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Birth statistics for African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants in human care: History and implications for elephant welfare

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Abstract

African (*Loxodonta africana*) and Asian elephants (*Elephas maximus*) have lived in the care of humans for many years, yet there is no consensus concerning some basic parameters describing their newborn calves. This study provides a broad empirical basis for generalizations about the birth heights, birth weights, birth times and gestation periods of elephant calves born in captivity. I obtained data concerning at least one of these four characteristics for 218 newborn calves from 74 institutions. Over the past 30 years, newborn Asian elephants have been taller and heavier than newborn African elephants. Neonatal African elephants exhibited sex differences in both weight and height, whereas neonatal Asian elephants have exhibited sex differences only in height. Primiparous dams ex situ are at least as old as their in situ counterparts, whereas ex situ sires appear to be younger than sires in range countries. Confirming earlier anecdotal evidence, both African [N= 47] and Asian [N = 91] dams gave birth most often at night.

Introduction

To understand the transition of zoos from places for holding collections of animals for human entertainment (menageries) to institutions promoting conservation, education and research (modern zoos), it may help to put the past 30 years in an historical context. Humans have managed Asian elephants for thousands of years [Kisling, 2001a; Sukumar, 2003a], and standardized husbandry practices have been in place during much of that time [Edgerton, 1931; Lahiri-Choudhury, 1992; Sukumar, 2003a]. Civilizations in India, Mesopotamia and Egypt had established collections of exotic animals by 1500 BCE [Kisling, 2001a; Lahiri-Choudhury, 1992], and by 100 CE elephants almost certainly were included in animal collections in China, Greece and Italy [Hoage et al., 1996]. The situation seems to have been different for African elephants: Except for a period between 300 and 200 BCE, when both the Egyptians and the Carthaginians trained African elephants for war [Gowers, 1947], the Belgians made the earliest attempt to domesticate African elephants, between 1900 and 1960 CE [Iverson, 1993; Watson, 1990].

Between the Renaissance and the beginning of the 19th Century, European aristocrats established menageries (collections of animals maintained for entertainment purposes) [Rothfels, 2002; Veltre, 1996]. For example, Louis IX of France (1214-1270) returned from the Crusades with an elephant [Kisling, 2001a], Henry III of England owned an elephant in 1254 [Koebner, 1994] and

Frederick II (1194-1250), Emperor of the Holy Roman Empire, had at least one elephant in his menagerie in Palermo, Italy [Hoage et al., 1996; Kisling, 2001a].

The oldest European zoo, Tiergarten Schönbrunn in Vienna, Austria [Schwammer, 2003], founded in 1752, was based on an Imperial collection. Its first elephant, a male Asian elephant, arrived in 1770 [Strehlow, 2001]. The first zoo dedicated to scientific principles and education, "Enlightenment principles," was the Ménagerie du Jardin des Plantes in Paris. It was founded in 1793, just after the French Retgqciaution [Hoage et al., 1996], and the first two elephants in its collection, Hans and Parkie, had been confiscated from the Dutch royal family by the French army [Mann, 1944].

In quick succession, zoos were opened in countries throughout Europe [Hoage et al., 1996]: for example, the London Zoological Gardens (1828), the Berlin Zoological Gardens (1844) and the Budapest Zoo (1866), Switzerland (Basel, 1874). Over the same period, prominent zoos were opened in countries worldwide: for example, Australia (Melbourne, 1972), the United States (Philadelphia, 1874), India (Calcutta, 1876), Japan (Ueno, 1882) [Hoage et al., 1996] and Argentina (Buenos Aires, 1888: http://www.zoobuenosaires.com.ar). In the United States, the forerunners of the Central Park Zoo (1861) and the Lincoln Park Zoo (1868) held animals before the Philadelphia Zoo opened in 1874, but they were relatively small menageries [Kisling, 2001b; Koebner, 1994].

The first elephants to be exhibited in North America, and the first captive births, were managed by circuses, menageries and traveling shows, rather than by zoos. The first elephant in North America is thought to have arrived at New York on April 13, 1796 [Goodwin, 1925] and the first captive live birth probably occurred on May 31, 1875 [Reynolds, 2007]. Soon after that, birth heights and weights were recorded for two circus-affiliated female Asian calves: "Columbia" was born in Philadelphia, PA, in 1880 [Brown, 1880] and "America" was born in Bridgeport, CT, in 1882 [Arstingstall, 1882].

The first live births of elephants in European and North American zoos are surprisingly recent, and occurred after the live birth of an Asian elephant in Buenos Aires Zoo (1905) (http://www.asianelephanLnet/buenosaires/buenosaires.htm). In 1906, an Asian elephant calf survived at the Vienna Zoo, Tiergarten Schönbrunn [Schwammer, 2003], whereas in 1918 "Prince Utah," a male Asian calf, was born at the Salt Lake City Zoo in Utah (now the Hogle Zoo) to the dam "Princess Alice." However, his dam bred with Snyder, a bull in the Sells-Flo to Circus, presumably before the Salt Lake Zoo purchased her in 1916 (Alexander, 2000; http://www.hoglezoo.org). The first elephant to be sired and born in a North American zoo was "Packy," born in 1962 in the Oregon Zoo [Maberry, 1962]. The first African elephant born in Europe was "Adam," at the Munich Zoo in 1943 [Schwammer and Stoerger-Horwath, 2005], and the first African elephant born in a North American zoo was "Little Diamond," born at the Knoxville, Tennessee Zoo in 1978 [Hargis, 2003].

Table 1. Group mean mortality statistics for elephants in the care of humans

Source	Management style[b]	Mortality[a] measure (%)		
		Stillbirth [*N*]	One year	Five years
Doyle et al. [1999]	Intensive		16 [74]	
Keele [1996]	Intensive	19 [95]	29 [95]	
Kurt and Mar [1996]	Intensive	26 [50]		
Schmid [1998]	Intensive		37 [141]	
Taylor and Poole [1998]	Intensive	25 [92]		42 [92]
Kurt and Mar [1996]	Extensive	0 [17]		
Mar [2002]	Extensive	3 [3,070]		24 [3,070]
Schmid [1998]	Extensive			8 [—]
Sukumar et al. [1997]	Extensive		19 [232]	
Taylor and Poole [1998]	Extensive	3 [238]		10 [238]

The sample size [*N*] follows each probability score. Some individual elephants may be included int he data sets for several studies.

[a]For the 1- and 5-year time periods, "mortality" = 100[(stillbirths + calf deaths) / (stillbirths + live births)]%

[b]Using Kurt and Garai's [2007] terminology: "Intensive" refers to locations at which a small number of elephants are kept in a limited area under a rigid management system without the types of social relationships typical of elephants living in situ; "Extensive" refers to locations at which large groups of elephants are maintained in large spaces under a flexible management system, but the location lacks the types of social relationships typical of elephants living in situ.

It seems appropriate to consider 1978 the first year of the "modern veterinary period" of zoo elephant reproduction because that year coincides with the beginning of an increase in the number of live births, the number of institutions yielding calves and the number of zoos reporting birth statistics for their calves. Specifically, I was able to acquire at least partial data on almost 200 live births between 1978 and 2008, but for fewer than 20 live births during the preceding 30 years (1948-1977). According to Dan Koehl's elephant database [Koehl, 2008], there were 66 live births in North America and Europe between 1948 and 1977, but 445 between 1978 and 2007.

There are several reasons why successful reproduction by elephants in human care is important. One is that, primarily because of competition between humans and elephants for space and resources [human-elephant conflict: Sukumar, 2003a], the long-term survival of Asian elephants in situ is, at best, uncertain. Human-elephant conflict is also a growing problem in Africa [Naughton et al., 1999]. Another reason is that neither species is reproducing at sustainable levels under human care in North America [Clubb and Mason, 2001; Olson and Wiese, 2000; Wiese, 2000] and the Asian elephant is not reproducing at sustainable levels in Europe [Wiese and Willis, 2006]. A third issue is that the Convention on International Trade in Endangered Species of Wild Fauna and Flora severely restricts the importation of Asian and African elephants from "range" countries, and this limitation is unlikely to be removed.

Unless zoos, circuses and wild animal parks make dramatic revisions in their management programs [Rees, 2003a-c; Taylor and Poole, 1998; Veasey, 2006; Wiese and Willis, 2006], their collections of African and Asian elephants will disappear within the next 50 years [Olson and Wiese, 2000; Wiese, 2000]. There is an ongoing debate over whether such changes would be desirable or even feasible [Clubb and Mason, 2001; Cohn, 2006; Faust et aI., 2006; Rees, 2003a-c; Schmid, 1998; Sukumar, 2003a,b].

Previous research indicates that gestation periods are longer, and birth weights and neonatal mortality are higher, for Asian elephant calves born in European and North American zoos than for those born in elephant centers in Asia, that is, working camps and orphanages [Doyle et al., 1999; Jayewardene, 1999; Keele, 1996; Kurt and Mar, 1996; Taylor and Poole, 1998]. Although the topic receives relatively little attention, some data suggest that the range-country elephant centers themselves lack important characteristics of the in situ environment: In particular, the rich social structure of that environment [Kurt, 2006]. Moreover, elephant calf mortality rates sometimes may be much higher than commonly supposed in elephant centers in Asia (). In fact, Kurt [2006] has suggested that none of the captive Asian elephant populations are self-sustaining.

Discussions concerning the viability of the populations of elephants in human care have resulted in a three-way categorization of management systems [Kurt and Garai, 2007, p 68-69]: "Extensive" (for example, jungle-based timber and wildlife camps), "Intensive" (for example, urban tourist centers, some zoos and circuses) and "Alternative" (modern zoos, elephant parks). A "modern zoo" may be defined as one that mimics, at least, the critical elements of the social characteristics of in situ elephant groups: extended "families" of genetically related females [Leuthold, 1976; Moss and Poole, 1982; Vidya and Sukumar, 2005], natural breeding rather than artificial insemination, parturition in a social group rather than in isolation, allomothering [Dublin, 1983; Rapaport and Haight, 1987], several adult males, a broad range of ages of both males and females and flexible access among the animals. Garai and Kurt [2006] and Kurt and Garai [2007] argue that such social enrichment features are more important than physical/ nonsocial forms of enrichment [already common in zoos: McCormick, 2003; Shyne, 2006; Swaisgood and Shepherdson, 2005; Wiedenmayer, 1998] or the geographical size of the elephant facility [Clubb and Mason, 2001]. Garai and Kurt [2006] cited Emrnen, Hamburg, Rotterdam, Cologne and Zurich as modern zoos in Europe, whereas suggesting that Ramat Gan Zoo in Tel Aviv [Terkel, 2000], with over 40 births [Koehl, 2008], is the most successful prototype for conservation breeding programs. At Ramat Gan Zoo, one Asian bull elephant (Yossi) sired 20 calves and another bull (Motek) sired 15 calves. At the same institution, an Asian elephant cow, Warda, has given birth 11 times, and an African cow, Norris, has given birth to six calves [Koehl, 2008].

Currently, there are no unambiguous answers to a number of basic questions about the birth of elephants in human care [Sukumar, 2003a]. For example: What do newborn elephants weigh? Do newborn male calves weigh the same as newborn female calves? Do newborn Asian elephant calves weigh the same as newborn African elephant calves? Similar questions may be asked about height, time of birth and gestational periods. This article addresses these questions. I have collected information on the births of 218 calves in 75 locations. For most calves, I have only partial data: That is, I do not have the birth time, the birth weight, the birth height and the gestation period for each calf. However, I have been able to acquire reasonably large samples for the time of birth [N = 138], weight at birth [N = 154], neonatal height [N = 78], gestation period [N = 49], age of dam [N = 186] and age of sire [N = 180]. It has been possible to compare the relevant statistics for male and female Asian and African elephant calves born during the past 30 years. The remainder of this article concerns such statistics.

Methods and Procedures

I obtained information about newborn elephant calves under the care of humans from a variety of sources: journal articles, books and book chapters, technical reports, conference proceedings, newspapers, magazines and from news releases and web sites associated with specific zoos, animal parks and professional organizations. In cases where media and professional sources provided conflicting information, I have used the data from the professional sources. When initial estimates for weights, heights, gestation periods and times of birth were revised at a later date, I have used the revised data. Most heights and weights were measured within hours of birth; all heights and weights were obtained during the first 2 days of the calfs life.

Data were collected from 202 singleton elephant calves born [N = 187] or stillborn [N = 15] between 1978 and 2008. Most of the live births [N = 120, 64M, 56F] and of the stillborn calves [9M, 3F] were Asian elephants, with the remaining elephants being African [live births: 33M, 34F; stillbirths: 3M, 0F]. All births occurred at institutions accredited by the relevant national or international associations of zoos and aquariums (Canada, Europe, Japan and USA), except for those at the Ringling Bros. Center for Elephant Conservation and at Riddle's Elephant and Wildlife Sanctuary. These latter two institutions have internationally recognized breeding programs and are centers promoting conservation, research and education. In addition, I obtained the birth weights for 15 Asian elephants and 1 African elephant born between 1934 and 1977. Table 2 provides a list of the 218 calves, arranged by source, species and sex.

Where possible, I confirmed the names and ages of dams and sires on a calfs day of birth using recent elephant studbooks [Beiterman, 2007; Keele, 2007; Olson, 2008]. For a few cases in which no studbook information was available, I relied on an elephant database [Koehl, 2008] and summaries by Shoshani [Lash, 1982; Shoshani, 1986, 1987, 2000]. In general, there were only rare, small inconsistencies in the reports of calves' times of birth, weights, heights and gestation periods. However, except for animals born in captivity, various sources occasionally disagreed over the age of a particular dam or sire. For these animals, I used the ages on which most sources agreed, or the mid-point of the estimates (rounded off to an integer). For wild-born elephants, I followed the standard procedure of assuming that the animal was born on January 1 of the birth year. For captive-born elephants, I calculated ages from the known dates-of-birth.

Data Analysis and Statistics

Unless otherwise stated, the criterion for the statistical significance of any effect was $\propto < 0.05$ (two-tailed test). For analyzing birth times, I used the Kolmogorov-Smirnov one-sample and two-sample tests [Siegel, 1956]. For analyzing weights, heights and gestation periods, I used

Table 2. Birthplaces of the calves in this study

Source	Calves	Source	Calves
African Lion Safari	2.4	La Palmyre, France	2.0
Albuquerque	0.1	Leipzig, Germany	0.1
Alwetter Zoo	1.0	Lincoln Park, IL	0.1
Amersfoort	0.1	Los Angeles	1.0
Amsterdam	0.1	Louisville, KY	[1.0]
Basel	[0.1]	Lowry Park	[1.0]
Berlin	1.0	Maryland, USA	[1.0]
Berlin-Friedrich.	3.3 [3.4]	Miami	1.0
Boras, Sweden	[0.2]	Montgomery, AL	[0.1]
Bronx Zoo	1.0	National Zoo, DC	1.1
Busch Gardens	0.1	Nyiregyhaza, HU	[1.0]
Cabarceno	[3.4]	Oakland, CA	0.1 [4.0]
Calgary	1.3	Oregon	6.4
Chester	4.3	Paris: Parc	1.0
Cincinnati	1.0	Phoenix, AZ	1.0
Cleveland	[0.1]	Pittsburgh, PA	[1.2]
Colchester	[2.0]	Port Lympne	3.0
Cologne	0.2	Riddle's EWS	[1.2]
Columbus, OH	2.0	Ringling Bros, FL	7.7
Copenhagen	2.1	Rome	1.1
Dickerson Park	2.3	Rosamond G	3.4
Disney Animal King.	[2.2]	Rotterdam	2.1
Dresden	[1.0]	San Diego WAP	2.0 [3.5]
Dublin	1.1	Seneca Park	[1.0]
Emmen	5.2	St. Louis, MO	1.2
Fort Worth	0.2	Tama, JP	[1.0]
Gunma SP, JP	[2.1]	Tisch Family Garden	1.0
Hagenbeck	3.2	Toledo, OH	[2.0]
Hanover	2.4	Toronto, CA	[0.1]
Have Trunk	2.1	Tulsa, OK	1.0
Houston	4.2	Usti Nad Labem CZ	1.0
Howlett's WAP	[1.1]	Vienna	[1.1]
Indianapolis, IN	[2.2]	Warsaw, Poland	0.1
Jacksonville	0.1	Whipsnade, UK	2.2
Knowsley Park	[0.1]	Woodland Park, WA	0.1
Knoxville, TN	[0.2]	Wuppertal, Germany	[2.2]
Le Pal, France	0.1	Zurich	4.3

I have used the standard studbook notation to indicate males and females: The notation "2.4" indicates two males and four females. To save space, numbers for African elephant calves are enclosed in brackets "[ ]"; numbers for Asian elephant calves are not bracketed: WAP, wild animal park; SP, safari park; EWS, elephant and wildlife sanctuary.

two-factor analyses of variance [Kirk, 2008]. The sample sizes were large, each sample produced a median very similar to its mean and the distributions of the sample were unimodal and symmetrical, justifying the use of the (parametric) analysis of variance tests [Kirk, 2008]. I used the Pearson product-moment correlation coefficient [Kirk, 2008] to compare birth heights and birth weights, and to compare dates-of-birth with birth height and birth weight.

The allometric relations among such characteristics of elephants as height, weight and age have been studied using a variety of transformations [Sukumar, 2003a]. In this study, I calculated correlations using the standard logarithmic transformation of the body-scaling equation: $\log(Y) = \propto\log(X) + \log(\beta)$, where X and Y are the variables of interest and $\propto$ and β are constants [for a discussion of some limitations on biological scaling analyses, see Martin et al., 2005]. Although the data are not reported here, other metrics, such as a linear comparison ($Y = \propto X + \beta$), a power law transformation ($Y = \propto X^{\beta}$) and a Spearman rank correlation test [Siegel, 1956], produced the same pattern of correlations as the $\log(X)/\log(Y)$ analyses reported in the Results.

Results

Weights, Heights and Gestation Periods of Newborn Elephants

Before comparing the birth statistics of the live-born elephant calves, I performed Tukey's box-plot test for outliers in the 1978-2008 samples [Kirk, 2008] and removed the outliers from further consideration. There were no outliers in the gestation data. There were only two outliers out of the 78 height samples, both in the Asian-female sample (66 and 120 cm). There were 4 outliers, out of 154 observations, for the weight data: Two for the African-male sample (46 and 180 kg), one for the Asian-male sample (42 kg) and one for the Asian-female sample (53 kg).

The birth weights, heights and gestation periods of the remaining calves are summarized in Table 3 and a summary of the results of relevant statistical tests is given in Table 4. Asian newborn calves (mean weight 117.9 kg) were heavier than African neonates (mean weight 103.1 kg), and male calves (115.7 kg) were heavier than female calves (108.8 kg). There was also an interaction between the Sex and Species variables: The mean weights of male and female African calves differed, 112.0 and 95.1 kg, respectively, whereas the weights of the male and female Asian calves did not, 118.1 and 117.8 kg, respectively.

Both sex and species influenced the calves' neonatal heights: African elephants (mean height = 89.9 cm) were significantly shorter than Asian elephant neonates (mean height = 93.7 em), and males (94.8 cm) were significantly taller than females (89.7 cm). The mean gestation period was considerably longer for the Asian calves (657.8 days) than for the African calves (640.1 days). There was no sex difference in the gestation period and the interaction between Sex and Species was not statistically significant.

Relationships Between Birth Height and Birth Weight During the Past 30 Years

Because of the sex and species differences in birth height (BH) and birth weight (BW), it was necessary to consider the BH/BW relationship separately for each of the four categories of calves: male Asian elephant, female Asian elephant, male African elephant and female African elephant (with the height and weight outliers removed). The correlation between 10g(BH) and 10g(BW) reached statistical significance ($\propto = 0.05$) for male ($r = 0.516$, $N = 18$) and female ($r = 0.619$, $N = 20$) Asian elephant calves and for male African elephant calves ($r = 0.707$, $N = 14$).

Table 3. Mean values for birth weight, birth height and gestation period

Variable	African elephant Male	African elephant Female	Asian elephant Male	Asian elephant Female
Birth weight (kg)	112.0 ± 3.5 (27)	95.1 ± 2.5 (30)	117.8 ± 3.5 (49)	118.1 ± 3.1 (44)
Birth height (cm)	93.4 ± 2.1 (16)	86.8 ± 1.1 (18)	95.9 ± 1.2 (19)	91.9 ± 1.3 (23)
Gestation (days)	634.5 ± 2.1 (10)	645.2± 3.0 (11)	660.6 ± 5.8 (16)	654.0 ± 4.3 (12)

The number of animas contributing to each mean is shown in parentheses (*N*). Each mean score is accompanied by the standard error of the mean [±SEM].

The correlation between birth height and birth weight was positive, but not statistically significant, for female African elephant calves (r = 0.416, N = 17, P = 0.097).

There was no consistent tendency for newborn calves to become heavier or taller over the past 30 years. Because each of the four categories of calf exhibited a different pattern of births between 1978 and 2008, I used a linear timescale indicating the number of months between January 1, 1978, and the date-of-birth of each calf: For example, a calf born on January I, 1988, was born at time t = 120 months. Using logarithmic transformations of both birth weight and date-of-birth data, the correlation between date-of-birth and birth weight was statistically significant only for the male Asian elephant calves (r = 0.319, N = 49, P = 0.026). The correlations for the female Asian elephant calves (r = -0.001, N = 44), the male African elephant calves (r = -0.045, N = 27) and the female African elephant calves (r = 0.168, N = 30) were not statistically significant. Comparing logarithmic transformations of date-of-birth and shoulder height, only the female African elephant calves exhibited a significant correlation between date-of-birth and birth height (r = -0.553, N = 18, P = 0.017). There was no significant correlation between date-of-birth and shoulder height for the male Asian elephant calves (r = 0.112, N = 18), the female Asian elephant calves (r = 0.294, N = 25) or the male African elephant calves (r = 0.144, N= 16).

Asian Elephants Born in Zoos Between 1934 and 1977

Five male and 10 female Asian elephants born in Europe and North America between 1934 and 1977 provided weights. On average, they weighed less than the more recently born (1978-2008) Asian elephants, 99.8 and 116.45 kg, respectively (Table 4). There was not sufficient data (N = 1, 113 kg) to analyze the births of African elephants before 1978.

Age of the Dams and Sires

Table 5 gives the mean ages for the dams and sires connected with all live births, and the mean ages of dams and sires for the primiparous dams only. The number of cases contributing to each mean is given in the table. I conducted an analysis of variance for all of the first-born calves (Species × Sex). For the primiparous dams (N = 97, mean age = 16.4 years), there was no effect of Species, F(l, 93) = l.93, P = 0.17, or Sex (of the calf), F(l, 93) = 2.03, P = 0.16, and no statistical interaction, F(l, 93) = 0.42, P = 0.52. Similarly, there were no statistically significant differences among the sires of those dams related to either the species or sex of the calf, F(1, 90)

Table 4. Summary of the results of the analyses of variance comparing the weights, heights and gestation periods of newborn African and Asian elephant calves

Characteristic	Comparison	Result/effect	Value of statistic	Probability
Weight—all (kg)	Species	Asian calves > African calves	$F(1, 146) = 18.46$	$P < 0.001$
	Sex	Male calves > female calves	$F(1, 146) = 4.28$	$P < 0.040$
	Species × Sex	Sex difference only for African calves	$F(1, 146) = 5.35$	$P < 0.022$
Height (cm)	Species	Asian calves > African calves	$F(1, 72) = 6.93$	$P < 0.010$
	Sex	Male calves > female calves	$F(1, 72) = 12.58$	$P < 0.00$
	Species × Sex	—	$F(1, 72) = 1.16$	$P < 0.285$
Gestation (days)	Species	Asian calves > African calves	$F(1, 45) = 14.08$	$P < 0.001$
	Sex	—	$F(1, 45) = 0.03$	$P < 0.86$
	Species × Sex	—	$F(1, 45) = 3.34$	$P < 0.074$
Weight/Asian only	Time period	1978-2008 calves > 1934-1977 calves	$F(1, 106) = 6.18$	$P < 0.015$
	Sex	—	$F(1, 106) = 0.03$	$P < 0.860$
	Time period × Sex	—	$F(1, 106) = 1.48$	$P < 0.227$
Weight/Asian only	Survival	Stillborn > live	$F(1, 101) = 6.90$	$P < 0.010$
	Sex	—	$F(1, 101) = 0.1$	$P < 0.750$
	Survival × Sex	—	$F(1, 101) = 0.0$	$P < 1.000$

= 2.92, $P = 0.091$, and $F(1, 90) = 0.3$, $P = 0.59$, respectively, and there was no Species/Sex interaction, $F(1, 90) = 2.03$, $P = 0.158$. The average age of the sires of primiparous dams was 20.4 years and the average age of all sires was 22.9 years.

For the institutional births between 1978 and 2008, only 2.7% (5/186) of the cows were under 10 years of age. These five Asian dams gave birth at 5, 5, 8, 9 and 9 years of age. In contrast, 3 out of 10 Asian dams with known ages in the 1934 - 1977 group were under 10 years of age.

Time of Birth

Reports for 91 Asian elephants and 47 African elephants included the time of day at which parturition occurred. The times of birth were sorted into eight 3-hr categories (Table 6). A Kolmcgorov-Smirnov two-sample test indicated that the distributions of African elephant births and Asian elephant births did not differ significantly, $D = 0.162$, $P > 0.10$. A Kolmogorov-Smirnov one-sample test on the combined data showed that births were not evenly distributed throughout the day, $D = 0.154$, $P < 0.0l$. Both the Asian and the African cows tended to give birth at night.

Stillbirths

I collected the weights of 12 stillborn Asian elephant calves: 9 males and 3 females, all of which occurred between 1987 and 2006. Comparing the mean weights of the stillborn and live-born calves in an analysis of variance, the stillborn calves (136.3 kg, both sexes combined) were significantly heavier than the live-born calves (117.9 kg). Neither of the other effects (Sex, Sex × Survival) approached statistical significance. There were not enough African elephant stillbirths between 1978 and 2006 ($N = 3$, mean = 123.3 kg) to meaningfully compare the weights of the stillbirths and the live-born calves [Kirk, 2008].

Table 5. Mean values for the ages (years) of the dams and the sires: for all births and for only the dam's first parturition

	African elephant calves		Asian elephant calves	
Variable	Male	Female	Male	Female
Dam: all births	19.2 ± 0.8 (33)	17.3 ± 0.4 (34)	19.9 ± 0.9 (63)	19.9 ± 1.0 (56)
Dam: first births	18.0 ± 0.8 (21)	16.3 ± 0.8 (25)	16.4 ± 1.2 (28)	15.0 ± 0.9 (23)
Sire: all births	20.6 ± 0.9 (28)	19.4 ± 1.0 (32)	24.4 ± 1.2 (64)	24.3 ± 1.1 (56)
Sire: dams' first births	19.6 ± 1.1 (19)	18.5 ± 1.2 (24)	20.3[a] ± 1.6 (28)	23.2 ± 1.8[a] (23)

Each mean score is accompanied by the standard error of the mean [±SEM]. The number of animas contributing to each mean is shown in parentheses (*N*).
[a]One sire died between conception and parturition. The average indicates the age that sire would have attained at the time of parturition.

Table 6. The number of Asian and African calves born during each 3-hr time period in a day

Species	0:00-2:59 hr	3:00-5:59 hr	6:00-8:59 hr	9:00-11:59 hr	12:00-14:59 hr
Asian	11	24	14	9	9
African	7	11	6	2	1
Total	18	35	20	11	10

Data for male and female calves are combined

Species	15:00-17:59 hr	18:00-20:59 hr	21:00-23:59 hr
Asian	1	9	14
African	1	8	11
Total	2	17	25

Data for male and female calves are combined

Discussion

The main finding of this survey is that, in the care of humans, Asian elephants exceeded African elephants in mean birth height (93.7 vs. 89.9 cm), birth weight (116.5 vs. 103.5 kg) and gestation period (657.8 vs. 640.1 days). Meyer et al. [2004] recently reported some species differences in "the endocrinology of pregnancy in elephants" (p 263) and there are numerous physiological differences between the species [Olson, 2004, p 178-209], suggesting that species differences at all levels of analysis may be greater than hitherto appreciated. Therefore, in the future it would seem more appropriate to describe the species differences, as Stevenson and Walter [2006] do in the BIAZA management guidelines, rather than to give a single estimate combining data from both species of elephant, as has been standard practice in the past [Emanuelson, 2006; Niemuller et aI., 1999; Schmidt, 1999; Schmitt, 2003].

The current gestation data resemble those obtained by Oerke et al. [2006], who determined the gestation periods of African and Asian elephants born in European facilities to be 642 and 655 days, respectively (significantly different, $P < 0.02$). The similarity in results is compelling, given that the present sample [$N = 49$] and that of Oerke et al. [2006: $N = 45$] have only eight animals in common. On the other hand, using somewhat smaller samples, Meyer et al. [2004] found no significant difference between the gestation lengths of Asian (664 ± 11 days, $N = 19$) and African elephants (mean = 657 ± 6 days, $N = 8$), although the difference was in the same direction as in the other studies. Similarly, although Doyle et al. [1999] estimated the gestation period of Asian elephants to be similar to the current result (656 vs. 658 days), the current estimate for African elephants in the care of humans (640 days) is lower than Moss's [1983] estimate of 656 days for African elephants in situ. The range of gestation periods for both African elephants (625-667 days) and Asian elephants (617-690 days) in the current samples is so broad that prediction of parturition can only be made on an individual basis [Hildebrandt et al., 2006], by either behavioral or endocrinological measures [Hildebrandt et al., 2006; Szdzuy et al., 2006].

Although neonatal heights differed statistically across species and sex in this study, in absolute terms the differences were small. The Asian calves, with a mean birth height of 89.9 cm [N = 44], were similar in height to samples from other studies: 88.9 cm for Asian calves in zoos [Doyle et al., 1999], 89.9 cm for 10 (3.7) newborn Asian calves in forestry camps [Nair, 1989; Sharma and Krishnamurthy, 1984] and 88.8 cm reported for 16 neonates at Pinnawela Elephant Orphanage [Jayewardene, 1999]. The Asian elephant calves born between 1978 and 2008 were only slightly taller than the average height of 85.7 cm for four calves born over 100 years ago: two in working camps in 1789 and 1795 [Corse, 1799] and two in circuses in 1880 and 1882 [Arstingstall, 1882; Brown, 1880].

Similarly, the African neonates (89.9 cm, $N = 34$) were slightly taller than the mean height of 84.3 em reported for three orphaned male African elephant calves, all estimated to be less than 3 weeks or age [Bellinge and Woodley, 1964; Taylor, 1955; Woodford, 1970: Note that these reports described calves born several decades before the calves in this study]. One recent study [Morgan and Lee, 2003] provides only the minimum heights observed in samples of African forest elephants (*Loxodonta africana cyclotis*) and savannah elephants (*L. africana africana*): 69 and 79 cm, respectively. The small amount of available evidence suggests that newborn captive elephants are similar to, or slightly taller than, extensively managed neonates [Kurt and Garai, 2007].

The results for the birth weights of the calves are difficult to interpret. The Asian elephants were heavier, on average, than other samples of Asian elephants taken in North American zoos [105.3 kg, $N = 46$; Doyle et al., 1999], Europe [105.1 kg, $N = 19$; Kurt and Mar, 1996] and an elephant center in Sri Lanka [Pinnawela, 74.1 kg, $N = 16$; Jayewardene, 1999]. As in the current sample, there was no evidence of sex differences in the data collected by either Jayewardene [1999] or Kurt and Mar [1996].

On the other hand, there was a large sex difference in birth weight for the African calves, and I could find no organized set of data with which to compare my results. It remains to be determined why one species would exhibit a clear sex difference in birth weight whereas the other would not.

As in previous studies, stillborn Asian calves weighed more than live-born calves [Doyle et al., 1999; Kurt and Mar, 1996]. Kurt and Mar [1996] suggest that the difference in weights is correlated with differences in gestation period between live- born and stillborn calves, and I have no data that allow me to contradict their conclusion.

Cows of both species gave birth to their first calves in their mid-to-late teens (14-18 years), at mean ages comparable to, though slightly older than, those observed for primiparous elephant cows in situ [Moss, 2001; Sukumar, 2003a]. Moss [2001] found that African elephant cows in Amboseli gave birth for the first time at a mean age of 13.7 years and Sukumar [2003a, p. 258] found that more than half of the populations he examined had a mean age of first conception of 12.5 years or less (13/22 studies: both African and Asian elephants). Both Buss and Smith [1966] and Smuts [1975] concluded that virtually all of the female African elephants they studied had conceived by the ages of 12-14 years, and several authors have obtained evidence of 7-year-old cows that were pregnant [Buss and Smith, 1966; Moss, 2001; Smuts, 1975] or had already given birth [Taylor and Poole, 1998] in situ. Thus, it would seem to be entirely appropriate to attempt conception, either natural breeding or artificial insemination, starting at about 10 years of age, and to breed the same cow repeatedly. According to Sukurnar [2003a, p. 258-260], about 80% (18/22) of the elephant populations studied have involved mean intercalving intervals of between 3.5 and 6.0 years; therefore, it would seem reasonable to start attempting conception in the care of humans, either by natural breeding or artificial insemination, when the cow is about 10 years of age, and then to allow cycling cows to breed every 5 years or so. In contrast, the average age of the sires in this study (22.9 years) was much lower than the average of sires in situ [Hollister-Smith et al., 2007], where most sires were more than 35 years old.

The time of birth data indicate that both species of elephants tended to give birth at night, with about one-quarter of all births occurring between 3 and 6 AM. This pattern of births is consistent with suggestions concerning African elephants in situ [Moss, 1988, p. 151], and with reports from various facilities that virtually all births occur at night, most often between midnight and 7 AM [Copenhagen: Eriksen, 1978; Ramat Gan: Terkel, 2003; Pinnawela: Kurt and Garai, 2007].

Implications for the Welfare of Elephants Under the Care of Humans

In recent years, there have been startling gains in our understanding of the physiology [Brown, 2000; Hermes et al., 2008; Hildebrandt et al., 2006], behavior [Leighty et al., 2008], cognition [Bates et al., 2007; Dale, 2008], social organization [Garai and Kurt, 2006], development [Lee and Moss, 1999; Poole, 1994] and diseases [Schmitt, 2003] of elephants. However, there is still little empirical data on which to make decisions concerning the management of elephants.

It is clear that the social environments of both species of elephant are complex [Charif et al., 2005; Freeman et al., 2004; Garai and Kurt, 2006; Sukumar, 2003a; Wittemyer and Getz, 2007], and that disrupting the elephant's social system may have tragic consequences [Bradshaw et al., 2005; Siebert, 2006] such as those resulting from the relocation of juvenile bulls in the absence of mature males [Slotow et al., 2000]. There are also risks involved in breeding elephants in captivity, such as the elephant endotheliotropic herpesvirus [Ehlers et al., 2006; Richman et al., 1999; Ryan and Thompson, 2001]. However, the fact that there is not a clear understanding of something as basic as the birth weights and heights of elephants suggests that much more research will be required to discover even the basic aspects of "elephant life."

Perhaps it is time to follow the advice of Hutchins and Thompson [2008], and to develop a set of priorities for research programs involving elephants. These programs should involve multiple institutions, cooperating rather than competing. There are multiple unanalyzed data sets in file cabinets and on hard drives scattered around the world or, at least, the information has not been made available to the broader community of scientists, handlers and managers. If we are to make sound decisions about the future care of elephants, they need to be based on empirical data, not anecdotes or emotions.

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