DRAUGHT EFFICIENCY OF ELEPHANTS IN TIMBER MILLS

By

PRASAD. A.

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Veterinary Science

Faculty of Veterinary and Animal Sciences
Kerala Agricultural University

Department of Livestock Production Management
COLLEGE OF VETERINARY AND ANIMAL SCIENCES
MANNUTHY, THRISSUR - 680651
KERALA, INDIA

2001

DECLARATION

I hereby declare that this thesis entitled **"DRAUGHT EFFICIENCY OF ELEPHANTS IN TIMBER MILLS"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy,
3. 1. 2001

PRASAD, A.

CERTIFICATE

Certified that the thesis, entitled **"DRAUGHT EFFICIENCY OF ELEPHANTS IN TIMBER MILLS"** is a record of research work done independently by **Dr. Prasad, A.,** 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.

Dr. P.C. Saseendran
(Chairman, Advisory Committee)
Associate Professor
Department of Livestock Production Management
College of Veterinary and Animal Sciences, Mannuthy

Mannuthy,

CERTIFICATE

We, the undersigned members of the Advisory committee of **Dr. Prasad, A.,** a candidate for the degree of Master of Veterinary Science in Livestock Production Management, agree that the thesis entitled **"DRAUGHT EFFICIENCY OF ELEPHANTS IN TIMBER MILLS"** may be submitted by Dr. Prasad, A., in partial fulfilment of the requirement for the degree.

Dr. P.C. Saseendran
(Chairman, Advisory Committee)
Associate Professor
Department of Livestock Production Management
College of Veterinary and Animal Sciences, Mannuthy

Dr. C.K. Thomas
(Member, Advisory Committee)
Professor and Head
Department of Livestock Production Management

Dr. P.C. Alex
(Member, Advisory Committee)
Associate Professor and Head
Department of Clinical Medicine

Dr. K.S. Anil
(Member, Advisory Committee)
Assistant Professor
Department of Livestock Production Management

19.1.2001
External Examiner
Dr. V. Ramesh Saravana Kumar

ACKNOWLEDGEMENTS

I would like to express my deep sense of gratitude to Dr. P.C. Saseendran, Ph.D., Chairman of Advisory Committee and Associate Professor, Department of Livestock Production Management, College of Veterinary and Animal Sciences, Kerala Agricultural University for his generous help, inspiring guidance and encouragement throughout the study.

I am grateful to Dr. C.K. Thomas, Professor and Head, Department of Livestock Production Management for his invaluable suggestions and providing facilities in carrying out my research work. I am indebted to Dr. P.C. Alex, Associate Professor and Head, Department of Clinical Medicine for his constructive criticism and meticulous correction. I am extremely thankful to Dr. K.S. Anil, Assistant Professor, Department of Livestock Production Management for his help, advice and suggestions.

I express my sincere and heartfelt thanks to owners and mahouts of the elephants for their kind help during the course of my research work. I would also like to thank Scientists of Central Institute of Fisheries Technology for providing technical help for the study.

My cordial thanks to Dr. K.S. Sebastian, Dr. Leena Anil and Dr. Francis Xavier for their encouragement.

I am indeed fortunate to have Suraj .P.T. and Dinesh, M.T. as my colleagues. Their cordiality is unforgetable. I wish to convey my sincere thanks to Biju, Hari, Bipin, Ramakrishnan and Vijay who constantly helped at each stage of this study.

It is my pleasure that I acknowledge the help rendered by Mr. Gopi and other staff members of the Department of Livestock Production and Management.

Finally I thank Mr. O.K. Ravindran, C/o Peagles, Mannuthy for the preparation of this thesis scrupulously.

PRASAD, A.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

INTRODUCTION

Elephant, the Lord of the jungle is fighting a loosing battle against loss of its habitat, blocking of its corridors and poaching. Elephant once found all over the country except in Himalayan mountain ranges and coastal mangroves have become isolated and scattered in more than 15 states with an estimated population of 15,000 to 20,000.

The jumbo power of the largest terrestrial animal was being used by the mighty ancient rulers of the Indian subcontinent and elephant became a part of the culture and epics in India. It was venerated as Lord Ganesha in Hindu mythology. Thus the tradition of keeping elephants came to stay in India, and now about 10 to 20 per cent of elephant population remains in captivity.

The traditional bond of love, respect and understanding between man and elephant underwent a transformation over the years and further eroded in the present market economy and increasing mechanisation. In Kerala, economic returns for the elephant owner is accrued through the hiring charges of elephants for festivals and timber hauling operation in which a stable income is obtained by hiring out or using elephants for timber mills. Sustainability of captive elephant population largely depends upon the efficiency of elephants as work animal in timber mill. In Kerala there has been long history of using elephants in timber mill, but no systematic study was made to measure its efficiency. The present

study was undertaken to get a first hand information on the work efficiency of elephants in timber mills with the following objectives.

1. Evaluate the feeding and management of work elephants.

2. Find out the type of work, its duration and the daily work schedule of elephants in timber mills.

3. To estimate the draught potential and fatigue level of elephants during different types of work.

4. To compare the methods of assessing draught power viz., formula using angle of pull and Elephant Draught Power Monitor

5. Assessing the physiological changes of elephants at work.

Review of Literature

REVIEW OF LITERATURE

Early literature on Elephants

Archeological evidence of taming of elephants in India dates back to 3500 BC as evidenced in the engravings of Mohanjo Daro (Induchudan,, 1989). Elephants were the integral part of the cultural and social life of ancient past and was referred in ancient texts like Gajasasthra of Palakapya, Bhasha Prabudha of Raja Serfoji and other works in Sanskrit by Vyasapayana Nakula. There were innumerable references about the human elephant association in ancient Tamil Sangham literature. The description of elephant diseases, treatment and musth episodes were described in ancient literatures of Mathangaleela of Neelakandan Nambisan, Gajaraksha Thanthram and Hastyayurveda (Ananthasubramaniam, 1979; Induchudan, 1989).

Use of elephant as work animals

Asian elephant occurred in Bangladesh, Bhutan, Brunei, Cambodia, China, India. Indonesia, Laos, Malaysia, Myanmar, Nepal, Sri Lanka, Thailand and Vietnam (IUCN 1996).

According to Lair (1997) there were.2500-4000 domesticated elephants in India of which more than 600 were in Kerala.

Legal aspects

Convention on International Trade in Endangered Species (CITES) on wild flora and fauna came into effect on July, 1975 in order to protect wild flora and fauna against over - exploitation through international trade. Elephant was listed in Appendix I of CITES which included the species threatened with extinction.

The Asian elephant whether domesticated or wild came under the wildlife (protection) Act, 1972, (as amended upto 1993) (Anon, 1997; Choudury, 1993). It was listed in schedule I of the wild life (Protection) Act and its possession and transaction were legally controlled.

Draft proposals on captive elephant management by the Forest department stipulated registration certificate from chief wild life warden, licence for the mahout, maintenance of register, daily bathing and veterinary check up every six months as the legal requirements. According to the proposals elephants less than 1.5m height should not be used for work; and those above 2.5 m height were allowed to carry 400 kg and haul 1000 kg weight of logs. Retirement age of working elephants was fixed as 65 years but provision was given for allowing them for smaller works after retirement.

Management of Working Elephants

Management of captive elephants started with the establishment of good relationship between elephant and mahout while they were in the Kraal immediately after their capture. The taming started with good feeding, regular bathing and teaching commands. Work elephants were given one or two hours of training in a day initially by making the elephant obey the simple tasks of sitting, walking and lifting the limbs on commands (Panicker, 1985).

Krishnamurthy (1989) described the ideal management of working elephants covering the whole spectrum from mahouts, bathing, foot care and work load.

Regular bathing of working elephants established good relationship between mahout and elephant and helped to loose the old skin that build up on its body and allowed the new skin to come to surface (Ponnappan, 1998).

Implements used in working elephants

The captive elephant's limbs were tied to restrict its movement by special chains provided with hooks called shackles. A 2½ inch thick and 1.25 m long flexible wooden stick known as cherukol, spear, one meter long stick with hook a tone end called thotty, and a knife were observed to be the usual implements carried by mahouts (Panicker, 1985).

For tethering elephants, chains of varying thickness of ½ inch, 5/8 inch and 3/4 inch were found to be in use. A neck collar made up of thick double rope had been put to the elephant for anchoring and giving foot commands by the mahouts while riding the elephant (Cheeran, 1998).

Duration of Work for elephants

A working duration of 6-7 hours for elephants was reported by Panicker (1985). Nair (1996) reported that the ideal duration for continuous work as three hours at 20 per cent draught level and 2 hours at 30 per cent draught. Forest department of Kerala put the elephants for 6 hours of work daily from 8 am to 11 am in the morning and 3 pm to 6 pm in the evening on normal days, and from 7 am to 10 am in morning on 4 pm to 7 pm in the evening on hot days (Mohandas, 1998). The elephants were given few minutes of rests immediately after work before they were taken for a drink or shower. One day rest per week for working elephant was also suggested (Ponnappan, 1998).

Health care of working elephants

Elephants were observed to be affected with contagious diseases like Anthrax, Tuberculosis and Pasturellosis and vaccination was suggested for protection. Working elephants were injured by nylon vakkas or rough vakkas at their mouth, feet and body. Root of tusks were reported to become oeodematous by excessive use of tusks to carry the load. Selection of steep route and rough

planes for logging operations were found to injure the foot of elephants (Krishnamurthy, 1998; Poomulli, 1998 and Cheeran, 1998).

Feeding management of elephants

According to Ananthasubramanyam (1979) a dry matter consumption of 1.18 per cent of body weight was observed in adult Asian elephant.

In Kerala the staple food of elephants in captivity was palm leaves (*Caryota urens*). Palm leaf with a leaf stem ratio of 1:1 was reported to contain 38.8 per cent dry matter, 2.0 per cent protein, 9.3 per cent crude fibre, 22.9 per cent nitrogen free extract and 3.5 per cent total ash with 0.35 per cent calcium and 0.23 per cent phosphorus (Bhaskaran and Ananthasubramaniam *et al.*, 1982).

Quantitative and qualitative deficiency of diet may result in illness like severe anaemia especially among young elephants (Schulze, 1986). He recommended as a thumb rule 100-150 litres of clean drinking water and 100 kg good quality feed daily, with supplementary vitamins and minerals. He further proposed tethering of elephants to avoid faecal and urinary contamination of feeds.

Karsten (1987) suggested that the elephant must be fed large amounts of hay to fill out their intestinal tract. Amount of hay for adult elephants were 250-300 pounds per day. Elephant rolled on wet ground, which caused folding over

of intestine section, telescoping etc., if the animals were fed on concentrates lacking the fibrous bulk. The food bulk kept the organs in position.

Most elephants prefer palm leaves (*Caryota urens*) to coconut leaves. But there was scarcity for Caryota leaves. Elephants were given concentrate feed once a day in most of the captive establishments (Ponnappan, 1998).

Elephants were observed to take a wide variety of food ingredients. In the wild they have a wide choice of food materials. Elephants in Wayanad in Kerala state were observed to feed about 97 species of plants and the grass dominate among them (Easa and Sankar, 1999).

Draught animal status

India had a draught animal population of over 13 million consisting of about 75 million bullock and 8 million buffaloes (Srivastava and Ojha, 1987). In addition to this two million cows, two million camels and equines put together and about 0.004 million elephants were being used for animal draught power in India (Ramaswamy, 1988, Lair, 1997).

Draught animal power was estimated to worth 1500 billion rupees and produce 40 million hp in terms in terms of energy output. The value of elephant draught was not estimated. However a rough estimate may put it as 4000 million rupees.

Draught animals were the major and dependable source of power on Indian farms especially for crop production. About 80-90 per cent of the tillage work were being carried out using draught animals. Fourteen of the 26 well defined breeds of cattle in India were draught type. The existing stock of draught animals in developing countries was about 400 million. Most of these were bovines and equines. Other draught animals used were camels, elephants and Llamas (Hedman, 1991, Cockril, 1989).

Assessment of draught

For a short duration an initial draught of 200 per cent of body weight in single donkeys and horses, 155 per cent of body weight for a pair of donkeys and 104 to 150 per cent for a pair of bullocks were reported to be possible (Anon, 1972). This high level may not be possible in continuous work which is around 7.5 to 24.50 per cent for bullocks, 15-20 per cent for donkeys and above 25 per cent for buffaloes and 10-15 per cent for other work animals (Maurya, 1985). While carrying horses and mules were found to carry a load equivalent to 10-14 per cent of their body weight and donkeys and camel carried 27-40 per cent of their body weight.

For measuring the work performance in animals, maximal load drawn by the animal (expressed as percentage of their body weight), time taken for performing a specified work, period of continuous working without break (endurance) and changes in physiological responses were employed (Mukherjee,

1961; Rao, 1964; Singh *et al.*, 1968; Singh *et al.*, 1970; Rao *et al.*, 1974; Acharya *et al.*, 1979; Upadhyay, 1987).

Draught assessment by indirect method

Singh *et al.* (1970) stated that the application of draught from an animal for pulling a particular implement depended upon several factors like animal breed, health, body weight, method of harness, training and field working conditions.

According to Maurya and Devadattam (1982) draught can be measured by

Draught = load x Cos θ

Arora and Garg (1995) have stated that for assessing work performance, the speed, draught and horse power had to be measured.

Direct Method

O'Neill *et al.* (1987) explained the general specification for a system which directly measures the performance of draught animals. The system must be such that it did not interfere with the normal working routine nor imposed any extra load or stress on the animals; it must be compact, portable, durable and capable of operating at high environmental temperature and humidity. Such a system was reported to have three sub-systems (i) sensors, (ii) signal conditioning unit and (iii) the data logger. The system was designed to monitor the performance variables like heart rate, breathing rate, temperature and

stepping rate of animal and draught load, draught angle and forward speed of the implement.

Pandey and Bohra (1987) reported that while testing of the animals for their draughtability the force is measured by any force transducer which can be mounted between animal and the loading device. The different types of force transducers were spring dynamometers, hydraulic dynamometer and strain gauge load cells.

Speed of Work

Average speed of walking without load in elephants ranged from 3 to 3.5 km/h (Krishnamurthy,1989). Speed and duration of work were inversely proportional (Anon 1972, Agarwal *et al.*1989). Upadhyay (1987) revealed that speed of work limited the respiratory frequency and ventilation volume. Speed of work was found to decrease with increase in working time and the operating draught (Rautaray, 1987).

Nair (1996) reported a significant reduction in speed of work ($P > 0.01$) with the increase in level of draught.

Speed had a negative correlation with respiratory frequency in bovines in different climatic conditions. This directly revealed that speed of work limit the frequency and hence ventilation volume (Upadhyay, 1982).

Work Output

The work performance largely depends upon animal structure and co-ordination in various physiological capacities related to work. The work is said to be done when there is motion to the point of application of a force and is measured by multiplying the force and displacement of its point of application in the line of action.

Work = Force exerted x distance through which the force is moved.

The work performance of animal was measured by quantifying their capacity to generate power. The efficiency of work production in animals was closely related to the energy consumed, retained energy expanded and environmental condition (Brody, 1945).

The relationship between the draught and power clearly indicated that the power output increased with increase in draught (Maurya and Devadattam, 1982). In order to get maximum power output highest draught is desirable without affecting the speed (Goe, 1983).

Horse power (HP) was widely used as a measure of animal power which was calculated by the formula

$$\text{Horse Power} = \frac{\text{Draught x Speed in m/s}}{75}$$

(Maurya and Devadattam, 1982) – the equation for converting the HP was given as 1 KW = 1.34 hp by Goe (1983).

The work output may be expressed in terms of kilowatts also.

1Kw = 1.34 hp (Goe ,1983)

The average power developed by various work animals was estimated as 0.56 kw for bullocks, Buffalo - 0.55 kw, horse 0.75 kw, Donkey 0.25 kw and mule 0.52 kw (Hopfen, 1969).

Work and Rest Cycle

Work and rest cycle schedule was developed to avoid excessive fatigue of animals during work. In addition to the degree of fatigue, environmental factors, work load, convenience of operator and adequate time for feeding of animal were the important consideration in developing a work rest cycle. A schedule of work-rest cycle was followed by forest Department of Kerala (Mohandas, 1998).

Physiological changes during work

Perusal of literature revealed that reports on physiological changes on elephants were scanty.

Exercise involved neuromuscular co-ordination and complex physical changes involving aerobic and anaerobic reactions. For this purpose the tissue must be supplied with oxygen and excess carbon dioxide must be removed from

the body. The respiratory and circulatory systems adjusted automatically for this purpose. A large proportion of the energy released by muscles was converted to heat.

Nirmalan and Nair (1971) reported that the rectal temperature and respiratory rate were positively correlated with air temperature, but negatively with relative humidity.

Exercise demanded increased nutrients and oxygen supply. Exposure to solar radiation and other climatic elements also influenced their physiological reaction (Smith and Hamlin, 1970; Thomas and Razdan, 1973).

Work load produced tachycardia in bovines. The level of tachycardia depended on environmental conditions (Upadhyay, 1987). Studies reported by Upadhyay and Madan (1985) indicated that the rise in environmental temperature was parallel with rise in body temperature (correlation 0.71, $P<0.01$) in Zebu cattle. The respiratory frequency also increased several fold during work which depended upon intensity of load and climatic conditions.

Studies on the draughtability in Indian camels at the national research centre on camel revealed the following results. The respiration rate showed an increase of 67.267 per cent over initial values while pulse rate increased by 41 to 70 per cent and rectal temperature by 2.1-3°C. The magnitude of increase did not exactly match the increase in load. There were indications that seasons had remarkable influence on the level of increase of these physiological attributes.

Although the respiration, pulse and rectal temperature declined after an hour rest, they remained higher (100 per cent), 29 per cent and 2°C respectively than initial values (Rai and Khanna, 1991)

When a muscle contracted against a load large amounts of ATP was cleared to Form ADP, the greater the amount of work performed by the muscle the greater the amount of ATP that is cleaved (Fenn effect) (Guyton, 1991).

During work the animal had to adjust to local condition and to work. In hot climate the adaptation is two fold: first to work, second to climate. The adjustment to the limiting factors is related to the physiology of the animal, ie oxygen supply to working muscle, increased heat of work and environmental heat; all involve definite systems within the body for optimum oxygen supply to working muscle, increased heat of work and environmental heat; all involve definite systems within the body for optimum oxygen utilisation, loans part and thermo regulation. The various performance limiting factors in draught animals are physiological, cardio respiratory metabolic and energy demand (Upadhyay, 1982). Nair (1996) reported that there was gradual rise in respiration, pulse and rectal temperature in elephants as duration of work increased.

Muscle fatigue

Muscle was able to contract and perform work for certain periods even in the absence of oxygen but until it get fatigued. It is a stage of exhaustion when no more response is widened. In a thoroughly fatigued muscle, muscle ATP and

glycogen were fully exhausted and there was marked accumulation of lactic acid. When a fatigued muscle is further supplemented with oxygen lactic acid decreased and glycogen and ATP were regenerated. However, if the anaerobiosis is further prolonged fatigue becomes permanent (Nagabhushanam and Kodakkar, 1978).

Prolonged and strong contraction of a muscle lead to the state of muscle fatigue. Muscle fatigue increased in almost direct proportion to the rate of depletion of muscle glycogen. Therefore, most fatigue probably resulted from inability of the contractile and metabolic process of the muscle fibres to continue supplying the same work out put. However, experiments showed that transmission of the nerve signal through neuromuscular junctions, can occasionally diminish following prolonged muscle activity, thus further diminishing muscle contraction (Guyton, 1991).

Fatigue score card: Used to measure the fatigue level of the animal. A fatigue score card prepared by Upadhyay and Madan (1985) for working bullocks was based on physiological parameters namely heart rate, respiration rate and rectal temperature. The fatigue score totalled 40 points and animals attained, a score of 20 were declared fatigued. Nair (1996) studied the fatigue level of elephants in a simulated condition by making the elephants pull 10 per cent, 20 per cent and 30 per cent of their body weight for different schedule of work. He observed a significant increase in respiration rate, pulse rate, rectal temperature than normal

level at the end or one hour work but there were no signs of fatigue at that stage. At 20 per cent and 30 per cent level elephants started showing fatigue signs.

A score chart was prepared based on the physiological reactions. A score of one was given for every unit increase of pulse and respiration from normal level at the end of each hour of work. In the case of temperature a score of one was given for every 0.1 unit increase in rectal temperature from normal level. For every unit of reduction of speed at the end of each hour of work from the normal level a score one was allotted. Animals attaining a score of 15 were found fatigued. (Nair, 1996).

Machine Vs elephant draught

Ojha (1987) reported that in comparison to animal power the mechanical power was likely to be preferred to complete the operation faster and economical Indian farms were managed by means of animal and human power sources mainly till the tractors were introduced in 60's and the growth of mechanical power and that of electrical power sources came at a very fast rate in India. The number of draught animals had remained stagnant whereas the number of tractors, power tillers, oil engines, electronic motors and other power machines in use had very high growth.

The exact status of use of machines in timber hauling, replacing the use of elephants could not be traced. Draught Animal Power (DAP) was complementary to petroleum based power. While mechanisation, as a process of

naturalisation and development continued at a pace technically feasible, DAP was utilised where ever it is inevitable or appropriate. Studies showed that efficiency of DAP system was very low. As DAP was used largely by farmers and poor men there was an urgent need to modernise the system (Ramaswamy, 1988). The Winrock International Organisation in USA had made exhaustive calculation of relative power consumption in many regions. According to them animal power as a proportion of mechanical plus animal power was over 80 per cent in most of the third world countries, and was as much as 95 per cent or more in the far east and South Asia. (Ramaswamy, 1988).

Materials and Method

MATERIALS AND METHODS

The experiment was designed to study the draught efficiency of elephants in actual working condition in the timber mills. Six elephants in four private timber mills of Trichur district of Kerala state in India were selected for conducting the experiment. The study was conducted during 01.01.2000 to 30.06.2000.

Details of elephants

Elephant No.	Age	Address
I	29	EMKE Timbers Thiruvullakkavu
II	35	Saj Timber Perumbillisseri
III	40	Bastian timbers Perumbillisseri
IV	33	Saj Timbers Perumbillisseri
V	26	Bastian Timbers Perumbillisseri
VI	44	Chevur Timbers Chevur

I Estimation of body weight

Weight of the elephant was estimated from chest girth and neck girth employing the equation.

$$W = 12.8 (g + ng) - 4281$$

Where W = weight in kg.

g = chest girth in cm

ng= neck girth in cm (Ananthasubramaniam, 1979)

The weight thus obtained was used to estimate the draught efficiency in terms of body weight of the elephant and nutrient requirement.

II. Collection of management details

Data on feeding and management of elephants in selected timber mills were collected. The schedule of feeding and type and quantity of feed given were observed for seven days continuously in each timber mill. The dry matter intake and approximate nutrient availability of the given feed were calculated using the known data available (Ananthasubramaniam, 1979).

Schedule of work of each elephant, type of work available during the entire day, the peak work hours, facilities provided for drinking water, bathing and rest were documented.

III Classification of type of work

After a preliminary observation for one week, the works for which the elephants were engaged in timber mills were classified as follows.

Hauling:- Hauling is the method of dragging timber using 'vakka' attached to the log by means of a chain on one end and the other end of which is held by the elephant between its upper and lower molars. Trunk is occasionally used to help in the process. The weight of the log thus hauled, the percentage of hauling in the total work done by the elephant, average speed during hauling, distance

travelled and draught developed during hauling were measured in the present study.

Carrying: Logs of smaller magnitude were carried on the tusks or by the trunk, Here the log did not come in contact with ground during transportation. The weight of the log thus carried, percentage of carrying in the total work done by the elephant, average speed during carrying and the distance traversed during carrying, were documented.

Moving: The Elephant use its forehead, trunk and limbs to move the log for short distances especially during stalking. The percentage of moving in the total work done by the elephant was calculated in the present experiment.

IV. Estimation of weight of log

A sample of each type of log available in timber mills were collected. The weight of each sample was measured directly using balance. The volume of the sample were estimated by the amount of water displaced by it. The density per unit volume of the log was estimated. Volume of the entire log was calculated by the formula $\prod r^2 l$ where l is the length of the long and r is the radius. Length and girth of each log transported were measured. The weight of the entire log transported by the elephant was found out by multiplying the volume with unit density. The total quantity of log transported by elephants per day was worked out.

V. Assessment of draught

The working hours in timber mills on an average was between 8.30 AM to 4.30 PM. The entire work carried out by elephants in a day was observed by complete recording of the work from 8.30 AM onwards. The parameters observed for each type of work were:

a) Length, girth and type of wood

b) Time spent for carrying out each work

c) Distance covered for transporting each log.

Out of the total work performed by the elephant the respective percentage for stalking, hauling and carrying were worked out.

A. Carrying

The draught developed while carrying the log was calculated by finding the total weight of the log carried. This was expressed in terms of percentage of body weight. The weight of each log carried by elephant was recorded and the average weight of the log transported by carrying was found out.

B. Stalking/moving

The draught developed while moving the log was calculated by finding the total weight of the log moved. This was expressed in terms of percentage of body weight. The weight of each log transported by moving was found out.

C. Hauling

The heavier logs were transported in timber mills by hauling. Weight of each log hauled was calculated. Measurement of draught developed during the work was done by direct and indirect methods.

C (i) Indirect method: While hauling the log will be lying parallel to the ground. One end of the rope (Vakka) is attached to the adjacent end of the log and the other end is held by the elephant by its mouth. An angle is formed at the point of attachment of the log forming the ground as the base and the rope as the hypoteneous of the triangle. The length from the point of attachment to the point perpendicular to the mouth of the elephant was measured as the base of the triangle. The length of the rope from the point of attachment to the point where animal held the rope was measured to find out the angle of pull.

Draught developed was indirectly measured by the formula

Draught = Load x Cos θ

(Maurya and Devedatham , 1982; Nair, 1996)

C (ii) Direct method: Measured the draught developed directly in an electronic instrument called Elephant Draught Power Monitor (EDPM), developed by Central Institute of Fisheries Technology (CIFT).

Parts of the Elephant draught power monitor sensor

Sensor

Important part of the sensor was a spring, which can withstand high tension. The tension developed during timber hauling was converted to electrical impulses which was digitally displayed in the monitor.

Monitor

The tension developed during timber hauling by elephants was digitally displayed by the monitor in kilograms.

Graphical Recorder

In order to get a recording of the fluctuating force during timber hauling, an electronic graphical recorder was utilized. The graph thus obtained was analyzed to arrive at the average draught developed during timber hauling.

Estimation of draught

The force exerted by elephant while hauling the log was graphically recorded using the instrument.

Average force developed was derived from the graph and was taken as the draught developed by elephant. The values were used to arrive at a regression equation which predicted the draught developed for the given weight of the log.

The values obtained by direct recording were compared with the values obtained by the indirect method.

VI. Speed of work

The distance covered to move a log from one point to another and time taken for it were measured. The speed of work expressed as metre per second (m/s) was estimated from the above data. Speed of work during different types of work were estimated. The change in speed of work with increasing levels of draught was calculated.

VII. Horse-Power

The power developed by the draught elephant could be better expressed by converting the draught power into kilowatts or horse-power. HP was calculated using the formula

$$HP = \text{Draught} \times \frac{\text{Speed (m/s)}}{75}$$ (Maurya and Devadattam, 1982)

VIII. Work Output

Draught expressed in kilogram (kg) was converted to Newton by multiplying with 9.81 and the work output was calculated as the product of draught x displacement, expressed in joules.

Cumulative work output of elephant in a day was estimated from the data. The work output from different types of work were also calculated.

IX. Daily Work Schedule

Duration of each schedule of work was noted. Rest period given to elephants were simultaneously recorded. From these observations the daily work schedule of elephants were calculated. The observations were made under actual field conditions in the timber mills.

X. Observation of physiological parameters

Observations of respiration, pulse and rectal temperature of elephants selected for study were made every two hours on a rest day in all the timber mills. The diurnal variation of these readings were noted for each elephant.

Respiration rate, Pulse rate and rectal temperature were recorded before the commencement of work and immediately after completion of each schedule of work and rest periods.

Respiration rate was counted by keeping the palm close to the nostrils of the elephant. Pulse rate was taken by placing index finger on the ear artery at the base of the ear. Rectal temperature was measured by inserting a clinical thermometer in the rectum and keeping its bulb touching the rectal mucosa for a minute.

XI. Observation of fatigue signs

Fatigue signs of elephants like, increased fanning of ears, increased frequency of spraying saliva, reluctance to move and appearance of tears from

eyes during rest period and different stages of work were observed. The maximum value obtained for each fatigue sign during long period of work schedule was observed. These observations were compared with the corresponding physiological changes. The maximum tolerable level of increase in physiological parameters was ascertained.

XII. Machine power Vs elephant draught

Purchase value of elephant was collected from each timber mill and daily maintenance cost was calculated by computing the feeding cost, labour cost and other miscellaneous cost.

The details of alternative mechanical power used in timber mills were collected. Comparative maintenance cost and performance cost of mechanical and elephant draught power were analysed.

Results

RESULTS

Estimation of body weight

The mean body weight of elephants under study was estimated to be 4627.80 ± 114.15 kg. The body weights of all the six elephants are given in table 1.

Table 1 Body measurements and weight of elephants

Elephant No.	Neck girth (cm)	Chest girth (cm)	Weight (kg)
1	285.00	425.00	4807.00
2	290.00	428.00	4909.40
3	276.00	420.00	4627.80
4	281.00	430.00	4819.80
5	261.00	400.00	4179.80
6	270.00	410.00	4423.00
Mean			4627.80
SE			114.15

Feeding and Management

Feeding: The type and quantity of feed available by working elephants, its dry matter content, DCP and TDN available are given in table 2. Palm leaves (*Caryota urens*) containing 38.80 per cent dry matter, 1.45 percent DCP and 24.60 per cent TDN was the major roughage available and concentrate was parboiled cooked rice (*Oryza sativa*). The dry matter content, DCP and TDN available in rice were 86 per cent, 7 per cent and 8.1 per cent respectively.

Table 2. Feeding details of work elephants

Elephant No.	Age (years)	Body weight (kg)	Roughage (kg)	Concentrate (Kg)	TDN (kg)	DCP (kg)	Dry matter (kg)
1	26	4179.8	196 ±11.4	6 ± 0.5	53.496	3.262	81.388
2	29	4807.0	211 ±2.34	10 ±0.35	60.706	3.760	90.768
3	33	4819.8	220 ± 06.3	7 ± 1.2	60.260	3.680	91.590
4	35	4909.4	219 ± 4.1	7 ± 1.1	60.034	3.666	91.202
5	40	4627.8	222 ± 2.3	7 ± 0.8	60.772	3.709	92.366
6	44	4423.0	210 ± 1	8 ± 0.4	58.700	3.605	88.600
Mean			213 ± 3.33	7.5 ± 0.47			

An average of 150g of common salt and 25g of turmeric powder were used as additives in the preparation of concentrate mixture. In addition to this working elephants consumed occasionally small quantities of human food offered by the mahout and the bark of some timbers, the quantity of which was difficult to determine.

An adult elephant required 168g/kg$^{0.73}$, dry matter, 6g/kg$^{0.73}$, DCP and 58 g/kg$^{0.73}$ of TDN for maintenance. (Ananthasubramaniam, 1979). From the above data nutrient requirement of elephant for maintenance were worked out. The nutrient availability of the feed consumed by elephant was compared with the nutrient requirement for maintenance (Table 3).

Table 3

Dry matter content (kg)			
Elephant No.	Required	Available	Difference
1	73.918	81.388	+ 7.470
2	81.861	90.768	+ 8.907
3	82.020	91.590	+ 9.570
4	83.130	91.202	+ 8.072
5	79.622	92.366	+ 12.744
6	77.034	88.600	+ 11.566
Mean	79.597	89.319	+ 9.721
SE	1.441	1.668	+ 0.837

Table 4

DCP (kg)			
Elephant No.	Required	Available	Difference
1	2.460	3.262	+ 0.622
2	2.924	3.760	+ 0.836
3	2.929	3.680	+ 0.751
4	2.969	3.666	+ 0.697
5	2.844	3.709	+ 0.865
6	2.751	3.605	+ 0.854
Mean	2.842	3.613	+ 0.770
SE	0.051	0.073	+ 0.040

Table 5

TDN (kg)			
Elephant No.	Required	Available	Difference
1	25.519	53.496	+ 27.977
2	28.262	60.706	+ 32.444
3	28.316	60.280	+ 31.964
4	28.700	60.034	+ 31.334
5	27.489	60.772	+ 33.283
6	26.595	58.700	+ 32.105
Mean	27.480	58.998	+ 31.517
SE	0.497	1.142	+ 0.754

Elephants consumed 213 ± 3.338 kg roughage and 7.5 ± 0.475kg of concentrates. Dry matter available from it was 89.319 ± 1.668 kg, which was 9.721 ± 0.837 kg more than the requirement for maintenance alone. The DCP obtained for working elephants was 3.613 ± 0.073 kg as against the maintenance requirement of 2.842 ± 0.051 kg. The excess intake of DCP by working elephants over and above the maintenance requirement was 0.77 ± 0.040 kg. The TDN available was 58.99 ± 1.142 kg and the maintenance requirement was 27.48 ± 0.49 kg. The elephant obtained 31.517 ± 0.754 kg TDN over and above the maintenance requirement for performing work.

Bathing Elephants were given one to two hours of scrub bath everyday after the day's work. Coconut husk was used for scrubbing. Two out of the four timber mills had its own bathing tank

for the purpose. The elephants in the other two timber mills were taken to nearby streams for bathing. The bathing tanks had an area of $49m^2$ and a depth of 0.75m. A sand bed of 0.25 m thickness was laid at the bottom. The elephants were made to lie on its side in the tank during bathing. The water in the tank had to be changed every day. It was observed that when water is not changed frequently it caused allergic diseases in mahouts.

Implements

Mahouts used different kinds of implements for controlling the elephant. A stick with hook at one end (Cherukol) and one metre long flexible stick were the common implements used by mahouts during work. The 'Vakka' was used for hauling timber. Mahout prepared it from Nylon and Manila ropes. The elephants were kept chained on its hind legs to concrete pillars with strong base.

Assessment of Draught

1. Estimation of weight of the log

Unit density of the different varieties of timber transported by elephants in timber mills is given in table 6.

Table 6.
Unit density of different timbers

Type of wood	Density (kg/m^3)
Pincoda	1010.00
Teak	1264.00
Parijatham	1173.33
Rose wood	1175.00
Churuli	1232.00
Vaka	942.22
Violet	917.50

2. Classification of type of work

a. Carrying

Plate.1

Mean draught developed during carrying was 445.095 ± 22.448kg or 4366.381 ± 220.214 N. The draught developed, percentage of load carried to the body weight; maximum and minimum load carried by each elephant is given in table 7.

Table 7. Draught developed during carrying

Elephant No.	Average weight of the log carried (kg)	Draught developed (kg)	Weight carried as percentage body weight	Maximum Weight carried (kg)	Minimum Weight carried (kg)	Range
1	400.458	400.458	9.581 %	1110.730	181.650	925.051
2	425.528	425.528	8.852 %	1002.354	178.540	823.614
3	423.000	423.000	8.770 %	1201.070	197.248	1004.331
4	550.325	550.325	11.210 %	1200.500	180.240	1020.260
5	458.000	458.000	9.897 %	1008.754	105.246	843.509
6	413.258	413.258	9.343 %	900.457	154.700	745.767
Mean	445.095	445.095				
SE	22.448	22.448				

b. Stalking/moving

Plate. 2

Mean draught developed during stalking was 353.824 ± 15.316kg or 3471.013 ± 150.249 N equivalent to 7.636 ± 0.211 per cent of the body weight of elephants. Draught developed during stalking, as percentage of body weight and maximum load transported during stalking is given in table 8.

Table 8.

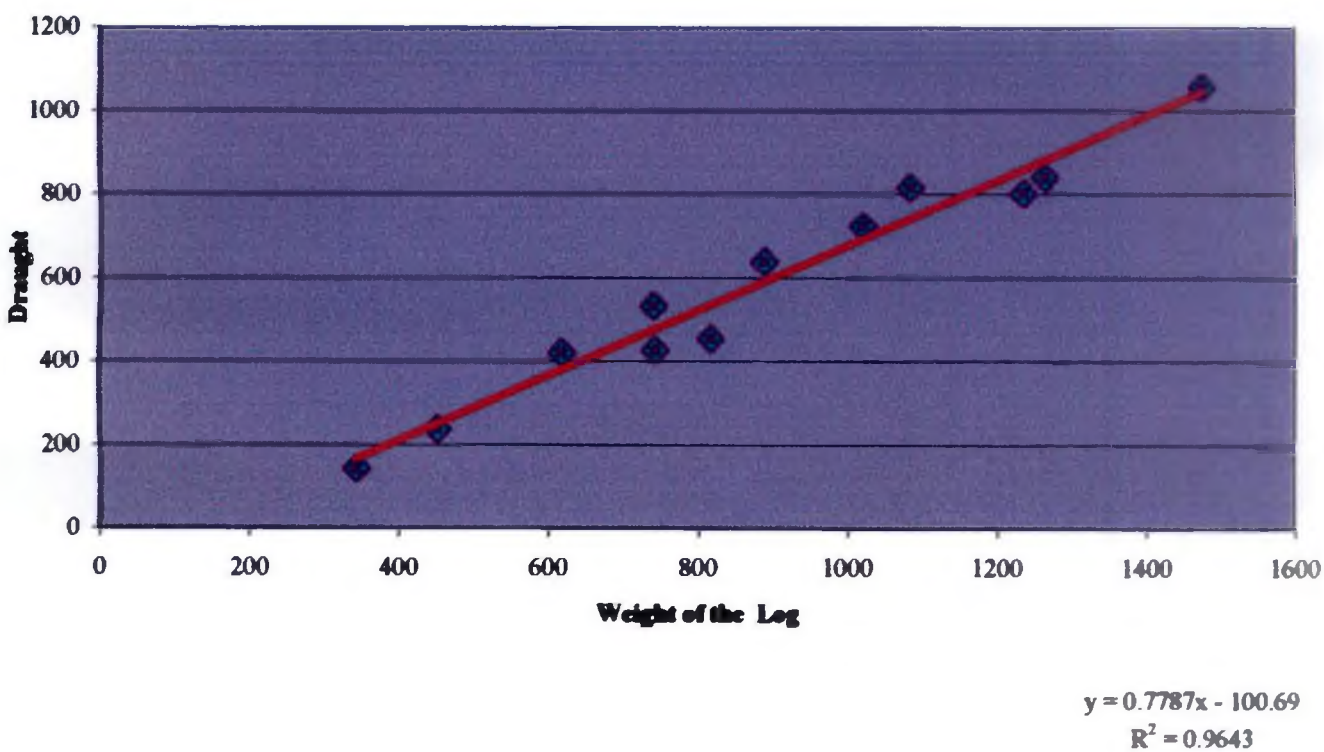
Elephant No.	Average weight of the log (kg)	Draught developed (kg)	Weight as percentage body weight	Maximum (kg)
1	314.930 ± 13.681	314.930	7.535 %	405.877
2	350.397 ± 14.348	350.307	7.289 %	617.386
3	300.419 ± 27.381	300.419	7.478 %	584.710
4	405.877 ± 20.611	405.877	8.262 %	600.131
5	381.491 ± 9.98	381.901	8.262 %	490.105
6	309.419 ± 11.334	309.419	6.996 %	381.656
Mean	353.824	353.824	7.6361 %	
SE	15.316	15.316	0.2116	

. Hauling

Plate. 3

The average of the peak values was worked out to estimate the force developed during hauling. The graphs were plotted during hauling of different logs in different terrain, through a fixed distance of 30 m. The speed of the graph was set at 25 cm/min. The draught developed during hauling was predicted using a regression equation from the available data. Relation between the weight of the log hauled and draught developed during hauling is illustrated by the fig (2). The relation is given by the regression equation Y= 0.7787 x -100.69 with a regression coefficient (R^2) of 0.9643 where Y= draught developed and X = the weight of the log.

Fig 2. Direct measurement of elephant draught



Indirect Method

The average draught developed during hauling estimated using the regression equation was 1779.391kg. The average draught developed during hauling worked out using formula was found to be 1050.257 ± 72.836 kg

Table (9) gives the draught developed during hauling as estimated by formula and by the regression equation, weight hauled as percentage of body weight and the maximum weight hauled by elephants.

Table 9. Draught developed during hauling.

Elephant No.	Average Wt of log (kg)	Draught developed (kg)	Draught estimated from EDPM equation	Weight hauled as percentage of body weight	Maximum recorded value
1	2029.574	882.865	1479.739	48.557 %	9814.289
2	2458.325	1069.371	1813.602	51.140 %	8562.145
3	2862.230	1245.070	2128.129	59.385 %	9500.458
4	2945.364	1281.233	2192.865	59.994 %	10023.547
5	2145.779	933.414	1570.228	46.367 %	7505.196
6	2045.030	889.588	1491.775	46.236 %	7001.320
Mean	2414.384	1050.257	1779.391		
SE	167.440	72.836	130.386		

Speed of work

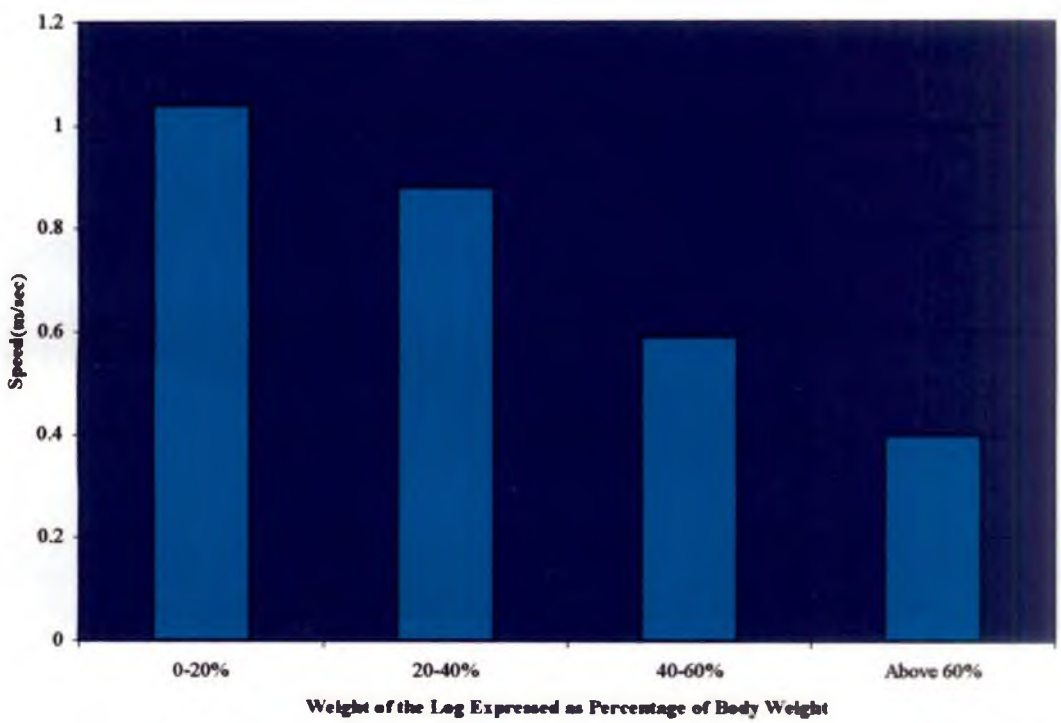
Speed of work of elephant during different types of work is given in table 10. Average speed of elephant during carrying, moving, stalking and hauling was 1.333 ± 0.075 m/s, 0.630 ± 0.014 and 0.701 ± 0.014 m/s respectively.

Table 10. Speed of work of elephants (m/s)

Elephant No.	Carrying	Moving/stalking	Hauling
1	1.278 ± 0.060	0.594 ± 0.023	0.651 ± 0.0141
2	1.599 ± 0.087	0.650 ± 0.082	0.682 ± 0.028
3	1.155 ± 0.029	0.610 ± 0.011	0.750 ± 0.032
4	1.355 ± 0.077	0.680 ± 0.024	0.713 ± 0.060
5	1.480 ± 0.091	0.646 ± 0.038	0.720 ± 0.512
6	1.130 ± 0.018	0.598 ± 0.018	0.690 ± 0.481
Mean	1.333	0.630	0.701
SE	0.075	0.014	0.014

The relationship between the speed of work and the weight of the log transported is illustrated in Fig. (3).

Fig 3. Speed of Work of Elephants



Horse Power

Average horsepower developed by elephants at different types of work is expressed in table (11). The average horsepower developed during carrying, moving/ stalking and hauling were 7.116 ± 0.106, 2.566 ± 0.048 and 7.138 ± 0.280 respectively.

Table 11. Horsepower of elephants at work

Elephant No.	Carrying	Moving	Hauling
1	6.768 ± 0.112	2.450 ± 0.051	6.100 ± 0.18
2	7.195 ± 0.098	2.566 ± 0.062	7.600 ± 0.099
3	7.270 ± 0.090	2.550 ± 0.088	7.100 ± 0.134
4	7.500 ± 0.108	2.660 ± 0.016	7.800 ± 0.014
5	6.967 ± 0.111	2.735 ± 0.022	7.670 ± 0.019
6	6.977 ± 0.078	2.433 ± 0.032	6.560 ± 0.025
Mean	7.116	2.566	7.138
SE	0.106	0.048	0.280

Work output

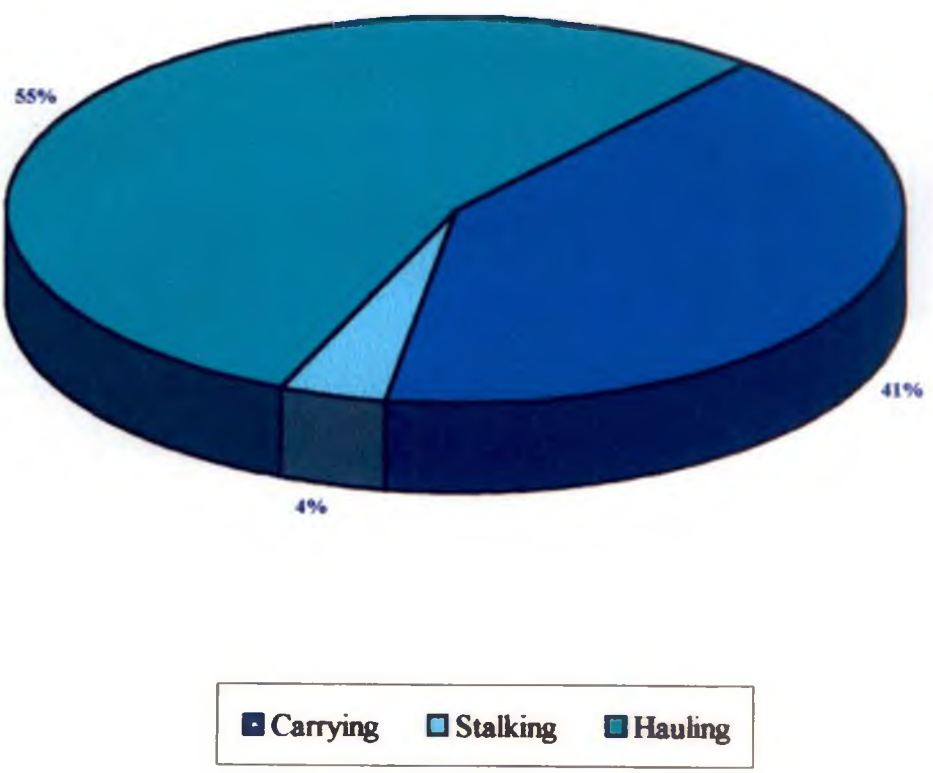
The average work out put per day during different types of work is given in table (12). The average work output during carrying, moving and hauling were 1819.004. ± 92.619, 179.718 ± 5.955 and 3375.373 ± 16.885KJ respectively.

Table 12. Work output of elephants/day (Kilo Joules)

Elephant No.	Carrying	Moving	Hauling
1	1592.708	181.242	3290.944
2	1907.502	159.459	3490.359
3	1822.927	178.790	3392.259
4	2213.963	204.766	3392.259
5	1755.542	174.974	3392.259
6	1623.344	179.077	3392.259
Mean	1819.004	179.718	3375.373
S. E.	92.619	5.955	16.885

Work output of different types of work per day is illustrated in Fig 4.

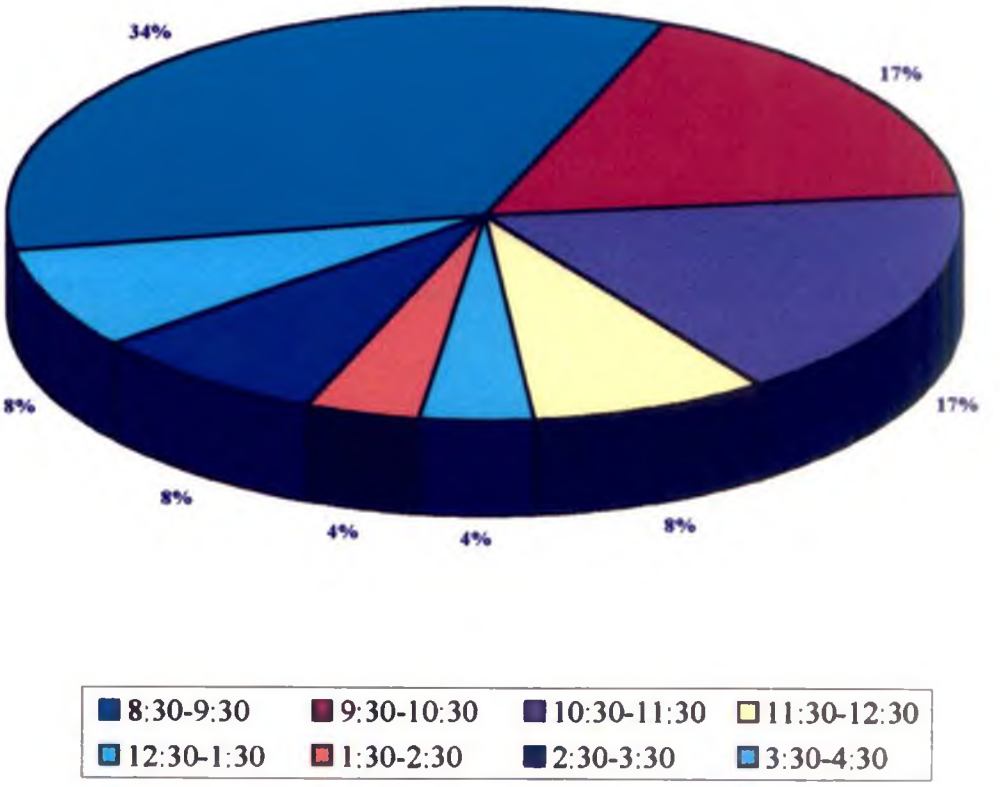
Fig. 4. Percentage of Various Types of Work in the Total Work Output



Daily work schedule

The working period of timber mills was from 8.30 am to 4.30 pm. The percentage of work during each hour is illustrated in fig (5). Maximum work (34%) occurred during 8.30 to 9.30 am and minimum work during 12.30 pm to 2.30 pm.

Fig. 5. Daily Work Schedule



Physiological parameters

Diurnal change in body temperature, pulse rate and respiration rate is depicted in Fig. 6, Fig. 7 and Fig. 8 respectively. Diurnal fluctuation was estimated during rest days.

Fig. 6 Diurnal fluctuation of body temperature

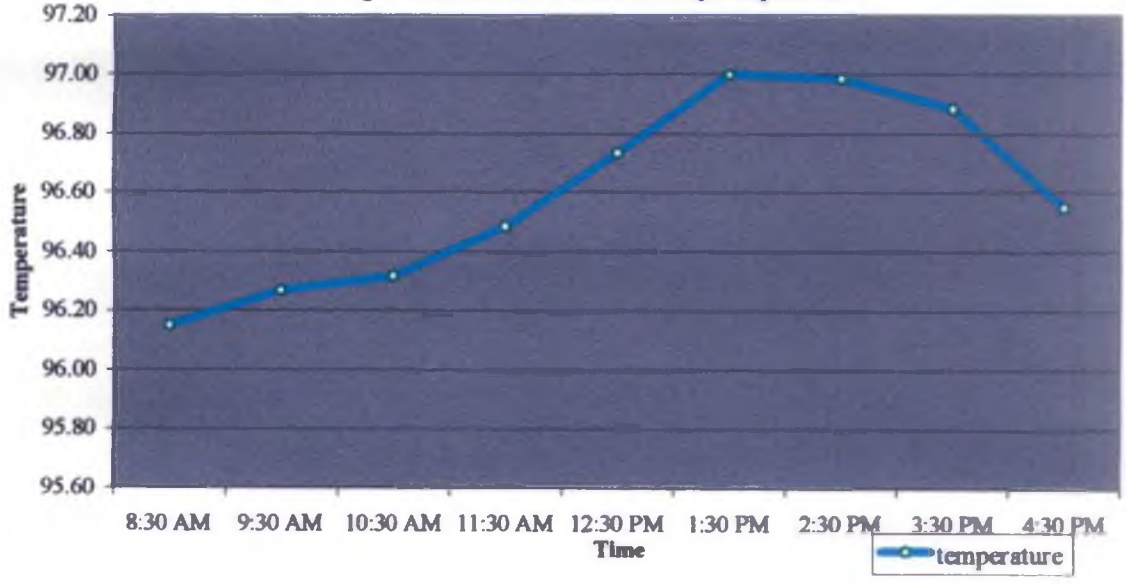


Fig. 7 Diurnal fluctation of pulse rate

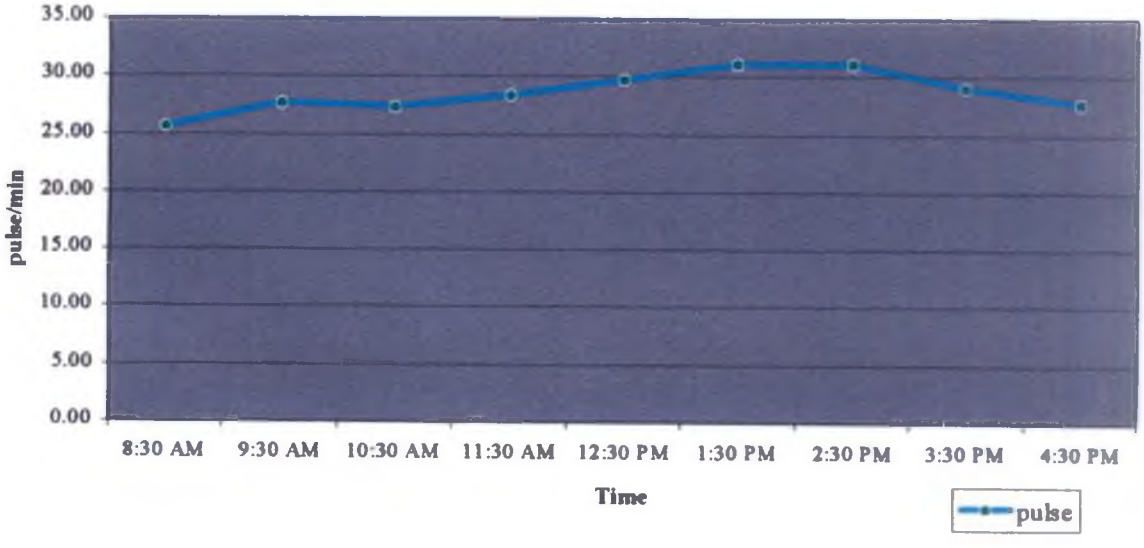
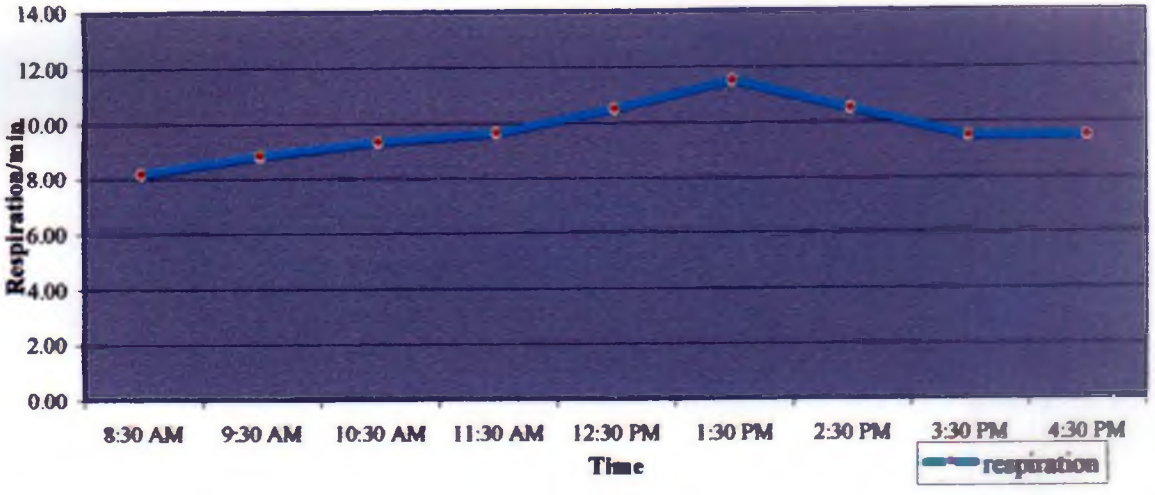


Fig. 8 Diurnal fluctuation in respiration

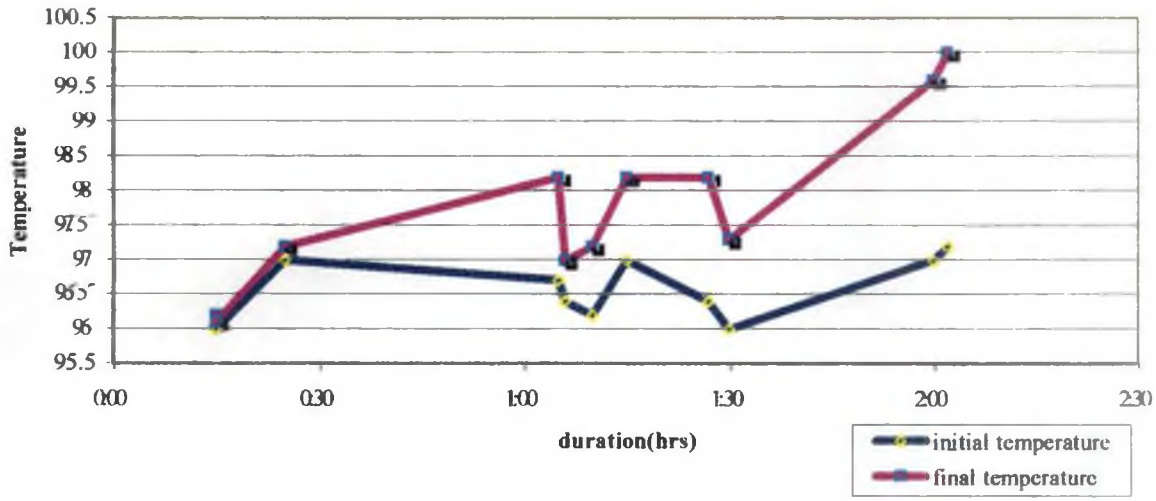


Changes in physiological parameters during work.

1. Temperature

Change in rectal temperature with duration of work is given in fig.9. Maximum-recorded temperature corresponding to duration of continuous work of two hours and ten minutes was 100^0 F. The blue line corresponds to the rectal temperature at the start of each schedule of work and red line denotes the corresponding rectal temperature at the end of each schedule of work. The initial temperatures vary with time of recording and previous schedule of work, but the difference between the initial and final temperature increases as the duration of continuous work increases.

Fig. 9 Change in temperature with duration of work

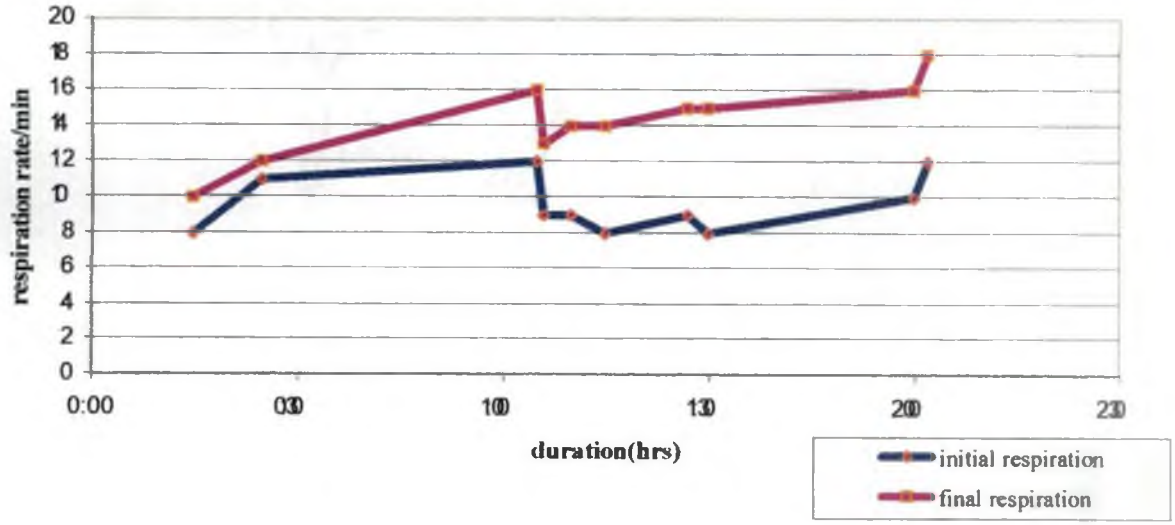


2. Respiration

Change in respiration with duration .10

Initial and final respiration rate increases as the duration of continuous work increases.

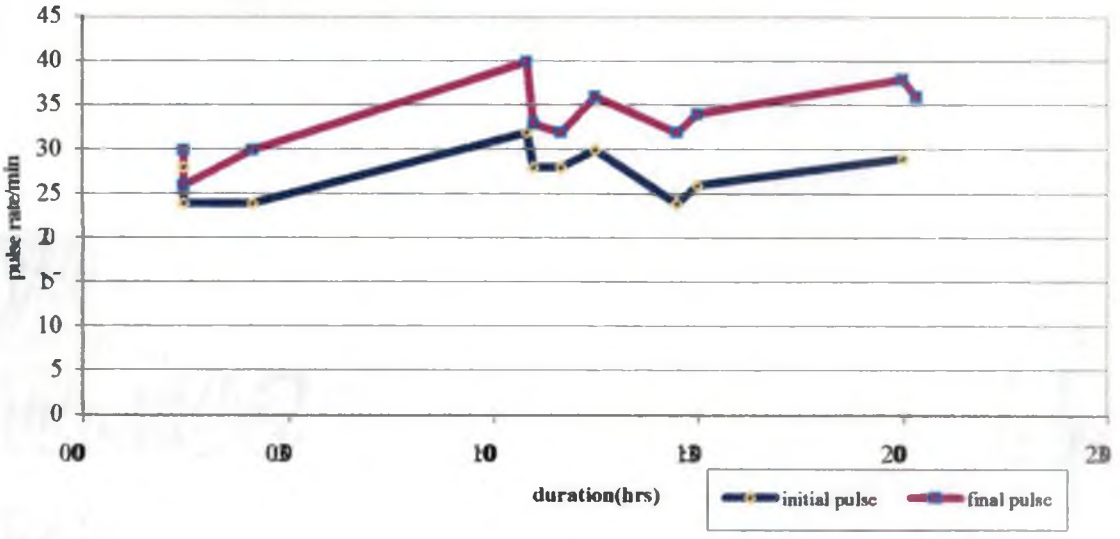
Fig. 10 Change in respiration rate with duration of work



Change in pulse rate of work elephant with duration of work is illustrated in fig. 11.

The difference between the initial and final pulse rates increases as the duration of continuous work increases.

Fig. 11 Change in pulse rate with duration of work



Fatigue signs

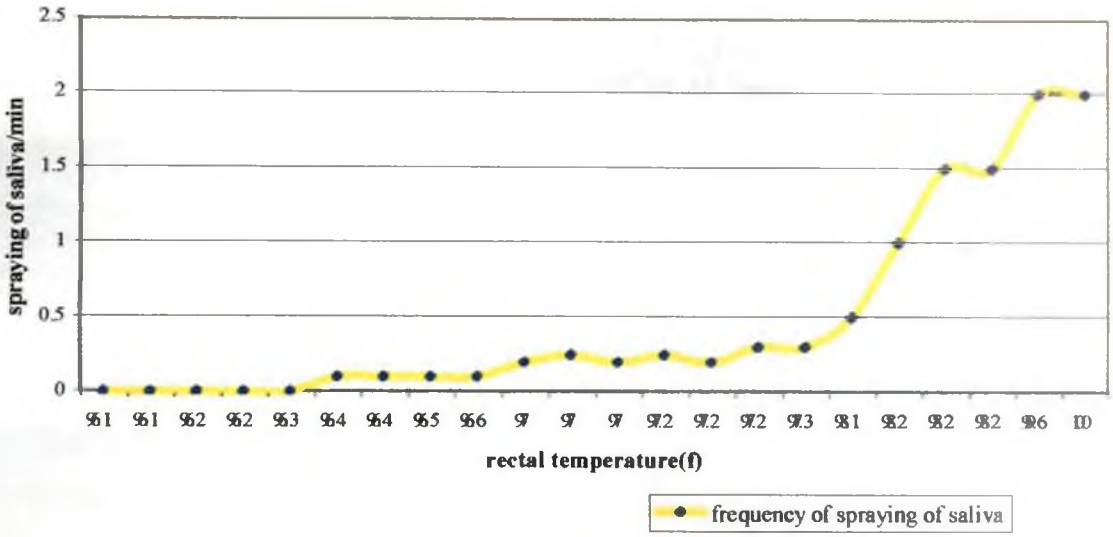
The fatigue signs noted were spraying of saliva and incr

Maximum frequency of spraying of saliva was during the entire study period was 2/min, and the maximum frequency of fanning of ears was 45/min. The value of rectal temperature, respiration and pulse rate corresponding to the maximum

18/min and 36/min respectively.

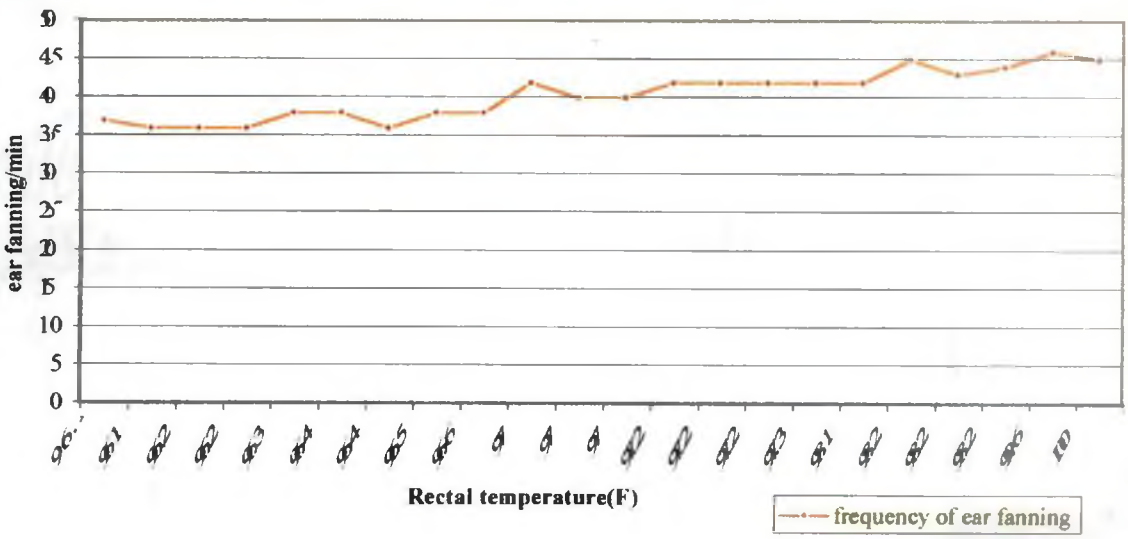
The relationship between rectal temperature and spraying of saliva is illustrated in fig. 12.

Fig.12 Relation between frequency of spraying of saliva and rectal temperature



The Fig 12 gives relation between ear fanning frequency and rectal temperature

Relation between frequency of ear fanning and rectal temperature



Machine power V/S Elephant power

Plate 4

Technical considerations

Maximum draught developed by elephants during the entire study period for carrying, stalking and hauling was 1201.578 kg, 600.131 kg and 7702.641 kg. respectively. During the study it was observed that machines that could carry weights up to 10000 kg were commonly used in timber mills. The speed of work of elephants during carrying, stalking and hauling were on an average 1.333 ± 0.075 m/s, 0.630 ± 0.014 m/s and 0.701 ± 0.014 m/s respectively where as the machines were found to carry logs with a speed of 2.01 ± 0.015. Elephants had better maneuverability than machine during stalking. Machines were observed to cause environmental pollution where as elephants were more environmental friendly. Elephants were better compared to machines in difficult and muddy terrains during work.

Economic considerations

Table. 13

Elephant		**Machine**
1. Capital involved: Rs.11, 00,000		1. Capital involved: Rs.12, 00,000
2. Feed cost/day		2. Diesel charge/day Rate Rs.18/ litre Quantity: 20 L Rs.360 / day
Roughage	Concentrate	
Rate Rs.1.50/kg Quantity 213 kg Amount Rs.319.50 Total: Rs 372/day	Rate Rs.7/kg Quantity 7.5 kg Amount Rs.52.50	
3. Mahouts wages Rs.75/head for 3 personsRs225/day		3. Drivers wages: Rs.100/day
4. Veterinary & Miscellaneous Rs.10/day		4. Maintenance charge Rs.100/day
Total recurring expenditure: Rs 607/day		Total recurringexpenditureRs560/day

Discussion

DISCUSSION

Estimation of body weight

The body weight of adult male Asian elephant was estimated to be 4627.80 ± 114.15 kg based on a formula (W=12.8 (g+ng) -4281) developed by Ananthasubramaniam (1979). The result was in agreement with the estimations done by Sreekumar (1986).

Feeding and Management

Elephants consumed 213.00 ± 3.338 kg roughages (palm leaves) and 7.50 ± 0.475 kg of concentrates (rice) daily. The dry matter available from it was 89.319 ± 1.668, i.e., 1.93 per cent of the body weight of elephants. Ananthasubramaniam (1979) reported that elephants required 168 $g/kg^{0.73}$ of the body weight i.e., 1.72 per cent of the bodyweight. An increased dry matter supply equivalent to 0.21 per cent of the body weight of elephant was observed in the present study. Increased amount of dry matter consumption by working elephants over and above their maintenance requirement could be attributed to increased requirement for performing work. Increase in DCP and TDN consumption over and above the maintenance requirement was 0.77 ± 0.040 kg and 31.517 ± 0.754 kg respectively. Ponnappan (1998) reported that palm leaves (*Caryota urens*) was the staple food of elephants in Kerala. The present study reaffirms the importance of palm leaves. According to elephant owners and mahouts scarcity of Caryota leaves was a major constraint in elephant keeping.

Conservation and propagation of *Caryota urens* can be suggested as a long term strategy for elephant conservation in the state. It was noted that the work elephant were offered a monotonous diet and there was chance of mineral deficiencies especially when they have no access to tree barks.

Easa and Sankar (1999) identified 97 natural herbage frequently consumed by wild elephants in Wayanad. The possibility of inclusion of any of these in the diet of work elephants has to be explored.

Assessment of draught

Carrying: The elephants in timber mills were observed to carry smaller logs on their tusk. The mean weight of the log carried was 445.095 ± 22.448 kg equivalent to 9.62 per cent of the bodyweight. Highest average weight carried was recorded as 1.21 per cent (550.32 kg).

The maximum weight of the log carried by an elephant during the entire study period was recorded to be 1201.00 kg. The average maximum weight carried by elephants was estimated to be 1070.157 ± 49.26 kg equivalent to 23.12 per cent of the average body weight of elephants.

In the draft proposals on captive elephant management the Forest Department has stipulated 400 kg as the maximum weight allowed to be carried by an elephant. In the light of the results of the present study the proposal by Forest department seems to be difficult implement. The weight carrying capacity varied from elephant to elephant and the limit of maximum weight carried can be

expressed in terms of body weight. Considering the prevailing situation, to be on the safer side (from animal welfare point of view) 20 per cent of the body weight (i.e., a round figure below the observed maximum limit) may be proposed as the maximum weight that can be allowed to be carried by elephants on its tusks.

Cheeran (1998) reported that root of the tusks became oedematous by excessive use of tusks to carry the load. History collected during present study could not trace any incident of oedema of the root of the tusk to any of the elephants studied. So it could be assumed that the extent of carrying observed in the present study was tolerable. But it needs further investigation to establish long term effects of carrying the load on the tusk by work elephants.

Stalking/Moving: The average weight of the log during stalking was observed to be 353.82 ± 15.316 kg equivalent to 7.636 ± 0.211 per cent of the body weight. The maximum weight recorded during stalking was 600.131 kg. The type of work during stalking was comparatively lighter and maximum limit may be proposed as the same for carrying.

Hauling

Direct method: O' Neill *et al.* (1987) explained the general specification for a system which directly measures the performance of draught animals. The Elephant Draught Power Monitor (EDPM) developed by Central Institute of Fisheries Technology (CIFT) for the present study conformed to many of these

specification and was calibrated to measure upto 1000 kg draught. It was compact and did not cause additional stress to elephants.

The graphical output from EDPM (Fig.1) demonstrated that the force exerted by elephant was not uniform, but fluctuated continuously during hauling. Each peak indicated the instantaneous draught developed. The average of all the peaks in the graph was taken as the draught developed during hauling of a given weight of the log through a specified distance. The instrument developed for the present study was not enough to measure the draught developed during hauling of big timbers, as the calibration was only upto 1000 kg. Exact measurement of draught developed by elephant can be obtained only by better instrument which can measure upto 7000 kg of draught with a compact wireless sensor and automatic data analysis system. In order to predict the draught developed during hauling of bigger timbers a regression equation was formulated from the data obtained.

$$Y = 0.7787\,x - 100.69$$

The equation had a regression coefficient (R^2) of 0.9643. This regression equation which can be referred to as EDPM regression equation was used for indirect measurement of draught during hauling.

Indirect method

Nair (1996) employed the formula (Draught = load x Cos θ) for measurement of elephant draught. In the present experiment both the formula

(Draught = load x Cos θ) and the EDPM regression equation (Y=0.7787 x - 100.69) where employed for the indirect assessment of draught developed during hauling.

Average draught developed during hauling worked out using regression equation was 1779.391 ± 130.586 and the average draught developed during hauling worked out using Nair's formula was 1050.252 ± 72.836 N. There was significant difference between the values obtained from the formula and EDPM regression equation (P value 0.00064). The formula (draught = load x Cos θ) applied to cattle (Maurya and Devadattam, 1982) indicated the draught but it did not give accurate measurement of draught in elephant.

Average of the maximum weight which was hauled by each elephant under study was 8734.493 ± 513 i.e., 188.74 per cent of the body weight. Earlier reports suggested that for a short duration an initial draught of 200 per cent of bodyweight in single donkeys and horses, 155 per cent of body weight for a pair of donkeys and 104 to 150 per cent for a pair of bullocks were possible (Anon., 1972). This high level was not possible during continuous work which was around 7.5 to 24.5 per cent for bullocks (Maurya, 1985).

The draft proposals of Forest department stipulated 1000 kg as maximum weight that would be hauled by an elephant. In the light of the present study it may be proposed that maximum limit for continuous work during hauling could be 38 per cent of body weight (round figure close the highest average recorded

value). For instantaneous draught development involving very short time elephant could be allowed to haul upto 188 per cent (round figure close to highest maximum recorded value) of its body weight.

Speed of work

Krishnamurthy (1989) reported that average walking speed in elephants ranged from 3 to 3.5 km/h i.e., 0.833 to 0.972 m/s. Nair (1996) estimated speed of elephants during different draught levels and at different times of work. Initial speed was reported to be 4.83 km/h i.e., 1.34 m/s and the speed at the end of three hours of continuous work at 30 per cent draught level was 2.35 km/h i.e., 0.652m/s. In the present study the speed of work of elephant during carrying, moving and hauling was estimated as 1.33 ± 0.075m/s, 0.630 ± 0.24 m/s and 0.701± 0.014 m/s respectively. Higher values indicated that the elephants were made to work more in private timber mills. Elephants performed faster during carrying. The analysis of change in speed during different levels of draught indicated significant reduction in speed during higher draught levels as reported by Rautary (1987), Upadhyay (1987) and Nair (1996).

Horse power

In terms of horse power the approximate power developed by various animals was reported. Horse – 1.0, Bullocks – 0.74; Buffalo – 0.75, low – 0.45, mule – 0.75, donkey – 0.35 (Anon, 1972). Maximum horse power of elephants recorded during the present study was 7.8 ± 0.014. The average horse power

during carrying/moving and hauling where 7.116 ± 0.106; 2.566 ± 0.048 and 7.138 ± 0.280 respectively. In comparing working abilities of animals, it was reported that the draught developed by the animal was generally proportional to its body weight (Sastry *et al.*, 1991). The present study indicated that it was true for elephants as well.

There was significant difference between horse power generated during carrying and moving, and moving and hauling. But there was no significant difference between horse power generated during carrying and hauling. This was because carrying was performed faster eventhough the draught developed was much higher during hauling.

Work output: Quantification of work output is of immense value in assessing the use of elephants as work animals. Work is said to be performed when the body moves in the direction of application of force. When force is measured in Newton and displacement in metres, the work output is expressed in Nm or Joules.

Average work output of elephants/day during carrying moving and hauling were 1819.004 ± 92.619 KJ, 179.718 ± 5.955 KJ, 3375.373 KJ respectively. Maximum work output was obtained during carrying.

Daily work schedule

The documentation of time of work of elephants in the timber mills during the entire study period indicated that maximum work occurred during

morning hours. Thirty four per cent of the entire work in a day was performed between 8.30 am and 9.30 am. Elephants were made to work only rarely during 12 pm to 2.30 pm. Mohandas (1998) reported that the work schedule of elephants was 8.00 am to 11.00 am and 3.00 am to 6.00 pm. The observed work schedule was almost in conformation with the reported schedule for elephants.

Physiological parameters

Physiological parameters like body temperature, pulse rate and respiration rate showed definite changes during work. The change was also influenced by the environmental factors like solar radiation and ambient temperature. There was significant changes in rectal temperature, pulse and respiration rates of elephants at different hours of the day. Scrupulous monitoring of physiological parameters during rest days was performed in order to assess the changes purely due to environmental effect. It was revealed that there was an average of 0.84°F increase in body temperature from 8.30 am to 1.30 pm during rest days, even when elephants were kept in shady places. Similarly corresponding increase in respiration rate and pulse rates was recorded.

During work, increase in rectal temperature was proportional to the duration of work. Maximum duration of continuous work without any break was two hours and ten minutes. Corresponding temperature was 100°F. Similarly respiration rate and pulse rate increased proportionately to the duration of work. This was in confirmation with the results obtained for earlier workers (Nirmalan and Nair, 1971; Rai and Khanna, 1991 and Nair, 1996).

Of the three physiological parameters taken for the study, rectal temperature was found to be more reliable. Counting respiration rate and pulse rate in elephants had more chance for error. More over fatigue score cards prepared using too many factors were of little value in practical situation. Hence the rectal temperature could be suggested as an indicator of level of fatigue in working elephants.

Fatigue signs: Fatigue signs like reluctance to move, number of beatings an elephant got during work, speed of work, disobedience to commands, appearance of tears from the eye, spraying of saliva on the body and change in frequency of fanning of ears were observed during the entire study period to identify suitable fatigue signs which can be correlated with rectal temperature in order to arrive at a measurable point of fatigue.

It was observed during the study that only spraying of saliva and fanning of ears showed definite increase in frequency with duration of work. Maximum frequency of spraying of saliva was two per minute and the maximum frequency of fanning ears was found to be 45/minute. The rectal temperature corresponding to the maximum frequency of spraying of saliva was 98.6°F. So this temperature can be regarded as critical for an adult male elephant during work. It can be proposed that the elephants should be given rest before reaching this temperature in order to avoid undue stress and fatigue. The mahouts should be trained in the simple technique of taking rectal temperature for the purpose.

Machine power v/s elephant power

Machine was observed to be more efficient in terms of load carrying capacity and speed of work. Elephants were observed to have better maneuverability and worked in difficult terrains. Ojha (1987) reported that in comparison to animal power, the mechanical power was likely to be preferred to complete the operation faster and more economical. The present study indicated that it was true in case of elephant draught power also.

Use of machine and elephant in timber mill had comparable economics. But the machines use non-renewable petroleum resources whereas elephants can survive on tree leaves without taxing on our resources. Machines cause pollution whereas elephants are environmental friendly. Captive elephants attract tourists and thus indirectly add to our economy. Therefore the state should take active measures to conserve elephants. Propagation of *Caryota urens* on a large scale, scientific monitoring of work load of elephants, training to mahouts and exploring new avenues for utilizing elephant draught power are needed to achieve better utilization and thereby conservation of elephants in captivity.

Summary

SUMMARY

The objective of the experiment was to study the draught efficiency of elephants (*Elephas maximus*) in actual working condition in timber mill and to suggest measures to improve. Six adult male elephants owned by four timber mills in Trichur district were studied. The average weight of elephants under study was 4627.80 ± 114.15 kg.

Analysis of feeding details were conducted. Elephant consumed 213.00 ± 3.338 kg roughages (palm leaves) and 7.50 ± 0.475 kg of concentrate (cooked rice). Working elephants obtained 9.72 ± 0.837 kg dry matter, 3.613 ± 0.075 kg DCP and 31.517 ± 0.754 kg of TDN over and above their maintenance requirement. It was assumed that this was utilized for work performance.

Work elephants were observed to be given one to two hours of scrub bath everyday. The facilities for bathing and implements used for restraint were documented.

After a preliminary observation for one week the work for which elephants were engaged in timber mills were classified as carrying, moving/stalking and hauling.

Mean draught developed during carrying was 445.095 ± 22.448 kg. Maximum weight carried was 1201.070 kg. It was proposed that elephant could be allowed to carry weights upto 20 per cent of their body weight on their tusks.

Mean draught developed during stalking was 353.824 ± 15.316 kg. Maximum limit during stalking was proposed as the same for carrying.

Draught power of work elephants during hauling was measured by direct and indirect method. Direct method was by an instrument (Elephant Draught Power Monitor) developed for the purpose by Central Institute of Fisheries Technology (CIFT). The instrument recorded continuously fluctuating force applied by the elephant during hauling. Analysis of the graph output of the instrument predicted draught development through a regression equation $Y = 0.7787x - 100.69$ where Y in the draught developed and x is the weight of the log. Indirect method utilized the regression equation for the measurement of draught developed during hauling. A formula originally used for cattle (Draught = load x Cos θ) was also used for draught development by indirect method.

Average draught developed during hauling estimated by EDPM regression equation was 1779.391 ± 130.386 kg and by formula was 1050.257 ± 72.836 kg. There was significant difference between the two. Highest maximum limit of weight that can be hauled during instantaneous force development was 188 per cent of the body weight and maximum limit of weight that can be hauled during continuous work was 38 per cent of body weight.

Speed of work of elephants during different types of work was estimated. The speed of work during carrying, moving and hauling was 1.333 ± 0.075,

0.630 ± 0.014 and 0.701 ± 0.014 m/s respectively. Speed of work decreased with increase in weight of the log during all types of work.

Horse power developed was estimated by using the formula

$$HP = \frac{\text{Draught x speed (m/s)}}{75}$$

The average horse power developed during carrying, moving and hauling were 7.116 ± 0.106 hp, 2.566 ± 0.048 hp and 7.138 ± 0.280 hp respectively.

Work output of elephant during work was estimated by the formula work output = force x displacement. The average work output per day during carrying moving and hauling were 1819.004 ± 92.619 KJ, 179.718 ± 5.955 KJ, 3375.373 ± 16.885 KJ respectively. Maximum work output was obtained during hauling.

The working period of timber mills was from 8.30 am to 4.30 pm. Maximum work (34 per cent) occurred during 8.30 to 9.30 am and minimum work during 12.30 pm to 2.30 pm.

Physiological parameters like rectal temperature, pulse and respiration rates were noted during rest days and work days. During rest days hourly recording of physiological parameter was conducted during day time to record the diurnal fluctuation due to the environmental influence.

During work days physiological parameters were recorded at the beginning and end of each schedule of work to analyse the drainage in temperature, pulse and respiration during different duration of work.

Simultaneously fatigue signs like, spraying of saliva and frequency of fanning of ears was also noted. Rectal temperature was identified as the most reliable physiological parameters can be used as indicator of fatigue. Maximum recorded temperature corresponding to two hour and ten minutes of continuous work without any break was 100°F. Corresponding respiration and pulse rates were also noted. Maximum frequency of spraying of saliva during the entire study period was 2/min and maximum frequency of fanning of ears was 45/min. The value of rectal temperature corresponding to the maximum frequency of spraying saliva and fanning of ears was 98.6°F. It was proposed that elephant should be given rest before reaching this temperature.

Comparison of the use of elephant and mechanised power in timber mills was done. The machines were recorded to be faster and performed more work in unit time. Machines were stronger in terms of carrying and hauling timber. Elephant had better maneuverability and performed better during stalking. Economic analysis showed that on an average recurring expenditure/day for elephants and machines were Rs.607 and Rs.560 respectively. Elephants utilized renewable resources and cause no pollution whereas mechanised power consumed non-renewable petroleum resources causing environmental pollution.

References

REFERENCES

Acharya, S., Mishra, M. and Nayak, J.B. (1979). Working capacity and behaviour of crossbred versus non-descript-indigenous bullocks under Orissa conditions. *Indian J. Dairy Sci.* **32**(1): 37-42.

Agarwal, S.P., Sharma, D.N. and Dwarknath, P.K. (1989). Work performance of crossbred bullocks under different conditions of pay load and terrains. *Indian J. Anim. Sci.* **59**(6): 747-750.

Ananthasubramaniam, C.R. (1979). Studies on the nutritional requirement of the Indian elephants. Ph.D. Thesis, Kerala Agricultural University, Thrissur.

Anon (1972). The employment of draught animals in agriculture. FAO, Rome, Italy: 2-3.

Anon (1997). The wildlife (Protection) Act 1972 as amended upto 1993. 4th edn. Nataraj Publication.

Arora. C.L. and Garg, R.C. (1995). Draught animal power - a potential animal energy resource in India-a review. *Agricultural Reviews*, Karnal. 16: 1-2:41-51.

Bhaskaran Nair, N. and Ananthasubramaniam, C.R. (1982). Studies on the nutritional requirement of the elephant (*Elephas maximus*) evaluation of the nutritive value of palm leaves (*Caryota urens*). *Indian Vet. J.* **59**: 110.

Brody, S. (1945). Bioenergetics of growth. Rein Hold Publ. Corp. New York USA.

Cheeran, J.V. (1998). Management practices in Kerala privately owned elephants. Practical elephant management. pp.29.

Choudhury, L.D.K. (1993), Conservation of the Asian elephant 1971-92. An overview. In A week with elephants Proc. Intl. seminar on Conservation of Asian elephant. *Bombay Nat. Hist. Soc.* Pp. 81.

Cockrill, W.R. (1989). World Association for Transport Animal Welfare and studies. Inaugural meeting. Wolfson College, Oxford, 12 December 1989. Working Animals International. pp:78.

Easa, P.S. and Sankar, S. (1999). Study on man wildlife interaction in Wayanad Wildlife Sanctuary Kerala, KFRI Research Report No.166, KFRI, pp. 182.

Goe, M.R. (1983). Current status of research on animal traction. *World Anim. Rev.* **45**: 2-17.

Guyton, A.C. and Hall, J.C. (1991). Textbook of medical physiology. 9th edn. W.B. Saunders Company, Philadelphia. pp. 83-84.

Hedman, L. (1991). The use of draught animals in Forestry and a survey of literature Working paper. International-Rural-Development-Centre-Swedish-University of Agricultural sciences, Garpenberg, Sweden No.166, pp. 85.

Hopfen, J.J. (1969). Farm implements for Arid and Tropical regions, FAO, Rome.

Induchudan, V.T. (1989). The elephant in Indian mythology and history. Souvenir symposium on ecology, biology management and diseases of the Asian Elephant. Kerala Agricultural University. pp. 4-6.

IUCN (1996). Red data list of threatened animals, Gland, Switzerland.

Karsten, P. (1987). Special diets of reptiles, birds, amphibians and mammals. *Zoozen* 3(1): 26-28.

Krishnamurthy, V. (1998). Management Practices of state owned elephant Tamil Nadu, Practical elephant management. pp.31.

Krishnamurthy, V. (1989). Management of elephants in camp. Asian Elephant Group Newsletter, No.4.

Lair, R. C. (1997). Gone astray. The care and Management of the Asian elephant in domesticity. RAP-publication, FAO. No. 16.pp:52.

Maurya, N.L. and Devadattam (1982). Responses of some physiological parameters of crossbred bullocks to different draught and ambient conditions. *Indian J. Dairy Sci.* **35**(2): 18-25.

Maurya, N.L. (1985). Status of animal energy research in India. Proc. SJC, ISAE 1(1): 1-6.

Mohandas, P. (1998). Elephant Management in Kerala Forest Department. Practical elephant management - Handbook of Mahouts - Elephant Welfare Association, Thrissur, pp. 30.

Mukerjee, D.P., Dutta, S and Bhattacharya, P. (1961). Studies on the draught capacity of Hariana bullocks. *Indian J. Vet. Sci.* **31** (1): 39-50.

Nagabhushanam, R. and Kodakkar, M.S. (1978). Textbook of Animal Physiology. 2nd edn. pp.238.

Nair, A.K. (1996). Draught efficiency of Asian elephants (*Elephas maximus indicus*). M.V.Sc. thesis, Kerala Agricultural University.

Nirmalan, G. and Nair, S.G. (1971). Physiological responses of domestic animals under varying conditions. *The Kerala J. Vet. Sci.* **2**(2): 23-24.

Ojha, T.P. (1987). Draught animals vis a vis tractor power on Indian farms. In: Proceedings of the national Seminar on Status of Animal Energy Utilization, Central Institute of Agricultural Engineering, Bhopal. pp.240.

O'Neill, D.H., Howell, P.J.L., Paire, M.E.R. and Kemp, D.C. (1987). An instrumentation system to measure the performance of draught animals at work. Utilization and Economies of Draught Animal Power. Central Institute of Agricultural Engineering, Bhopal. pp. 121-122.

Pandey, M.M. and Bohra, C.P. (1987). Loading devices for draughtability assessment of animals. CIAE Bhopal. pp. 162-180.

Panicker, K.C. (1985). Aana Kadhayum Karyavum (Malayalam). Kerala Agricultural University, Thrissur. pp. 61-74.

Ponnappan, A.K. (1998). Timber hauling. Practical elephant management - A handbook for mahouts, Elephant Welfare Association, Thrissur. pp.43.

Poomulli, N.N. (1998). Management – Traditional perspective, practical elephant management – a handbook for mahout. Elephant Welfare Association, Thrissur. pp.23.

Rai, A.K. and Khanna, N.D. (1991). Studies on draughtability in Indian camels at the National Research Centre on Camel. *Cartman* 4(2): 6-8.

Ramaswamy, N.S. (1988). Importance of DAP in third world. *Cartman* 1(2): 23.

Rao, S.A.A. (1964). Report of bullock harness Project, Allahabad Agri. Instt. Allahabad.

Rao, M.V.N, Indian, R.N., Raina, V.S. Toman, O.S., Relnomi, L.L. and Sharma K.N.S. (1974) Annual Report, NDRI Karnal.

Rautaray, S.K. (1987). Work output of bullocks during field operations on black soil. Utilization and economics of draught animal power. Proceedings of the National Seminar on Status of Animal Energy Utilization, Central Institute of Agricultural Engineering, Bhopal. pp.244.

Sastry, N.S.R., Thomas, C.K.. and Singh, R.A. (1991). Livestock Production Management. 2nd edn. Kalyani Publications, New Delhi. pp. 605.

Schulze, W. (1986). Keeping of circus elephants and their minimum nutritional requirements. *Praktische Tierarzt* **67**(9): 809-811.

Singh, S.P., Soni B.K. and Bhatacharya N.K. (1968). Physiological responses in Hariana bullocks while performing different types of agricultural operation. *Indian Vet. J.* **45**(1): 34-40.

Singh, S.P., Soni. B.K. and Mehta M.M. (1970). Studies on the performance of survival bullocks during various agricultural operations. *Indian Vet. J.* **46** (4): 218-222.

Smith, C.R. and Hamlin, R.L. (1970). Duke's Physiology of Domestic Animals. 8th edn. Cornell University Press, Ithaca. pp. 237-249.

Sreekumar, K.P. (1986). M.V.Sc. Thesis. Kerala Agricultural University, Thrissur.

Srivastava, N.S.L. and Ojha, T.P. (1987). Utilization and economics of draught animal power. Proceedings of the national seminar on status of Animal Energy Utilization, Central Institute of Agricultural Engineering, Bhopal. pp.244.

Thomas, C.K. and Razdan, M.N. (1973). Adaptability of ½ Sahiwal, ½ Brown Swiss cattle to subtropical conditions. 2. Physiological reactions. *Indian J. Anim. Sci.* **43**(5): 358-363.

Upadhyay, R.C. (1987). Factors limiting work capacity and fatigue assessment in draught animals. Paper presented at National seminar in Jan. 24-25, 1987 on "Status of Animal Energy Utilization" at CIAE, Bhopal.

Upadhyay, R.C. (1982). Work efficiency and associated physiological changes in Haryana and crossbred bullocks. Ph.D. Thesis, Kurukshetra University.

Upadhyay, R.C. and Madan, M.L. (1985). Physiological responses to work in bullocks. *Indian J. Comp. Anim. Physiol.* **3**: 43-49.

DRAUGHT EFFICIENCY OF ELEPHANTS IN TIMBER MILLS

By

PRASAD. A.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Veterinary Science

Faculty of Veterinary and Animal Sciences
Kerala Agricultural University

Department of Livestock Production Management
COLLEGE OF VETERINARY AND ANIMAL SCIENCES
MANNUTHY, THRISSUR - 680651
KERALA, INDIA

2001

ABSTRACT

Six elephants working in four different private timber mills in Trichur district were selected for the present study. Average weight of elephants estimated using formula was 4627.80 ± 114.15 kg. Elephants consumed 213.00 ± 3.338 kg roughages and 7.50 ± 0.475 kg of concentrate. They obtained 9.721 ± 0.837 kg dry matter, 3.613 ± 0.075 kg DCP and 31.517 ± 0.754 kg of TDN over and above maintenance requirement, which may be the amount of nutrients utilized for work performance. Elephants were engaged for three types of work in timber mills, carrying, moving/stalking and hauling timber logs. Mean draught developed during carrying was 445.095 ± 22.448 kg. Elephant could be made to carry weights upto 20 per cent of their body weight on their tusk during carrying and stalking/moving timber. A new instrument called Elephant Draught Power Monitor was fabricated to measure the draught developed during hauling timber. A regression equation, $Y = 0.7787x - 100.69$ (where Y is the draught developed and x is the weight of the log hauled) was developed from the measurements. The draught power estimated this equation was compared with the values obtained by the formula draught = load x $\cos\theta$. It was assumed that the formula draught = load x $\cos\theta$ was not suitable for elephant draught power measurement. The average draught developed during hauling was 1779.391 ± 130.386 kg. Highest maximum limit of weight that an elephant could be made to haul during instantaneous force development was 188 per cent of the body weight. Maximum limit of weight that an elephant could be made to haul during

continuous work was 38 per cent of its body weight. Speed of work of elephants during carrying, moving and hauling was 1.333 ± 0.075, 0.630 ± 0.014 and 0.701 ± 0.014 m/s respectively. Speed of work of elephants decreased with increase in weight of the log transported. The average horse power developed during carrying, moving and hauling were 7.116 ± 0.106, 2.566 ± 0.048 and 7.138 ± 0.280 respectively. The average work output per day during carrying, moving and hauling were 1819.004 ± 92.619 KJ, 179.718 ± 5.955 KJ, 3375.373 ± 16.885 KJ respectively. Maximum work output from elephant was obtained during hauling. Maximum work output (34 per cent) occurred during 8.30 am to 9.30 am in timber mills. Elephants were made to work minimum during 12.30 pm to 2.30 pm. Rectal temperature was identified as the most reliable physiological parameter which can be used as an indicator of fatigue. Maximum body temperature recorded during work was 100°F. Maximum frequency of spraying of saliva during the entire study period was two/minute and maximum frequency of fanning of ears was 45/min. The value of rectal temperature when the elephants were fatigued was 98.6°F. Work may be stopped and elephant should be given rest before reaching this body temperature to avoid undue fatigue. Mechanised power which replaces elephant power in many timber mills has certain advantages . But use of elephant has got the advantage of utilization of renewable resources environmental friendliness and greater maneuverability during work