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Enclosure utilisation and activity budgets of disabled Malayan sun bears (*Helarctos malayanus*)

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ABSTRACT

Captive bears are housed in environments that differ greatly from their natural habitat, restricting their ability to perform normal species-specific behaviours. This may be detrimental to welfare, with disabled individuals at particular risk. The effect of physical disability on behaviour and enclosure utilisation was assessed in 12 adult Malayan sun bears (*Helarctos malayanus*) using 10 min interval scan sampling. Amputees spent less time performing locomotor behaviours than able-bodied bears, used their enclosures less evenly, but did not exhibit obvious stereotypies. This was possibly due to the increased energy demands of locomotion, or residual pain in amputated limbs. Amputees spent less time grooming, but did not differ in time spent climbing compared with non-amputees. Partially sighted bears did not differ from able-bodied controls in enclosure use or behaviour. Age was positively correlated with stereotypical behaviour, and negatively correlated with maintenance and resting. Medication use was associated with more resting and grooming, and reduced stereotypy. The findings suggest that enclosures for amputees can be smaller than those for able-bodied bears, but should still contain a variety of climbing structures. Partially sighted bears fare well in enclosures designed for able-bodied bears, not requiring any special provision.

1. Introduction

The Malayan sun bear (*Helarctos malayanus*) is the smallest of the extant bear species, inhabiting the dense lowland tropical rainforests of Southeast Asia (Shepherd and Shepherd, 2012). The species is currently listed as Vulnerable in the IUCN Red List of Threatened Species 2008 (Fredriksson et al., 2008). Servheen (1999) stated that the Malayan sun bear was the least researched of the world's bears, and that this lack of knowledge threatened the success of conservation efforts. Servheen (1999) also suggested that research on this species should be of the highest priority, yet 18 years later, there remains a paucity of information regarding Malayan sun bears both in the wild and in captivity.

Although quantitative data are lacking, it has been suggested that extensive deforestation has led to a more than 30% reduction in Malayan sun bear numbers in the last 30 years (Fredriksson et al., 2008). The trade in wild bears and their body parts also poses a major threat to Malayan sun bear populations. Poachers are known to remove cubs from mothers to sell on as pets, trade in Malayan sun bear gall bladders for use in Chinese medicine, and to sell bear paws as expensive delicacies (Fredriksson et al., 2008). In partnership with government authorities, Free the Bears manages a number of sanctuaries throughout Southeast Asia for Malayan sun bears affected by such anthropogenic activities. The Free the Bears Cambodian sanctuary at Phnom Tamao Wildlife Rescue Centre has almost 100 Malayan sun bears, providing a unique opportunity to study this species in captivity. A number of bears arrive at sanctuaries with physical disabilities, or develop them whilst there. The Free the Bears Cambodian sanctuary is home to bears with a range of disabilities including missing limbs and paws, and impaired eyesight. Physically disabled bears are at particular risk of reduced welfare because of the difficulties they experience in moving, obtaining food, and manipulating objects in their enclosures (Dallaire et al., 2012). Furthermore, amputees may also suffer from chronic pain, as persistent pain is highly prevalent among human amputees, even several years after amputation. Persistent pain is also a risk factor for further physical (Ephraim et al., 2005) and psychological disorders (Singh et al., 2009).

Physical impairment has been shown to impede locomotion, foraging, social interaction, enrichment use, and enclosure utilisation across a variety of species. Human leg amputees, even with prostheses, walk more slowly and consume more energy whilst walking than non-amputees (Houdijk et al., 2009). Similarly, a malformed infant Japanese

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Table 1
Bear demographics. Disabilities were categorised as either amputee (A), partially sighted (PS), or able-bodied control (C). Animals were categorised as having medication during data collection (Y) or not receiving medication (N). Romdool and Booga-Bob used their outdoor enclosure individually on a daily rotation due to high levels of aggression towards other bears.

Bear	Disability	Sex	Age (years)	Mass (kg)	Enclosure no.	Medication
Ralph	A	M	15	72.0	5	Y
Holly	A	F	7	66.5	23	N
Romdool	PS	M	14	62.0	11A	N
Kong	PS	M	19	59.0	5	Y
Molly	C	F	8	57.0	23	N
Dilli	C	F	8	60.5	23	N
Koh	C	F	18	54.0	23	N
Di-Mroi	C	F	11	60.0	23	N
Hefty	C	M	8	68.0	5	N
Booga-Bob	C	M	10	61.0	11A	N
Buddy	C	M	7	58.0	17	N
Bangles	C	M	7	63.5	17	N

macaque (*Macaca fuscata*), with missing hands and distorted feet, had substandard locomotive ability compared with normal infants (Nakamichi et al., 1983). The macaque also played less with other infants and juveniles, preferring to interact with adults. Asiatic black bears (*Ursus thibetanus*) with amputations were less active and spent less time standing than non-amputees (Dallaire et al., 2012). They also stereotyped less frequently, and used their enclosures less extensively and evenly. In contrast, a one-armed white-cheeked gibbon (*Nomascus leucogenys*) did not demonstrate lower activity levels than able-bodied companions (Sayer et al., 2007). Despite the amputation the gibbon preferred suspensory locomotion to other locomotive forms. As two-armed brachiation was not possible the gibbon opted to utilise the more energetically expensive one-armed brachiation, yet was still able to maintain activity levels. Where limbs play a major role in feeding, such activities may also be affected by amputation. Wild chimpanzees (*Pan troglodytes*) with severe snare injuries are less efficient at feeding, but are able to use novel techniques for processing food (Stokes and Byrne, 2001).

Limited vision and blindness have also been shown to alter bear behaviour. Three blind European brown bears (*Ursus arctos arctos*) demonstrated limited exploration, even failing to discover the entrance to a second section of their enclosure (Koene, 1998). They also spent a large proportion of their time sleeping and, although contact with electric fences were infrequent, if a shock did occur the blind animals would instantly retreat to a familiar and enclosed area. Similarly, blind Asiatic black bears reduce activity compared with sighted conspecifics (Dallaire et al., 2012). They also spend less time eating food dispersed around the enclosure, manipulate feeders and enrichment objects less often, and stereotype less frequently.

Captive bears are housed in environments that differ greatly from their natural habitat (Tan et al., 2013). Restrictions in the ability to perform normal species-specific behaviours may lead to stress and frustration, and be detrimental to welfare. This often manifests as alterations to behavioural patterns, such as the development of stereotypical behaviours (Mason et al., 2007). The expression of these behaviours may also be influenced by individual variation, enclosure features, or by external factors. For example, time spent performing stereotypical behaviour varied with season in an American black bear (*Ursus americanus*) (Carlstead and Seidensticker, 1991) and in giant pandas (*Ailuropoda melanoleuca*) (Owen et al., 2005). Age also influences bear behaviour, with a positive correlation between stereotypy frequency and age reported in the brown bear (Montaudouin and Le Pape, 2005) and in a group of Malayan sun and Asiatic black bears (Vickery and Mason, 2003, 2004). Malayan sun and Asiatic black bears also demonstrated a decrease in normal (locomotive and maintenance) activity with age. With regard to enclosure features, in the brown bear a reduction in the incidence of stereotypy was associated with larger enclosures, the provision of a medium to large pool, and having surroundings visible to inhabitants (Montaudouin and Pape, 2004).

The above studies demonstrate that disabled individuals are likely to differ in their activity, behaviour, and enclosure usage from able-bodied counterparts, but that other factors may also influence behaviour. Physical disabilities may potentially compound these other factors, because disabled individuals are further restricted in the enclosure features that they are able to access or utilise. Quantifying the influence of disability on behaviour is likely to be important for understanding the impact on welfare. The present study firstly aimed to determine whether limb-amputated and partially sighted Malayan sun bears utilise their enclosures differently and have altered time budgets compared with able-bodied bears. The goal was to establish whether any specific enclosure or husbandry modifications were needed to improve the welfare of disabled Malayan sun bears in captivity. It was hypothesised that amputees would utilise a smaller area of the enclosure and spend less time in locomotion than able-bodied controls. A secondary aim was to determine whether other factors, namely sex, age, mass, differing enclosures, and the administration of medication, would influence bear activity budgets and enclosure use.

2. Materials and methods

2.1. Animals and housing

The project was conducted in accordance with the ethical framework set out by Manchester Metropolitan University. Subjects were twelve adult Malayan sun bears (Table 1), housed either singly or in small groups at Free the Bears Cambodian Sanctuary, Phnom Tamao Wildlife Rescue Centre, Cambodia. Bear demographic information was obtained from sanctuary records. Subjects had been brought to the sanctuary following confiscation by the Cambodian authorities either directly from poachers, or from restaurants or private homes. Two bears were missing limbs (Ralph and Holly) and two had impaired vision (Kong and Romdool) (Table 1). Of the two amputees, Ralph was missing the right hind limb below the knee and Holly was missing the left hind paw. Causes of amputations were unknown, however it was suspected that they were caught in snares. Kong was previously blind due to poor living conditions as a cub, however, following cataract surgery, some sight was restored. Romdool suffered damage to his retinas following a paresis in 2014. Throughout data collection Ralph was medicated topically with Betadine for a shoulder injury, and Kong was administered with Amlodipine daily for an eye complaint.

The four bear enclosures consisted of one to four inter-connected indoor dens and an outdoor paddock. Dens were concrete floored, measuring between 4 m^2 and 9 m^2, and separated by metal bars. Outdoor areas ranged in size, with enclosure 5 measuring approximately 970 m^2 with two dens available on a typical day, enclosure 11A measured 230 m^2 with one den, enclosure 17 measured 760 m^2 with two dens, and enclosure 23 measured 2670 m^2 with four dens typically available. All outdoor enclosures were furnished with a pool, rocks,

Table 2
Ethogram of Malayan sun bear behaviours.
Adapted from Tan et al. (2013) and Vickery and Mason (2004).

Category	Behaviour	Definition
Maintenance	Feed	Ingestion of edible material, including food processing
	Drink	Ingestion of liquids
	Defecate	Elimination of faeces from the body
	Urinate	Elimination of urine from the body
	Autogroom	Washing or smoothing fur using mouth, tongue or forelimbs
	Other maintenance	Any other non-stereotypic maintenance activity (eg. scratch, lick, rub, shake, stretch, swat away flies)
Resting	Rest	Sitting or lying with body motionless; may be alert or asleep
Locomotor activities	Stand – bi-pedal	Bi-pedal stationary stance
	Stand – quadrupedal	Quadrupedal stationary stance, or tripedal in amputees
	Walk	Movement from one location to another at low speed. May be bi-pedal or quadrupedal.
	Run	Quadrupedal movement from one location to another at high speed
	Climb	Locomotion above floor level, with no body weight supported by enclosure floor, including locomotion on platforms.
	Change stance	Any changes between stances (lie, sit and stand) at floor level
Investigation	Sniff	Inhalation of air during olfactory investigation
	Dig	Breaking up soil or creating a hole in the ground with its paws
	Scratch	Scraping the surface of an object with its claws
Solitary play	Object play	Hold, pull or stretch a non-edible object, or put object in mouth
	Non-object play	Roll, turn or manipulate own body parts in a relaxed manner
Social interactions – affiliative	Contact	Affiliative contact with a conspecific, such as sniffing, leaning, or nuzzling
	Allo-groom – give	Grooming a conspecific
	Allo-groom – receive	Being groomed by a conspecific
	Social play	Energetic, non-aggressive play and/or wrestle with a conspecific
Social interactions – agonistic	Displace	Forceful removal of a conspecific from its original position, either physically or by vocalisation
	Threaten	Snout wrinkled upwards, mouth open, showing canines; often accompanied by loud vocalisations
	Attack	Violent attempt to injure another individual, by swiping paws and/or trying to bite
Abnormal behaviours	Pace	Continuous walk back and forth in a repetitive manner, at least 3 times
	Weave	Locomotion (to left and right alternately) with body perpendicular to cage bars or wall: forefeet occupy two or more positions, hind feet may be repositioned or only shuffled
	Patrol	Locomotion repeatedly tracing a certain path around the enclosure
	Oral stereotypy	Any stereotypy involving the mouth, such as self-sucking or jaw clamping
	Deprivation behaviour	Pica, coprophagia, or uriposia
	Other stereotypy	Any repetitive, invariant and seemingly functionless behaviour not described above
Other	Out of sight	Bear is in a den or the majority of the body is obscured, making accurate identification of behaviour impossible
	Other behaviour	Any behaviour that has not been described above

hammocks, climbing frames, native vegetation, and enrichment toys.

2.2. Data collection

Data were collected five days per week (Mon–Fri), between 4th May and 10th June 2016. Morning observations started between 0850 h and 0950 h, following the bears' release into their outdoor paddocks, and finished at 1150 h. Dens were typically closed in the early part of this session for cleaning and reopened between 1000 h and 1150 h. On one occasion the den was not unlocked until 1328 h, and on two occasions bears remained locked in the outdoor enclosure for the entirety of both morning and afternoon observation sessions. Afternoon observations began between 1300 h and 1320 h and typically finished between 1445 h and 1545 h, when bears were secured in their dens to allow keepers to enter the outdoor enclosure for husbandry and enrichment duties. Thunderstorms prevented one afternoon session from being undertaken and, on a separate occasion, led to a 1430 h finish at two enclosures. On two occasions the bears were locked in their dens early (1408 h and 1350 h) for reasons unrelated to the experimental protocol (a keeper meeting and bear training respectively).

Three observers collected almost 178 h of behavioural data. Observers were trained and tested by the lead researcher, with observers required to exceed 85% agreement with the lead researcher in interobserver reliability tests. Due to methodological constraints, it was not possible to rotate observers between all four enclosures. For each bear observed by more than one researcher, Spearman rank correlation coefficients between time budgets were calculated for pairs of observers. As bears were observed at different times these comparisons were not expected to be perfect, however there were significant correlations between time budgets for each pair of observers at each enclosure ($\rho = 0.72$, $P < 0.001$; $\rho = 0.69$, $P < 0.001$; $\rho = 0.74$, $P < 0.001$; $\rho = 0.67$, $P < 0.001$; $\rho = 0.75$, $P < 0.001$; $\rho = 0.73$, $P < 0.001$). The four enclosures were each observed for a total of eight morning sessions and seven or eight afternoon sessions. Bears were observed from positions adjacent to their outdoor enclosures, where they were accustomed to the presence of visitors or staff. It was not possible to observe bears inside their dens except when they were located directly behind the den entrance. Bears were identified using clearly distinguishable physical characteristics. For groups that could not be individually identified reliably, coloured marks were applied to the back of bears' heads and necks using wax-based Raidex™ Animal Markers.

Outdoor enclosures were visually divided into 8 sectors of approximately equal size, with boundaries defined by landmarks within the enclosure. Dens were designated as a ninth sector. Data were recorded by instantaneous scan sampling at 10 min intervals. At each scan the observer performed a visual sweep of the enclosure from left to right. As each subject was encountered, its behaviour (Table 2) and the sector in which it was located were recorded. The total number of scans for each individual was 226.25 ± 9.82 (mean ± sd). Due to the large size of enclosure 23, a modified scan sample technique was utilised. The observer was positioned with the den entrance in sight. Every 10 min the observer would perform a scan sample, as described above, then walk quickly and quietly with head lowered to a pre-determined position further along the enclosure fence. At the new position the researcher raised their head and performed a second instantaneous scan sample. This was repeated a further two times along the enclosure perimeter. The four scans were combined to provide the complete scan for the given time interval. If behaviour for a bear was recorded twice in a complete scan, only the first observation was included in analysis.

2.3. Data analysis

Evenness of space use for each bear was assessed using the Shannon index on the number of instances the bear was observed in the different grid sectors. The Shannon index is typically used to classify species diversity, however it has also been successfully used as a measure of space use evenness (Dallaire et al., 2012). A high Shannon index indicated that a bear visited all sectors, spending even amounts of time in each. A low Shannon index indicated that a bear spent the majority of its time in only one or a few sectors, infrequently visiting others.

Data were analysed using R version 2.15.0 (R Core Team, 2014) with packages corrplot (Wei and Simko, 2016), ggplot2 (Wickham, 2009), gridExtra (Auguie, 2016), and gridBase (Murrell, 2014). Generalised Linear Models (GLMs) were used to test the effect of disability type on Shannon indices and behavioural variables. Included in initial models were: disability type, sex, age, mass, enclosure, number of years spent at sanctuary, and whether the animal was administered medication or not during data collection. Number of years spent at the sanctuary was subsequently removed from analysis due to a strong positive correlation with age. Factors which were least significant ($P > 0.05$) were systematically removed from a model until only disability and all remaining factors which reached significance remained in the model.

Data were assessed for normality using Shapiro-Wilk tests. Where there was a clear normal distribution in the data, arbitrarily set at $P > 0.4$, GLMs were fitted using a Gaussian distribution. Where the final model was a poor fit to the data, the best-fitting earlier model, containing a greater number of factors, was selected by assessment of model validation plots and R^2 values. Where data were not normally distributed ($P < 0.05$) or not clearly normally distributed ($0.05 \leq P \leq 0.4$), data were fitted using three alternative models; a GLM with Gaussian distribution, GLM with Poisson distribution, and a GLM with Gaussian distribution after arcsine-square root transformation. The best fitting GLM, via assessment of validation plots and R^2 values, was then selected. If none of these models fit suitably, behavioural time budgets were compared between disabilities by using a non-parametric Kruskal-Wallis test or a parametric one-way Analysis of Variance (ANOVA), depending upon whether the data met the test assumptions. Where omnibus tests were significant, post-hoc Tukey comparisons were used to identify where significant differences lay between groups.

A number of variables included too many zeros in their distributions to undergo statistical analysis. Behaviours were therefore also combined to allow behavioural categories (Table 2) to be modelled as above. It should be noted that, due to being housed singly, Romdool and Booga-Bob were unable to perform affiliative social behaviours or the agonistic social behaviour 'attack'. The agonistic social behaviours 'displace' and 'threaten' were possible with bears in the neighbouring enclosure, however, despite being observed in both individuals, these were not sampled throughout the study period.

3. Results

3.1. Effect of disability

Amputees had a significantly lower Shannon index than non-amputees (Table 3, Fig. 1), indicating that they tended to remain in only one or a few sectors of the enclosure, travelling to other sectors infrequently (Fig. 2). Amputees also spent significantly less time performing locomotor behaviours than controls (Table 3). Autogrooming was seen significantly less often in amputees than in non-amputees. There were no significant differences between amputees and controls in the proportion of time spent performing maintenance, resting, feeding, climbing, standing quadrupedally, sniffing, or undertaking investigative behaviour. Amputees did not spend a significantly different proportion of time performing abnormal behaviours, neither did they spend a significantly different amount of time performing locomotor stereotypies or pacing. No stereotypical behaviours, however, were seen in either amputee. All partially sighted and control bears, with the exception of one, demonstrated some level of stereotypic behaviour.

Shannon indices for partially sighted bears were not significantly different to those of controls, but were significantly greater than that of amputees (Table 3, Fig. 1). Partially sighted bears spent significantly more time performing maintenance behaviour than both amputees and controls. There were no significant differences between partially sighted bears and controls in other behavioural groups and sub-groups able to undergo statistical analysis (Table 3).

Table 3
Enclosure use and behavioural comparison of amputees, partially sighted and able-bodied control Malayan sun bears. Where the assumptions for normality were met, values shown are mean ± s.d. For tests using transformed data (*), data were first back-transformed before means were calculated. For non-parametric data (**) the values shown are medians surrounded by lower and upper quartiles. Significant differences between disabled bears and controls are shown in bold.

				Effect of disability	
	Amputees	Partially sighted	Controls	Amputation	Partial sightedness
Enclosure use					
Shannon index	1.06 ± 0.22	0.62 ± 0.27	1.66 ± 0.16	**$F_{2,9}$ = 8.18, P = 0.009**	
Behavioural categories					
Maintenance	2.59% ± 1.38	7.61% ± 5.59	3.52% ± 1.99	R^2 = 0.72, P = 0.735	**R^2 = 0.72, P < 0.001**
Resting	79.70% ± 3.62	44.42% ± 26.86	48.45% ± 19.30	R^2 = 0.97, P = 0.861	R^2 = 0.97, P = 0.363
Locomotor	11.18% ± 1.36	24.21% ± 6.64	24.73% ± 9.03	**R^2 = 0.48, P = 0.029**	R^2 = 0.48, P = 0.903
Investigation	4.74% ± 1.38	7.99% ± 0.98	5.67% ± 3.66	R^2 = 0.76, P = 0.838	R^2 = 0.76, P = 0.719
Solitary play**	0.27 – 0.53% – 0.81	1.48 – 1.80% – 2.12	0.00 – 0.00% – 1.14	NA	NA
Social – affiliative**	0.13 – 0.27% – 0.40	1.22 – 1.22% – 1.22	0.00 – 0.00% – 1.11	NA	NA
Social – agonistic**	0.00 – 0.00% – 0.00	0.00 – 0.00% – 0.00	0.00 – 0.00% – 0.00	NA	NA
Abnormal behaviour*	0.00% ± 0.00	12.78% ± 14.62	13.07% ± 10.16	R^2 = 0.98, P = 0.780	R^2 = 0.98, P = 0.468
Locomotor stereotypy*	0.00% ± 0.00	12.49% ± 14.22	12.34% ± 9.90	R^2 = 0.97, P = 0.784	R^2 = 0.97, P = 0.487
Behaviours					
Feed**	0.76 – 0.98% – 1.21	1.48 – 1.80% – 2.12	0.00 – 0.73% – 1.94	χ^2 = 0.78, P = 0.677	
Autogroom**	0.80 – 0.89% – 0.99	3.08 – 4.95% – 6.81	0.00 – 1.41% – 2.65	**R^2 = 0.93, P = 0.033**	R^2 = 0.93, P = 0.148
Stand – quadrapedal	3.67% ± 0.14	8.60% ± 0.09	10.65% ± 4.93	χ^2 = 4.81, P = 0.090	
Climb	1.97% ± 1.76	1.22% ± 1.72	1.92% ± 1.00	R^2 = 0.63, P = 0.349	R^2 = 0.63, P = 0.236
Sniff	3.84% ± 1.63	6.81% ± 1.00	4.85% ± 3.07	R^2 = 0.85, P = 0.250	R^2 = 0.85, P = 0.657
Pace**	0.00 – 0.00% – 0.00	7.47 – 12.49% – 17.52	1.43 – 8.49% – 15.99	R^2 = 0.78, P = 0.725	R^2 = 0.78, P = 0.530
Other behaviour	0.98% ± 0.63	0.58% ± 0.82	3.24% ± 1.98	$F_{2,9}$ = 2.58, P = 0.130	

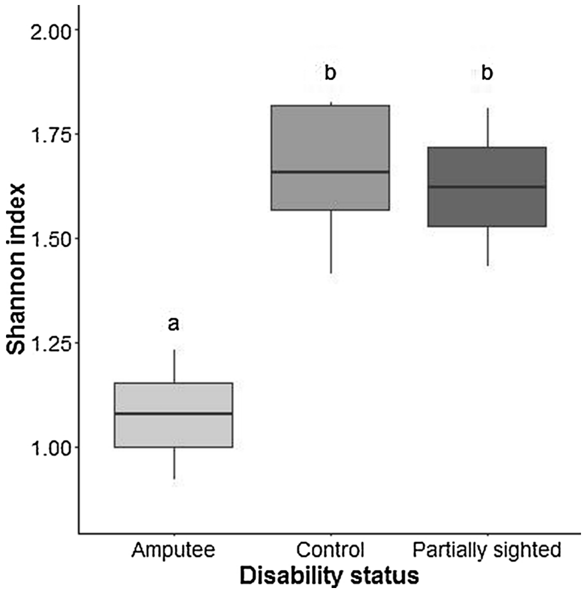

Fig. 1. Median Shannon Indices of enclosure use for amputees and partially sighted bears compared with able-bodies controls. Medians which do not share a letter are significantly different ($F_{2,9} = 8.18$, $P = 0.009$).

3.2. Other influential factors

Age was negatively correlated with time spent performing maintenance behaviours (GLM: estimate ± SE, −0.18 ± 0.06; $z_{11} = -2.73$ $P = 0.006$) and resting (GLM: −3.72 ± 0.70; $t_{11} = -5.29$, $P = 0.006$). Bears administered medication spent a greater time resting than those who were not medicated (GLM: $t_{11} = 7.23$, $P = 0.002$), and spent less time performing abnormal behaviours (GLM: $t_{11} = -7.47$, $P = 0.002$) and locomotor-specific stereotypy (GLM: $t_{11} = -6.16$, $P = 0.004$). Age was positively correlated with both abnormal behaviour performance (GLM: 0.05 ± 0.01; $t_{11} = 7.67$, $P = 0.002$) and locomotor-specific stereotypy (GLM: 0.05 ± 0.01; $t_{11} = 6.74$, $P = 0.003$). Pacing was positively correlated with age (GLM: 0.05 ± 0.01; $t_{11} = 3.13$, $P = 0.020$), those being administered with medication paced less (GLM: $t_{11} = -3.27$, $P = 0.017$), and males paced more than females (GLM: $t_{11} = 2.53$, $P = 0.045$). Autogrooming was positively correlated with mass (GLM: 0.02 ± 0.01; $t_{11} = 3.79$, $P = 0.019$), and those taking medication autogroomed more (GLM: $t_{11} = 3.28$, $P = 0.031$).

There were significant differences between enclosures in the time bears spent resting (GLM: $R^2 = 0.97$, df = 11, $P < 0.05$), performing abnormal behaviour (GLM: $R^2 = 0.98$, df = 11, $P < 0.05$), investigating (GLM: $R^2 = 0.76$, df = 11, $P < 0.05$), autogrooming (GLM: $R^2 = 0.93$, df = 11, $P < 0.05$), sniffing (GLM: $R^2 = 0.85$, df = 11, $P < 0.05$), and performing locomotor stereotypies (GLM: $R^2 = 0.97$, df = 11, $P < 0.05$) (Fig. 3).

4. Discussion

Significant differences were found between bears with missing limbs, partially sighted, and able-bodied bears. Amputees spent half as much time performing locomotor behaviours as non-amputees, and this could be due to a number of reasons. Dallaire et al. (2012) found that amputee Asiatic black bears spent less time on their feet, suggesting that standing and walking may be energetically costly for these individuals. In agreement, Houdijk et al. (2009) found that human leg amputees consume more energy whilst walking than non-amputees. There may also be additional pain or sensitivity associated with using the amputated limb during movement. Neuromas, bundles of nerve fibres which develop when axons are severed, have been found in the tail stumps of docked pigs (Simonsen et al., 1991), sheep (French and Morgan, 1992), and cattle (Eicher et al., 2006). These can increase sensitivity to pain (Lewin-Kowalik et al., 2006), and may also be present in the amputation stumps of Malayan sun bears. It was observed that when walking, amputees utilised their stump as a forth limb. Increased sensitivity in an amputation stump may lead the animal to avoid using the stump whenever possible, in this case via a reduction in standing and walking. Comparison of the sensitivity and receptivity to pain in the remaining paws versus the stumps of amputees would establish if this is indeed the case. Chronic pain is highly prevalent among humans following limb removal, regardless of time since amputation (Ephraim et al., 2005), and it is possible that a similar effect occurs in bears. Low levels of pain in amputees may not be detected and treated, but may still reduce the amount of time these individuals spend standing and walking.

Interestingly, amputees spent a similar amount of time climbing as non-amputees. Climbing was defined as any above-ground locomotion, and included movement across raised platforms and structures. The

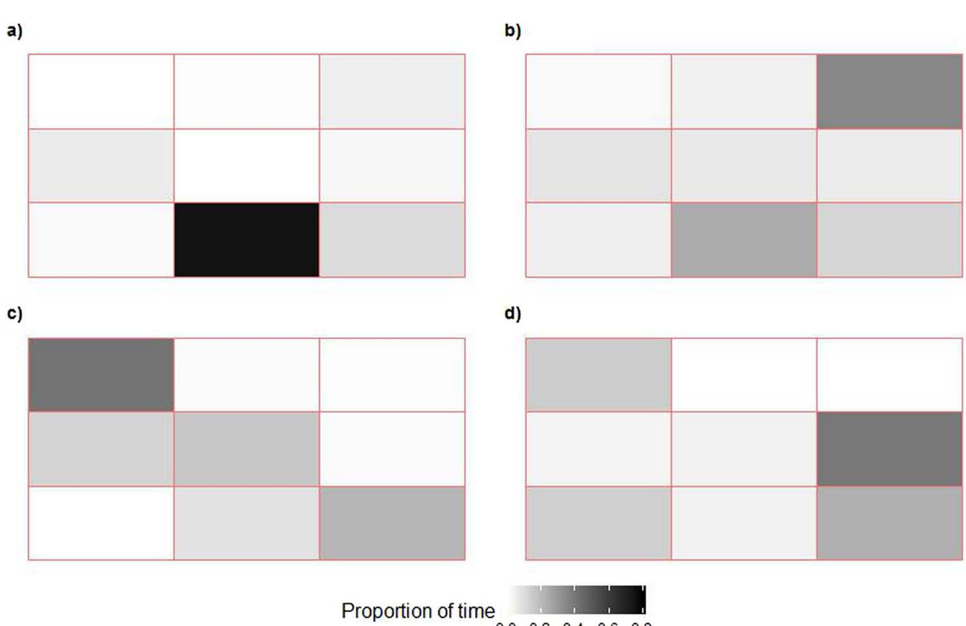

Fig. 2. Enclosure use grids for amputees Ralph (a) and Holly (c) next to pair matched controls (b and d, respectively). Pairs were matched by enclosure, sex, and age. The more even the colour shading throughout the grid, the more evenly the bear utilised the enclosure space.

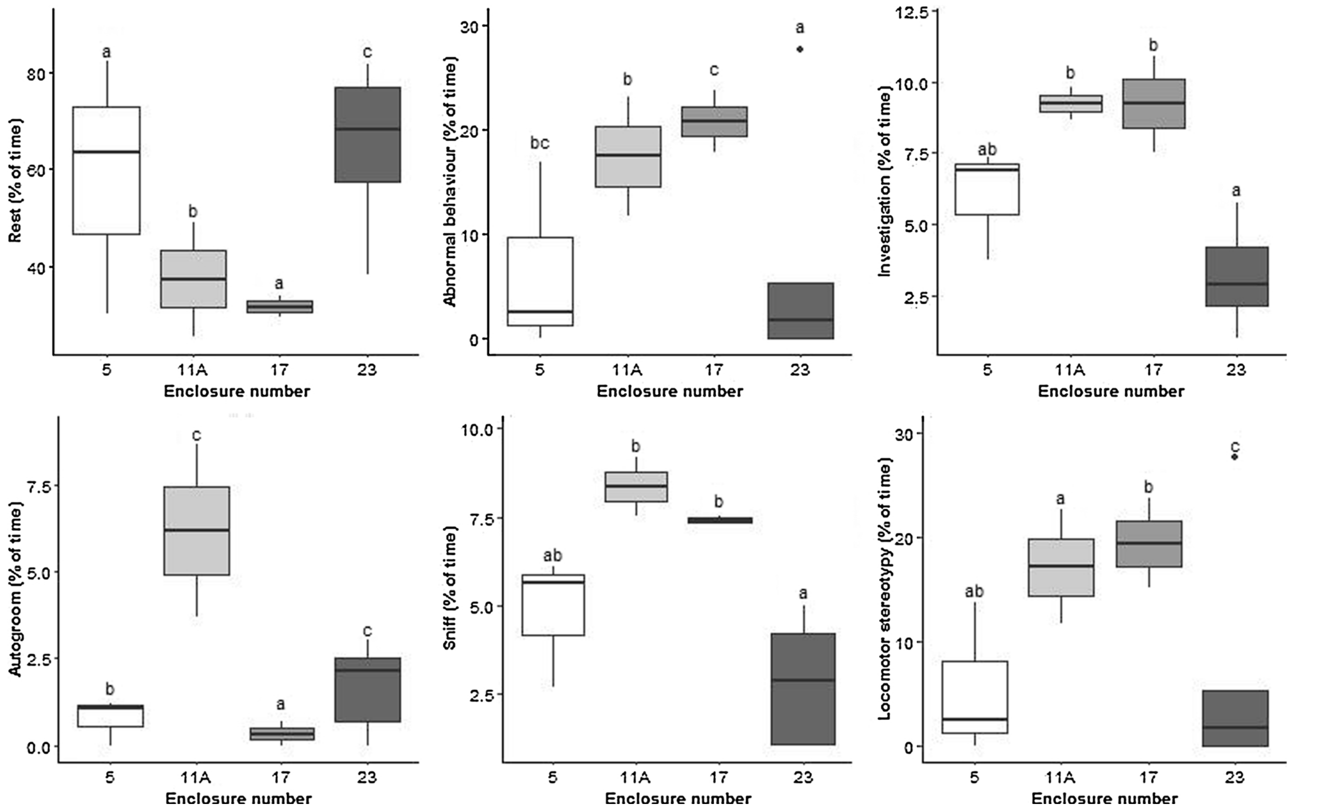

Fig. 3. Significant differences between bear enclosures for time spent performing (top left to bottom right) rest, abnormal behaviour, investigation, auto-groom, sniff, and locomotor stereotypy. Medians which do not share a letter are significantly different ($p < 0.05$). For sniff and investigation, enclosure was the only remaining significant factor in the model. The four other models included one or more other significant factors.

same effect has been reported in Asiatic black bears (Dallaire et al., 2012). It was observed that Ralph, and to a lesser extent Holly, climbed at a slower pace than non-amputees. Taking longer to travel the same distance may explain why they spent a similar proportion of time performing this behaviour as non-amputees. Ralph spent the same amount of time climbing as walking on the enclosure floor, whilst all other bears spent a far greater time walking than climbing. It is difficult to discern whether this was due to differences in pace, or a greater preference for climbing, as Ralph also walked at a reduced pace across ground. More research, quantifying distances travelled and pace of movement, is required to establish which is the case.

Amputees used their enclosures less extensively and evenly compared to other bears. A similar trend was noted in Asiatic black bears, although did not quite reach significance (Dallaire et al., 2012). The Shannon index is not sensitive to frequency of movement between enclosure sectors, merely how much time is spent in each, so reduced locomotion should not confound this result. Dallaire et al. (2012) explained the reduction in enclosure use as an artefact of reduced foraging. Foraging was not defined in the ethogram of the present study, however amputees did not spend less time feeding or performing investigative behaviours compared with non-amputees, suggesting this was not the case here. A possible explanation may be that amputees prefer to remain in certain areas of the enclosure to avoid agonistic interactions as chasing or fighting potentially have very high energy demands. Ralph was observed to spend the majority of his time in the vicinity of one climbing tower, using threat behaviour when an unwanted individual approached. He was never observed moving away from the tower during such conflicts. Unfortunately, due to the nature of scan sampling, too few agonistic interactions were recorded to identify whether amputees were involved in fewer agonistic exchanges than non-amputees. Future research should consider the effect that amputation has on the frequency and nature of agonistic interactions.

Although amputees did not spend significantly less time performing stereotypical behaviours than non-amputees, it is interesting that no stereotypical behaviours were recorded in either amputee. The increased energy and pain demands of locomotion in amputees could be responsible for the lack of long duration locomotor stereotypies in these individuals. It should be noted that some oral stereotypies were observed in these bears, however scan sampling was not sensitive to these short duration abnormal behaviours. In non-amputees the most frequently exhibited stereotypy was pacing, and only two bears sampled exhibited stereotypies that were non-locomotor. This appears to be in agreement with Vickery and Mason (2003, 2004, 2005), who found locomotor stereotypies to be significantly more prevalent than oral or other forms of stereotypy in Malayan sun bears, with pacing being the most common. Further research, using sampling methods sensitive to short duration behaviours, is required to establish if this is truly the case.

Amputees spent less time grooming themselves in comparison to other bears, however the reason behind this is unclear. It may be that they have less energy to indulge in such behaviours due to increased costs of movement, or that the movement itself is more difficult to perform. Alternatively, it is possible that these animals are displaying symptoms of depressive states. In human amputees there is a positive correlation between chronic pain and depressive symptoms (Ephraim et al., 2005). Although nothing is known regarding this phenomenon in bears, it is plausible that amputee bears living with chronic pain may have similar affective or psychological changes, leading to a subsequent reduction in grooming or locomotive activity and this possibility should be investigated in future studies.

Stereotypies are commonly used as welfare indicators in animals (Mason and Latham, 2004). Although amputees showed significantly altered behaviour in comparison to able-bodied bears, this potential reduction in welfare was not reflected in their level of stereotypy. This implies that stereotypic behaviour is not a useful welfare indicator in amputees. Mason and Latham (2004) suggested that individuals without stereotypies in stereotypy-eliciting circumstances may actually be experiencing the worst welfare, as stereotypies may act as a coping mechanism. It would still seem imperative that an alternative method of measuring welfare be established for use in disabled animals.

The behaviour and enclosure usage of partially sighted bears did not differ from that of sighted controls, with the exception of time spent performing maintenance behaviour. This was unexpected, as blind Asiatic black bears were found to have lower levels of activity and stereotypic behaviour than sighted controls, and spent less time eating and manipulating enrichment objects (Dallaire et al., 2012). Interspecies variation may account for the differences in results, however it seems unlikely that this would account for such large dissimilarities. The bears in the present study still retained some sight. It may simply be that having reduced vision does not present a captive bear with challenges significantly great enough to elicit alterations in behaviour as it does in blind individuals.

Medication administration was associated with a greater proportion of time spent resting, and lower levels of abnormal behaviours, locomotor stereotypies, and pacing. This general lack of activity may have been a side effect of the pharmacological agent being administered. Reported side effects of Amlodipine administration include fatigue in humans (Pfizer, 2017) and drowsiness in animals (petMD, 2017), however to the author's knowledge fatigue has never been reported as a side effect of topical Betadine use. Alternatively low level residual pain may have been responsible, the effects of which have been described earlier. As expected, age was positively correlated with time spent performing stereotypical behaviours. Similar relationships between stereotypy frequency and age have been noted in a group of Malayan sun and Asiatic black bears (Vickery and Mason, 2003, 2004) and in the brown bear (Montaudouin and Le Pape, 2005). Age was negatively correlated with time spent resting and performing maintenance behaviours. It could be suggested that as Malayan sun bears age, stereotypy performance replaces resting and maintenance behaviours in activity budgets; however further investigation is required to establish whether this is the case and its associated mechanisms. Future study should aim to determine the enclosure requirements of aging bears by identifying how the behaviour of Malayan sun bears changes with age.

Unexpectedly, autogrooming and body mass were positively correlated. The body size principle predicts that species with smaller body size, and therefore a larger body surface-to-mass ratio, groom more frequently than taxonomically related species of larger size (Hart and Pryor, 2004). This is because parasitism is considered more costly for small individuals. The principle has been documented between related taxa (e.g. Hart et al., 1992) and within species (e.g. Hart and Pryor, 2004), although it has not been documented in bears. Low variation in mass between individuals in the present study suggests that this result was therefore probably due to chance. Comparing body size or mass with time spent grooming in a large population of healthy adult individuals would establish whether Malayan sun bears follow the pattern predicted by the body size principle, or whether the findings of the present study are correct.

Enclosure was a major predictor of behaviour in the Malayan sun bear, however it was outside the scope of this project to identify specific eliciting enclosure features. Four weeks prior to data collection, bears housed in enclosure 23 had been relocated from a neighbouring enclosure. Relocation between enclosures can significantly affect bear behaviour (Koene, 1998; Maslak et al., 2013; Ryan and Litchfield, 2016). Additionally, all females in the study resided in the same enclosure, while males were spread throughout the remaining three enclosures. This confound made statistical modelling using both sex and enclosure problematic, with sex often not included in models. This may account for some of the discrepancies in behaviour observed in this group. It is clear that further research is required to fully understand the effect of enclosure characteristics on Malayan sun bear behaviour.

The present study had two key limitations, season and sample size. All observations were performed in May and June. Seasonal variation in behaviour has been noted previously in captive bears (Carlstead and Seidensticker, 1991; Owen et al., 2005), although no such data exists for the Malayan sun bear at present. Year round observations are required to determine whether the differences observed between disabled and able-bodied bears occur across seasons. A further limitation was the small sample size. Some behavioural differences between disabled and able-bodied bears may not have been identified due to a lack of power in analysis. Furthermore, some behaviours were rare or of typically short duration, and were likely missed due to the nature of scan sampling. Some of these behaviours, for example oral stereotypy, may be absent in the majority of animals. Use of all-occurrence sampling, continuous sampling, or a longer period of data collection may establish which is the case.

4.1. Enclosure and husbandry implications

Amputee Malayan sun bears should be provided with a variety of climbing structures, similar to those of non-amputees, although more research is required to determine the quality of above ground movement in disabled individuals. Potentially, enclosures designed for amputees can be smaller than those for non-amputees, however the optimal enclosure size for amputees should firstly be established. A priority for future research should be the establishment of a reliable method of determining welfare in amputee bears. Partially sighted bears appear to fare well in enclosures designed for able-bodied bears, and should not require any special provision unless their sight begins to deteriorate. Enclosures designed for bears regularly given medication should provide an ample number of resting areas. Older bears require sufficient space to perform stereotypical behaviours. Restricting the ability to perform stereotypies could be detrimental to welfare, as they may serve as a coping mechanism (Mason and Latham, 2004). Enclosures have a significant effect on time budgets of Malayan sun bears, however further research is required to determine causes and effects before recommendations can be made.

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