POPULATION, REPRODUCTION AND MANAGEMENT OF CAPTIVE ASIAN ELEPHANTS (*ELEPHAS MAXIMUS*) IN JALDAPARA WILDLIFE SANCTUARY, WEST BENGAL, INDIA

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Introduction

There are about 3,500 captive Asian elephants (*Elephas maximus*) being managed by temples, private owners and State Forest Departments at the timber camps, nature reserves and zoos in India (Bist, 2002). The West Bengal Forest Department holds a stock of about 120 captive elephants (Anon., 2004), of which 48 elephants are placed at Jaldapara Wildlife Sanctuary located in the northern region of the state. The captive elephants in this sanctuary have been sourced from the wild elephant populations of North-Eastern and Central India. The Forest Department has been maintaining captive elephants for more than 40 years, mainly for patrolling the forest areas and, to a lesser extent, for wildlife tourism. Jaldapara is known for the greater one-horned rhinoceros (*Rhinoceros unicornis*) that has been under serious poaching pressure in the past because of the perceived medicinal value of its horn (Menon, 1996), though the population has since recovered to over 70 individuals in 2002 (Anon., 2003) and over 100 individuals in 2004 (unpublished results of census by Forest Department). The presence of rhinos in this tall grass habitat makes patrolling on foot a difficult task; hence, the Forest Department uses captive elephants for this purpose. 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 the global captive Asian elephant constitutes about a third of the total Asian elephant population, a proper policy for welfare, management and breeding of captive elephants is important for conservation of the species (Santiapillai and Sukumar, 2006). Although the northeastern and eastern states hold well over 60% (2,000 elephants) of India's captive population (Anon., 2004), there has been no recent scientific data on population structure, fecundity, mortality and management of these elephants as compared to the southern Indian captive elephant population (Krishnamurthy, 1995; Krishnamurthy and Wemmer, 1995; Sukumar *et al.*, 1997; Vanitha, 2007). In this connection, the present study was carried out to document the status of the population, reproduction and management of captive elephants of Jaldapara Wildlife Sanctuary during 2004 with a view to

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comparing this with other captive elephant populations and to make recommendations for improved management wherever needed.

Methods

Study area : Jaldapara Wildlife Sanctuary (JWLS) is located in the northern part of West Bengal State (Fig. 1). The sanctuary covers an area of 216 km^2 and lies between 25° 58" and 27° 45" N latitude and 89° 08" and 89° 55" E longitude. Situated along the Eastern Himalayan foothills in the floodplains of river Torsa, this Sanctuary has special significance in maintaining the remnant Tarai grasslands that harbour several endangered species such as Greater Indian one-horned rhinoceros (*Rhinoceros unicornis*), Hog deer (*Axis porcinus*) and Hispid hare (*Caprolagus hispidus*) specialized to the floodplain habitats. The area receives an average annual rainfall of about 4,000 mm, predominantly from the southwest 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. River Torsa, along with its numerous tributaries, provides water round the year for wildlife and for the captive elephants. The mosaic of tall tropical grassland and wooded forest provides the diverse fodder resources for wild and captive elephants (Sukumar *et al.*, 2003).

Data collection : Age-sex data were collected from the records of Service Registers maintained by the Forest Department at Jaldapara Wildlife Sanctuary for all the elephants managed during 2004. These records go back to 1976 for the oldest elephant alive during 2004. Additionally, for individuals caught or rescued from the wild, the age was verified using the shoulder height measurements as described by Sukumar *et al.* (1988). The elephants were broadly classified into calf (<1 yr), juvenile (1-5 yrs), sub-adult (5-15 yrs) and adult (>15 yrs) for subsequent observations and data analyses. To assess the reproductive status, records of dates of calving, number and sex of calves were collected for all the adult females managed during 2004 from these registers. From these data we estimated the age of sexual maturity and first calving, inter-calving interval, calving seasonality and maternal investment in terms of the sex of calves in relation to mother's age (Sukumar *et al.*, 1997). As regards to elephant management, data on housing, daily routine and workload, food and feeding were collected for each elephant from register records as well by direct observations and by interviews with the concerned staff.

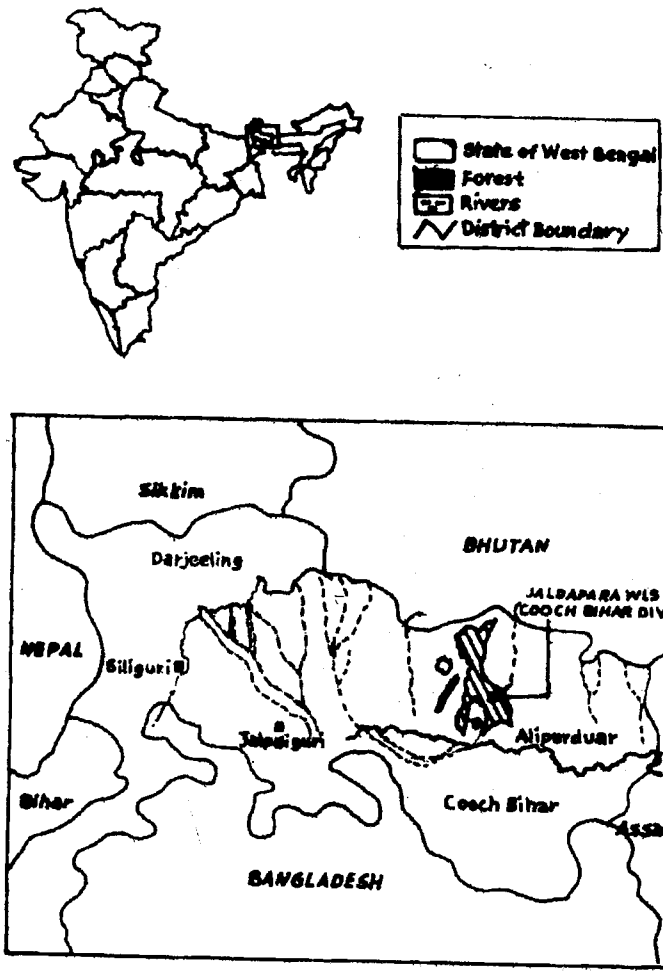
Results and Discussion

Population

In total 48 captive elephants were managed during 2004 at the Jaldapara Wildlife Sanctuary. These elephants were placed in 13 different "beats" (administrative units) spread across the sanctuary. Among the 13 locations, Hollong had the highest number of elephants, as this is the main training center for captive elephants as well as being the 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

Fig. 1



Jaldapara Wildlife Sanctuary in the northern West Bengal landscape

individuals shows that 38% of the population was constituted by adults and of the remaining 62%, sub-adults formed 35% and juveniles 27%, with no calves during the study period (Table 1). More than two-thirds (67%) of the elephants were female with an overall male to female ratio of 1:2, indicating a moderate skew towards females. Although some skew is natural in a polygynous mammal (Trivers, 1972) such as the elephant (Ramakrishnan *et al.*, 1998), the sex ratio in relation to different age-classes shows 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 total captive population) were females with the majority being adults (10 out of

Table 1

Age-sex composition of captive elephants managed at Jaldapara Wildlife Sanctuary in 2004 (n = 48)

Age class	Jaldapara		Tamil Nadu timber camps[1]		Myanmar timber camp[2]	
	Female	Male	Female	Male	Female	Male
Adult	33.3	4.2	26.0	48.0	37.3	27.6
Sub-adult	18.8	16.7	6.0	12.0	12.2	11.1
Juvenile	14.6	12.5	2.0	2.0	5.2	4.4
Calf	0	0	2.0	2.0	1.1	1.2
Overall	66.7	33.3	36.0	64.0	55.8	44.2

[1] Vanitha (2007) - data from captive elephant population recorded in 2005
[2] Mar (2005) - data from captive elephant population recorded 1999-2000

13) at the time of the study. However, such a biased sex ratio in adults need not be detrimental to breeding because most of the cows in captivity mate with the wild bulls present in the sanctuary. Among the males, juveniles, sub-adults and adults comprised 37.5%, 50% and 12.5%, respectively. This shows that >80% of the males are sub-adults and juveniles. Most of the sub-adults males were used for patrolling. On the other hand, when we consider the female segment, juveniles, sub adults, and adults constituted 22%, 28% and 50%, respectively. This shows that half of the female population comprised adults that were used for patrolling, wildlife tourism and breeding.

The results of age class distribution showed a higher proportion (62%) of younger age segments such as sub-adults (35%) and juveniles (27%) compared to adults (38%), which is a possible sign of a growing population. The absence of calves in 2004 is not a cause for concern, as elephants are known to have a longer inter-calving period of 4–5 years (Daniel *et al.*, 1987) and also a high proportion of the females calving in any given year results in very few females being available for calving in the subsequent 2–3 years (Douglas-Hamilton, 1975; Sukumar, 1989). The captive elephant population at Jaldapara Sanctuary with a high proportion of females and substantial proportion of the younger age-class segments as compared to the forest camp populations elsewhere (Table 1) in Tamil Nadu (Vanitha 2007) and Myanmar (Mar 2007) indicates its potential to grow at a faster rate than any other captive population.

Management of captive elephants

Housing : The chaining or tethering site is commonly known as 'than' or 'pilkhana'. It is generally located 5–50 m away from the mahout's residence or the beat office. The floor of the 'than' is generally made of concrete though until a few years ago all

the 'pilkhanas' had earthen floors or allowed the elephant to stand on dry unused fodder. There was no roof at the 'pilkhana' for the adults, but the sub-adults and juveniles had artificial roofs made of asbestos (a banned construction material in many countries). During the night, elephants in most of the 'pilkhanas' remain without light with the exception of Hollong beat. The distance between two elephants is maintained at about 15-20m. Electrified-wire fence or elephant–proof trench encircle some of the tethering sites to protect captive elephants from wild elephant attacks at night.

Food and feeding : The captive elephants are allowed to feed on wild plants in the sanctuary, and are also provided cut fodder and a supplementary diet of rice and pulses. Apart from natural feeding on wild grass and browse species during day time, the elephants are provided in the evening with species of wild grasses cultivated by the Forest Department (*Themeda villosa*, *Saccharum* spp.) as well as harvested from the wild. The cut fodder supplied during the rainy season is mainly of mixed grass species. During the winter and dry seasons, when the availability of grass decreases, banana stems and leaves collected from the nearby villages are supplied in addition to browse from the natural habitat.

After fodder collection between 07:00 and 08:00 hrs, the elephants are allowed to forage freely in the nearby grasslands for six to eight hours between 08:00 and 16:00 hrs. In the late afternoon, they are provided with supplementary food known as 'kheer' according to the prescription of the veterinary doctor. A veterinarian has formulated for each elephant a ration chart showing a fixed diet of soaked rice and pulses (red lentil, *Lens esculenta*). An adult elephant is provided 3-4 kg rice and 2 kg of pulses per day. Juveniles, sub-adults and adults are provided 1.5 kg, 4 kg and 6 kg rations per day, respectively. The grass-cutter makes the 'kheer' 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 cut fodder collected in morning.

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).

Work Load : The elephants in the sanctuary are used mainly for patrolling (2-3 hrs/day) and tourism (3-6 hrs/day). Additionally, the elephants are also used for cleaning their tethering yards and fodder collection. Only adults and sub-adults are used for work. However, the males in musth, and adult females in advanced stage of pregnancy or with suckling calves are not used for work.

Health care : A veterinary doctor based at the sanctuary takes care of health and disease management of the captive elephants with periodic health checkups. Pregnant mothers, injured elephants and calves are paid special attention.

Reproduction

Age of sexual maturity : The earliest age at which a female gave birth was 13 years 3 months by a cow named Muktirani. This suggests that she was sexually matured by about 11.0–11.5 years. The data is not exceptional as a similar

aged cow dropped its first calf in Mudumalai, Tamil Nadu, Southern India (Sukumar *et al.*, 1997). All the other cows have either calved for the first time well beyond 14 years or, in some cases, beyond 25 years. The oldest age of first parturition was 28 years by Madhumala. Among captive-born elephants whose ages are accurately known, the highest age at first calving was 19.7 years by Sakuntala. At present the sanctuary has 16 adult females, of these three females are yet to calve.

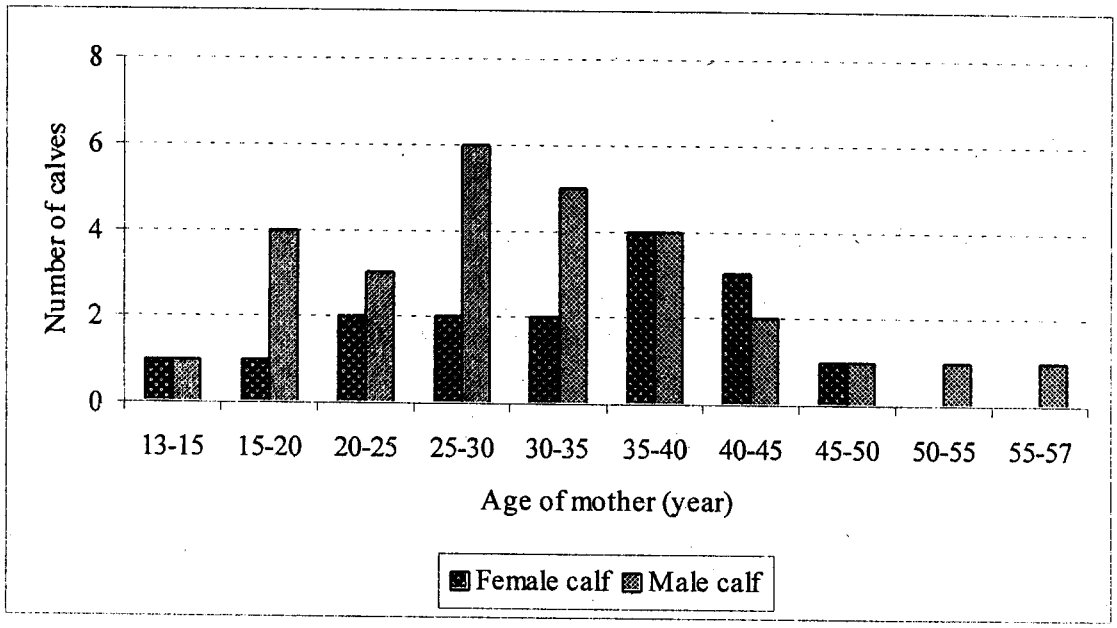
An elephant named Shree, aged 61 years, had given birth to the maximum number of calves (11 calves). However, data on her first five calvings were not available as she was a wild-caught elephant purchased from a neighbouring state. This observation is comparable to that reported for captive elephants of southern India (Krishnamurthy, 1995). Two cases of abortion were recorded. There have been no instances of twin calves out of 53 successful parturitions in captivity, but this could be simply due to chance as the incidence of twinning in elephants is only about 1% (Sukumar *et al.*, 1997).

The age at first calving in captive-born elephants (mean = 17.3 yrs, (n = 5) min = 13.3 and max = 19.6) was lower than that of wild-caught elephants (mean = 21.8 yrs (n = 5), min = 14.9 and max = 28).

Inter-calving interval : Out of 13 breeding females, 11 have given birth more than once. Analyses of 35 inter-calving intervals from these 11 cows showed a mean inter-calving interval of 4.7 years (SD = 2.89) with a minimum of 2.3 years and a maximum of 14.9 years. The calving interval (4.7 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).

Sex ratio of calves in relation to the age of the mother : Out of 53 calving records, the sex was known for 51 calves, 31 were males and 20 were females, which is not statistically different from a 1:1 ratio (χ^2 = 2.37, P > 0.1). In spite of lack of statistical significance because of the small sample size, this pattern of male-biased calves may be biologically important among captive elephants (Sukumar *et al.*, 1997). 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 significantly more male calves than female calves (χ^2 = 3.27, P < 0.1) as compared to younger (χ^2 = 1.33, P > 0.1) or older cows (χ^2 = 0.66, P > 0.1) (Fig. 2) indicating that middle-aged cows are biasing their investment towards male calves. Physical and physiological condition of mothers in the 20-40 years age group could be expected to be relatively good. This observation may confirm to the Trivers and Willard (1973) model of adaptive variation in sex ratio at birth of offspring. 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),

Fig. 2



Sex of elephant calves in relation to the age of mothers recorded in captive elephants at Jaldapara Wildlife Sanctuary (n = 44)

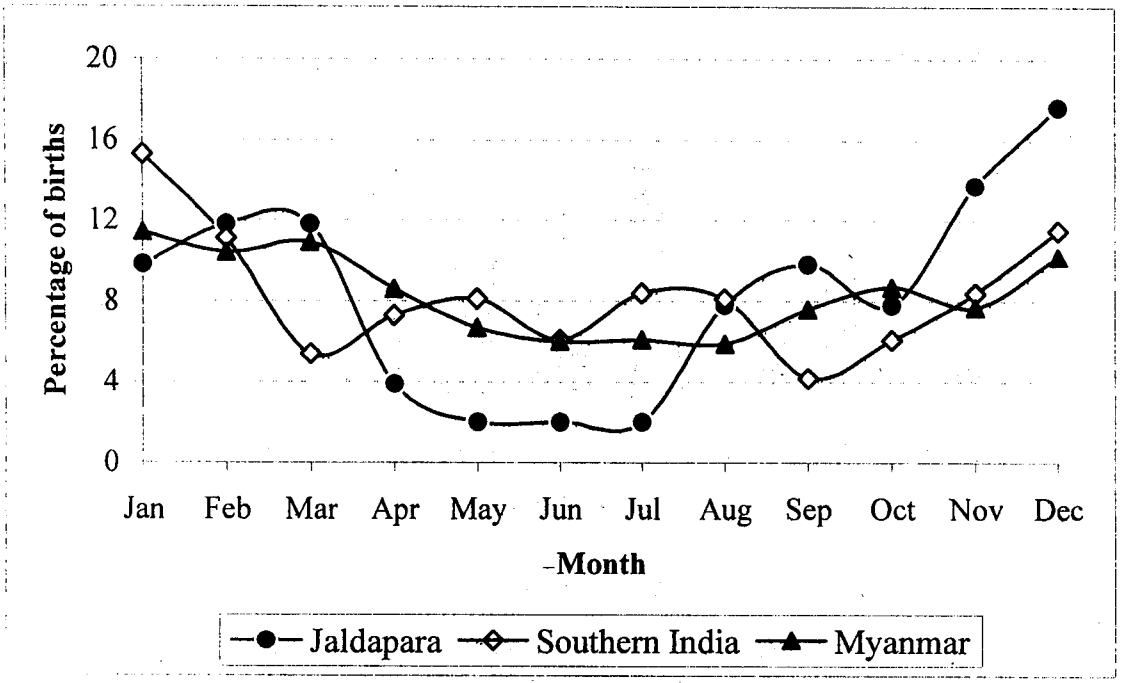
and in several other mammalian species, *e.g.* Caribou *Rangifer tarandus* (Thomas *et al.*, 1989), Mule deer *Odocoileus hemionus* (Kucera, 1991).

Seasonality of birth : Date of birth was available for 51 births and the data (Fig. 3) showed a clear seasonality in births between November and March, with a peak in December (18% of all births). Between April and July the calving rate remained low (2-4%). Peak calving occurs in December, at the beginning of the dry season. This indicates that conception period peaked during February and April assuming a mean gestation period of 20-22 months (Sukumar, 1989). Similar seasonality in calving during November-March has been reported for captive elephants elsewhere in India (Sukumar *et al.*, 1997) and in Myanmar (Mar, 2002). Among captive elephants the work regimen would be expected to influence the period of conception, especially if female body condition were to play a role in the estrus cycle and ovulation. 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).

Conclusions and Recommendations

The captive elephant population at Jaldapara with more than 60% of sub-adults and juveniles, and 13 adult females with an average inter-calving period of about 5 years indicates that breeding at a rate comparable to a wild population. Such

Fig. 3



Per cent frequency distribution of elephant calves born during different months of the year in Jaldapara (n = 51) in relation to Southern India (Tamil Nadu forest camps n = 261) and Myanmar (n = 3,070) captive birth

a high breeding rate has not been recorded among captive elephant populations elsewhere. All indications are that this is a healthy population under effective management. The following observations are made for the better management of these captive elephants.

1. *Feeding and nutrition* : Supplementary diets in cooked condition would enhance the assimilation rate of nutrients among captive elephants (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 Tamil Nadu, instead of feeding them solely with grains soaked in water.

2. *Housing* : Elephants that are forced to stand or move for considerable periods 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. Similarly, the asbestos used in roofing of the elephant housing is known to cause serious health problems such as lung cancer and respiratory diseases among human beings (Doll and Peto, 1985; Mossman, 1993); thus the asbestos roofs have to be urgently replaced with other non-toxic material.

3. *Immuno-contraception* : 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), as the global captive Asian elephant populations are not self-sustaining due to poor breeding and high mortality (Kurt and Mar, 2003; Sukumar, 2003; Vanitha, 2007; Leimgruber *et al.*, 2008), and inputs from the wild population are required to sustain the existing captive populations at most places.

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SUMMARY

The population structure, reproduction and management of captive Asian elephants managed by the Forest Department at Jaldapara Wildlife Sanctuary was studied during 2004. The sanctuary managed 48 captive elephants (18 adults, 17 sub-adults and 13 juvenile) with an overall male to female ratio of 1:2. Although there was no calf in this group during 2004, juveniles constituted a significant (27%) proportion of the population, indicating high reproduction in the preceding years. Selected individuals were used for work 2–3 hours/day, for patrolling and wildlife tourism. The elephants were allowed to graze freely in the natural habitat, as well as provided cut fodder and supplementary diet. There were 16 adult cows of which 13 were breeding regularly, while the remaining three cows were yet to calve though two of them were > 45 yrs. Mean age at first calving in the population was 19.5 yrs. Females born in captivity calved at a younger age (17.2 yrs) as compared to females caught or rescued from the wild (21.7 yrs). Mean inter-calving interval was 4.7 yrs. Sex ratio of 51 calves showed a male-biased sex ratio (1.6 male: 1 female). Middle-aged mothers produced more male calves than female calves as compared to younger or older mothers. A distinct seasonality in calving was observed. Overall, this is a healthy captive elephant population under effective management; we make some suggestions for improvement of this management.

Key words : **Captive elephants, Population, Reproduction, Management, Jaldapara Wildlife Sanctuary.**

बन्दी रखकर एशियाई हाथी (*एलिफस मैक्सीमस*) की जलदपाड़ा वन्य प्राणि अभयारण्य, पश्चिम बंगाल, भारत में संख्या पुनरुत्पादन और प्रबन्धन

सारांश

एन० भास्करन, शुमोय दास व आर० सुकुमार

हमने 2004 में जलदपाड़ा वन्य प्राणि अभयारण्य में वन विभाग द्वारा प्रबन्धित बन्दी रखे एशियाई हाथियों की संख्या रचना, पुनरुत्पादन और प्रबन्धन का अध्ययन किया। इस अभयारण्य में 48 बन्दी हाथी (18 वयस्क, 17 उप–वयस्क और 13 बच्चे) प्रबन्धित हैं। उनका समग्र नर मादा अनुपात 1:2 है। हांलाकि 2004 में इस समूह में कोई छोटा बच्चा नहीं था, इसमें बाल–हाथियों की संख्या काफी (27%) थी जिससे विगत वर्षो में अधिक उत्पत्ति रहने का संकेत मिलता है। चुने हुए कुछ हाथियों से 2–3 घंटे/दिन गश्त लगाने और वन्य प्राणि पर्यटन के लिए काम कराया जाता था। हाथियों को प्राकृतिक प्राकृतावास में खुले रह चरने दिया जाता तथा अनुपूरक आहार रूप में कटा चारा भी खिलाया जाता था। यहाँ 16 वयस्क हथिनियां थी जिनमें से 13 नियमित प्रजनन कर रही थी जबकि बाकी हथिनियों को अभी बच्चे देना शेष था हालांकि उनमें से 2 हथिनियां > 45 वर्ष की थी। इस संख्या की प्रथम बच्चा देते समय मादय उम्र 19.5 वर्ष थी। जंगल से पकड़ी या बचाई हथिनियों की बच्चा देने की उम्र (21.7 वर्ष) की तुलना में बन्दी रखी गई हथिनियां उससे कम उम्र (17.2 वर्ष) में ही बच्चे देने लगती है। दो बच्चो की बीच रहता माध्य अन्तराल 4.7 वर्ष रहा। 51 बाल हाथियों को लिंग अनुपात नर पक्षपात वाली लिंग अनुपात (1.6 नर : 1 मादा) रहता दिखाई पड़ा। मध्यम उम्र वाली हथिनियों के नर बच्चे मादा बच्चों की अपेक्षा कम उम्र वाली या ज्यादा उम्र वाली हथिनियों के बच्चा उत्पादन से अधिक रहे। बच्चे उत्पन्न होने की एक स्पष्ट मौसमीयता रहती पाई गई। समग्रतः प्रभावकारी प्रबन्धन में बन्दी रखे हाथियों की यह समूह–संख्या स्वस्थ या ठीक ही कही जाएगी। हमने प्रबन्ध में सुधार लाने के कुछ सुझाव भी दिए हैं।

References

Anon. (2003). *Glimpse of wildlife statistics 2002–2003*. Central data bank, Wildlife wing headquarters, Forest Directorate, Government of West Bengal.

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

Benedict, F.G. (1936). *The physiology of the elephant*. Carnegie Institute, Washington, DC.

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

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

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

Doll R. and J. Peto (1985). Asbestos: Effects on health of exposure to asbestos. *Review* prepared at the request of Health and Safety Commission, U.K.

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

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

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

Krishnamurthy V. (1995). Reproductive patterns in captive elephants in the Tamil Nadu Forest Department: India. *A Week with Elephants* (Daniel J.C. and H.S. Datye, eds.). Oxford Univ. Press and Bombay Natural History Society, Bombay. pp. 450–455.

Krishnamurthy, V. and C. Wemmer (1995). Timber elephant management in Madras Presidency of India (1844-1947). *A Week with Elephants* (Daniel J.C. and H.S. Datye, eds.). Oxford Univ. Press and Bombay Natural History Society, Bombay. pp. 456-472.

Kucera, T.E. (1991). Adaptive variation of sex ratio of offspring of nutritionally stressed mule deer. *J. Mammalia,* **72**: 745-749.

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

Leimgruber, P. Senior, S. Uga, M. Aung, M.A. Songer, T. Mueller, C. Wemmer and J.D. Ballou (2008). Modeling population viability of captive elephants in Myanmar (Burma): implications for wild populations. *Animal Conservation,* **11**(3): 198-205.

Mar, K.U. (2002). The studbook of timber elephants of Myanmar with special reference to survivorship analysis. *Giant on our hands : Proc. Intl. Workshop on the domesticated Asian elephant*, Bangkok, Thailand. pp. 195-211.

Mar, K.U. (2007). The demography and life history strategies of timber elephants in Myanmar. *Ph.D. Thesis*, University College, London.

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

Mossman, B.T. (1993). Cellular & molecular mechanism of disease. *Health effects of mineral dust* (Guthrie, G.D. Jr. and B.T. Mossman, eds.). *Reviews in Mineralogy and Geochemistry*, **28** : 513-521.

Ramakrishnan, U., J.A. Santosh, U. Ramakrishnan and R. Sukumar (1998). The population and conservation status of Asian elephants in Periyar Tiger Reserve, Southern India. *Current Science,* **74** (2):110-113.

Santiapillai, C. and R. Sukumar (2006). An overview of the status of the Asian elephant. *Gajah,* **25**: 3-8.

Sukumar, R. (1989). *The Asian Elephant: Ecology and Management*. Cambridge University Press, Cambridge. 251p.

Sukumar, R. (2003). *The Living Elephants: Evolutionary Ecology, Behaviour and Conservation*. Oxford University Press, New York. 478p.

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

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

Sukumar, R., A. Venkataraman, N. Baskaran, D. Guha and M. Roy (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. Dec.

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

Trivers R.L. (1972) Parental investment and sexual selection. *Sexual Selection and the Descent of Man* (Campbell, B., ed.). Aldine, Chicago. pp. 39-179.

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

Vanitha, V. (2007). Studies on the status and management of captive Asian elephants (*Elephas maximus*) at Tamil Nadu in Southern India. *Ph.D. Thesis*, Bharathidasan University, Tiruchirapalli, India.