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Research article

Locomotion in captive Asian elephants (*Elephas maximus*)

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Abstract

It is of great importance that zoos provide animals with enclosure space and enrichment to replicate their natural existence. The aim of this study was to examine and calculate the total distance travelled and utilisation of enclosure space by the Asian elephants housed at the Royal Melbourne Zoological Gardens (Melbourne Zoo), Victoria, Australia. The distance travelled was calculated via video analysis, using a grid overlay system to manually track an adult bull and four adult cow elephants between 0600 and midnight. The mean daily distance travelled over the 18-hour active period was 9.05±0.61 km, with an individual range of 6.21–15.00 km. In comparison, when living in non-extreme environmental conditions, wild Asian and African elephants have been estimated to travel an average of 5–10 km each day, demonstrating that Melbourne Zoo's elephants travel at the top end of their wild counterparts' range of daily travel distances. The techniques used in the present study allow for the approximate calculation of distance travelled by urban zoo elephants, and could potentially be applied to a range of species kept in captivity. Being able to measure distance travelled could be a very useful tool in furthering welfare considerations and management in a captive environment.

Introduction

It is of great importance that zoos provide animals with enclosure space and enrichment to replicate the animals' natural existence. Animal welfare groups are often at the forefront of arguing that when housed in a captive environment, large animals, including elephants, have insufficient space for appropriate exercise and freedom to move (Clubb and Mason 2002; Hutchins and Thompson 2008). There is an obligation therefore for zoos to "determine accurate baseline movement rates of the elephants housed in [their] facilities to contribute empirical data to discussions of elephant welfare" (Leighty et al. 2009).

It has been shown that medical issues in captive elephants, including obesity, chronic arthritis, degenerative joint disease, the incidence of stereotypies and foot problems, can be linked to a lack of exercise (Fowler and Mikota 2006; Hittmair and Vielgrader 2000; Hutchins 2006; Leighty et al. 2009; Veasey 2006).

Because of a lack of studies on captive animals, the management and welfare of elephants in captive situations is usually compared with wild elephant behaviour, for which there is considerable information available. The activity patterns of wild elephants have been studied using a variety of methods, including the use of VHF radio collars, satellite telemetry including global positioning system (GPS), and following elephant herds, both on foot and by vehicle, using either fresh tracks, a range finder or an odometer. This has resulted in the documentation of a large range of daily distances travelled by free-ranging wild African elephants, though fewer studies have investigated wild Asian elephants (Blake et al. 2001; Leighty et al. 2009). A number of factors might influence distance travelled including collection method, resource distribution, season, presence of calves and reproductive status (Leighty et al. 2009; Slotow and VanDyk 2004; Whitehouse and Schoeman 2003). The values reported for daily distance covered by both wild African and wild Asian elephants are summarised in Table 1. In comparison, there is a surprising lack of published data on captive elephant locomotion (Clubb et al. 2008). The limited studies all focus on African elephants in Europe and the USA (Kinzley 2006; Leighty et al. 2009; Reimers et al. 2001; Rothwell et al. 2001; Schmid 1993) and are also presented in Table 1.

Table 1. Comparison of the distance travelled by wild Asian elephants (*Elephas maximus*), and wild and captive African elephants (*Loxodonta africana*).

Species/gender	Location	Daily distance range/day	Average distance/ sample time	Distance range/ hour	Average distance/hour	Reference
Asian herds	Wild	1–9 km/day	3.2 km/day	0.01–1.5 km/hr		Clubb and Mason 2002; Leighty et al. 2009
Asian males	Wild	1–14.4 km/day	3.6 km/day			Clubb and Mason 2002
Asian males (in musth)	Wild	2.8–15 km/day	8.9 km/day			Clubb and Mason 2002
African herds	Wild	3–17.8 km/day	12 km/day	0.13–0.63 km/hr		Clubb and Mason 2002; Leighty et al. 2009; Rothwell et al. 2001
African males	Wild	2.3–28.4 km/day	9.5 km/day 3.0 km/day		0.5 km/hr	Clubb and Mason 2002; Slotow and VanDyk 2004
African males (in musth)	Wild	4.1–27.5 km/day	5.3 km/day		0.22 km/hr	Clubb and Mason 2002; Leighty et al. 2009
African	IZW Berlin		3.0 km/8.7hr		0.345 km/hr	Schmid 1993
African females	Vienna Zoo		3.10 km/12hr		0.258 km/hr	Reimers et al. 2001
African males and females	Oakland Zoo		3.22 km/24hr		0.134 km/hr	Kinzley 2006
African females	Disney's Animal Kingdom		3.68 km/9hr	0.33–0.56 km/hr	0.409 km/hr	Leighty et al. 2009
African females	San Diego Zoo's Wild Animal Park		6.04 km/14.84hr	0.16–0.81 km/hr	0.411 km/hr	Rothwell et al. 2001

From the data available, both captive elephants and wild elephants show similar activity periods of 15–20 hours, and both species are least active from 0000 to 0600 (Blake et al. 2001; Brockett et al. 1999; Wilson et al. 2006).

However, even the available data suffers from inconsistencies. Instantaneous recording is useful for measuring activity budgets in captive animals, but it does not give the duration of behavioural bouts, nor does it pick up rare behaviours. Monitoring behaviour with continuous recording is more time consuming and data analysis is often challenging due to the amount of detail collected (Martin and Bateson 2007). Video recordings have been successfully used in captive elephant behavioural research (Clubb and Mason 2002; Elzanowski and Sergiel 2006; Hutchinson et al. 2006), and in modern zoo environments, closed circuit television (CCTV), which is commonly used for security and animal monitoring purposes, has the potential to accurately track animal movements.

The objectives of this study were to utilise CCTV video monitoring to estimate the daily distance travelled over an 18-hour period by individual captive Asian elephants (*Elephas maximus*) at the Royal Melbourne Zoological Gardens (Melbourne Zoo), Victoria, Australia, and to assess the effectiveness of this monitoring methodology. The hope is that these estimates of distance can serve as an indication of the baseline activity levels that can be achieved by Asian elephants in an urban zoo situation, and provide possible avenues for updating, improving and quantifying management and welfare protocols.

Methods

Animals and their history

Data were collected from five Asian elephants (*Elephas maximus*): one mature male bull and four adult female cows housed at Melbourne Zoo. The male, Bong Su, and the eldest female, Mek Kapah, were both captured as calves from the wild in Malaysia. Bong Su has been housed at the zoo since 1978 (estimated age 34 years) with a history of ongoing foot problems. Mek Kapah has been at the zoo since 1979 (estimated age 35 years). Mek Kapah and Bong Su were both relocated to the present enclosure in 2004. The three younger female cows – Dokkoon (15 years), Kulab (9 years) and Num Oi (7 years) – were transferred to Melbourne Zoo in 2006, from working camps in Thailand, particularly for socialisation and breeding purposes. Dokkoon was successfully artificially inseminated in April 2008.

Housing

The enclosure consists of three inter-connected outdoor paddocks and two indoor barns (as shown schematically in Figure 1), totalling 5,143 m². The elephants are given access to the paddock and barn areas in various combinations. The main barn consists of four stalls and the bull barn is a single stall. The outdoor paddocks are designed to represent a naturalistic habitat featuring swimming pools, mud wallows, upright and horizontal logs for scratching, rocks and other various substrates such as mulch and clay and dirt mounds. Outdoor shelters are also provided in each paddock. Various enrichment items including tyres, hallow barrels and puzzle feeders are added to the paddocks on a rotational system as part of an enrichment programme.

During the time of this study, Bong Su was housed separately from the females at night, with access to the Bull Barn and Paddock 3. The females were separated into two groups over night according to their social status: the "big girls" (Mek Kapah and Dokkoon) and the "little girls" (Kulab and Num Oi). Each group had access to both Stalls 1 and 2, with Paddock 1 *or* Stalls 3 and 4 with Paddock 2 (see Figure 1 for details).

Husbandry

Zoo keeping staff were in attendance at the facility between 0745 and 1715. The four female elephants were managed by free contact, with keepers having direct access to the animals, and the male elephant was trained via protected contact. (Melbourne Zoo has managed the entire elephant herd via protected contact since April 2014).

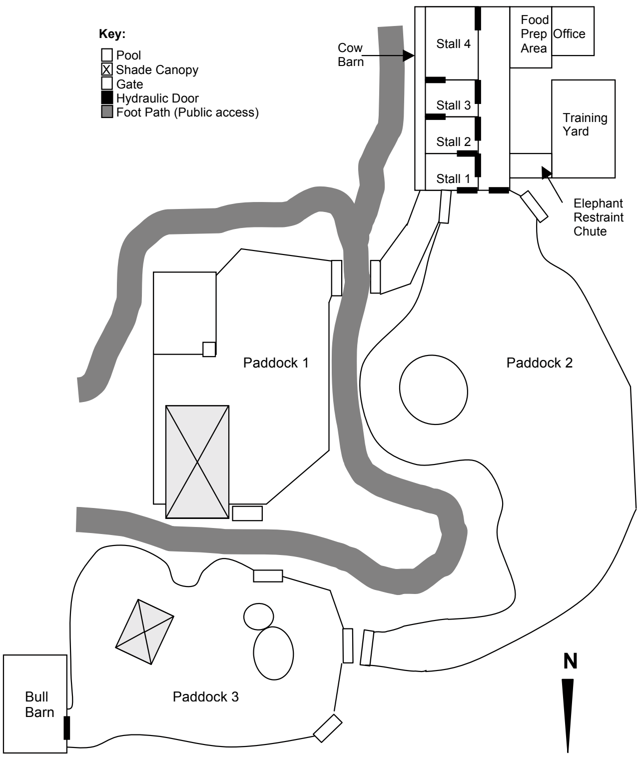

Figure 1. Schematic drawing of the elephant facility at Melbourne Zoo.

Data collection

Data were collected by monitoring approximately 58 hours of CCTV video footage between July and September 2008. To calculate distances travelled, 16 existing CCTV cameras and software (Clear View Security Systems ®) were used. The software allowed camera footage to be viewed on a computer monitor in real time or to review stored footage from all 16 cameras.

A measuring wheel 1 m in circumference was used to measure out the paddock and barn space, interconnecting laneways between exhibits and key distances of fixed objects within the exhibit (pools, shelters and tree trunks) used for reference points. Specifically, a regular path taken by the elephants in Paddock 2 was measured with the measuring wheel for later assessment of the grid accuracy.

A scaled grid was drawn up on transparent paper and overlaid on top of the computer monitor for each of the 16 camera views (see Figure 2), with 5 m x 5 m quadrats used for the paddocks and 1 m x 1 m quadrats for the barns. These grid overlays were used to calculate the distance traversed by each elephant, by noting where they travelled and then calculating the corresponding distance by using the fixed reference points within the enclosure.

Samples were taken at 2-min intervals, with a sample duration of 20 mins. An 18-hour active period, 0600–0000, was used for analysis, as this is when the elephants were found to be most active. This was broken up into three time blocks: morning (0600–1200), afternoon (1200–1800) and night (1800–0000), allowing for balanced time point sampling and analysis of variations between the time blocks. These three blocks were further broken up into 2-hour intervals. For each day of the study, a 2-hour interval was randomly selected and this interval was used to select a 20-min sample for every individual elephant.

For each 20-min sample, distance travelled was documented on an observation sheet at 2-min intervals. Measurements were taken from the front edge of the foot that took the first step in that 20-min sample. Where an animal moved less than 1 m in a sequence, no measurement was recorded. In the case where an animal moved out of the camera view and to a different camera view, the time was noted, the camera view and grid overlay were changed over and the sample resumed at the noted time to ensure there was no overlap of distance travelled.

Once an observation sheet was completed, the distances recorded for each of the 2-min intervals for the 20-min sample were added together and multiplied by three to give the average distance travelled in an hour.

To validate the measuring system, a path regularly taken by the elephants in Paddock 2 was measured with the measuring wheel to be 106.6 m; assessing its length by use of the grid overlays gave a value of 107 m. All barn space was in view of the cameras: however, approximately 495m^2 of the exhibit was out of view.

Statistical analysis

Mean, standard error (SE) and coefficient of variation (CV) for each individual as well as an overall group mean were calculated for the average daily distance and average hourly distance travelled. Skewness testing revealed the data were not normally distributed: however, mean and SE were still used to remain consistent with the literature.

Figure 2. Pictures of the grids overlaid on computer monitor showing (left) Bong Su in Stall 1 of the Bull Barn; 1m × 1m grids and (right) the four females (L–R: Mek Kapah; Dokkoon; Num Oi and Kulab) in Paddock 2; 5m × 5m grids.

Table 2. The weight, mean daily distance (± SE) and mean hourly distance (± SE) moved for each elephant at Melbourne Zoo.

Elephant (weight in kg)	Mean daily distance (km) ± SE	Mean hourly distance (km) ± SE	Coefficient of variance	Observations (n)
Bong Su (4917)	6.21±0.982	0.35±0.055	92.16	34
Mek Kapah (3196)	6.60±0.779	0.37±0.043	68.85	34
Dokkoon (2624)	7.49±1.210	0.42±0.067	94.33	34
Num Oi (2408)	9.71±0.986	0.54± 0.055	60.92	36
Kulab (2350)	15.00±1.940	0.83±0.108	76.32	35
Overall mean	9.05±0.605	0.50±0.034	88.05	

The three periods (morning, afternoon and night) were compared against individual elephant using chi-squared tests (significance level 0.05). Mean weight was correlated with daily distance travelled using a Spearman's rank correlation (significance level 0.05).

Comparisons were made between distances travelled by the elephants that had come more recently to Melbourne Zoo (Dokkoon, Kulab and Num Oi), and those elephants that had been at the zoo for some time (Bong Su and Mek Kapah).

Results

For a typical 18-hour active period, the average daily distance travelled by the Asian elephants at Melbourne Zoo was 9.05 km. The least distance travelled was 6.21 km/day (Bong Su) and the greatest was 15.00 km/day (Kulab). The mean hourly distance across all five elephants was 0.50 km/hr, with a range from 0.35 km/hr (Bong Su) to 0.83 km/hr (Kulab), as presented in Table 2.

The mean distance travelled was plotted in 2-hour intervals to look at changes in activity levels over a day. For individuals, the hourly distance traversed did not differ significantly between the blocks of morning, afternoon and night ($\chi^2 = 0.725$, df = 8, $p>0.05$), as shown in Figure 3.

Spearman's Rank correlation was applied to the distance data compared with weight, but the sample size was too small to give a full output.

Discussion

The results of this study show that the average daily distance covered by elephants housed at Melbourne Zoo was 9.05 km. Over the 18-hour active period, this equated to moving 0.50km/hr. The mean hourly distance moved by the Asian elephants at Melbourne Zoo ranged from 0.345 km/hr to 0.833 km/hr, and the findings of this study show that these Asian elephants are travelling greater distances than those reported for captive African elephants, which have mean hourly distance values between 0.134 km/hr (Kinzley 2006) and 0.411 km/hr (Rothwell et al. 2001). Currently no previously published studies have calculated the distance travelled in a day by captive Asian elephants.

In non-extreme conditions, wild free ranging elephants of both species travel between 5 and 10 km per day (Leighty et al. 2009). Wild Asian elephants are estimated to travel between 1 km and 9 km/day in herds, and males in musth can travel up to 15 km in a day (Clubb and Mason 2002). Wild African elephants travel between 3 km and 17.8 km/day in herds, and males in musth have been reported to travel further than 27 km/day (Clubb and Mason 2002; Leighty et al. 2009), as seen in Table 1. African elephants that have large home ranges – upwards of 2,000 km² – on average cover 6–8 km in their daily activity (Foguekem et al. 2007). As nature is often used as the yardstick in zoo animal welfare and management protocols, the results of this study show that the elephants housed at Melbourne Zoo are travelling at comparable distances to wild, free-ranging elephants of both species living in non-extreme conditions.

Reproductive status may be a contributing factor to variations in daily travel distances. Changes in exercise during pregnancy in both captive and free-ranging elephants are relatively unknown

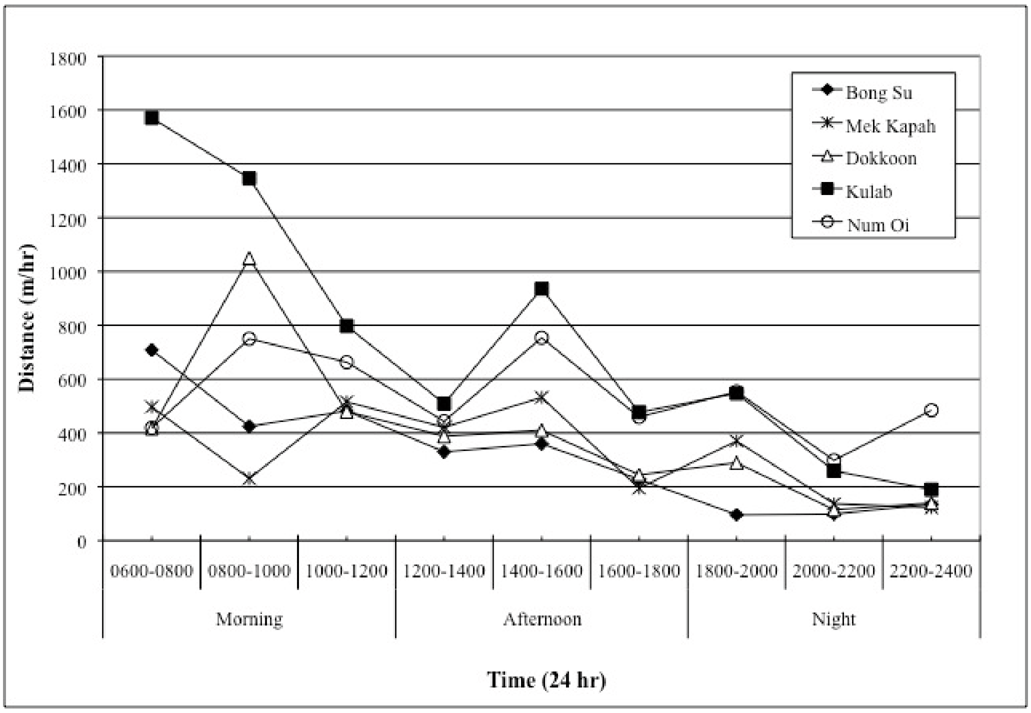

Figure 3. Average distance travelled by each Asian elephant, per 2hr interval.

(Leighty et al. 2010). As Dokkoon was pregnant at the time of the study, her baseline activity levels outside pregnancy require further investigation, as would the effects of the presence of young calves in the herd. Variations seen in distance travelled due to reproductive status is not limited to female elephants. Wild African male elephants in musth travelled further than those in a non-musth state (Table 1), and their movements are more directional (Clubb and Mason 2002; Slotow and VanDyk 2004; Whitehouse and Schoeman 2003). Although Bong Su was not in musth during this study, it is plausible that, like wild African elephants, when he was in musth his daily activity levels would increase.

Outside musth, males can generally be expected to travel shorter distances than females due to differences in the feeding habits of the sexes. When elephants are feeding they are also often stationary (Rees 2009). In wild African elephants, it has been found that males have longer feeding bouts than females with greater quantities of feed ingested (Shannon et al. 2006). The results of this study show that the bull, Bong Su, travelled the shortest distance, 6.21 km/day. Bong Su is given a larger quantity of food, which may be a contributing factor to the lower distance he covered, as he spent more time stationary eating food compared to the females. A higher body mass also requires greater energy expenditure over a unit of distance (Altman 1987). This greater energy expenditure can be met by increasing the intake of food energy or by a decrease in the energy allocated to other activities (Altman 1987). Bong Su weighs well over a tonne more than the heaviest female, and this could account for his lower travel distances. The high coefficient of variation (92.16) of Bong Su*'s* distance data suggests that his bouts of activity are not constant, which might reflect these food and weight differences. Weighing more also puts increased pressure on the body's joints, and thus can limit the amount of movement that is comfortable for the elephant (Veasey 2006).

Age might also play a role in the amount of daily activity an elephant undertakes. Not surprisingly, smaller elephants are relatively more athletic than larger ones (Hutchinson et al. 2006). Accordingly the younger animals at Melbourne Zoo had higher mean distances travelled than the older animals. In the UK, it is known that many older zoo elephants suffer from locomotory and lameness problems (Harris et al. 2008; Zoos UK Forum 2010). Bong Su is an older elephant and has a history of ongoing foot problems, which might hinder his ability to move about comfortably.

Health issues, particularly foot problems, might also influence an individual elephant's daily activity levels. Foot problems in Asian elephants are perhaps the biggest single health problem and the second biggest cause of morbidity (Veasey 2006). A lack of exercise combined with obesity, climate, improper substrates (i.e. concrete), unhygienic or moist substrates within the enclosure and stereotypic behaviours are also factors which are thought to contribute to the foot problems of elephants (Clubb and Mason 2002; Harris et al. 2008; Hittmair and Vielgrader 2000; Olson 2004; Ramanathan and Mallapur 2008; Zoos UK Forum 2010; Veasey 2006).

Another contributing factor to variations in daily distance travelled could be group dynamics. A study of resource use in captive African elephants showed that dominant females had increased access to the watering hole (Leighty et al. 2010). This suggests that a dominant animal with greater access to resources might travel less distance than a subordinate. Mek Kapah had the lowest mean distance travelled of the females and is the most dominant female in the herd.

Finally, time of day can affect exercise levels. The most active period of the Asian elephants at Melbourne Zoo was 0600– 0000, which is consistent with both other captive elephants and wild elephants (Blake et al. 2001; Brockett et al. 1999; Gröning and Saller 1999; Whitehouse and Schoeman 2003; Wilson et al. 2006). High activity levels by captive elephants in the morning hours have been noted (Brockett et al. 1999; Wilson et al. 2006), with wild female African elephants being more active during the day than at night (Tchamba et al. 1995). Analysis of the data for this study showed no significant difference in distances travelled throughout the day, but further investigation is warranted to confirm if time of day is a factor in differences in daily travel distance.

Collection method might account for variations in calculating distance travelled. As a technique, the use of video monitoring in this observational study offered a cheaper alternative as it utilised existing infrastructure and negated some of the issues encountered by more technically advanced methods. GPS technology incurs costs for purchasing units. and its use (apart from locomotion studies) is limited. The battery life of the GPS units limits the observation periods and the accuracy can range from 0.5 m to as large as ±5 m, resulting in overestimation of distance (Leighty et al. 2009; Rothwell et al. 2001). Furthermore, GPS can provide information about enclosure use and social spacing, but the units can also encounter errors caused by signal delay, interference by the atmosphere, or signal deflection off buildings or terrain (Rothwell et al. 2001). Future technological advancements in GPS technology might address these issues and allow for further applications. Accelerometers have also been used by Rothwell et al. (2001) and are cheaper than GPS units, but also suffer from variations as large as ±7 m. Accelerometers provide continuous recordings over 24-hour periods, and record step count and activity levels; however, step count is unreliable due to the need to calculate stride length (Rothwell et al. 2001). Perhaps the biggest factor to consider with both GPS and accelerometer assessment tools is that they require adequate training of staff and animals in the outfitting of collar or anklet attachments on the animals prior to the start of data collection (Horback et al. 2012; Leighty et al. 2009; Rothwell et al. 2001). Video monitoring systems can capture information for a variety of uses – particularly monitoring pregnant females and infants – though one limitation of video monitoring is that there is a restricted field of view. For the present study, barn space had 100% coverage, and approximately 90% of paddock space was captured in camera view. However, the use of video monitoring could pose a challenge for larger facilities, with specific detail becoming harder to gauge the further away it is from the camera. Video observations are also more time consuming. Observational studies allow for behaviour to be viewed unimpeded, and the use of grids in this study was highly accurate (99.6%) in calculating distance travelled.

The results of this study provide an indication of the levels of walking activity that can be achieved by Asian elephants in an urban zoo situation. The methods used in this study can provide a cost-effective and relatively accurate calculation of distance travelled by large captive vertebrates. Given the popularity of housing wild animals in a captive environment, in Australia and worldwide, as well as the attention zoos receive from animal welfare groups, it is vital that information regarding their daily locomotion is collected to provide possible avenues for updating, improving and quantifying management and welfare protocols.

Future baseline studies of distances travelled by captive elephants (in particular Asian elephants) will be necessary to establish normalised data. As the study was limited to five animals, further studies across a number of facilities are warranted to develop broad averages of distances travelled by captive elephants. This study therefore provides the foundation for future cutting-edge research into the utilisation of enclosure space and the distances captive animals cover compared to their wild counterparts.

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