INTERNATIONAL ELEPHANT CONSERVATION
AND
RESEARCH SYMPOSIUM

October 21-22, 2006
Copenhagen Zoo, Denmark

PROCEEDINGS

Status and management of captive Asian elephants in northern West Bengal, northeastern India

N. Baskaran[1], Subhamoy Das[2] and R. Sukumar[3]

[1] Asian Elephant Research and Conservation Centre (a division of Asian Nature Conserv. Foundation), c/o Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India – 560 012,
[2] Department of Zoology, Mahishadal Raj College, Purba Medinipur, West Bengal and
[3] Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India – 560 012

Abstract:

The status and management of captive elephants maintained by the Forest Department at Jaldapara Wildlife Sanctuary, West Bengal, India, were assessed in 2004. The sanctuary managed 48 captive elephants kept at thirteen locations. The overall male to female ratio of these animals was 1:2; the Forest Department favoured females as they are easier to manage as compared to the males. Adults (38%) and sub-adults (35%) were almost equal in number. Although there were no calves (<1 yr old) in 2004, juveniles (1-5 yr old) constituted a significant (27%) proportion of the population.

The reproductive status of 16 adult females showed that most of them were breeding regularly with the exception of three cows aged 45, 48 and 49 years that had never calved. Among the breeding females, age at first calving was between 13 and 28 years (mean 19.5 yr). Females born in captivity, calved at a relatively younger age (17.2 yr) compared to females brought or caught from the wild (21.7 yr). No instance of twin births was observed. Sex ratio of 48 calves born in captivity showed a male-biased sex ratio (1.7:1). Middle-aged mothers (25-35 yr) produced more male calves than female calves compared to younger or older mothers. Although calves were born throughout the year, a distinct seasonality in calving was observed between November and March. An inter-calving interval of 4.8 years was estimated from 33 instances (ranging from 2.4-15.0 years). This is thus a healthy, breeding population.

Behavioural data of calves showed that on average calves suckled 0.85 times/hr and the mean suckling duration was 93 sec/hr with a mean bout time of 42 sec/bout. The suckling behaviour in terms of frequency of suckling and bout decreased with increase in age of calves. Mothers were the nearest neighbours of calves more often (68%) than allomothers (24%) while feeding in the grassland. At the tethering site, however, where mothers and allomothers were restrained with chains, calves spent more time with other young calves. Allomother care increased with increase in age of calves.

The captive elephants, both adults and sub-adults, were mostly used for patrolling the sanctuary and for tourism. The work period was restricted to 2-3 hours/day, with alternate shifts in the morning and evening on consecutive days. Adult females in advanced stage of pregnancy or with calves, and adult males in musth were not used for these activities. The elephants were allowed to forage in the forest during the day and were provided with cut fodder during the night, apart from supplementary diet (twice a day) of rice and pulses. We make some recommendations for the management of these captive elephants.

I. Introduction

Jaldapara Wildlife Sanctuary located in the northern region of the state of West Bengal, India, maintains nearly 50 captive elephants (*Elephas maximus*), or about half the state's captive population of this species. The captive elephants in this sanctuary have been sourced from the wild elephant populations of northeastern and central India. The Forest Department of West Bengal has maintained these elephants for more than 40 years, mainly for patrolling the forest areas and, to a lesser extent, for tourism. Jaldapara is known for the greater one-horned rhinoceros (*Rhinoceros unicornis*) that has been under severe poaching pressure in the past because of the perceived medicinal value of its horn (Menon, 1996). The presence of

rhinos in this tall grass habitat makes patrolling on foot a difficult task; hence, the use of captive elephants. Many of the elephants in the present stock are captive-born but others have been caught from the wild, probably more than 15 years ago, or have been orphaned and rescued from the wild.

Since an estimated 3500 elephants are being held in captivity in India – in temples, timber camps, nature reserves and zoos (Bist, 2002) - it is clear that proper welfare, management and breeding of captive elephants is important for conservation of the species (Sukumar *et al*., 1997). Although the northeastern states hold more than half of India's captive population (Anon, 2004), scientific information about these elephants is meagre as compared to the southern Indian captive elephant population. The present study thus aimed to document the status of population, reproduction and management of captive elephants of Jaldapara Wildlife Sanctuary in northern West Bengal and make recommendations for the effective management of this captive group in relation to the broader management goals of the captive population of the species.

II. Methods

2.1 Study area:
Jaldapara Wildlife Sanctuary (JWLS) is located in the northern region of West Bengal state. The sanctuary covers an area of 216 km[2] and lies between 25° 58" and 27° 45" North latitude and 89° 08" and 89° 55" East longitude (Figure 1). Situated at the foot of the Bhutan hills (Eastern Himalaya), the Jaldapara Wildlife Sanctuary has special significance in maintaining the remnant *terai* grassland that harbours endangered species such as Greater Indian one-horned rhinoceros (*Rhinoceros unicornis*) and hispid hare (*Caprolagus hispidus*) that are specialized to the floodplain habitats. The area receives an average annual rainfall of c.4000 mm, predominantly from the summer monsoon, while the temperature varies from a cool 14°-26°C (mean minimum and maximum temperature) during November-March to a warm and humid 23°-32° C (mean minimum and maximum temperature) during April-October.

The sanctuary is divided into several administrative units or "beats" for effective patrolling of the sanctuary. River Torsa, along with its numerous tributaries, provides water round the year for various wildlife and the captive elephants. Jaldapara has a multi-tier vegetation assemblage and is broadly classified as a moist tropical forest along with grassland and plantations (Sukumar *et al*., 2003). The mosaic of tall grassland and wooded forest provide the diverse fodder resources for wild and captive elephants.

2.2 Population size and structure:
Data on age/sex of all captive elephants, both wild caught and born in captivity, maintained in the year 2004 by the Forest Department at Jaldapara were collected from the Service Register records. These records go back to the year 1976 in the case of the oldest elephants alive during 2004. Additionally, for individuals caught or rescued from the wild, the age was verified using shoulder height as described by Sukumar *et al*. (1988). Elephants were broadly classified into calf (<1 yr), juvenile (1-5 yr), sub-adult (5-15 yr) and adult (>15 yr) for subsequent observations.

2.3 Reproduction and maternal investment in calf:
The dates of first calving and successive calving thereafter were recorded to estimate the age of sexual maturity and the average inter-calving periods, respectively. In the case of abortion during pregnancy, the data were not taken into account. The attainment of sexual maturity was also compared between wild- and captive-born mothers to discern differences, if any. Maternal investment in terms of the sex of calves in relation to mother's age was assessed to know whether investment is uniform or biased towards a particular sex.

2.4 Suckling behaviour:

Suckling behaviour was studied in seven calves aged between 14 and 28 months; calves above the age of 28 months are usually weaned from the mother. Using focal sampling method (Altmann, 1974) calves were observed between 06:00 hr and 18:00 hr as there was no clustering of suckling during the day or night (Lee and Lindsay, unpublished data). The observations were recorded in the grassland, the tethering site and while patrolling. A total of 497 hours of observation was made on the seven calves. During each observation, the starting and ending time of suckling was recorded following Lee (1987).

2.5 Nursing behaviour of mother and allomother:

Focal sampling method (Altmann, 1974) was employed on individually-recognized suckling calves to study the nursing behaviour of mother and interactions with other members of the group. Observations were carried out between 06:00 and 18:00 hrs. Each observation hour was divided into four sample blocks (15 min each) and in each sample block 10-min observation was made with a break of 5 min (Lee and Moss, 1986). In total, 208 hours of observation were made. For each observation, activity of calf, it's nearest neighbour and distance from the calf, and distance of calf to its mother and her activity were recorded**.** If the nearest neighbour to a given calf was not its mother, that individual was considered as the allomother (Nair, 1983). The data were used to compute the time spent by the mother and the allomother, separately for foraging and tethering sites. In total, 8320 records (scans) of nearest neighbour distance were recorded during the 208 hours of observation. Apart from these, *ad libitum* observations of rarely occurring events such as supplants between females, calf distress, and inter-family interactions were recorded.

III. Results and discussion

3.1 Population Size and Structure:

During the study period a total of 48 elephants was managed at the Jaldapara Wildlife Sanctuary and these elephants were placed in 13 "beats" or locations of the sanctuary (Appendix 1). Among the 13 locations, Hollong had the highest number of elephants, as this place is the main training center for captive elephants and also the main tourism hub of the sanctuary. Of the 48 elephants, 33 individuals (69%) were born in captivity while the rest were caught or rescued from the wild.

The age class distribution of the 48 individuals indicated an almost equal number of adults (38%) and sub-adults (35%). While the juveniles represented 27% of the overall number, there were no calves during the study period (Figure 2). Of the 48 elephants, nearly two-thirds (67%) were female with an overall male: female ratio of 1:2, indicating a moderate skew towards females. Although some skew is natural in a polygynous species such as the elephant, the age-class specific sex ratios showed a much higher skew towards females in the adult class (1:8) as compared to sub-adults (1:1.1) and juveniles (1:1.2). Such a skew could be due to the fact that 87% of the wild caught or rescued individuals that formed 31% of the population were females with majority being adults (10 out of 13) at the time of the study. However, such a biased sex ratio in adults need not be detrimental to reproduction because most of the cows in captivity breed with wild bulls present in the sanctuary. Among the males, juveniles, sub adults and adults comprised 37.5%, 50% and 12.5% of this segment, respectively. This shows that >80% of the males are either sub-adults or juveniles. Most of the sub-adults are used for patrolling. On the other hand when we consider the female segment, juveniles, sub adults, and adults constituted 22%, 28% and 50% of the population respectively. This shows that half of the females were adults, which are needed for patrolling, tourism and breeding purposes.

The results of age class distribution showed a higher proportion (63%) of younger age segments such as sub-adults and juveniles compared to adults (37%), which is a possible sign of a growing population. The absence of calves need not be a cause for concern as elephants are known to have a long intercalving period of 4-5 years (Daniel *et al*., 1987); a higher number of females calving in any given year results in very few females for calving in the subsequent years (Douglas-Hamilton, 1972; Sukumar, 1989; Baskaran and Desai, 2000). The high proportion (27%) of juveniles in the overall population suggests a recent boom

in births here. Similarly, the highly skewed sex ratio towards females among the adults also need not be viewed negatively from the point of genetic diversity as wild bulls have sired most of the calves born to captive cows in the sanctuary.

3.2 Reproduction and Maternal Investment:
Age of sexual maturity

The earliest age at which a female gave birth was 13 years 3 months by a cow named Muktirani (first calving on 13th January 1998). Muktirani herself was born in captivity on 5th October 1984 and thus her age is known accurately. This suggests that she was sexually mature by about 11.0–11.5 years. The data is not exceptional because Sukumar *et al.* (1997) also found a similar age (13 years 4 months) of earliest first calving in a captive-born elephant (Meenakshi) in Tamilnadu, southern India. The next earliest age of first calving was 14 years 11 months by Kuntalini (captured at the age of 9 months). All the other cows have either calved for the first time well beyond 15 years or, in some cases, beyond 25 years. The oldest age at which a cow gave birth to her first calf was by Madhumala at the age of 28 years (she was purchased at an estimated age of 8 years). Among captive-born elephants whose ages are accurately know, the highest age of first calving is 19.7 years in Sakuntala. At present JWLS has 16 adult females, of these four females are yet to calve. Among these four, one is a young adult (Srilochana –17.8 years) and remaining three adult females (Chambakali – 45 years, Urvasi - 48 years and Poornima - 49 years), though quite old, are yet to give birth. Significantly, all these three cows were wild caught ones purchased from the famous Sonepur Mela (an annual animal fair) in Bihar state.

From the available data (of 12 calving females with 50 calves), an elephant named Shree, presently aged 61 years had given birth to the maximum number of calves (11 calves). However, data on her first five calvings were not available, as she was a wild caught elephant purchased from another state. These observations are comparable to that reported for captive elephants of southern India (Sukumar *et al*., 1997). Two cases of abortion were recorded. There have been no instances of twin calves out of 50 successful parturitions in captivity, but this could be simply due to chance as the incidence of twinning in elephants in only about 1% (Sukumar *et al*., 1997).

Another interesting feature is that when age at first calving of captive-born elephants and wild-caught elephants is compared, captive-born elephants showed earlier calving (mean = 17.3 yr (n = 5), min = 13.3 and max = 19.6) as compared to wild caught (mean = 21.8 yr (n = 5), min = 14.9 and max = 28). This difference may be due to the fact that wild-caught elephants may have to spend considerable time to adapt to the new environment and, thus, take relatively longer time to start breeding. Another possibility is that this could be biased by the fact that some of the wild caught elephants could have become captive when they were already adults, and thus the age of first calving is overestimated.

Sex ratio of calves in relation to the age of the mother:

Out of 50 calving records, the sex was known for 48 calves, 30 males and 18 females or a male:female ratio of about 1.7:1. The sex of the calves in relation to the mother's age showed that middle-aged females, especially 25-35 years old, gave birth to more male calves than female calves as compared to cows of other age classes (Figure 3). From the above results we can conclude that middle-aged cows are biasing their investment towards males. Physical and physiological condition of the mothers in the 20-40 years age group could be expected to be relatively good. This may conform to the Trivers and Willard (1973) model of adoptive variation in offspring birth sex ratio. According to this model, in a polygynous species for which the male has higher variation in lifetime reproductive success than does the female, a mother in good condition should invest preferentially in sons because a high quality male is likely to enjoy high reproductive success. Such a pattern has been observed in captive Asian elephants in southern India (Sukumar *et al*., 1997), and in several other mammalian species, *e.g.* caribou *Rangifer tarandus* (Thomas et *al*., 1989), mule deer *Odocoileus hemionus* (Kucera, 1991), although contradictory patterns are seen in certain species (Robinette *et al.,* 1973; Slagland, 1986).

Seasonality of Birth:
Seasonality or date of birth was available for 48 births. This shows (Table 1) a clear seasonality in births between September and March, with a peak in December (19% of all births). Between April and July the calving rate remained low (< 4%).

Peak calving occurs in December, at the beginning of the dry season. This indicates that conception period peaked during February and March assuming a mean gestation period of 20-22 months (Sukumar, 1989). Similar seasonality in calving has been reported for captive elephants elsewhere in India (Sukumar *et al*., 1997) and in Myanmar (Mar, 2002). In some wild elephant populations in Africa, a seasonal peak in birth has been observed at the beginning of the wet season, when nutritious forage would be ensured for the lactating mothers, a pattern that would be favored by natural selection (Laws *et al*., 1975; Hanks 1979).

Inter-calving interval:
Out of 12 breeding females, ten have given birth more than once. Analyses of 33 inter-calving intervals from these 10 cows showed a mean inter-calving interval of 4.8 years (SD = 2.95) with a minimum of 2.3 years and a maximum of 14.9 years. The calving interval (4.8 years) estimated in the present study is much lower than the calving interval of 6.5 years estimated over a longer period for "timber camp" elephants of southern India (Sukumar *et* al., 1997). Although the artificial weaning of calves is expected to alter the inter-calving interval among captive elephants, this is more comparable to the 4-5 year interval estimated for wild Asian populations (Daniel *et al*., 1987; Sukumar, 1989; 2003).

3.3 Suckling behaviour:
Suckling behaviour observed in eight calves for 255 hours showed that the calves suckled in total 216 times with an average frequency of 0.85/hr. In total, 6.5 hrs of suckling was observed with a mean suckling duration of 93.4 (± 5.56) sec/hr.

The influence of the age of calves on suckling frequency and duration is presented in Figure 4. Sucking frequency decreased with increase in age (Kendal's Tau = -0.619, n = 7, p = 0.05) while suckling duration did not change much (Kendal's Tau = -0.238, n = 7, p = 0.45). These results suggest that as calves grow older, they suckled less frequently with more or less the same suckling duration exhibited by the younger calves.

3.4 Nursing behaviour of mother & allomother:
Elephants live in social groups notable for its high degree of allomothering and allomaternal care (Lee and Moss 1986, Lee 1987, Nair, 1983; Gadgil and Nair, 1984). Captive elephants were allowed in mixed groups of various age classes to feed in the natural habitat. In the grassland all members are free and, thus, the mother or allomother regulates the distance of the calf, whereas at the tethering sites the calf determines the distance to the neighbour because the mother and the allomother are chained. Hence, data were analyzed separately for the time when all members remain free for interacting, and when only the calf is free but the movements of all other members are restrained by chains.
The result of time spent by various age groups of calves with mother and other members in the grassland is shown in Figure 5. The results show that the time spent by mother as the nearest neighbour to the calf declined as calf's age increased. Similarly, the time spent by calves with other calves also showed a similar trend with age. On the other hand, time spent by allomother as the nearest neighbour to the calf increased positively with increase in the age of calves. The decline in time spent by mother as nearest neighbour to calf with increase in age seems to be compensated by the allomothers. Among African elephants such care shown by animals other than mothers has been viewed as important in the maintenance of the matriarchal society (Douglas-Hamilton and Douglas-Hamilton, 1975; Moss, 1982). The decline with age in time spent by calves with other calves could be due to the increase in time spent on feeding by calves with increased age. Lee (1987) also found a similar pattern in the case of African elephants. On the other hand, at the tethering site (Figure 6), time spent by calves with allomothers decreased with age, while time spent with other calves increased. Time spent by calves with their mothers did not show any pattern.

3.5 Management of captive elephants:

Housing
The tethering sites of all the captive elephants are located near the houses of the mahouts or the grass-cutters and even the beat office. The chaining or tethering place is commonly known as *than* or *pilkhana*. It is generally located 5–50 m away from the mahout's residence or the beat office. At any given time, the elephants are in the vicinity of the concerned authorities. The floor of the *than* is generally made of concrete though until a few years ago all of the beat offices used earthen floors or allowed the elephant to stand on dry unused fodder. These days the elephants spend their nights on concrete flooring. There is no roof at the *than* for the adults that are forced to stay under the open sky, but the sub-adults and juveniles have roofs made of asbestos (a banned substance in many countries). During the night, elephants in most of the beat offices remain without light with the exception of Hollong beat. The distance between two elephants is maintained around 15-20 m. The tethering place is encircled by electrified-wire fence to protect them from wild elephant attacks at night. Tethering sites are cleaned every morning and left vacant from 7 am to 4 pm, when elephants are taken for work or grazing.

Food and Feeding
The captive elephants in the sanctuary are allowed to graze freely, as well as fed with natural fodder cut from the sanctuary and a supplementary diet of rice and pulses. They predominantly feed on grass throughout the year due to the presence of extensive grasslands. Apart from grazing of wild grasses and browse, the elephants are also provided at night with wild grass cultivated by the Forest Department as well as harvested from the wild. The natural fodder used is also mainly grasses from April to November, during the rainy season. During winter and dry season the availability of grass decreases and, hence, banana stems and leaves are collected from the nearby villages (2-6 km away). Apart from these, browse (leafy branches and twigs) from wild trees are also provided.

In the morning (07:00-08:00 hrs), each grass cutter or *patawala*, goes with the elephant to collect fodder (grass) from the nearby grassland. The elephant is given commands to uproot grass methodically and pile them with the help of the grass cutter and carry these bundles back to the tethering site. Old, pregnant and injured elephants are exempted from collecting fodder. After the fodder collection, the elephants are allowed to freely forage in the nearby grasslands for six to eight hours from 08:00 to 16:00 hrs. In the grasslands, elephants mostly feed on grass as well as a few herbs, shrubs and, occasionally, bark and leave of trees. During winter and the dry season, they feed on large quantities of leaves as the availability of palatable grass decreases as reported elsewhere in the natural habitat (Sukumar 1989). The increase in the consumption of browse during winter and dry season could also be ascribed to higher protein availability as reported for the free ranging elephants elsewhere in Asia (Sukumar, 1989; Sivaganesan and Johnsingh, 1995).

During the afternoon, after bathing they are provided with supplementary food known as *kher* according to the prescription of the veterinary doctor. Every elephant has a ration chart, which shows a fixed diet consisting of soaked rice and pulses. An adult is provided 3-4 kg rice and 2 kg of pulses per day. The grass-cutter makes the *kher* by putting the grains and pulses in packets of long grass and feeding the elephant slowly to avoid wastage. After consuming the supplementary food, elephants are chained at the tethering site and provided with cut fodder collected in morning.

A veterinary doctor based in the sanctuary performs monthly health checks. Pregnant mothers, injured elephants and calves are paid special attention. Juveniles, sub-adults and adults are provided 1.5 kg, 4 kg and 6 kg rations per day respectively. During winter and dry season, managing the elephants becomes difficult due to the scarcity of forage in the sanctuary.

Bathing
Elephants are bathed once every day in the river. The time of bathing is generally from 15:00 to 16:00 hrs and the duration varies from 15 to 80 minutes (average of 60 minutes). The grass cutter cleans the skin using a stone. Care is taken to clean the nails, legs, eyes and ears and genitalia. The calves are not cleaned

and they remain free all the time. Besides this, each elephant takes dust bath, mud bath and water bath as they wander freely in the grassland.

Work Load
The elephants here are used generally for patrolling the sanctuary and for tourism.

Patrolling: Adult males and females, sub-adult males (from 10 years onwards) and sub-adult females (12 years onwards) are generally used for patrolling for 2-3 hrs in the morning (from 06:00 to 09:00 hrs) or at evening (from 16:00 to 19:00 hrs). They are generally used alternatively in the mornings and evenings of consecutive days. Mothers in advanced stage of pregnancy, injured members, and juveniles are not used for patrolling.

Tourism: A few healthy adult and sub-adult elephants of the sanctuary are used for tourism especially at Hollong lodge and Kunjanagar beat. They carry up to 6 visitors and a mahout from 06:00 to 09:00 hrs and from 15:00 to 18:00 hrs. From June 15th to October 15th the sanctuary is generally closed for tourism because of heavy rains. During this period the elephants are rested.

Than cleaning**:** Every morning elephants clean their own tethering place. At first the grass cutter collects the dung and puts it into an open box with two wheels. The elephants pull the box to the dumping place with trunk. The unused fodder is gathered by the elephant at a single place and then they are commanded to push the waste using the foreleg to the nearest dumping place, which is 20 – 200 m apart. Un-weaned calves and juveniles are not used for cleaning.

Fodder collection: Another minor workload is fodder collection from the nearby grasslands. During the rainy season, the elephants collect grass within 1-2 km of the tethering yard, while during winter and the dry season they collect branches of trees with leaves and banana stems from a radius of about 6 km. Injured members and mothers are not used for fodder collection for 1-2 months prior to and after calving.

IV. Conclusions and recommendations
The captive elephant population at Jaldapara with >60% of sub-adults and juveniles, and 12 adult females with an average inter-calving period <5 years indicates a population that is breeding at a rate comparable to a wild population. Such a prolific breeding rate has not been recorded among captive elephant populations elsewhere. An analysis of the overall dynamics of this population, including survivorship rates, would help place its demography in perspective. All indications are that this is a healthy population under effective management. However, we make following observations for the welfare of these captive elephants.

Supplementary diets in cooked condition would enhance the assimilation rate of nutrients (Krishnamurthy and Wemmer, 1995) as elephants are known to have low digestive efficiency (Benedict, 1936). The Forest Department may thus consider introducing cooked rice and pulses, as practiced in Tamilnadu state, instead of feeding them with cereals soaked in water.

Elephants that are forced to stand or move for considerable periods of time on concrete flooring are known to develop various afflictions of the footpad (Club and Mason, 2002). In fact, this is recognized as one of the major problems faced by captive elephants in western zoos. The recent change at Jaldapara in the flooring of the tethering site or '*than'* to concrete is thus highly undesirable. Therefore, converting the flooring back to earthen ones would help avoid the appearance of foot problems in these elephants.

The Forest Department presently finds it difficult to manage the increasing numbers of juveniles and sub-adults because of inadequate resources. Thus, the department has plans to introduce contraception to reduce the number of births. Testing immuno-contraception (Fayrer-Hoskin *et al.* 2000) in a few individuals would certainly enhance our knowledge about the efficacy of this technique in controlling births, and even be useful for introducing in wild populations where necessary. However, it would be desirable to consider the management of the Jaldapara elephants within a broader framework of sustainable management of captive Asian elephants at the regional and national level (or even global level). In spite of

a history of taming that goes back 4500 years ago, the captive elephant populations are not self-sustainable because of poor breeding and high mortality (Kurt and Mar, 2003; Sukumar 2003), and inputs from the wild population are required to sustain the existing captive populations at most places. This has resulted in depletion of wild stocks of the Asian elephant in many countries. Any "surplus" numbers of elephants in captivity would thus be an enviable situation at a time when many western zoos are spending huge amounts of money to build facilities to breed elephants! We thus feel that a perspective plan for management of captive elephants at all geographical scales will have to be prepared and agreed upon such that we ensure the sustainable management of both captive and wild Asian elephant populations.

V. Acknowledgments

VI. References

Anon, 2004. Government of India, Ministry of Environment and Forest, Project Elephant. *Report of expert committee on assessment of status of captive elephants*. 2004.

Altman, J. 1974. Observational study of behaviour: Sampling methods. *Behaviour* 69: 227-267.

Baskaran, N. and Desai, A. A. 2000. Elephant population estimation in Mudumalai Wildlife Sanctuary and National Park. Final report 1999-2000. Bombay Natural History Society, Bombay.

Benedict, F. G. 1936. *The physiology of the elephant*. Carnegie Institute, Washington D.C.

Bist, S. S. 2002. An overview of elephant conservation in India. *The Indian Forester* 128: 121-135.

Club, R. and Mason, G. 2002. *A review of the welfare of zoo elephants in Europe*. A Report commissioned by RSPCA.

Daniel, J. C., Desai, A. A. and Sivaganesan, N. 1987. Ecology of Asian elephant in Mudumalai Wildlife Sanctuary. Annual report 1985-1987. Bombay Natural History Society, Bombay.

Douglas-Hamilton, I. and Douglas-Hamilton, O. 1975. *Among the elephants*. Collins and Harvill Press, London.

Fayrer-Hoskin, R.A., Grobler, D., Van Altens, J.J., Bertschinger, H.J. and Kirkpatrick, J.F. 2000. Immuno-contraception of African elephants. *Nature* 407: 149.

Gadgil, M. and Nair, P. V. 1984. Observation of the social behaviour of free ranging groups of tame Asian Elephant (*Elephas maximus* Linn). *Proceeding of Indian Academy of Science* (*Anim. Sci.*) 93: 225-233.

Hanks, J. 1979. *The struggle for survival: the elephant problem*. New York, Mayflower Books.

Kucera, T. E. 1991. Adaptive variation of sex ratio of offspring of nutritionally stressed mule deer. *Journal of mammalia* 72: 745-749.

Kurt, F. and Mar, Mar, K. U. 2003. Guidelines for the Management of captive elephants and the possible role of the IUCN/SSC Asian elephant Specialist Group. *Gajah* 22:30-42.

Laws, R. M., Parker, I. S. C., Johnstone, R. B. C. 1975. *Elephants and their habitats: The ecology of elephants in North Bunyoro. Uganda*. Clarendon Press, Oxford, U. K.

Lee, P. C. 1987. Allomothering among African Elephants. *Animal Behaviour*. 35: 278-291.

Lee, P. C. and Moss, C. J. 1986. Early maternal investment in male and female elephant calves. *Behavioural Ecology and Sociobiology*. 18:353-361.

Mar, K. U. 2002. The studbook of timber elephants of Myanmar with special reference to survivorship analysis. *In*: *Giant on our hands*. ProceedingS of the International workshop on the domesticated Asian elephant, Bangkok, Thailand. 195-211.

Menon, V. 1996. *Under Siege: Poaching and Protection of Greater one-horned Rhinoceros in India*. TRAFFIC

Moss, C. J. 1982. *Portraits in the wild*: Behaviour studies of east African mammals. Boston: Houghton Mifflin.

Nair, P. V. 1983. Studies on the development of behaviour in the Asiatic elephant. Ph.D., thesis, Indian Institute of Science, Bangalore.

Robinette, W. L., Bear, C. H., Pilmore, R. E. and Knittle, C. F. 1973. Effects of nutritional change on captive mule deer. *Journal of Wildlife Management,* 37: 312-326.

Sivaganesan, N. and Johnsingh, A. J. T. 1995. Food resources crucial to the wild elephants in Mudumalai Wildlife Sanctuary, Tamil Nadu, India. *In*: *A week with elephants*. Proceedings of the Intern. Seminar on the conservation of Asian elephant. Mudumalai Wildlife Sanctuary, June 1993. (Eds. J. C. Daniel & H. S. Datye). Bombay Natural History Society, Bombay. pp:405-423.

Slagland, T. 1986. Sex ratio variation to maternal condition and parental investment in wild reindeer, *Rangifer t. trandus. Oikos* 46: 417-429.

Sukumar, R. 1989. *The Asian Elephant*: *Ecology and Management*. Cambridge University Press, Cambridge.

Sukumar, R. 2003. *The Living Elephants*: *Evolutionary Ecology, Behaviour and Conservation*. Oxford University Press, New York.

Sukumar, R., Joshi, N. V. and Krishnamurthy, V. 1988. Growth in Asian elephant. *Proceedings of the Indian Academy of Science (Animal Sciences)*, 97: 561-571.

Sukumar, R., Krishnamurthy, V., Wemmer, C. and Rodden, M. 1997. Demography of captive Asian elephants (*Elephas maximus*) in Southern India. *Zoo Biology* 16: 263-272.

Sukumar, R., Venkataraman, A., Baskaran, N., Guha, D. and Mukti, R. 2003. Study of elephants in Buxa Tiger Reserve and adjoining areas in northern West Bengal and preparation of conservation action plan. Final Report, Centre for Ecological Sciences, Indian Institute of Sciences, Bangalore – 560 012.

Thomas, D. C. Barry, S. J. and Kilian, H. P. 1989. Fetal sex ratio in Caribou: Maternal age and condition effects. *Journal of Wildlife Management* 53: 855-890.

Trivers, R. L. and Willard, D. E. 1973. Natural selection of parental ability to vary the sex ratio of offspring. *Science*, 179: 90-92.