after each of musth episode and presented in Table 22.

5.7 BEHAVIOURAL OBSERVATION

A method developed by Scott (2002) to score the animals based on their behavioral pattern was improved upon in the present study by including few more

important behavioural characteristics that is shown exclusively during musth. The score thus obtained from six experimental male captive elephants during normal, pre-musth musth and post- musth stages are furnished in Table 23.

The score obtained in normal stages of experimental animals was about 12.33 ± 1.22. In pre-musth stages together with increased intensity and incidence of musth symptoms, the behaviour score shot up to 34 ± 4.69. This was further increased and recorded the highest behaviour score of 70.29 ± 2.46 and 78.70 ± 2.48 in the first month and second month of musth. The behaviour score were reduced to from first month to 68.15 ± 3.31 in third month, 58.15 ± 5.55 in fourth month and 51.25 ± 14.44 in last month, respectively.

During normal and post-musth stage number of occurrence of musth behaviour given in the ethogram were very less. So the score 19.66 ± 3.10 was observed in post musth stage was more or less similar to normal stage score.

In the case of first, second, third, fourth and fifth month of musth stage number of occurrence of musth behaviour given in the ethogram were very high. These finding coincide with reports of Short *et al.* (1967), Lincoln (1971), Jainudeen *et al.* (1972), Poole and Moss, (1981), Rasmussen *et al.* (1984), Cooper *et al.* (1990); Niemuller and Liptrap (1991), Chandrasekharan *et al.* (1992), Fowler (1992), Thakuria and Barthakur, (1994), Sarma and Dutta (1996), Rasmussen and Perrin (1999), Scott (2002) and Rasmussen *et al.* (2003).

5.8 FAECAL TESTOSTERONE LEVEL

The faecal testosterone values of the experimental animal during the study period both for individual animal and in different stages of musth are furnished in the

Tables 24-25. It is seen that the faecal testosterone values varies in individual elephants and also in accordance with the different stages of musth in elephants. The maximum mean faecal testosterone value of 4307.81 ± 242.40(ng/g) was recorded in the second month of musth stage. The minimum faecal testosterone value of 1736.25 ± 157.20 (ng/g) was recorded during fifth month of musth stage. Faecal testosterone level of 770.91 ± 35.62 (ng/g), 1821.58 ± 129.07 (ng/g), 1072.75 ± 41.85 in normal, pre-musth and post-musth stages, respectively were observed. This strongly indicated that the estimation of faecal testosterone level could be a method of choice for monitoring the elephants in non-musth and musth stages. The elevated faecal testosterone level during the different stages of musth as found in the present study is in agreement with Schwarzenberger *et al.* (2001) who reported that faecal testosterone values were < 500 ng/g in non-musth bulls and > 1.0 μg/g in musth bulls with peak values up to 15 μg/g.

The mean faecal testosterone values were higher in the age of 32 to 42 years, where as the mean faecal testosterone value were lower in the age of 18 years. It seems those 32 to 42 years, probably be the prime age for the best breeding in the male Asian elephants. This was supported by Saseendran (1994) who observed higher serum testosterone level in the age group of 30 to 40 years, whereas lower level in the age group of 22 to 24 years. The result showed an age war difference in sex hormone. The highest level of 3740.75 ± 396.01 (ng/g) was observed in age group of 32 to 42 years and lowest level of 2111.68 ± 184.59 (ng/g) in the age of 18 years.

The significant differences in the faecal testosterone levels between normal versus pre-musth ($P<0.00001$), normal versus musth ($P<0.00001$), pre-musth versus musth ($P<0.00001$), musth versus post-musth ($P<0.0003$), normal versus post-musth ($P<0.00001$) and post- musth versus pre-musth ($P<0.0003$) were observed in the

present study. This indicates that rises and falls of faecal testosterone level were according to the stages of musth in individual elephant. Similar observation were made by Jainudeen *et al.* (1972), Rasmussen *et al.* (1984), Cooper *et al.* (1990), Niemuller and Liptrap (1991) and Saseendran (1994) in serum testosterone.

The overall positive correlation between behavioural score and faecal testosterone with 'r' value of 0.82 ($P< 0.0002$) was observed, which is accordance with Saseendran (1994) mentioned that behaviour score and serum testosterone is highly correlated with 'r' value of 0.72 ($P<0.01$). Comparison of faecal testosterone level and behavioural score of individual elephants are presented in the Figures 4 - 9.

5.9 INDICATORS OF MUSTH

In Kerala on an average nine persons were killed by musth elephants in every year, during festival season or procession. Renting out of elephants for festival and parades being the main source of revenue to the elephant owners, there will be economic compulsion to use the elephants irrespective, whether it is musth or non-musth. As there is no scientifically tested and validated protocol for weeding out the elephants in different stage of musth. Existing practice is to rely only on more conspicuous symptoms, which may not be accurate always. Based on the result of the present study the following musth indicators were developed, which can be worked out by observing the elephants for one hour, Quantitative and qualitative indicators, which are represented in figure, are given in the Tables 26 and 27.

Summary

6. SUMMARY

Adult male elephants periodically show the phenomenon of musth, a condition associated with increased aggressiveness, restlessness, significant weight reduction and marked elevation of androgen levels. It has been suggested that musth-related behaviour are costly and that therefore musth may represent a form of physiological stress. The present work is aimed to make a detailed study of behaviour of elephant in non- musth and musth stages in relation to corresponding testosterone profile, so that it form a suitable method to fore cast the incidence of musth in Asian elephants and to manage the animals in the musth period effectively.

The present study was carried out in captive male Asian elephants at the elephant's camp in Punnathurkotta during the period of October 2003 to September 2004. The objective of the study was to know the behaviour pattern of elephants during normal, pre- musth, musth and post-musth stages in relation to testosterone level. Out of 63 elephants, six male healthy bull elephant that had the history of yearly musth episode were selected for the study. Behavioural data collection was obtained by observing the each animal (focal animal sampling) for one hour during different stages in different periods of a day. A total of 193 hours of observation were carried out. The behaviour observed in this study were aggression, standing tall, erection/masturbation, mudding/dusting, throwing objects, relation to mahouts, flehmen responses, splashing water or saliva, freezing of ears, swaying, chain pulling, grooming, trunk rising, lifting legs, trunk on tusk, tethering, feeding, watering, urination, defecation, obeying, temporal gland enlargement temporal gland secretion, bulging of perineal gland.

The proximate analysis of feed given to the elephants was conducted by taking random feed sample. The nutrient availability of growing and adult elephants

was worked out. Existing managemental practices including musth management was studied. Documentation of behaviour pattern of musth and non- musth stages was done. The body weight of elephants was taken before and after musth period. The faecal sample were collected and stored at –20°c. It was processed and analyzed for estimation of faecal testosterone by radio immunoassay.

In the present study estimated nutrient availability for growing elephants and adult elephants were higher than the requirement. The occurrence of musth in the experimental herd was mostly in winter. The average age of first musth occurrence observed in the present study was 24.10 ± 0.50 years with standard deviation of 3.5. The duration of musth in age groups 20 to30, 30 to 40, 40 to50 years was increased, whereas decreased in age group of 50 to 60 years. The body weight loss in the experimental animals before and after musth period was 71.66 ± 25.77 Kg. The average behavioural scores obtained for elephants in normal stages was about 12.33 ± 1.22. In pre-musth stage scores and post- musth stage the score were 34 ± 4.69 and 19.66 ± 3.10, respectively. In musth the score shot up to 70.29 ± 2.46 in first month, 78.70 ± 2.48 during second month, 68.15 ± 3.31 in third month, 58.15 ± 5.55, 51.25 ± 14.44 in fourth and fifth month, respectively.

The mean faecal testosterone level during normal stage was about 770.96 ± 35.62(ng/g). The levels has increased to 1821.58 ± 129.54(ng/g) during pre-musth stages and reached a peak level of 4307.81 ± 242.40(ng/g) in second month of musth stage. This level has once again drop down to 1072.75 ± 41.85(ng/g) during post-musth stage. The highest level of 3740.75 ± 396.01 (ng/g) was observed in age group of 32 to 42 years and lowest level of 2111.68 ± 184.59 (ng/g) in the age of 18 years. The mean faecal testosterone level is higher in the age of 32 to 42 years, so this stage be the probably prime age for the best breeding in the male Asian elephant species.

Positive correlation between behavioural score and testosterone with 'r' value of 0.82($P<0.0002$) was observed. The significant differences in the faecal testosterone levels between normal versus pre-musth ($P<0.00001$), normal versus musth ($P<0.00001$), pre-musth versus musth ($P<0.00001$), musth versus post-musth ($P<0.0003$), normal versus post-musth ($P<0.00001$) and post- musth versus pre-musth ($P<0.0003$) were observed in the present study.

It could be summarized that correlation between behavioural observation and testosterone values can be used as a reliable, non invasive method to monitor and forecast the incidences and intensity of musth in captive Asian elephants. Based on the results of the study quantitative and qualitative indicators for musth have been developed.

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Appendix 1

Scoring of musth elephants

Sl.No	Behaviours	Scoring		
		5	3	1
1	Watering	1to 2 /hr	4/hr	>6to 8 /hr
2	Freezing of ears	Continuous/ > 10 Times	Intermittent/ < 10 Times	Normal
3	Swaying	Continuous/ > 15 Bouts	Intermittent/ < 15Bouts	Normal
4	Chain pulling	5 to 7	< 5	0
5	Alertness by sight of mahout	Excited	Attention	Non responses
6	Urination	Continuous	Intermittent	Normal
7	Trunk rising	> 20	5 to 19	< 5
8	Trunk on tusk	> 15	5 to 14	< 5
9	Aggression	High	Low	Mild
10	Erection	< 15 min	5 to 10 min	> 5 min
11	Bulging of perineal gland	> 12 inch	6 to 12 inch	< 6 inch
12	Defaecation	1 to 3 bolus	4 to 5	Above 6
13	Feeding	1 to 2 leaf	3 to 4 leaves	5 leaves and grass
14	Temporal gland enlargement	> 12 inch	6 to 12 inch	< 6 inch
15	Temporal gland secretion	Up to jowl	Half of jowl	Pointing

Sl.No	Behaviour	Scoring		
		5	3	1
16	Throwing of objects	> 5	1 to3	0
17	Tethering	Chain and rope 3 legs	Chain 3 legs	Chain 2 legs
18	Obeying commands	Bad	Moderate	Good
19	Flehmen response	6-8 Times	3-5 Times	< 3 Times
20	Standing tall	Continuous	Occasional	Normal

BEHAVIOUR PATTERN OF MUSTH AND NON MUSTH IN CAPTIVE ASIAN ELEPHANTS (*Elephas maximus*)

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ABSTRACT

Adult male elephants live in a highly dynamic world of changing sexual state, rank, association and behaviour. Physiologically musth is known to be associated with the elevated testosterone levels. There is a positive relationship between changes in testosterone and musth related behaviour, which make the animal in physiological stress. Captive male Asian elephants maintained in the elephant camp at Punnarthurkotta were utilized for the study. Experimental animals were grouped into normal, pre-musth, musth and post-musth stages. A total of 193 hours of observation were carried out by focal animal sampling technique using a behaviour score sheet. Faecal samples were collected from each animal in all stages and stored at -20^0 c, until it was extracted for measurement of faecal testosterone by RIA technique.

The staple food for the elephants under study was palm leaves and napier grass. The amount of palm leaves and napier grass given to growing elephants were 60 to 100 Kg and 20 to 50 Kg, respectively. Similarly for adult elephants amount ranges from 140 to 240 Kg and 50 to 100 Kg, respectively. The nutrient availability of growing and adult elephants was calculated, which shows greater than the required level. The maximum percentage of musth episodes was occurred in winter (30 %) followed by summer (29 %), post monsoon (27 %) and monsoon (14 %). The body weight loss in the experimental animals before and after musth period was about 71.66 ± 25.77 kg. The age at which first musth occurrence was about 24.10 ± 0.50 years. Age groups of 20 to30 (78 ± 3.95 days), 30 to 40(114.53 ± 8.9 days), 40 to 50 (120.37 ± 15.74 days) years elephants shows increasing trend in duration of musth, but vice versa in the age group of 50 to 60 years(90.00 ± 12.82 days). The average behavioural scores obtained for elephants in normal stages was about 12.33 ± 1.22. In pre-musth stage scores and post- musth stage the score were 34 ± 4.69 and

19.66 ± 3.10, respectively. In musth the score shot up to 70.29 ± 2.46 in first month, 78.70 ± 2.48 during second month, 68.15 ± 3.31 in third month, 58.15 ± 5.55, 51.25 ± 14.44 in fourth and fifth month, respectively. The mean faecal testosterone level during normal stage was about 770.96 ± 35.62(ng/g). The levels has increased to 1821.58 ± 129.54(ng/g) during pre-musth stages and reached a peak level of 4307.81 ± 242.40(ng/g) in second month of musth stage. The positive correlation ($r = 0.82, P < 0.0002$) was obtained between faecal testosterone and behavioural score in all stage of the experimental elephants. The significant differences in the faecal testosterone levels between normal versus pre-musth ($P < 0.00001$), normal versus musth ($P < 0.00001$), pre-musth versus musth ($P < 0.00001$), musth versus post-musth ($P < 0.0003$), normal versus post-musth ($P < 0.00001$) and post- musth versus pre-musth ($P < 0.0003$) were observed in the present study. Quantitative indicators of musth are enlargement of perineal gland was 2.75 ± 0.2, 7.15 ± 0.7, and 4.75 ± 0.1 in normal, second month of musth and pre-musth, respectively. Temporal gland enlargement was 3.5 ± 0.3, 3.15 ± 0.5 9.5 ± 0.9, in normal, post-musth and second month of musth, respectively. Flehmen response (per hour) was 3, 5 and 8 in normal, pre-musth and second month of musth, respectively. Trunk rising (per hour) was 3,8 and 17 in normal, pre-musth and second month of musth, respectively. Freezing of ears (per hour) was 0,8 and 17 in normal, pre-musth and second month of musth, respectively. Qualitative indicators at the most intensive musth stage of second month were temporal gland secretion up to jowl region, disobedience to mahout, alertness, throwing objects, urine dribbling and green penis syndrome. In addition to that in captivity swaying and stereotypic behaviours was observed.

The results of present study suggest that integrating the behavioural and endocrine level could potentially provide a more meaningful measure of musth in captive male elephants and can help to resolve the management problems.