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Research article

Estimates of locomotion in Asian elephants *Elephas maximus* using video monitoring at Dublin Zoo, Ireland

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Abstract

Welfare of elephants in zoos is a major concern within the public and zoo community. Asian elephants *Elephas maximus* are classified as endangered with one in three currently in human care. Elephants, in particular, are known to suffer from a number of health and behavioural issues when held in a zoo environment and physical activity is particularly important, with a lack of exercise leading to health issues, such as obesity, arthritis and foot problems. The aim of this study was to examine locomotory behaviour and associated habitat use in the adult members of the Dublin Zoo herd over a 2-month period using pre-recorded closed circuit television (CCTV) footage. Distance travelled was calculated using video footage and a grid overlay system to manually track the movements within the habitat. A total of 84 randomly selected 20-min focal observations were collected per individual over a 42 day period. Overall, the elephants in Dublin Zoo were found to display behaviours and travel distances comparable to those in the wild. The mean daily distance travelled (24 hours) was 9.35 km/day. Asian elephant herds in the wild travel distances of 5–10 km/day during non-extreme weather conditions. Free-ranging elephants are reported to spend 60–80% active hours feeding and up to 20 hours of their day is spent actively moving. The elephants in Dublin Zoo were found to spend 50% of their time foraging and 18% engaging in locomotion. Dublin Zoo elephants displayed locomotion and behavioural patterns more similar to the wild than to previous zoo studies. This study provides baseline data on the Dublin Zoo herd adding to existing knowledge about locomotion in Asian elephants in urban zoo environments in addition to demonstrating the applicability of CCTV footage to zoo behavioural studies.

Introduction

Asian elephants *Elephas maximus* have been classified as endangered on the IUCN Red List since 1996 due to a population decrease of over 50% during the past 60–75 years (IUCN 2016). Currently, one in three Asian elephants is in human care and this number is likely to increase (Sukumar 2003), due to ongoing reduction of available habitat and increasing human-elephant conflict (IUCN 2016). There are estimated to be 16,000 Asian elephants (Perera 2009) in areas such as working camps, private ownership, circuses, temples and zoos (Sukumar 2003). In 2006, the International Species Information System (ISIS) recorded 114 zoos housing Asian elephants with 47.4% of the global zoo population found in Europe (Rees 2008). As of January 2015, there are 298 Asian elephants listed in over 70 institutions (European Studbook for Asian Elephants 2015).

Elephant welfare in zoos is a major concern within the public and zoo community (Rees 2008). Animals housed in zoos are often held in artificial habitats with the potential to result in health issues. Causes may include restricted movement, reduced retreat space, forced proximity to humans, reduced feeding opportunities, maintenance in abnormal social groups and other restrictions of behavioural opportunities (Morgan and Tromborg 2007). Stress can result in low survivorship and low breeding rates with consequences for species conservation programs (Mason 2010). Elephants, in particular, are known to suffer from a number of health-related issues when held in a zoo environment (Clubb and Mason 2002). African elephants in zoos have a shorter life span than those that live in protected areas in the wild (Clubb et al. 2008). Asian elephants are reported to have a shorter life span than elephants living in Burmese timber camps (median age of 41.7 years) than females in zoos having a median life span of 18.9 years (Clubb et al. 2008). Zoo-housed Asian elephants often have severe reproductive problems such as high infant mortality rates and abnormal oestrous cycling (Clubb et al. 2009). Stereotypical behaviour is also a concern of Asian elephants in UK zoos, with over 50% reported to display this behaviour (Harris et al. 2008; Mason and Veasey 2010).

In general, such health and behavioural issues can be related to stress in zoos mainly due to the physiological and psychological needs of the species not being met (Mason 2010). Zoo-housed animals receive sufficient food and water (Mason 2010), reducing the need to work for their food, compared to Asian elephants in the wild that spend up to 60–80% of their time foraging (Baskaran et al. 2010). Behaviours learned in the wild are often no longer needed in zoos leading to reduced foraging behaviours. This may be a factor in developing stereotypical behaviours although other factors may still be involved (Clubb and Mason 2002).

Asian elephants in the wild are estimated to travel 5–10 km a day to obtain resources they need (McKay 1973; Kurt 1974; Sukumar 2003). Elephants in zoos are supplied with their needs in relatively small areas resulting in them not having to travel such great distances (Leighty et al. 2009a). Locomotion is important for Asian elephants as it has been reported that lack of movement can lead to health issues such as obesity, arthritis and foot problems (Hittmair and Vielgrader 2000; Roocroft and Oosterhuis 2001). Walking is a good source of exercise for elephants housed in zoos and has an effect on their overall health and welfare (Holdgate 2015; 2016). A survey carried out over 78 zoos found that elephants with a higher level of daily exercise had fewer problems with foot health (Lewis et al. 2010). Increase in walking distance was also correlated with metabolic rate; Morfeld and Brown (2017) found that there was an increase in leptin levels and maintaining healthy weight. Walking distance has been a proposed method for measuring the success of elephant programmes in achieving welfare standards (Hutchins 2006). Such studies should also examine behaviour to determine that it is not stereotypical pacing which is accounting for significant portions of distances travelled.

Several previous studies, using a variety of methods, have examined movement and daily distances travelled in zoo-housed Asian and African elephants (Leighty et al. 2009a; Rothwell et al. 2011; Rowell 2014; Holdgate 2015; 2016). However, there is no standard methodology and methods used to date have each had their limitations in terms of accuracy. Two popular methods used include GPS collars and accelerometers. GPS collars can limit the observation time and accuracy as they have a limited life span and range (Leighty et al. 2009a; Rothwell et al. 2011). GPS accuracy is also affected by habitat structure which may result in reduced communication with sufficient satellites to accurately estimate position or signals being received by the collar from multiple directions (the multipath effect) due to signal bounces off habitat structures (Holdgate 2015). They can also fail, resulting in loss of data collection (Blake et al. 2001) and are overall an expensive monitoring option with heavy reliance on system performance and accuracy, often leading to errors in the data collected (Holdgate 2015). Accelerometers can provide 24-hr data collection, but challenges can occur for step count as stride length needs to be calculated for accuracy (Rothwell et al. 2011). Another difficulty with GPS and accelerometer collaring is allowing time for the animals to become desensitised prior to any data collection. This can take up to several months (Leighty et al. 2009a; Rothwell et al. 2011; Horback et al. 2012; Holdgate 2015). There may also be unknown behavioural side effects for the elephant wearing the GPS collars (Horback et al. 2012). Previous studies on other species have demonstrated reduced rates of movement after collar application ranging from four days (common brush tail possum *Trichosurus vulpecula*: Dennis and Shah 2012) up to six weeks (black bears *Ursus americanus*: Cattet et al. 2008).

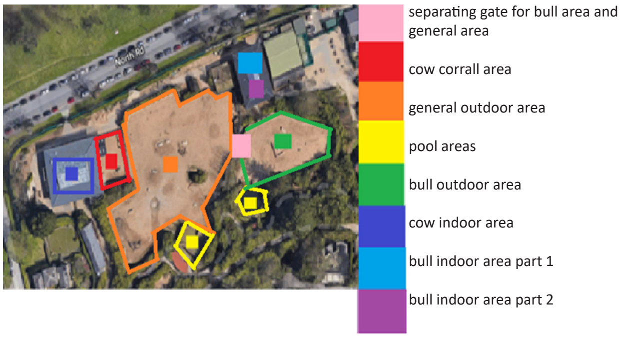

Figure 1. Aerial image of the Kaziranga forest trail (Google Maps 2015) indicating the habitat areas utilised in the study.

Estimating animal movements using direct observation also has its issues. In order to encourage animals to exhibit their natural behaviours, zoos must create habitats that resemble the animal's natural habitat to aid in the development and maintenance of natural behaviours (Keulartz 2015). Habitats that have varied terrain, feeding and social enrichment should result in the maximum movement, use and exploration of the habitat (Hutchins 2006). However, such enriched habitats can also make direct observations of animal movements difficult, as it is unlikely the entire habitat would be visible from a single vantage point resulting in data only being collected from a portion of the area which may not be representative. Direct observations may also suffer from the observer effect where the animals react to the presence of the researcher by changing their behaviour (Prins and Bokdam 1990). Observation time is also often restricted due to weather or timing issues (Scheibe et al. 2007) and issues of access to zoo habitats outside of opening hours.

An alternative method of data collection, which has the advantages of not interfering with animal's behaviour is the use of video recordings from in-situ fixed cameras. Utilising remote closed-circuit television (CCTV) camera footage is also advantageous in its potential to allow for 24 hr/7 day a week recording. Video recordings have been successfully used in ex-situ elephant behavioural research (Clubb and Mason 2002; Elzanowski and Sergiel 2006; Hutchinson et al. 2006; Rowell 2014) and have the potential to allow accurate monitoring of animal movement patterns throughout the day. Therefore, the aim of this study was to use CCTV footage to examine locomotory behaviour of five adult Asian elephants (four females and one male) housed in Dublin Zoo, Ireland and estimate their daily distance travelled compared to wild and other zoo-housed elephants. Additionally, spatial habitat-use data was analysed to determine if the habitat area was being utilised equally. Taken together, these data will provide a baseline estimate for the Dublin Zoo herd and inform future management decisions in addition to adding to the limited data available on elephant locomotion in an urban zoo setting.

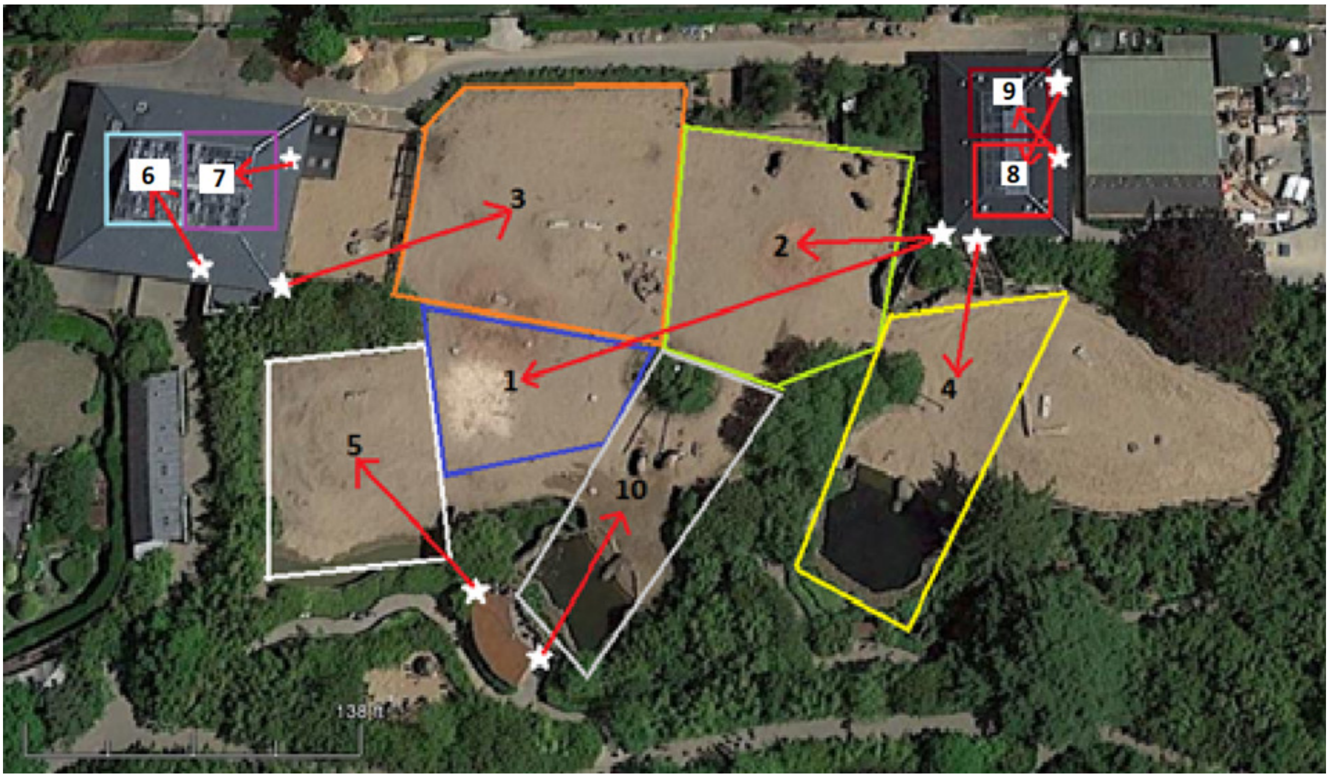

Figure 2. Aerial image of the Kaziranga forest trail (Google Maps 2015) indicating 10 (1–10 marked on map) areas utilised in the study. Stars indicate camera locations and arrows represent the camera views used in this study. One area in the bull area to the right of area 4 and a small section between camera 5, 1 and 10 were not covered by a camera.

Methods

Study site and subjects

Dublin Zoo was opened in 1831 (De Courcy 2009). The zoo covers over 28 hectares located in Phoenix Park in Dublin City Centre, Ireland. It is home to 500 specimens of 90 species (Molloy 2014). In 2007, the Kaziranga forest trail was opened and became home to the resident herd of Asian elephants (Figure 1).

Habitat and animal husbandry

The outdoor habitat measured approximately 8,500 m^2 and contained two pools, feeding structures, riverbed and various fitted and added enrichments. The habitat could be divided in two to separate the bull from the females as needed (see Figure 1). The female house measured 11×25 m with three separate training stalls. The house had 2-m deep sand flooring and contained walled time feeders, hanging feeders and various enrichments such as boomer balls, tree stumps, rocks and sand piles. A corral measured 20×15 m located outside of the main cow house. The bull house measured 10×12.5 m with 2-m deep sand flooring, and an indoor corral/training area measured 7×10 m.

The elephant house was staffed from 07.00 until 18.00 each day. The elephants were managed in protected contact. Daily training of both adults and calves took place roughly between 09.00 and 10.00. The elephants had access to their outdoor habitats at night throughout the summer (March to September) with the females and bull separated overnight between 16.00 and 11.00. The elephants were only kept in their houses during training time and times when the keepers were outside in the habitat for husbandry reasons. Daily scatter feeds were given and feeding enrichment was located throughout the habitat. The zoo's opening hours were between 09.30–18.00 during the summer months and at 12.30 a keeper talk about the elephants was presented in front of the main pool. Individual elephants were differentiated from each other by physical features (body size, individual shape of ears or tail).

Study animals

The herd consisted of eight individuals, five adults who form the basis for this study and three calves which were not examined (see Table 1). At the time of study, the elephants had no known health issues that would affect their locomotion. The herd also shared their habitat with a herd of Indian black buck *Antilope cervicapra*.

Observations

The study was carried out over a 42-day period between June and July 2015. Overall, 84 20-min samples were examined per adult elephant, one sample between 06.00 and 18.00 and another between 18.00 and 06.00 per day. Sample times were randomly selected using a random sample selection (SPSS Inc.) of 42 sample starting times per individual elephant from each 12-hour observation period. All observations were conducted from pre-recorded CCTV footage of the elephant habitat. It was understood that fisheye effect could be a potential problem, so the grids were drawn up accordingly to account for distortion (Figures 2 and 3).

Table 1. Elephant, sex, relationship and age at time of study, arrival to Dublin Zoo.

Elephant	Sex	Relationship	Age at time of study	Arrival to Dublin Zoo
Upali	Male	Father to 3 calves: Kavi, Ashoka and Samiya	24 years	From Chester Zoo arrived in 2012
Bernardine (Dina)	Female	Mother to Asha and Samiya	31 years	From Rotterdam Zoo, arrived in 2006
Yasmin	Female	Mother to Anak and Kavi	25 years	From Rotterdam Zoo, arrived in 2006
Anak	Female	Daughter of Yasmin. Mother to Ashoka	12 years	From Rotterdam Zoo, arrived in 2006
Asha	Female	Daughter of Dina. Sister to Samiya	8 years	Born in Dublin Zoo
Kavi	Male	Son of Yasmin	>1 years	Born in Dublin Zoo
Ashoka	Male	Son of Anak	>1 years	Born in Dublin Zoo
Samiya	Female	Daughter of Dina. Sister to Asha	>1 years	Born in Dublin Zoo

Distance travelled estimates

Based on a previous study (Rowell 2014), a gridding system was devised using 5×5 m measurement grids for the outdoor habitat areas and 2×2 m grids for indoor housing areas (see Figures 2 and 3 for examples). With the elephants locked in separate areas, measurements of each of the 10 habitat areas were conducted and marks corresponding to grid intersection points placed. Distances were measured using a 1-m circumference trundle wheel. CCTV camera footage showing the measurement markers was then reviewed. Ten camera views covered the areas required (Figure 2). The grids and measured features for each habitat area were plotted on a transparent sheet held over the viewed image of each area (Figures 3 and 4). Known distances from aerial views and blueprints of the habitat were additionally used to verify the accuracy of the grid system. One area of the habitat (~30×15 m) in the bull area was not observable from any camera angle and was not included in the study.

To obtain distance travelled estimates for each sample, the appropriate CCTV recording with the focal individual was cued to the selected starting time with the corresponding transparent

Figure 3. Indoor 2×2 m grid example from the female house (area 6).

grid sheet fixed over the observation screen. Within each 20-min sample, the distance travelled (m) was noted on the observation sheet at 1-min intervals and estimated on the basis of the movement pattern of the first front foot to move using the gridded overlay system. The position of this foot within each grid based on visual estimate together with the number of grids crossed over the time period was used to estimate the total distance for that interval. Observations were made by the same observer throughout to ensure consistency.

Statistical analysis was conducted using R (Core Development Team 2015) and all means are given ±SE. For the purposes of analysis, time of day was categorised into four time periods based on natural timing of event within the zoo: night (00.00–06.00), morning (06.00–13.00), afternoon (13.00–17.00) and evening (17.00–00.00). These were based on an initial examination of the data combined with the known daily schedule of the elephants. Sample estimates were standardised as distance per hour. Differences between time periods and between individuals were examined using Welch's F ratio test as the data did not meet the assumptions for ANOVA (Field et al. 2012). Post-hoc comparisons were conducted using pairwise t-tests with Bonferroni corrections. Significance was accepted at $P<0.05$. Based on the results of the analyses, estimates of the mean daily distance travelled by each elephant were calculated.

Behavioural activity and locomotion

As a measure of behavioural activity, the individual behaviour displayed at each 1-min interval point was noted on the observation sheet using instantaneous point sampling (Altmann 1974), during each 20-min sample. Behaviours recorded were defined using an ethogram (Table 2) on the known behaviour of the elephants based on previous studies (Whilde and Marples 2011). Swaying was the only stereotypical behaviour included in the ethogram as it was the only one observed during the study and the only type identified by the keepers as known to occur. Route tracing/pacing was not previously identified in this herd and was not observed. For the purposes of analysis, behaviours were grouped into eight main categories (foraging, stand, locomotion, maintenance, social, sleep, swaying and other). Based on the eight behavioural categories, activity budgets were created for the group as a whole, for each individual and for each of the four time periods. χ^2 tests were used to determine significant differences in the distributions of behaviours.

Habitat use

For each of the samples, the location of the elephant (area within habitat out of 10 indicated in Figure 2) was noted at each 1-min interval point. A spread of participation index (SPI) was calculated to estimate the use of the habitat for each individual elephant following Plowman (2003). This method takes into account differences between individual areas within the habitat, as found in the current study. If the elephants utilise their habitat areas equally, the SPIs calculated would be close or equal to zero. SPIs closer to one indicate preferential use of some habitat areas. SPI was calculated as follows:

$$\text{SPI Plowman} = \sum|fo - fe|\,|/2(N - fe\ min)$$

Figure 4. Outdoor 5×5 m grid example of the bull area (area 4).

where *fo* is the frequency of occupation of a particular zone, i.e., the number of observations of a particular animal in this zone; *fe* is the expected frequency of occupation of this zone, i.e., the expected number of observations of this particular animal in this zone in relation to the area of the total habitat (e.g., if zone is 10% of total area, 10% of total observations are expected in this zone); N is the total number of observations of a particular animal in all zones; and *fe min* is the expected number of observations of the particular animal in the smallest zone.

In addition to SPI, the location data were examined by comparing the expected number of observations in each habitat area based on equal use of all areas and adjusting for area of each grid similar to calculation of *fe* above. This examination allowed the identification of any over- or under-utilised areas of the habitat.

Results

Distance travelled

Time of day is likely to have an effect on the distance travelled due to the daily scheduling of activities such as feeding, opening hours and keeper interactions within the zoo. The distance travelled per hour was significantly different between different time categories (Welch's F(3, 198.50)=73.05, P<0.001) with the more active periods of walking being in the morning and afternoon (means: night=91±34 m, morning=497±105 m, afternoon=690±198 m, evening=370±47 m). Within each time category, there were also significant differences between individual elephants during the morning and evening time periods (Table 2; morning: Welch's F(4,34.43)=2.37, P<0.001; evening: Welch's F(4, 57.12)=4.65, P<0.01) but not during the afternoon or night periods (afternoon: Welch's F(4, 34.43)=2.37, P=0.07, ns; night: Welch's F(4-45.64)=0.40, P=0.81, ns). The bull Upali travelled the furthest both overall and within each time period. Among the females, the distance walked is least in the older and highest in the youngest females (Table 2).

Based on the above analyses, both time of day and individual identity influence the distance travelled. Taking these factors into account, a mean daily distance travelled estimate was calculated for each individual by estimating the mean hourly movement rate in each time period, multiplying this by the number of hours in each period and adding these together to get a daily estimate (Table 3). During a 24-hour period the mean estimated distance travelled by the elephants was 9.35±1.57 km/day. There was no significant difference between individuals in the proportion of observations in each time period.

Table 2. Ethogram of behaviour categories and definitions.

Behaviour category	Code	Definition
(1) Locomotion	B	Moving from one area to another keeping at the same pace
	C	Moving from one area to another at a quick pace
(2) Standing	D	Remain motionless in one spot
(3) Foraging	E	Standing while eating
	F	Walking while eating
	FF	Foraging
	G	Suckling (calf)
	H	Using enrichment (feeding wall, balls, hanging basket)
(3) Swaying	K	Head bobbing
	L	Other
(4) Maintenance	M	Scratching
	N	Dust bathing: spray or rolling
	O	Defecate
	Q	Drinking
	R	Bathing (depth of belly)
(5) Sleep	V	Laying down
(6) Social	X	Rub/touch elephant
	Y	Trunk investigation
	I	Playing with others
(7) Other	BC	Unclear behaviours
	CD	Interact with keepers
	A	Aggression: pushing/charging (not as part of play)
	SS	Sniffing air
(8) Unknown	AB	Not visible to observer

Behaviour

Behavioural data were collected to examine the amount of time spent walking (locomotion). An overall activity budget (Figure 5a) revealed that foraging (50%) and locomotion (18%) were the main behaviours displayed by both the herd overall and by most individuals, with Dina and Yasmin spending a significant proportion of their time standing still. Swaying behaviour (the only stereotypical behaviour observed) represented only 1% of all observations, and was confined to a single individual (Figure 5b) and therefore unlikely to influence the distance travelled. In a small number of cases, the behaviour was not visible to the observer due to the animal being obscured at the observation point or being in an area not visible on CCTV footage.

Time of day had an influence on the distribution of behaviours within the group (χ^2=4085.33, df=18, P<0.001). Locomotory behaviour represented between 5% of observations at night and 17–25% of observations at other times. Foraging behaviour during the night time only represented 20% of behaviours during that time, compared to morning, afternoon and evening time where it was seen roughly 65% throughout those times (Figure 5a). Sleep represented 45% of their time during the night period, compared to only 1–2% during the morning and evening periods (Figure 5a). Overall, the distribution of behaviours differed significantly between individuals (Figure 5b) (χ^2=1150.89, df=24, P<0.001). Foraging activity ranged from 55% of Upali's observations to 47% of Asha's. Locomotion accounted for 10–24% of observations overall However, when analysed as individual samples, there was no significant difference between individuals in the percentage of observations recorded in either behaviour (locomotion: Welch's F(4, 206.95)=1.36, P=0.25, ns; foraging: Welch's F(4, 207.17)=0.61, P=0.65, ns).

Spatial index

SPI for each individual indicated that the elephants are not using their habitats equally: Anak (0.62), Asha (0.50), Dina (0.56), Yasmin (0.57), Upali (0.64). The females were found to be over utilising area 6: their house. Additionally, they under-utilised area 2, an area within the habitat beside the bull house (Table 4). Similarly, Upali was found to over-utilise area 9, part of his house, and under-utilised areas 1, 2, 3 and 5 (Table 4).

Table 3. Hourly and daily distance travelled estimates for individual elephants. Significant differences: a ≠ b, c ≠ d, e ≠ f

Distance estimates		Upali (bull)	Dina (matriarch)	Yasmin	Anak	Asha
Hourly (m ±SE)	Night	105±29	103±43	102±29	66±30	63±34
	Morning	737±38a	326±60b	299±38bc	511±68	633±105d
	Afternoon	1055±88	518±86	537±38	573±94	789±103
	Evening	277±53f	239±37f	299±38f	426±62	619±99e
Daily (km ±SE)	14.05±1.82	6.12±1.18	5.9±1.13	8.7±1.34	11.51±1.89	

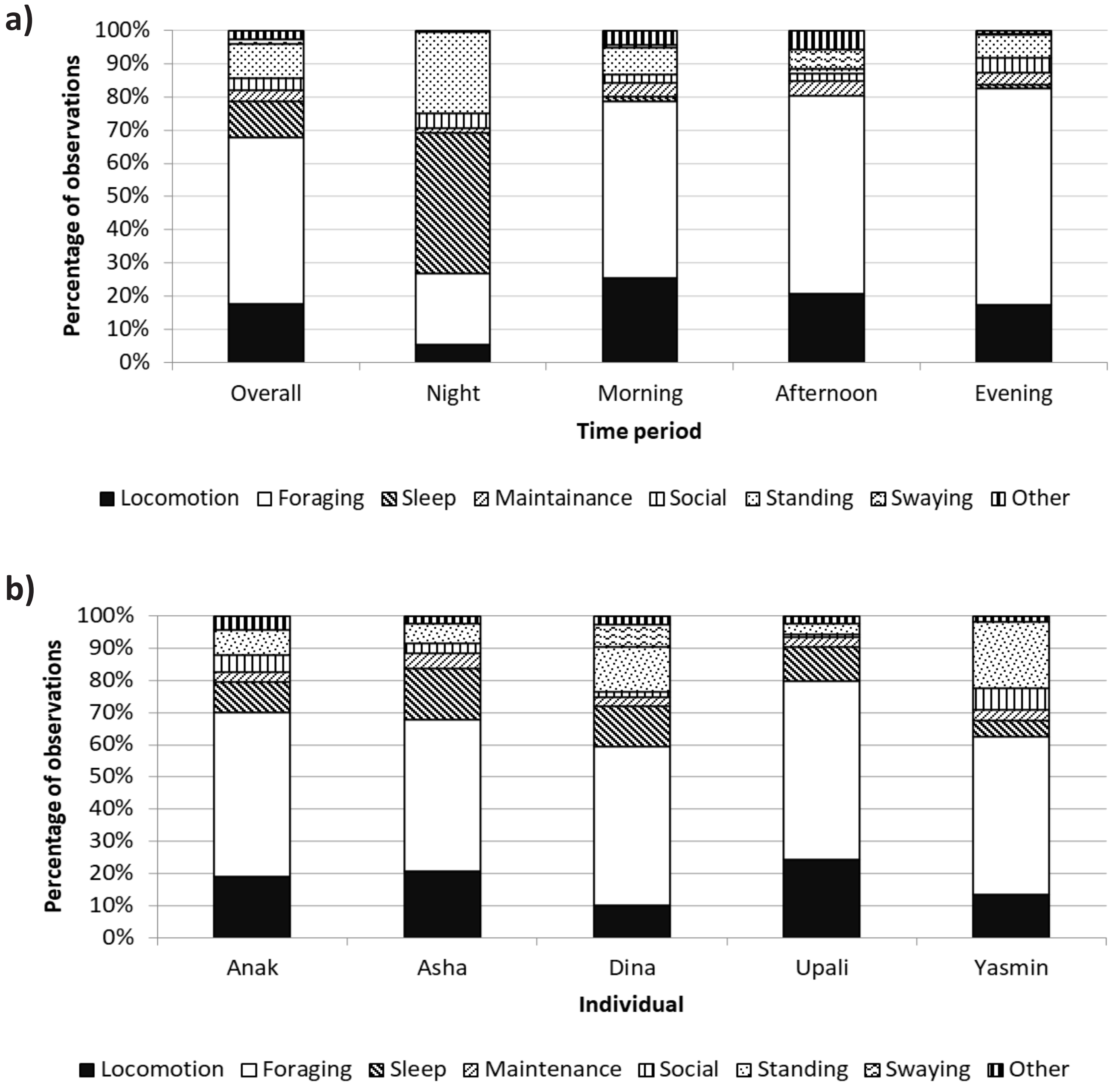

Figure 5. a) Overall behavioural activity budget during the study period (n=8400), b) Individual elephant activity budgets over all time periods.

Table 4. Observed and expected percentage of observations in each habitat area, reflective of access to area. Expected values (shaded cells) are based on equal use of the habitat corrected for area size. The cow house (6+7) is not accessible to the bull and vice versa for the bull house (8+9).

	Cows					Bull	
Area	Expected	Anak	Asha	Dina	Yasmin	Expected	Upali
1	8	3	2	2	3	9	1
2	25	4	8	3	3	26	2
3	22	12	15	18	13	23	8
4	19	0	3	3	6	20	17
5	10	4	6	4	4	11	1
6	4	61	42	49	58		
7	6	7	11	12	8		
8						2	13
9						3	54
10	6	9	12	9	6	7	5

Discussion

Asian elephants in Dublin Zoo travel comparable daily distances to those found in the wild. Asian elephant herds in the wild travel similar distances of 5–10 km/day and wild African elephants can travel 3–17.8 km/day in herds during non-extreme conditions (McKay 1973; Kurt 1974; Sukumar 2003). The mean daily distance travelled by the Asian elephants in Dublin Zoo was 9.35±1.57 km/day similar to a previous study of Asian elephants housed in Melbourne Zoo, Australia (9.05±0.605 km/day: Rowell 2014). Asian elephant bulls typically travel further than females and are estimated to travel up to 14.4 km/day and 15 km/day in musth (Sale et al. 1992; Reimers et al. 2001). Upali did not come into musth during time of observation. The Dublin Zoo bull Upali travelled 14.05 km/day, further than any of the females and similar to his wild counterparts.

The age of an elephant can influence locomotory behaviour (Rees 2009; Rowell 2014). Asha, the youngest adult in the herd, travelled the greatest distance (11.51±1.89 km/day) out of all the females. Rowell (2014) indicated similar results for zoo-housed Asian elephants with the second-youngest female also travelling the greatest distance (15.001±1.940 km/day). As younger elephants are more energetic than older elephants (Hutchinson et al. 2006), this result was expected. Comparisons between the daily distance travelled of the youngest of the herd, Asha (11.51±1.89 km/day), and the oldest, Dina (6.12±1.18 km/day) indicate significant differences in distance travelled, similar to that found in Rowell (2014: youngest: 9.71±0.986 km/day and the oldest: 6.60±0.779 km/day). At the time of the study, Dina was not known to suffer from health issues but older animals may be suffering from undiagnosed arthritis which would have an impact on movement. Yasmin moved the least in the herd (5.9±1.132 km/day). A previous study on the herd in 2008 also indicated she was less active than other members of the group at the time (Whilde and Marple 2011).

The amount of travelling an animal undertakes on a daily basis is typically related to the distribution of essential resources within their range (Leighty et al. 2009a). Zoos aim to create habitats that resemble the animal's natural range which aids in the development of natural behaviours (Keulartz 2015), including movement rates targeting an increased health status. In the wild, Asian elephants spend 60–80% active hours feeding (Baskaran et al. 2010), and up to 20 hr of their day is spent actively moving (Brockett et al. 1999). Estimates can vary substantially between zoos with previous studies generally indicating significantly lower levels of foraging and locomotory activity. Six female Asian elephants in zoos in Rotterdam, Munster and Hamburg spent only 37.7% of their time feeding (Schmid 2001) and in Chester Zoo, UK, eight Asian elephants observed spent 27.4–41.4% of their time feeding and 6.1–19.2% of their time walking (Rees 2008). Overall, the elephants in Dublin Zoo spend 50% of their time foraging, and engage in locomotion 18% of the time. These results concur with the previous study of the herd utilising 10 days of direct focal observations which suggests that the patterns observed are representative of the group over time (Whilde and Marples 2011: 10–35% of time walking and 20–40% of time feeding). Feeding, behaviour and locomotion patterns of the elephants in Dublin Zoo are more similar to Asian elephants found in the wild than Asian elephants housed in other zoos. Thus, the data suggest that their habitat produces movement patterns similar to free-ranging counterparts (Hutchins 2006).

How an animal utilises its range can influence the amount of movement observed. This is particularly important in zoo habitats where resources are typically provided in fixed locations (Leighty et al. 2009b). Over-utilisation of small resource areas can lead to a reduction in the need for locomotion, and in elephants may increase the risk for health problems such as obesity, arthritis and foot problems (Hittmair and Vielgrader 2000; Roocroft and Oosterhuis 2001). A spread of participation index (SPI) of the habitat indicated it was not being utilised equally by the herd. Both sexes are over-utilising their houses and under-utilising some of their outdoor areas, in particular area 2, an area without any fixed enrichments. Spatial use within habitats can be positively associated with dominance hierarchy (Leighty et al. 2009b). Dominant herd members can utilise spaces with amenities such as watering holes and shaded areas, relegating less dominant individuals to other areas (Leighty et al. 2009b). This was not observed to be the case for the Dublin Zoo herd. Dina, the matriarch, spent most of her time outdoors in area 3, in front of the female house and was found not to over-dominate areas

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with amenities. Future management of the Dublin Zoo herd could improve habitat utilisation with the addition of further enrichment features in area 2.

One difficulty in comparing and measuring distances travelled by elephants in zoos is due to the different methods that are used. The current study followed a method of data collection which utilised a grid and camera system (Rowell 2014). Other studies measuring distances in zoo-housed elephants used GPS collars (Blake et al. 2001; Leighty et al. 2009a; Leighty et al. 2009b; Horback et al. 2012), accelerometers (Rothwell et al. 2011), and direct observations (Rees 2008; Whilde and Marples 2011). Each of these methods have their drawbacks such as unknown behavioural side effects for elephants wearing monitoring technology (Horback et al. 2012) or observer effects (Prins and Bokdam 1990) and access issues for direct observation studies.

Estimation methods can also account for the variations in distances travelled estimates between studies. The current study was conducted over a 42-day period with 84 20-min samples taken per individual over a 24-hr period. This is in contrast to previous studies which observed the elephants over an 18-hr period over three months (Rowell 2014), an 8-hr period a day for duration of over a year (Leighty et al. 2009a), a 1-hr period a day over 30 days (Stoinski et al. 2000) and 6-hr a day over 35 days (Rees 2009). Given that the current study found significant differences between different times of day, it is likely that variation in observation schedules will affect distance travelled estimates between studies. Additionally, zoos worldwide have different husbandry practices and daily routines for their elephants which may have implications for distance estimates and observation scheduling. Variations in available habitat area/design and social grouping are also likely influences on the differences found between studies (Horback et al. 2012)

The method of collection for this study utilised existing software and was a cheaper alternative to the various other methods such as GPS collars. In fact, one study recommended using 24-hr video monitoring in addition to GPS collars to compensate for the lack of data collected using collars (Leighty et al. 2009). Video monitoring systems are able to capture data on behaviours and distance travelled estimates without disturbing the routine of the elephants and enable footage to be played in real time or viewed at a later stage. Such a system allows for 24/7 monitoring overcoming both weather and out-of-hours access issues. One disadvantage of video monitoring is the need for multiple cameras to cover the habitat, but many zoos have CCTV already in place within the zoo grounds covering the habitats for security and to monitor the animals (Rowell 2014). The current study utilised a significant number of cameras (10), however, there were still restricted views of one area within the habitat. This area was however within the bull area, was not utilised by the elephants frequently and thus did not significantly affect data collection.

This study provides baseline data on the Dublin Zoo herd adding to existing knowledge about locomotory behaviour in Asian elephants in urban zoo environments and provides a basis for future welfare recommendations. Further studies on locomotion in zoo-housed Asian elephants are required to gain a clearer understanding of the relationships between habitat components and animal husbandry practices on locomotory behaviour. By utilising the existing CCTV software this study promotes the use of monitoring technology for further zoo studies alleviating the need to attach sensors to animals. Where available, such a system allows for easy collection and storage of data for use in a variety of behavioural studies including activity budgets, habitat use and association index studies. This is especially relevant with the predicted increase in Asian elephants in human care as wild habitats are lost (Sukumar 2003). The results of such studies have the potential to aid in habitat design, further improve husbandry practices and ultimately increase elephant welfare in zoo environments.

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