

Research article

Sleep in Asian elephants (*Elephas maximus*): long-term quantitative research at Dublin Zoo

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Abstract

Sleep is an essential aspect of Asian elephant (*Elephas maximus*) wellbeing in zoos. Recent improvements in elephant habitats and husbandry, including sand substrates, feeding enrichments and related herds, have increased their wellbeing, but few studies have focused on night time behaviour. This study measured sleep behaviour in a group of Asian elephants in Dublin Zoo and how it related to elephant husbandry. A total of 704 nights of elephant behaviour were recorded over a 33-month period. Closed circuit television cameras, with infrared abilities, were used to record behaviour from 1900-0800 nightly. Eight elephants were studied: three related adult cows, both while they were pregnant and not pregnant, one sub-adult cow, one adult bull, two bull calves and one cow calf. Adults slept for an average of 3 hr 33 min per night, while calves slept an average of five hours eight mins per night. There was a clear relationship between age and sleep: older individuals slept less. One of the three elephants who became a mother during the study slept 68.3% less in the first nine months after giving birth. Another mother slept 13% less after parturition, while a third female slept more after giving birth (up 10.3%). Reduction in sleep duration appeared to be primarily because of calf guarding behaviour, but establishing successful suckling may also be a factor. On rare occasions, the adult cows were given the option of sand and concrete surfaces. The adult bull was given this option nightly. Both sexes always chose sand to sleep on. The bull showed consistent sleep duration, while sleep in the other elephants varied through pregnancy, parturition and the immediate post-partum period. Elephants live in related, matriarchal herds in the wild, where they traverse substrates of sand and soil. Results of this study suggest that zoos should aim to mimic these features to permit appropriate levels of sleep and improve wellness.

Introduction

Zoos have a great responsibility to provide the animals in their care with the highest possible level of wellbeing, satisfying both physical and psychological needs (Hosey et al. 2013). Elephants require comfortable surfaces to sleep on; those that replicate natural surfaces are important for increasing sleep quantities (Roocroft 2005). However, there have been few studies on the nocturnal behaviour of zoo-housed elephants (Harris et al. 2008) and further investigation is needed to evaluate the effectiveness of new, more natural elephant homes.

Asian elephants (*Elephas maximus*) lead complex lives in the wild, and are active for most of the day, walking distances of 10–30 km per day to find food and water (Poole and Granli 2009). Asian elephants are predominantly diurnal and rest more at night. Limited existing data indicate that they sleep

an average of four hours per day in the wild (Ganswindt and Munscher 2007). The elephants in three UK zoos, observed over a period of 91 days, also slept for four hours per day on average (Williams et al. 2015.)

In general, mammal feeding habits and their sleeping duration are linked. The daily amount of sleep is highest in carnivores, lower in omnivores, with herbivores sleeping the least (Siegel 2005). Sleep is an important aspect of life, and a lack of it may cause compromised immunity and other health issues in humans and other animals (Bryant et al. 2004; Farndon and Lampon 2014). Abnormal sleep patterns can also be a symptom of illness or poor welfare (Cheeta et al 1997; Bradbury et al. 1998). St Louis Zoo (personal communication) reported that their elephants slept on average one hour less per night during early stages of the onset of elephant endotheliotropic herpesvirus (EEHV). EEHV is a major threat to

zoo elephants and has caused the death of 25% of Asian elephants in North American zoos since 1983 (Keaggy 2013). Therefore, greater understanding of elephant sleep behaviour could be beneficial in identifying the early stages of EEHV, possibly resulting in earlier treatment which is considered a major advantage in its successful management (Bainbridge, personal communication).

At Dublin Zoo in 2012, a longitudinal study was initiated to monitor sleep of its elephant herd. The aims were to determine typical sleep patterns and to understand how age, sex, pregnancy, parturition and motherhood affect sleeping rates. Information on these aspects of elephant sleep may provide a foundation for further improving elephant management in zoos across the globe.

Methods

Study subjects

The study included all eight Asian elephants housed at Dublin Zoo during the study period: three males and five females aged from newborn to 31 years (Table 1). The elephants were observed from 1 October 2012 to 31 July 2015. In an attempt to replicate wild group dynamics the females are all related. Dina is considered to be the matriarch of the herd and is full sister to Yasmin and mother of Asha and Samiya. Anak and Kavi are Yasmin’s offspring. Anak is the mother of Ashoka. Anak and Asha have the same father. In the wild bulls spend most of the time alone or in small bachelor groups so Upali is kept separate from the cows and offspring for 86% of the time. Upali is the father of Kavi, Ashoka and Samiya.

Habitat and husbandry

The elephant herd was housed in Dublin Zoo’s Kaziranga Forest Trail habitat consisting of two large outdoor areas, two houses and a kraal (Figure 1). The outdoor cow habitat (circa 5000 m²) includes a hoist for elevating hay 4 m above ground, and four feed pipes hidden in the ground for feeding. The cow house (total 425 m²) contains a 275 m² sand area which is 1.8 m deep. Four automated hay feeders open four times throughout the night (between 2100

-0600) to provide hay through wall openings. The timings are changed bi-weekly to reduce predictability of feed access. There is one hay bale per box and this is part of the daily ration. In addition to the sand area there are three training stalls (50 m² each) with rubber floors that are only accessible when elephants are being trained (usually five mornings a week, for up to 90 minutes per day). There is an outdoor kraal area (450 m²) attached to the cow house. The bull outdoor habitat (circa 2800 m²) also contains a hay hoist and one feed pipe hidden in the ground. The bull house has a sand floor (200 m²) and a training stall (70 m²) which has a concrete floor both accessible at all times. Eight timed hay feeders open at different times during the night. Sand accounts for 95% of the overall substrate in the entire habitat, the remaining substrates being soil, wood chippings and clay. There are two outdoor water pools, the cow pool is 3.5 m deep and the bull pool 4.5 m deep.

The elephants have 24 hour access to their respective outdoor areas except when the temperature is predicted to drop below 6°C, when they are restricted to the indoor houses overnight. The indoor houses are maintained at 18-22°C. Upali, the adult bull elephant, is given access to the main herd and outdoor cow habitat six days a week from 1100-1530. He is never given access to the indoor cow house or kraal. When a cow is in oestrus the cows are given access to Upali’s bull area overnight. This happened on four occasions during the study period.

Dublin Zoo uses a protected contact management system for elephants, whereby keepers and elephants never share the same space. The elephants are trained using positive reinforcement, whereby individuals have a choice to participate and are rewarded

Table 1. Eight Asian elephants housed at Dublin Zoo and observed during the study, October 2012 to July 2015. Dina, Yasmin and Anak were all pregnant at the time the study started, Upali is the father of Kavi, Ashoka and Samiya.

Elephant	Sex	DOB and location	Arrived at Dublin Zoo		# nights studied
			Zoo	Age	
Upali	M	14/11/94 Zoo Zurich	06/07/12	17-20 yrs	628
Dina (Bernhardine)	F	16/06/84 Rotterdam Zoo	17/10/06	28-31 yrs	636
Yasmin	F	25/11/90 Rotterdam Zoo	17/10/06	21-24 yrs	617
Anak	F	26/7/03 Rotterdam Zoo	17/10/06	9-12 yrs	612
Asha	F	07/05/07 Dublin Zoo	mother Dina	5-8 yrs	566
Kavi	M	17/7/14 Dublin Zoo	mother Yasmin	0-12 mths	131
Ashoka	M	19/8/14 Dublin Zoo	mother Anak	0-11 mths	95
Samiya	F	17/9/14 Dublin Zoo	mother Dina	0-10 mths	75



Figure 1. The Kaziranga Forest Trail habitat for elephants at Dublin Zoo, showing indoor houses, outside kraal and locations of feed stations (hay hoists and pipes).

with food for doing so. Tasks such as elevating feet into foot ports for examination and foot health care, placing ears through ear chutes for inspection, and individual elephants entering transport crates have all been achieved at Dublin Zoo through this management system.

Hay, carrots and turnips are provided communally throughout the day. Concentrates (horse and pony cubes, bran, old world monkey pellets and coconut oil) and apple slices are offered whilst elephants are separated into stalls so individual daily rations can be controlled.

Data collection

Elephant behaviour was recorded from 1900-0800 each night using a high definition closed circuit television system (AXIS system), with infrared abilities. Cameras covered all areas, including both inside houses and outdoor habitats. Elephants were identified by their physical differences, such as body height, body length, torso shape, ear shape and position, hip and shoulder location/prominence, tusk/tush visibility and presence or lack of hair.

The five oldest elephants were recorded nightly from October 2012 until September 2014. Three calves were born between July and September 2014. This brought the elephant population to eight, making recording more time consuming. As a result, an eight day rolling timetable was created which included all eight elephants, but involved recording only four elephants per night.

'Sleep' was recorded when an individual was lying in a recumbent position, where the elephant was lying on either the left or right side of their torso, and their feet were not flat on the ground. Sleep was recorded as either 'left side' or 'right side', and duration of sleep was recorded correct to the nearest minute. Elephants have been reported to rest while standing up (Koyama et al. 2012), but due to difficulties with quantifying this behaviour it was not recorded as part of this study. It is believed that elephants will only go in to deep sleep, or rapid eye movement (REM) sleep if they are in a recumbent position (Koyama et al. 2012). Continuous sampling, correct to the nearest minute, was used to record data.

Results

Across the 33-month study period 704 nights of behaviour were recorded. The total mean nightly sleep quantity for all elephants over the entire study was 4 hr 16 min. The five adults (mean 3 hr 37 min) generally slept for less time than the three calves (mean 5 hr 8 min) although the youngest adult (Asha, 8 years) was intermediate (4 hr 45 min) (Figure 2). There was a significant negative relationship between age and mean sleep duration ($R^2 = 0.89$, $p < 0.05$).

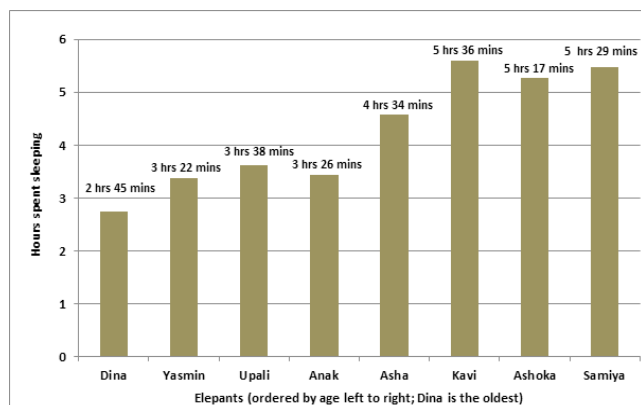


Figure 2. Mean nightly sleep values in hours for all elephants over entire study (Oct 2012 to July 2015 inclusive). Oldest elephant on left, decreasing age of elephants to right.

Table 2. Duration of total sleep per night (min) of elephant mothers and their calves at Dublin Zoo at various times after parturition.

Mother/ calf	Night				Monthly mean			Study mean ± std dev.
	1	2	3	4	1	2	3	
Yasmin	0	0	0	0	210	93	77	202 ± 84
Kavi	10	38	6	240	495	608	743	336 ± 98
Anak	22	40	110	196	330	227	303	206 ± 68
Ashoka	0	13	-	336	480	620	540	317.5 ± 86
Dina	0	0	0	4	209	141	146	165 ± 73
Samiya	0	4	279	268	406	591	344	329.5 ± 92

The only prolonged period of low sleep recorded during the study was for Dina who did not lie down for 11 consecutive nights in October 2012. Upali had reduced sleep on two nights (26th and 27th November 2012) when he only slept for one minute on each night. On these nights all the cows were housed in the bull area due to Anak being in oestrous and Upali showing intense interest in her. Upali was the only elephant to regularly have access to a concrete surface on which to sleep but he never slept on it, always choosing the sand. On the occasions when the adult cows had access to the bull house overnight, they also choose to sleep on sand and never laid down on the concrete.

Effects of birth

All three females who gave birth during the study slept very little in the first few nights after parturition but their average mean sleep duration for the first month after parturition was typical for the whole study (Table 2). Comparing pre- and post-birth periods over the whole study, on average Dina slept 10% (17 min) more per night after giving birth whereas the other two females both slept less: Yasmin by 68% (148 min) and Anak by 13% (24 min). The non-pariparous female Asha also slept less after the birth of the calves by 18% (52 min). For 90% of the time at least one adult female was standing while the calves slept, all elephants were only seen to lie down at the same time 10% of the time. Dina and Asha displayed the most obvious signs of protective behaviour of the calves, regularly standing very close to them when they were sleeping.

All three calves slept very little on their first few nights after birth but sleep duration increased rapidly reaching with all three sleeping for at least three hours by the fourth night (Table 4). Calves individually rose from sleep on average ten times a night. Following the calves first bout of sleep, the adult females appeared to become less protective spending less time standing very close to them. Sleep duration of all three calves remained quite variable for their first 3 months but settled down subsequently.

Discussion

The average nightly sleep duration (4 hr 16 min) of the elephants in this study is similar to the four hours recorded in the wild (Ganswindt and Munscher 2007) and in other zoos (Williams et al. 2015). Only two of seven elephants in the latter study (Williams et al. 2015) chose to sleep lying down on a rubber floor, and none on concrete. The current study confirmed that substrate is an important factor contributing to quantity of sleep and the elephants were observed to have a preference for sleeping on

natural substrates. None of the elephants were seen to sleep on concrete when they had a choice, always preferring sand. Depth of sand may also be important, the sand at Dublin Zoo is 1.8 m deep to allow good drainage of urine and water but also allows the elephants large scope for creating dips and mounds in the surface.

Factors affecting sleep quantity

Elephants, as extremely large herbivores, are less likely to suffer predation than smaller herbivores such as antelope and deer. This means they may sleep more deeply and do not require the 'drowsy' state that is reported in many ruminants (Ruckebusch 1972), but there may still be factors that inhibit sleep. In this study, all elephants except for Kavi had at least one night when they did not sleep.

Age

The inverse relationship between age and sleep quantity found in this study is consistent with many other mammal species in which juveniles sleep considerably more than adults. This is presumably associated with the need for more REM sleep (Siegel 2005) for brain development (Ferber 1985), essential in any animal's early years. Total nightly sleep increased and became less variable over the calves first months of life, perhaps due to decreased suckling time.

Social interactions

Dina's prolonged absence of sleep during October 2012 was possibly due to conflict with her sister Yasmin. Conflict was only evident during daytime observations when occasional physical tussles were recorded during the study, but not after October 2012. Upali, who was usually housed alone overnight so not exposed to social interference in sleep was the most consistent sleeper throughout the study. The two nights on which he slept very little were undoubtedly caused by the presence of the cows in his house when one was in oestrous.

Birth and presence of calves

Following the birth of the three calves, three of the four adult females (including the non-mother) all slept less than average and one (Dina) slept more. It seems that this was partly due to vigilance/protective behaviour of sleeping calves, but could also be due to increased disturbance from more animals waking and moving during the night.

Mothers and calves slept very little if at all on the first nights immediately post-birth. This may be an instinct to reduce risk of predation but suckling is also a likely factor: with calves and mothers taking time to develop the synchronisation and coordination for successful feeding. When they did start to lie down on the third and fourth night, calves were surrounded by the rest of the herd and all females, including and especially Asha who had not had a calf, tended to stand close to sleeping calves. This co-operative herd behaviour is typical of wild elephants, the allo-mothering behaviour being a driving and central component of elephant society (Schulte 2000). It appears this instinct remains very strong in a zoo environment and therefore it is important to facilitate this cohesive behaviour through holding related herds in appropriate group housing.

Conclusion

This study highlights the quantity of sleep elephants obtain each night whilst cared for in a zoo environment. An average of 4 hr 16 min is consistent with studies in both zoos and the wild. An important factor for an elephant to lie down appears to be a comfortable substrate. In Dublin Zoo, no elephant chose to sleep on concrete when they had sand as an alternative.

There is a significant negative relationship between sleep duration and age in elephants, with young animals (those under one year in this study) sleeping more than older ones.

All the elephants typically slept every night during the study, with rare exceptions: mothers and their newborn calves on the first few nights after birth, the normally solitary bull when the females had access to his house overnight, and one of the cows when she was possibly having some conflict with her sister.

Further research is required to investigate whether elephants prefer sleeping on a particular side of the body. This may highlight which side is most comfortable for them and emphasise the importance of freedom to choose how and where to sleep.

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